6-1-1927

The Recovery of Soil Nitrogen Under Various Conditions as Measured by Lysimeters of Different Depths

University of Tennessee Agricultural Experiment Station

C. A. Mooers

W. H. Macintire

J. B. Young

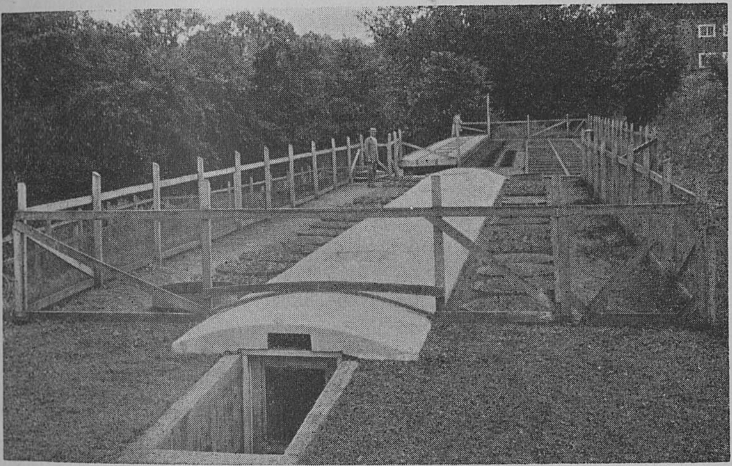
THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
Knoxville

BULLETIN NO. 138 JUNE, 1927

THE RECOVERY OF SOIL NITROGEN UNDER VARIOUS CONDITIONS AS MEASURED BY LYSIMETERS OF DIFFERENT DEPTHS

By

C. A. MOOERS, W. H. MACINTIRE, AND J. B. YOUNG



Issued in recognition of the visit of members of the first International Congress of Soil Science
June 24, 1927

Printed by
W. L. Warters Company
Knoxville, Tenn.

THE UNIVERSITY OF TENNESSEE AGRICULTURAL EXPERIMENT STATION
Knoxville

H. A. MORGAN, President

STATION OFFICERS

C. A. MOOERS, Director and Agronomist
M. JACOB, Veterinarian and Animal Husbandman
S. H. ESSARY, Botanist
W. H. MACINTIRE, Soil Chemist
C. E. ALLRED, Agricultural Economist
S. MARCOVITCH, Entomologist
C. D. SHERBAKOFF, Plant Pathologist
J. A. MCCLINTOCK, Horticulturist and Associate Plant Pathologist
MARGARET B. MACDONALD, Biochemist
W. M. SHAW, Associate Soil Chemist
H. P. OGDEN, Associate Agronomist
G. A. SHUEY, Associate Chemist
H. L. FACKLER, Associate Entomologist
L. S. MAYER, Assistant Agronomist*
J. B. YOUNG, Assistant Soil Chemist
MRS. HELEN B. HUTCHENS, Assistant Plant Pathologist
J. O. ANDES, Assistant Plant Pathologist
K. B. SANDERS, Assistant Soil Chemist
ESTHER M. CRAWFORD, Assistant Biochemist
S. A. ROBERT, Supt. West Tenn. Exp. Station, Jackson
L. R. NEEL, Supt. Middle Tenn. Exp. Station, Columbia
H. W. JONES, Assistant, Tobacco Experiment Station, Clarksville
REXFORD E. MARTIN, Assistant in Cooperative Experiments, Crossville
J. H. BAYER, Assistant in Cooperative Experiments, Murfreesboro
ELIZABETH CHEATHAM, Assistant Librarian
F. H. BROOME, Secretary
CARRIE B. CARTER, Stenographer
NEEDA SWANNER, Stenographer
MILDRED GALLAHER, Stenographer

*Cooperative with Office of Cereal Investigations, U. S. D. A.

The Agricultural Building, containing the offices and laboratories of the Experiment Station, the College class rooms, and the headquarters of the Agricultural Extension Service, is located at the University Farm, on Kingston Pike, about one mile west of the main campus. Farmers are cordially invited to visit the building and the experimental grounds.

Bulletins of this Station will be sent, upon request, free of charge, to any farmer in the State.

THE RECOVERY OF SOIL NITROGEN UNDER VARIOUS CONDITIONS AS MEASURED BY LYSIMETERS OF DIFFERENT DEPTHS

By

C. A. MOOERS, W. H. MACINTIRE, AND J. B. YOUNG

THE PROBLEM

At the outset of the lysimeter experiments at this Station the question arose as to what bearing depth of subsoil would have on the problems to be studied. That is, with a constant depth of surface soil, what would be the effects of variation in depth of subsoil on crop yield, and on amount of water and of nitrogen and other plant nutrients recoverable in the drainage? Much time and labor have been expended on this question, which is fundamental in lysimeter investigations. Incidentally data were obtained on the recovery in the drainage water of nitrogen from various nitrates applied as surface dressings.

After several years of preliminary study without crops, 14 lysimeters were cropped in alfalfa, and the same number in tall oat grass, for a 5-year period, to provide data on the comparative effects of these crops on the nitrogen content of the soil, losses of nitrogen in the drainage, and the amount of nitrogen attributable to fixation from the atmosphere.

THE TANKS

All the soil containers, or tanks, are made of heavy galvanized iron, and are cylindrical in shape, with a diameter of 3.33 feet, allowing a soil area of 1/5000 acre. At the bottom of each tank is a block tin pipe leading to a receiving can in the pit shown in the illustration. The tanks are of 4 depths: 1 foot, 2, 4, and 6 feet.

SOIL DESCRIPTIONS

In these studies, 3 soil types have been used, as follows:

1. Hagerstown loam—a fertile, well-granulated, brown-colored soil from Sumner County.

2. Cumberland clay loam—a fertile, brown-colored soil from "Cherokee" farm, Knox County. This soil is of excellent structure,

and belongs to the better class of uplands found in East Tennessee. It is considered well adapted to a great variety of crops.

3. Memphis silt loam—a poor, gray-colored heavy silt loam from Jackson, Madison County. This soil has little granulation and "cements" readily. It is commonly regarded as unretentive of manure, and as not responding well to manuring, and ranks low in popular esteem.

The first type was used in some preliminary experiments from 1909 to 1915. The last 2 types have been in use from 1915 to the present time.

The mechanical analyses and colloidal content of the last 2 are given in table 1.

TABLE 1—*Mechanical analyses of soils**

Conventional name	Diameter of particles	Cumberland clay loam	Memphis silt loam
	mm.	Per cent	Per cent
Gravel	2.000-1.000	0.0	0.0
Coarse sand	1.000-0.500	0.9	5.2
Medium sand	0.500-0.250	1.4	6.9
Fine sand	0.250-0.100	12.3	9.6
Very fine sand	0.100-0.050	15.4	6.1
Silt	0.050-0.005	48.6	62.5
Clay	0.005-0.000	21.4	9.7
		100.0	100.0
Colloids		21.5	9.4

*Furnished by Dr. R. O. E. Davis, U. S. Bureau of Soils

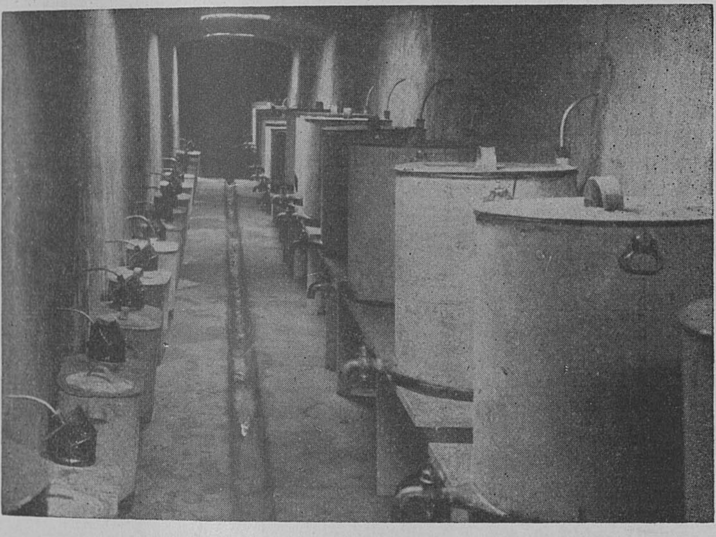
In every case the subsoil could be sharply differentiated from the surface soil by differences in color and, to a less extent, by texture. The subsoil of the Hagerstown loam was not poor in available nitrogen. At the outset the content of nitrogen was 0.0689 per cent, but it suffered an evident loss of this element for a depth of at least 6 inches below the surface layer. In the case of the Memphis silt loam the subsoil was poor, containing at the outset, in 1915, only 0.0342 per cent of nitrogen, which apparently increased to 0.0375 per cent by 1924. The subsoil of the Cumberland loam was purposely taken at a depth of about 2 feet below the surface soil in order to get subsoil low in available nitrogen. It contained 0.0601 per cent nitrogen at the time of placement, in 1915, and 0.0630 per cent in 1924. The writers have no satisfactory explanation of the increase in either instance, unless it may be accounted for by assuming that the upper part of the subsoil acted as filter which removed organic colloids from the leachings. The increases may be real or they may be due to analytical errors, though every effort was made to follow a uniform procedure throughout the period.

In this connection mention should be made of the fact that the last 2 feet of the Memphis silt loam subsoil in the 4-ft. tanks was a nearly pure quartz sand such as was found at this depth in the field. It would be expected to offer little obstruction to the passage of either water or nitrates.

AMOUNTS OF SOIL USED AND METHOD OF FILLING TANKS

The moisture-free weight of surface soil used in the first series —1909-1915—was nearly 500 pounds per tank. The subsoil weighed nearly 700 pounds per foot depth at time of placement.

In the second series a constant weight of 420 pounds of each



Interior view of pit

kind of soil was used at placement; also a constant weight of 840 pounds of subsoil was taken per foot depth. This amount was carefully weighed out and tamped in moderation to fill the allotted space. Placement was completed in November, 1915, and the deepest tanks became saturated early in 1916.

The calculated amount of water-free Memphis silt loam surface soil that would pass through a ½-mm. sieve was 155721 grams, and of Cumberland clay loam 166335 grams.

Care was taken to procure both soil and subsoil under moisture conditions favorable to the retention of good structure. The lots were carefully mixed by reshovelling and finally placed under cover in a temporary shed. The tanks were provided with lids so that rain did not interfere with their uniform filling. To fill tanks with subsoil so that uniform compaction is obtained, and at the same time admit of good drainage, is a somewhat difficult task. In the

TABLE 2—*Yields of various crops as affected by depth of subsoil—average annual yields of air-dry substance per tank* 1/5000 *acre*)

Four tanks at each depth

SERIES 1—5-YEAR PERIOD, 1909-1914

Soil	Containers	Total crop in grams, also in percentage of yield of 4-ft. tanks taken as 100					
		Oats One crop		Wheat Av. 3 crops		Millet Av. 2 crops	
		Grams	P. ct.	Grams	P. ct.	Grams	P. ct.
Fertile Hagerstown loam from Sumner County	1-ft. tanks (6 in. soil, no subsoil)	240.70	62.6	121.57	46.0	110.34	58.0
	2-ft. tanks (6 in. soil, 1 ft. subsoil)	351.63	91.5	166.51	63.0	189.48	99.6
	4-ft. tanks (6 in. soil, 3 ft. subsoil)	384.42	100.0	264.30	100.0	190.26	100.0
	6-ft. tanks (6 in. soil, 5 ft. subsoil)	418.34	108.8	484.06	183.1	190.46	100.1

SERIES 2—5-YEAR PERIOD, 1919-1924

Soil	Containers	Alfalfa 5-year av.		Tall oat grass 5-year av.	
Cumberland clay loam of medium productivity, from Knox County	1-ft. tanks (6 in. soil, no subsoil)	131.9	51.2	79.0	54.3
	2-ft. tanks (6 in. soil, 1 ft. subsoil)	232.6	91.0	123.9	85.1
	4-ft. tanks (6 in. soil, 3 ft. subsoil)	255.5	100.0	145.6	100.0
	6-ft. tanks (6 in. soil, 5 ft. subsoil)	242.9	95.1	204.3	140.3
Memphis silt loam, high in silt, of inferior productivity, from Madison County	1-ft. tanks (6 in. soil, no subsoil)	137.6	72.3	87.2	66.6
	2-ft. tanks (6 in. soil, 1 ft. subsoil)	183.7	96.5	151.5	115.7
	4-ft. tanks (6 in. soil, 3 ft. subsoil)	190.4	100.0	131.0	100.0

series with the Hagerstown loam the variation in amount of water leached from duplicate tanks indicated lack of uniform placement. Because of more attention to the details of subsoil placement, fairly satisfactory results were obtained in the second series, as indicated by the uniform discharge of drainage water.

CROP YIELDS AS INFLUENCED BY DEPTH OF SUBSOIL

Yields of air-dry substance, in grams per tank, are given in table 2 for oats, wheat, millet, alfalfa, and tall oat grass, when grown in tanks of different depths.

Since 6-ft. tanks were not available for one of the soils, the yields of the 4-ft. tanks are taken as 100 per cent for comparison. According to the results obtained, depth of subsoil affects some crops much more than others. In these trials wheat and tall oat grass were the only crops that gave materially better yields in the 6-ft. tanks than in the 4-ft. Although each kind of crop and soil may well be considered individually, the comparative yields of all crops averaged for each tank depth are of interest. In the following statement all the data for the Hagerstown and Cumberland loams are averaged together and the figures for the Memphis silt loam are given separately. This grouping appears justifiable because the Hagerstown and Cumberland loams are similar in color, structure, and crop response for the different depths, whereas the Memphis silt loam is of a widely different character.

COMPARATIVE CROP YIELDS

Tank depth	Hagerstown and Cumberland loams	Memphis silt loam
	Per cent	Per cent
1 foot	54.3	70.8
2 feet	85.5	107.1
4 feet	100.0	100.0
6 feet	126.1	----

It is of interest that the Memphis silt loam gave as good yields in the 2-ft. tanks, which contained only 1 foot of subsoil, as in the 4-ft. tanks, with their 3 feet of subsoil. On the other hand, the Hagerstown and Cumberland loams gave increasingly higher yields with increasing depth of subsoil. The yields from the 2-ft. tanks, however. were 85.5 per cent as high as those from the 4-ft. tanks.

EXPERIMENTAL RESULTS FROM UNCROPPED SOILS

Amounts of Water Leached through Tanks with Different Depths of Subsoil

Table 3 gives the rainfall and table 4 the pounds of water leached through the uncropped tanks for each of 2 soils, the Cumberland clay loam and the Memphis silt loam, in the course of a 3.43-year period, March 18, 1916, to August 23, 1919. As the average for all tanks, 50.7 per cent of the total rainfall leached through the Cumberland loam, as compared with 47.3 per cent for the Memphis silt loam. In the case of the Memphis silt loam practically the same amount of water was recovered from each depth, but with the

Cumberland clay loam the most water, 53.3 per cent of the rainfall, was recovered from the 4-ft. tanks, and practically the same amount, 52.6 per cent, from the 6-ft. tanks. The least recovery, 45.7 per cent, was from the 2-ft. tanks. Strangely enough, the recovery from the 1-ft. tanks, containing no layer of subsoil, was 51.3 per cent, or nearly the same as that from the 4-ft. tanks.

The low recovery in the case of the tanks containing only 1 foot of subsoil is noteworthy, especially in view of the close agreement between the individuals of this set and the distinct difference when compared with the results from either shallower or deeper tanks. The

TABLE 3—*Rainfall in inches—March 18, 1916, to May, 1927*

Month	Years without crops (Mar. 18, 1916, to Aug. 23, 1919)				Years with crops (Aug. 23, 1919, to May, 1927)								
	1916	1917	1918	1919	1919	1920	1921	1922	1923	1924	1925	1926	1927
Jan.	——	7.03	6.63	5.21	——	3.31	3.67	5.32	6.25	4.90	4.30	4.50	2.90
Feb.	——	3.20	2.35	2.09	——	5.79	5.07	4.18	4.93	4.79	3.19	3.68	8.27
Mar.	1.24	*13.99	1.43	5.66	——	4.69	3.04	8.32	8.06	4.50	1.80	3.63	4.30
April	2.03	2.35	6.37	4.06	——	6.05	4.70	5.25	5.65	5.75	2.57	3.34	0.94
May	4.71	2.55	4.27	4.44	——	2.95	2.38	4.91	4.52	4.00	2.09	3.40	——
June	5.29	6.42	4.42	5.76	——	7.79	2.02	5.30	3.49	2.67	1.77	6.19	——
July	6.48	14.06	2.34	6.59	——	1.73	8.00	3.68	4.25	3.56	1.64	3.00	——
Aug.	4.24	3.87	2.43	4.36	0.31	12.17	2.99	3.12	4.05	1.20	1.70	5.45	——
Sept.	2.84	3.29	0.40	——	0.96	3.66	1.77	2.83	1.55	5.43	2.71	2.23	——
Oct.	1.97	3.83	3.84	——	5.51	0.88	1.18	1.53	0.88	0.94	11.02	3.55	——
Nov.	2.55	1.27	2.16	——	2.19	1.19	5.74	1.88	2.31	0.91	5.13	5.52	——
Dec.	3.63	1.38	4.55	——	4.28	5.41	2.75	8.02	5.05	8.83	2.20	11.78	——
Total	34.98	63.24	41.19	38.17	13.25	58.62	43.31	54.34	51.89	47.48	40.12	56.27	16.41

*3.77 inches after March 19.

Note—The total rainfall per tank for the period March 18, 1916, to August 23, 1919, is 8,044 pounds, and for the period August 23, 1919, to December 8, 1924, is 12,181 pounds.

following is suggested as a possible explanation: No great resistance was offered to the passage of water through the soil of tanks 5 to 8, which contained no subsoil. In the case of tanks 13 to 16 the 1-ft. layer of rather heavy subsoil slowed the rate of percolation. In the case of the 4-ft. and 6-ft. tanks the subsoil after saturation exerted a suction, or pull, which drew the water more quickly out of the surface layer than in the case of tanks 13 to 16; the greater length of column more than offsetting the retarding influence of the subsoil. The effect is considered to be like that of filtration from long-stemmed as compared with short-stemmed funnels; the process

TABLE 4—*Rainwater and nitrogen leached from uncropped lysimeters under various conditions—3.43 years' exposure, March 18, 1916, to August 23, 1919*

Soil	Tank	Depth of subsoil	Water leached Amt.	Water leached Per cent of rainfall	Fertilizer nitrogen applied: Source	Fertilizer nitrogen applied: Date of application	Fertilizer nitrogen applied: Amt. of nitrogen	Total nitrate nitrogen in drainage	Recovery of applied nitrogen
			Lbs.				Grams	Grams	P. ct.
Cumberland clay loam. Heavy clay loam subsoil, uniform throughout	5	None	4137		Nitrate	Mar. 18, 1916	2.868	18.9807	129.9
					Cyanamid	Mar. 19, 1917	2.868		
	6	None	4053				None	11.8456	
	7	None	4137		Nitrate	Mar. 18, 1916	2.868	18.5956	123.2
					Nitrate	Mar. 19, 1917	2.868		
	8	None	4174				None	11.2106	
		Average	4125	51.3					126.6
	13	1 foot	3688		Nitrate	Mar. 18, 1916	2.868	18.3592	70.1
					Cyanamid	Mar. 19, 1917	2.868		
	14	1 foot	3666				None	13.6441	
	15	1 foot	3647		Nitrate	Mar. 18, 1916	2.868	19.0862	82.8
					Nitrate	Mar. 19, 1917	2.868		
	16	1 foot	3702				None	15.0291	
		Average	3676	45.7					76.5
	26	3 feet	4360				None	10.7740	
	27	3 feet	4312		Nitrate	Mar. 18, 1916	2.868	12.8249	47.8
	30	3 feet	4255				None	12.1347	
	31	3 feet	4220		Nitrate	Mar. 18, 1916	2.868	13.6936	39.0
					Cyanamid	Mar. 19, 1917	2.868		
		Average	4287	53.3					43.4
	33	5 feet	3979		Nitrate	Mar. 18, 1916	2.868	9.9833	53.6
					Cyanamid	Mar. 19, 1917	2.868		
	34	5 feet	4102				None	7.6530	
	35	5 feet	4318		Nitrate	Mar. 18, 1916	2.868	10.3195	59.5
					Nitrate	Mar. 19, 1917	2.868		
	36	5 feet	4540				None	6.1632	
		Average	4235	52.6					56.6
Memphis silt loam. Heavy silt loam subsoil, but only sand in last 2 feet of tanks 19, 20, 24, and 25	1	None	3712		Nitrate	Mar. 18, 1916	2.868	18.1561	*49.8
					Cyanamid	Mar. 19, 1917	2.868		
	2	None	3862				None	15.8262	
	3	None	3860		Nitrate	Mar. 18, 1916	2.868	20.8276	96.3
					Nitrate	Mar. 19, 1917	2.868		
	4	None	4018				None	14.7776	
		Average	3813	47.4					96.3
	9	1 foot	3897		Nitrate	Mar. 18, 1916	2.868	22.7524	115.0
					Cyanamid	Mar. 19, 1917	2.868		
	10	1 foot	4028				None	15.6876	
	11	1 foot	3745		Nitrate	Mar. 18, 1916	2.868	22.8397	116.5
					Nitrate	Mar. 19, 1917	2.868		
	12	1 foot	3877				None	16.6227	
		Average	3887	48.3					115.8
	19	3 feet	3650		Nitrate	Mar. 18, 1916	2.868	23.5261	109.8
					Nitrate	Mar. 19, 1917	2.868		
	20	3 feet	3483				None	17.4099	
	24	3 feet	3818				None	17.0511	
	25	3 feet	3911		Nitrate	Mar. 18, 1916	2.868	22.3566	89.4
					Cyanamid	Mar. 19, 1917	2.868		
		Average	3716	46.2					99.6

*Not included in the average.

being accelerated by the longer column of water in the long-stemmed funnel. This result is, however, not apparent in the case of the Memphis silt loam, which has a materially lower content of both clay and colloids.

INFLUENCE OF DEPTH OF SUBSOIL ON RECOVERY OF APPLIED NITROGEN

Table 4 summarizes the data obtained during a period of 3.43 years, from each of the 2 soils, on the recovery in the drainage of nitrogen applied to uncropped tanks containing subsoil of different depths. Nitrate of soda furnishing 2.868 grams of nitrogen per tank, or approximately 200 pounds of the nitrate per acre, was applied as a surface dressing to all odd-numbered tanks March 18, 1916. The even-numbered tanks were left without treatment for comparison. There were therefore 2 nitrated and 2 unnitrated tanks at each depth. On March 19, 1917, the application of nitrate was repeated for one tank of each set and to the other was substituted cyanamid furnishing an equal amount of nitrogen. One exception is to be noted: tank 27 received only one application, that of nitrate, March 18, 1916.

DISCUSSION OF THE DATA

The last column of table 4 gives the determined recovery of the applied nitrogen at the close of a period of 3.43 years from the time of the first application, or 2.43 years from the time of the second application. During this period the rainfall averaged 52.2 inches per year, with the monthly distribution as given in table 3.

In the case of the Cumberland clay loam, the shallow tanks containing only surface soil gave the highest recovery, 126.6 per cent. That the recovery should be over 100 per cent is not surprising, for with many soils, especially those poor in lime, as in this case, an application of nitrate is followed by increased nitrification of the soil's organic nitrogen. The presence of 1 foot of subsoil reduced the recovery to an average of 76.5 per cent. Similarly with 3 feet of subsoil the recovery was only 43.4 per cent, and with 5 feet 56.6 per cent.

It is evident, therefore, that with this type of soil a stratum of subsoil interferes seriously with nitrogen recovery.

The data of table 4 for the Memphis silt loam are quite at variance with those for the Cumberland clay loam, in that the presence of subsoil appeared to have little influence on the amount of nitrogen finally recovered. The data for this soil are somewhat irregular, and for that reason do not lend themselves well to discussion at this point, but will be referred to later in more detail. It is noticeable, however, that in 3 of the 6 conditions the recovery of nitrogen was well above 100 per cent.

Table 4 gives only the total recovery from each soil for the period, and these data fail to give an adequate idea of what transpired. Attention is therefore called to charts 1 to 7, which depict the progressive outgo, in grams of nitrogen per tank, for the period. In these charts the number of days from March 18, 1916, is shown on the abscissa and the grams of nitrogen found in the drainage water is shown on the ordinate.

Charts 1 to 4 record the outgo of nitrogen from the Cumberland clay loam.

Chart 1 depicts the nitrogen recovery from each of the four 1-ft. tanks, which contained a layer of surface soil without subsoil. The results for the check, or no-treatment, tanks, 6 and 8, are in close agreement, as are those for tanks 5 and 7, which received the fertilizer nitrogen. The data show that the increased outgo of nitrogen became noticeable in the drainage water on the 76th day after the application of March 18, 1916, and that it continued in evidence for 168 days thereafter. In the case of the second application the increase began on the 103d day and was in evidence for 41 days thereafter. Differences in rainfall probably account for the differences in time of recovery for the 2 applications.

Chart 2 depicts the nitrogen recovery from the same soil for each of the four 2-ft. tanks, which contained the same amount of surface soil as the 1-ft. tanks but underlaid with a foot of the clay loam subsoil. The agreement between the duplicates is fair for the first year, but less satisfactory afterward. The outgo of the applied nitrogen was considerably delayed, being possibly in evidence 129 days after the first application, but positively in evidence only at the end of 244 days, and was considered completed 74 days thereafter. The outgo of nitrogen from the second application appeared on the 126th day, and was completed 213 days thereafter. Another noticeable result is the smaller difference, or spread, between outgo of nitrogen from the treated and untreated tanks of this set as compared with those without subsoil.

Chart 3 depicts the nitrogen recovery from each of the four 4-ft. tanks which contained surface soil underlaid with 3 feet of subsoil. In this set the outgo of applied nitrogen was further delayed; one tank showing increased outgo on the 318th day following the first application, but the other showing no increase until the 484th day. The completion of the outgo is indefinite, but possibly it is on the 608th day, or the 290th day after the first indication. In this set neither the beginning nor the ending of the nitrogen outgo from the second application is clearly apparent. The spread between the outgo of nitrogen from the treated and from the untreated tanks is also greatly reduced as compared with that of either of the other 2 sets described.

Chart 4 depicts the nitrogen recovery from each of the four

6-ft. tanks, which contained the surface soil underlaid with 5 feet of subsoil. In this set the outgo of applied nitrogen is delayed most of all. In fact, owing to the wider divergence in the data from the duplicates, it is not apparent either when the applied nitrogen first appeared or when, if ever, the outgo was completed. The unsatisfactory record from these, the deepest tanks, shows very plainly the marked retarding action of this subsoil on the outgo of nitrate nitrogen.

Charts 5 to 7 record the outgo of nitrogen from the Memphis silt loam.

Chart 5 depicts the outgo from the 1-ft. tanks containing no subsoil. The results from the check, or no-treatment, tanks are fairly uniform, but there is a wide divergence in the case of the treated tanks, 1 and 3. Since the outgo of nitrogen from tank No. 1 is far out of harmony with all others receiving fertilizer applications, the results were not included either in calculating the average per cent recovery as given in table 4 or in the further discussion. In the case of tank 3 the outgo of the nitrogen from the first application appeared the 76th day and was completed 53 days thereafter. The second application appeared the 103d day and was completed 23 days thereafter.

Chart 6 depicts the outgo from the 2-ft. tanks containing 1 foot of subsoil underlying the same quantity of surface soil used in the 1-ft. tanks. The outgo of applied nitrogen was evidently delayed, though to a less extent than was the case with the Cumberland clay loam in tanks of like depth. It appeared on the 89th day, but completion is not indicated until 229 days thereafter. Similarly, in the case of the second application the increase appeared on the 103d day and was considered completed 140 days thereafter.

Chart 7 depicts the outgo of nitrogen from the 4-ft. tanks. In these tanks the surface soil was underlaid with 1 foot of the same kind of silt loam subsoil as used in the 2-ft. tanks, but below that depth was a layer of sand 2 feet deep, as found in the field from which this soil was taken. Retardation, however, due to this layer of sand was evident. The outgo of applied nitrogen appeared on the 129th day after the first application, and was considered completed 155 days afterward. In the case of the second application the rise in outgo of nitrogen did not appear until the 175th day, and was judged completed 165 days afterward.

CONTRAST IN RECOVERY FROM THE TWO SOIL TYPES

It is evident that the 2 soil types behaved alike in that the deeper the layer of subsoil the greater was the retardation in the outgo of nitrogen. On the other hand, the much higher recovery of nitrogen in the case of the deeper tanks, of the Memphis silt loam, and the fairly sharp lines of demarcation at the beginning and completion of the outgo of applied nitrogen at all depths, are in wide contrast with

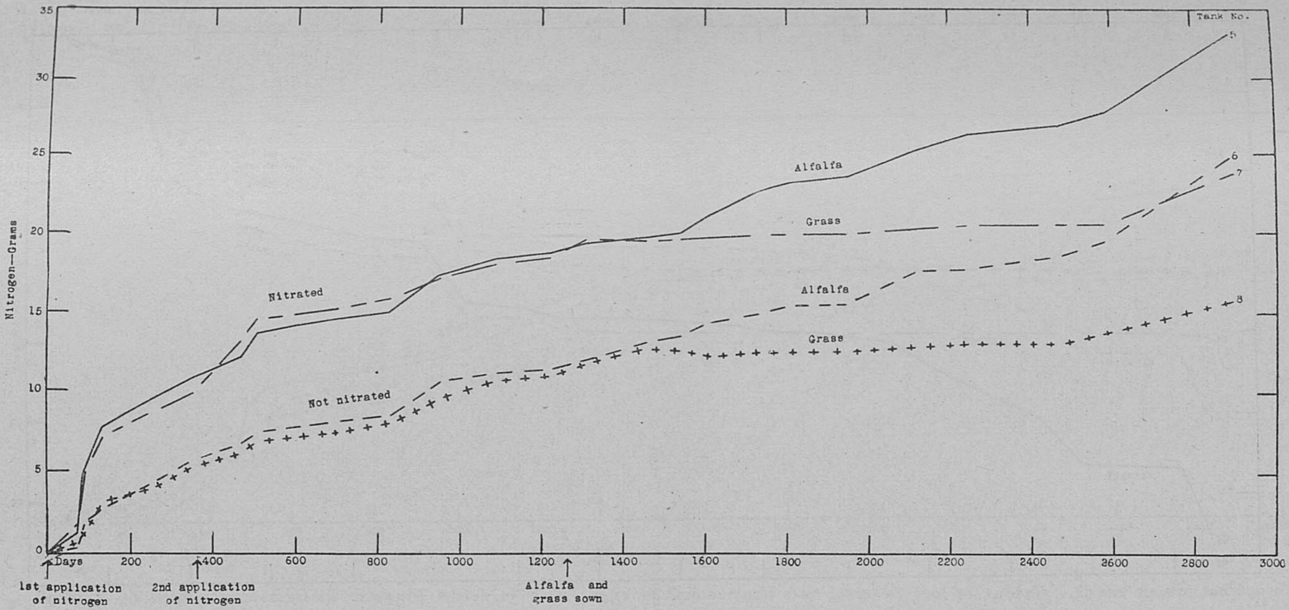


Chart 1—Nitrogen recovered in drainage water of 1-ft. tanks of Cumberland clay loam—no subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

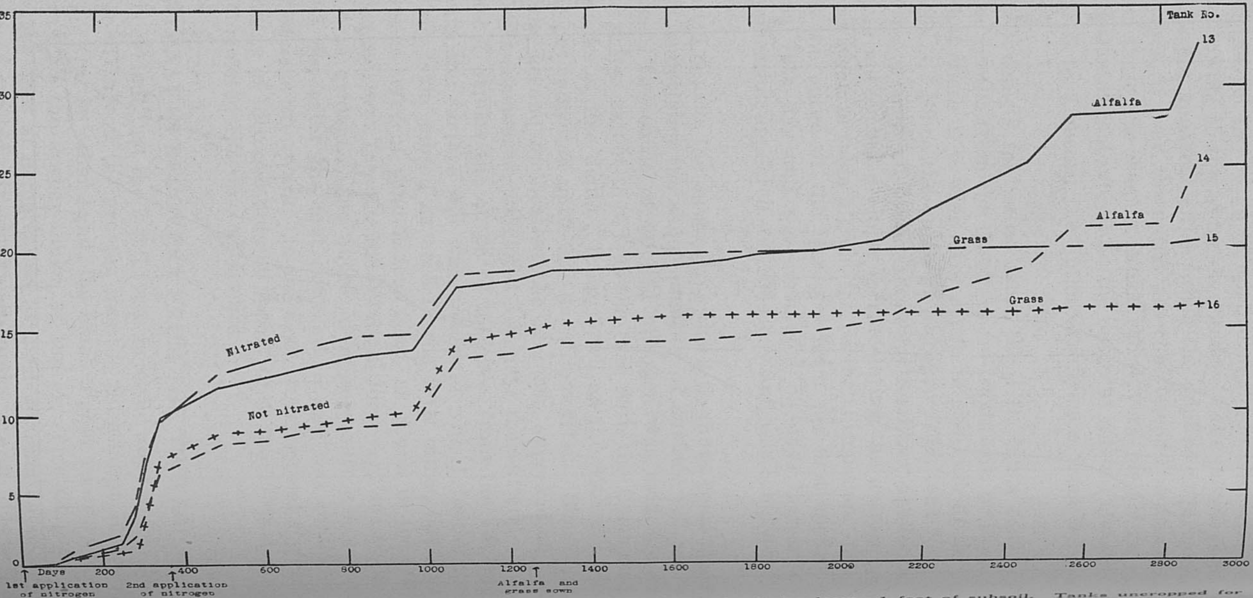


Chart 2—Nitrogen recovered in drainage water of 2-ft. tanks of Cumberland clay loam—1 foot of subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

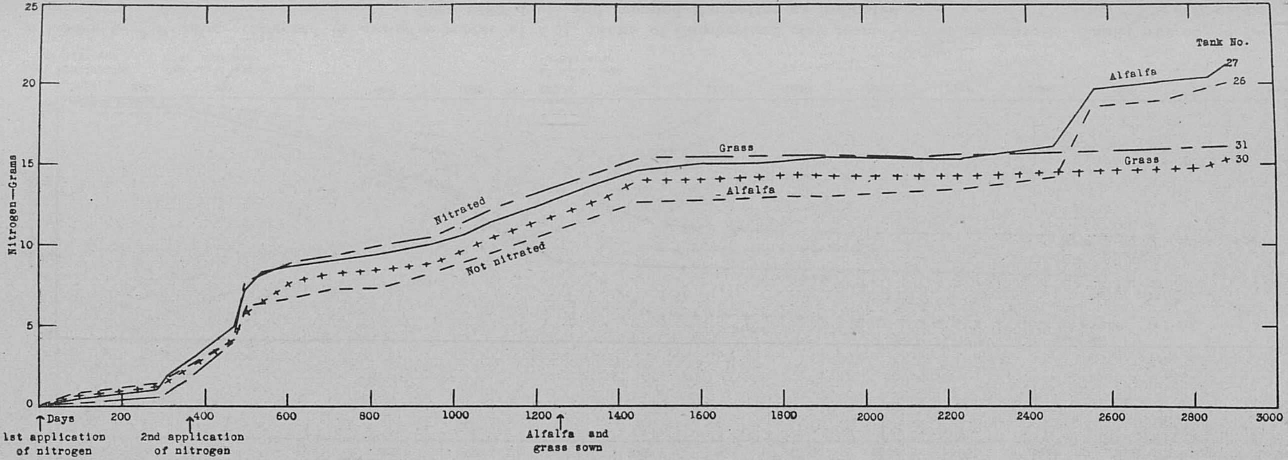


Chart 3—Nitrogen recovered in drainage water of 4-ft. tanks of Cumberland clay loam—3 feet of subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

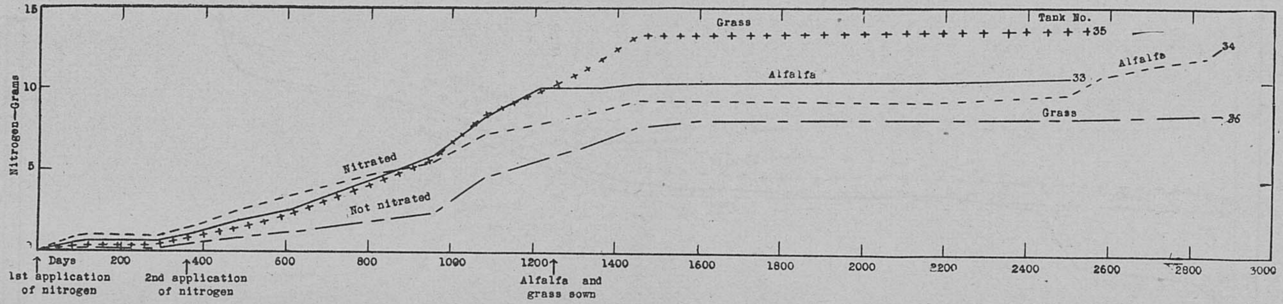


Chart 4—Nitrogen recovered in drainage water of 6-ft. tanks of Cumberland clay loam—5 feet of subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

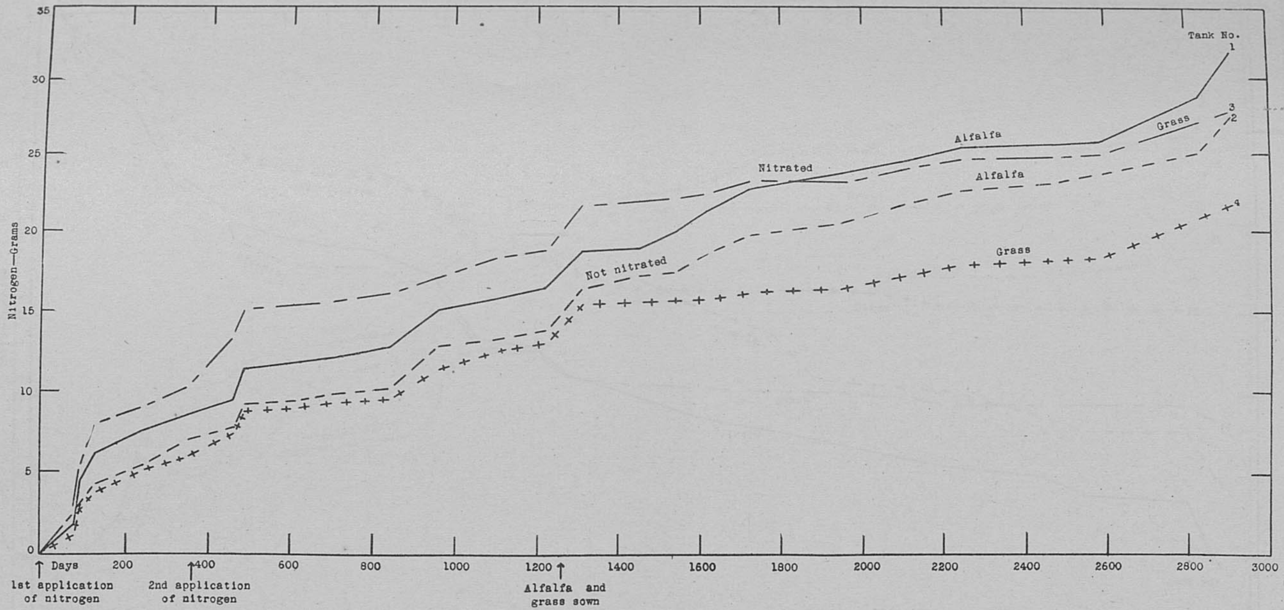


Chart 5—Nitrogen recovered in drainage water of 1-ft. tanks of Memphis silt loam—no subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

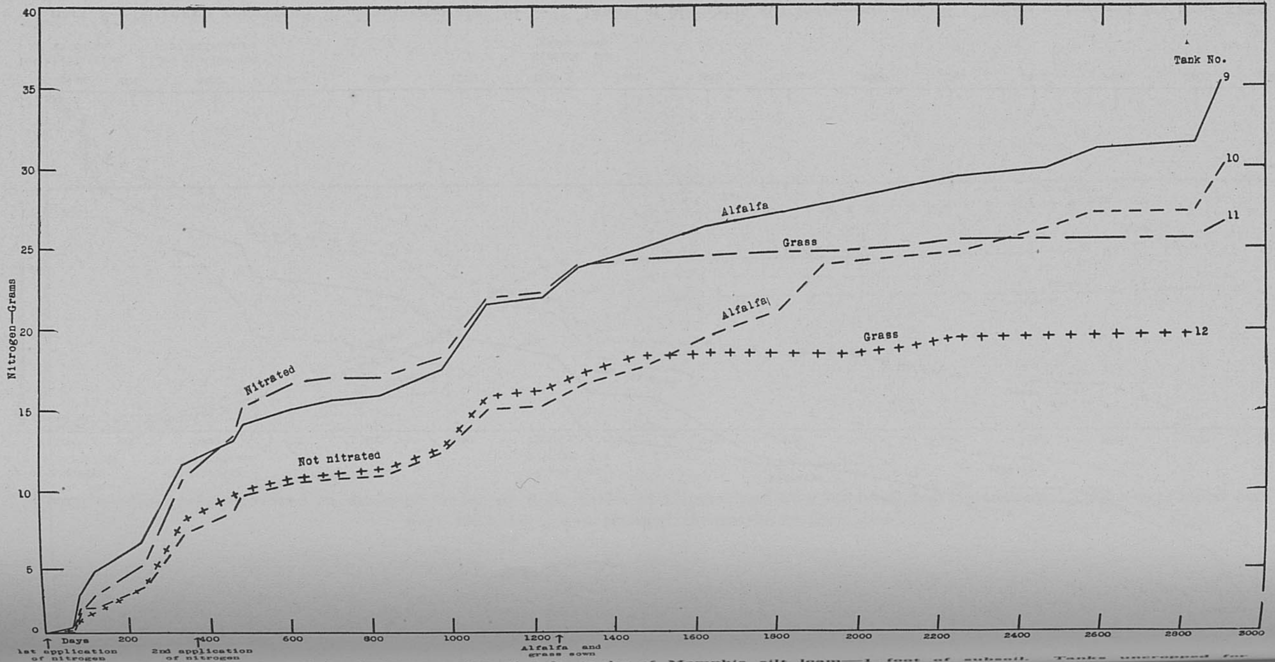


Chart 6—Nitrogen recovered in drainage water of 2-ft. tanks of Memphis silt loam—1 foot of subsoil. Tanks uncropped for first 1283 days, and cropped thereafter as indicated.

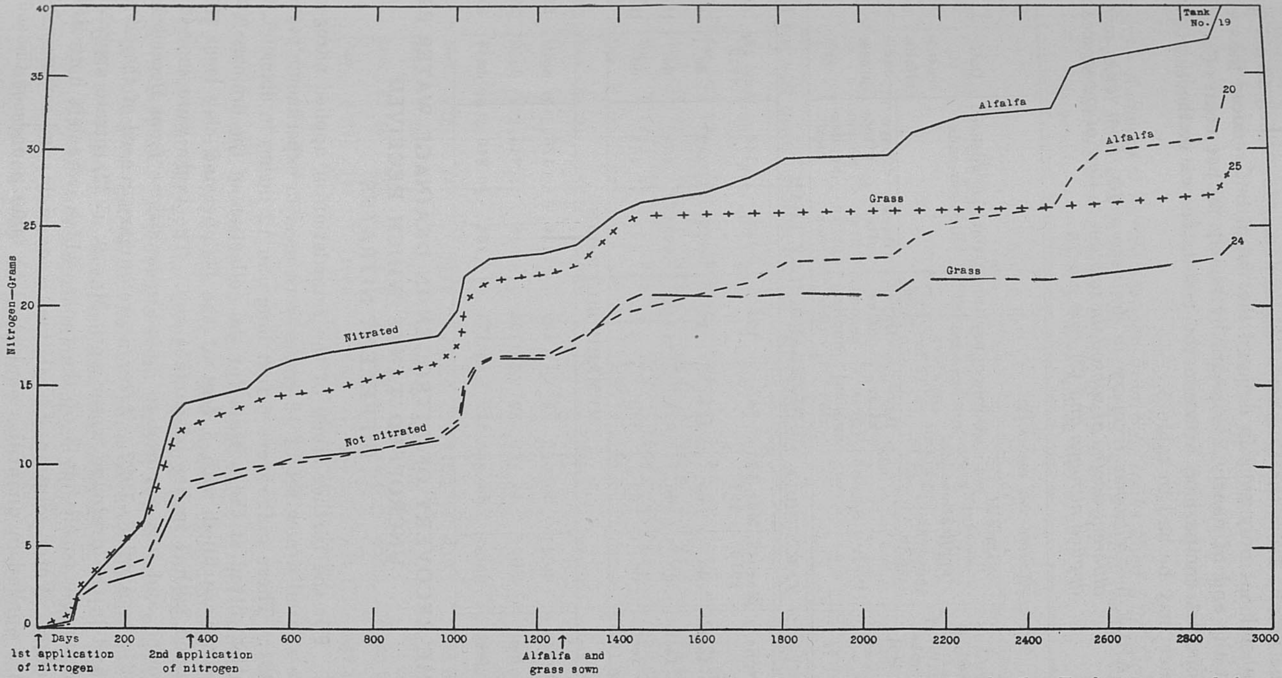


Chart 7—Nitrogen recovered in drainage water of 4-ft. tanks of Memphis silt loam—3 feet of subsoil. Tanks uncropped for first 1253 days, and cropped thereafter as indicated

the results from the Cumberland clay loam, for which even a foot of subsoil not only greatly delayed the outgo but reduced the recovery at the end of nearly 2½ years by nearly 40 per cent. For a more compact comparison between the results shown in the charts, reference may be had to table 5.

TABLE 5—*Nitrogen recovery in drainage water, from tanks containing different depths of subsoil, in relation to time of appearance of (1) applied nitrogen and (2) crop effects*

Depth of sub-soil	Date of nitrogen application		Outgo of applied nitrogen begins		Outgo of applied nitrogen ends		Date of seeding alfalfa and grass	Reduction in outgo of nitrogen from grass tanks begins
	First	Second	Days after first application	Days after second application	Days after first application	Days after second application		Days after seeding
CUMBERLAND CLAY LOAM								
None	Mar. 18, 1916	Mar. 19, 1917	76	103	244	144	Aug. 23, 1919	287
1 foot	do	do	129	126	318	342	do	860
3 feet	do	do	318	(?)	608(?)	(?)	do	1212
5 feet	do	do	(?)	(?)	(?)	(?)	do	1330
MEMPHIS SILT LOAM								
None	do	do	76	103	129	126	do	287
1 foot	do	do	89	103	318	243	do	282
3 feet	do	do	129	175	284	340	do	359

THE RECOVERY OF NITROGEN IN DRAINAGE WATER FROM UNCROPPED TANKS WHICH RECEIVED DIFFERENT NITRATES

For the further study of the retardation of applied nitrogen by the subsoil a new set of 12 tanks were used in experiments begun in 1921. These tanks were 6 feet long and 12 inches in diameter, with outlets fitted at the bottom for the collection of the drainage water. They were filled with 5 feet of the Cumberland clay loam subsoil topped with 7 inches of surface soil. The tanks were sunk in the ground and left exposed to open-air conditions from December 15, 1921, to April 8, 1927. After a preliminary record of the nitrogen found in the drainage water until May 9, 1922, nitrate applications were made to all but 3 of the tanks, which were left untreated as checks. Water solutions of calcium, magnesium, and sodium nitrates were applied in quantities equivalent to 6000 pounds of the sodium nitrate per acre, each kind of nitrate being applied in this equivalent to each of 3 tanks. Record of the nitrogen outgo was then made at various intervals until April, 1927, a period of practically 5 years. Table 6 summarizes the data, which are further depicted in chart 8.

TABLE 6—*Recovery of nitrate nitrogen from 6-ft. tanks filled with Cumberland clay loam surface soil, underlaid with 5 feet of heavy clay loam subsoil, from Dec. 15, 1921, to April 8, 1927*

988 pounds of nitrogen per acre applied May 9, 1922

Leaching	Date	No. of days between leachings	No. of days after addition of nitrates	Nitrogen per acre from Control tanks (average of 2)	Calcium nitrate tanks (average of 3)	Magnesium nitrate tanks (average of 3)	Sodium nitrate tanks (average of 3)
				Lbs.	Lbs.	Lbs.	Lbs.
1	Mar. 23 '22	98	——	1.5	1.9	1.8	2.6
2	May 9 '22	47	——	2.5	2.2	2.4	3.7
6000 POUNDS $NaNO_3$ PER ACRE OR EQUIVALENT ADDED MAY 9, 1922							
3	Dec. 4 '22	209	209	5.1	3.0	3.5	5.3
4	Jan. 31 '23	58	267	9.8	5.7	4.3	6.9
5	Apr. 18 '23	77	344	14.3	74.3	27.0	126.1
6	May 9 '23	21	365	14.8	100.8	53.0	188.3
7	Dec. 11 '23	216	581	16.6	151.8	98.1	321.0
8	Feb. 29 '24	80	661	18.7	275.1	224.9	508.4
9	May 12 '24	73	734	19.8	348.0	297.2	618.7
10	Dec. 9 '24	211	945	22.7	433.1	382.8	682.6
11	Feb. 20 '25	73	1018	25.3	508.8	460.7	730.3
12	Nov. 9 '25	262	1280	38.0	642.4	619.7	802.0
13	May 7 '26	177	1457	48.7	763.8	752.1	889.2
14	Dec. 22 '26	229	1686	58.7	844.3	825.5	963.7
15	Apr. 8 '27	107	1793	68.3	889.8	871.1	987.4
	Per cent recovery			——	83.08	81.19	92.95

Mention should be made of the fact that the original intention was to apply the nitrates at the rate of 600 pounds of sodium nitrate per acre, but that through an error in calculation 10 times this amount was applied. The results from such a heavy rate, which is far beyond practical usage, can not be taken as unqualifiedly indicative of what would have occurred had the original intention been carried out. A 6000-pound application might inhibit bacterial action, which under normal conditions, with a light application of nitrate, would be expected to play an important part in the retardation of nitrogen outgo. The results from this very heavy treatment would be expected, however, to give an index of the retardation due to other causes.

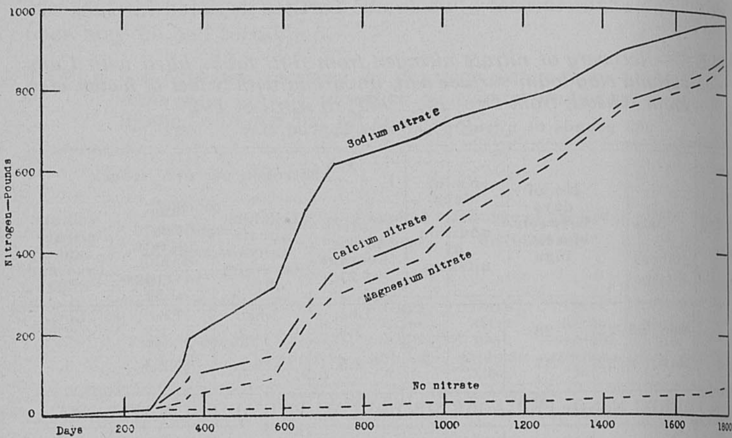


Chart 8.—Nitrogen recovered in drainage water following heavy dressing of various nitrates—Cumberland clay loam without crops—5-year period

DISCUSSION OF THE DATA

Recovery of applied nitrogen was not apparent until the fifth leaching, that of April 18, 1923, or 344 days after the application of the nitrates. From that time until April, 1927, the outgo was not only continuous but fairly constant in amount, especially in the case of the calcium and magnesium nitrates, as the chart indicates.

So far as the different nitrates are concerned, it is of interest that the most rapid leaching of nitrogen was from sodium nitrate and the least rapid was from magnesium nitrate. At the close of the 5-year period there had been recovered 92.95 per cent of the sodium nitrate applied, in comparison with only 83.08 per cent for the calcium nitrate and 81.19 per cent for the magnesium nitrate.

EXPERIMENTAL RESULTS FROM CROPPED SOILS

Manurial Treatments

Soil samples were taken for analysis from the 1/5000-acre tanks in August, 1919, after which the following materials were applied uniformly to every tank and well worked into the surface soil:

	Grams per tank	Equivalent rate per acre
Ground, dry stable manure	550	12 tons
Acid phosphate	90	1000 pounds
Muriate of potash	9	100 pounds
Ground limestone	360	2 tons

The nitrogen content of the manure was 2.19 per cent, so that the nitrogen applied per tank was 12.045 grams.

On August 23 one check, or no-treatment, tank of every depth for each soil was planted to alfalfa and the other to tall oat grass. In like manner one of the nitrated tanks was planted to alfalfa and the other to grass.

The air-dry weights of the crops harvested for the next 5 years are given in table 2, series 2. It should be noted, however, that this table gives only the annual yield per tank, so that multiplication by 5 is necessary to get the total yield for the period. The nitrogen content of the crops, in grams per tank for the entire period, is given in table 7. In the same table is given the nitrogen found in the drainage water from August 23, 1919, to December 8, 1924, or 5.3 years. In the last column is given the total amount of nitrogen lost from the soil in crops and drainage water for each depth.

As would be expected, the alfalfa crops contained much more nitrogen than the grass crops. As averaged in table 7, 24.39 grams of nitrogen per tank was found in the alfalfa crops grown in the Cumberland clay loam and 20.72 grams in those from the Memphis silt loam. In the grass crops from the Cumberland clay loam only 5.34 grams of nitrogen per tank was found, and in those from the Memphis silt loam 6.11 grams.

The nitrogen in the drainage water was also much greater from the alfalfa tanks than from the grass tanks. The averages per tank from the Cumberland clay loam were 13.25 grams for the alfalfa and only 3.63 grams for the grass. Similar results were obtained with the Memphis silt loam, 15.85 grams of nitrogen per tank being found in the drainage from the alfalfa tanks and 6.49 grams from the grass tanks.

When the total nitrogen per tank found in both crops and water for these 2 soils is compared, the interesting results are noted that the Memphis silt loam, though containing much less nitrogen than the Cumberland clay loam, and though generally regarded as a much inferior soil, gave up 97 per cent as much nitrogen when cropped in alfalfa as the Cumberland clay loam, and when cropped in grass it excelled the latter by 40 per cent.

The effect of cropping on the outgo of nitrogen at the various depths can best be understood by reference to charts 1 to 7, which show a practically unbroken rise in nitrogen outgo in the drainage wherever alfalfa was grown, but a marked and sudden falling off wherever grass was grown. In fact, there were long periods in which scarcely any nitrogen was found in the leachings from the grass tanks. It is of special interest that this sudden falling off not only is sharply defined but also varies with the depth of subsoil. With the Cumberland clay loam it appeared at the end of 287 days from the time of planting in the case of the 1-ft. tanks, 860 days for the

2-ft., 1212 days for the 4-ft., and 1335 days for the 5-ft. In t case of the Memphis silt loam the falling off in the nitrogen cont of the drainage water began at the end of 287 days for the 1- tanks, 282 days for the 2-ft. tanks, and 359 days for the 4-ft. tan

CHANGES IN THE NITROGEN CONTENT OF THE SOIL

Table 8 gives the percentages of total nitrogen found in t surface soils in 1915, 1919 and 1924. The Cumberland clay loa

TABLE 7—*Nitrogen in crops harvested and in water leached from lysi-eters (1/5000 acre each), with subsoil of different depths*

Water leached from August 23, 1919, to December 8, 1924—5.3 years
Crops grown for 5-year period, 1919-1924

Soil	Depth of subsoil	Crops	Nitrogen in		
			Crops	Water leached	Crops an water
			Grams	Grams	Grams
Cumberland clay loam. Heavy clay loam subsoil, uniform throughout	None	Alfalfa	15.57	14.92	30.49
	1 foot	do	27.45	14.51	41.96
	3 feet	do	30.15	10.33	40.48
	5 feet	do	*28.66	*3.02	*31.68
		Average	24.39	13.25	37.64
	None	Grass	3.63	5.95	9.58
	1 foot	do	5.70	1.66	7.36
	3 feet	do	6.70	3.27	9.97
	5 feet	do	*9.40	*5.16	*14.56
		Average	5.34	3.63	8.97
Memphis silt loam. Heavy silt loam subsoil, but only sand in last 2 feet of tanks 19, 20, 24 and 25	None	Alfalfa	16.72	13.77	30.49
	1 foot	do	22.32	14.72	37.04
	3 feet	do	23.13	19.06	42.19
		Average	20.72	15.85	36.57
	None	Grass	4.32	7.59	11.91
	1 foot	do	7.50	4.53	12.03
	3 feet	do	6.50	7.36	13.86
		Average	6.11	6.49	12.60

*Omitted from average.

contained 0.1011 per cent of nitrogen at time of placement, Novem ber, 1915, but only 0.0906 in August, 1919, nearly 3.75 years late or a loss of 10.4 per cent. In the same period the nitrogen cont of the Memphis silt loam fell from 0.0770 per cent to 0.0680 p cent—a loss of 10.4 per cent.

Under cropping in alfalfa the Cumberland clay loam maintained its nitrogen content, the average of 0.0978 in 1919, after the manurial application, being exactly the same as the average 5.3 years later. The nitrogen content of the Memphis silt loam, on the other hand, fell during the period from 0.0757 per cent to 0.0681 per cent—a loss of 10 per cent.

Under cropping in grass for the 5.3 years, the Cumberland clay loam lost 3.1 per cent of its nitrogen and the Memphis silt loam lost 11.6 per cent. The Cumberland clay loam therefore showed evident superiority in maintenance of nitrogen supply with both crops. It is of interest, however, that at best the nitrogen content was no more than maintained even under cropping in alfalfa.

TABLE 8—*Changes in nitrogen content of surface soil*

Soil samples taken: Nov. 1915, Aug. 1919, and Dec. 1924

Depth of subsoil	Per cent of nitrogen—m.-f. basis						
	1915 At time of placement	Cropped in alfalfa 1919-1924			Cropped in grass 1919-1924		
		1919 Before manuring	1919 After manuring	1924	1919 Before manuring	1919 After manuring	1924
CUMBERLAND CLAY LOAM							
No subsoil	0.1026	0.0936	0.1008	0.0943	0.0928	0.1000	0.0920
1 foot	0.1006	0.0911	0.0983	0.0968	0.0900	0.0972	0.0952
3 feet	0.1005	0.0884	0.0956	0.0986	0.0881	0.0953	0.0951
5 feet	0.1006	0.0891	0.0963	0.1016	0.0891	0.0963	0.0946
Average	0.1011	0.0906	0.0978	0.0978	0.0900	0.0972	0.0942
MEMPHIS SILT LOAM							
No subsoil	0.0774	0.0680	0.0757	0.0627	0.0708	0.0785	0.0663
1 foot	0.0776	0.0677	0.0754	0.0670	0.0683	0.0760	0.0644
3 feet	0.0759	0.0682	0.0759	0.0747	0.0670	0.0747	0.0719
Average	0.0770	0.0680	0.0757	0.0681	0.0687	0.0764	0.0675

The data of table 8 indicate that where no crops were grown there was a distinct tendency for the nitrogen supply to be better maintained in the shallow than in the deep tanks. Nitrification may have been more actively continued in the latter case, due to their slightly better maintenance of moisture in the surface soil, but actual proof is wanting. Under cropping, the reverse tendency shows itself. The larger crops in the deep tanks would take up more moisture than the smaller crops in the shallow tanks, and this might result in reduced nitrification and loss of nitrogen from the surface soil of the deep tanks. These effects are especially noticeable in the case of the Cumberland clay loam.

No reference has been made to the nitrogen brought down by rain and snow. This was found to average nearly 0.31 gram per tank per annum, or 1.06 grams for the period of 3.43 years when crops were grown. If 1.06 grams of nitrogen be added to that present in the soil at the outset, and from the sum there be subtracted the soil nitrogen at the end of that period, it will be found that the loss is the same, within a fraction of a gram, as the amount found in the drainage water from the Memphis silt loam for both the 1-ft. and 2-ft. tanks. In the case of the Cumberland clay loam, on the other hand, there was a discrepancy between the two estimates; the recovery of nitrogen in the drainage water from the 1-ft. tanks being 4.5 grams less than the loss calculated from the soil analyses, and from the 2-ft. tanks 2.5 grams less. The reason for these differences is not apparent.

If the changes in the nitrogen content of the soil during the cropping period and the amount of nitrogen found in the crops and drainage water be taken into consideration, the amount, if any, of nitrogen derived from atmospheric sources may be calculated. These data are summarized in table 9, for each tank depth, and with special regard to the comparative results from the 2 crops, alfalfa and grass. As would be expected, the data show that appreciable amounts of atmospheric nitrogen were utilized by the alfalfa. The calculated amounts varied from 10.24 to 52.48 grams per tank for the 5.3-year period. Whether there was fixation where the grass grew is uncertain. At first glance the evidence is in favor of fixation, since 5 of the 7 sets show from 3.73 to 9.63 grams of nitrogen as coming from this source. On the other hand, if only the 1- and 2-ft. tanks be taken into consideration the results show slight gains for the Cumberland clay loam and corresponding losses for the Memphis silt loam. It seems more probable, therefore, that there was little or no fixation where the grass grew. If that be true the calculated fixation must be attributed to minor inaccuracies of technic in the case of the shallow tanks, together with subsoil interference in the case of the deep tanks. For these reasons the best estimate of the amount of nitrogen secured from the atmosphere by the alfalfa appears to be derived from the difference between the calculated amounts for the alfalfa and grass, as is shown in table 9. These figures are fairly consistent with the yields obtained. By this method of calculation the alfalfa secured from the atmosphere, as an average for all tank depths for the 5 years, 30.26 grams of nitrogen in the case of the Cumberland clay loam and 25.73 grams in the case of the Memphis silt loam. These amounts, when calculated on the acre basis, are equivalent, respectively, to 66.8 pounds and 56.7 pounds of nitrogen per annum.

TABLE 9—*Nitrogen summary in grams per lysimete (1/5000 acre) for cropping period*

Only surface-soil nitrogen taken into consideration, together with the nitrogen in all crops grown, and in all drainage waters, from Aug. 23, 1919, to Dec. 8, 1924

Cropping	Depth of subsoil	Memphis silt loam			Cumberland clay loam		
		Nitrogen in		Nitrogen from atmosphere	Nitrogen in		Nitrogen from atmosphere
		Manured soil Aug. 23, 1919	Soil Dec. 8, 1924, all crops and drainage		Manured soil Aug. 23, 1919	Soil Dec. 8, 1924, all crops and drainage	
		Grams	Grams	Grams	Grams	Grams	Grams
Alfalfa	None	117.88	128.12	10.24	167.67	187.34	24.73
Grass	None	122.24	115.15	—7.09	166.34	162.61	3.73
		In favor of alfalfa		17.33	——	——	21.00
Alfalfa	1 foot	117.41	141.37	23.96	163.51	202.97	39.46
Grass	1 foot	118.35	113.27	—5.08	161.68	165.71	4.03
		In favor of alfalfa		29.04	——	——	35.43
Alfalfa	3 feet	118.19	158.51	40.32	159.01	204.49	45.48
Grass	3 feet	116.32	125.82	9.50	158.52	168.15	9.63
		In favor of alfalfa		30.82	——	——	35.85
Alfalfa	5 feet	——	——	——	148.20	200.68	52.48
Grass	5 feet	——	——	——	148.20	171.91	23.71
		In favor of alfalfa		——	——	——	28.77

SUMMARY AND CONCLUSIONS

1. Experiments with lysimeter tanks of different depths have been conducted at this Station since 1909. Results from 3 types of soil, Hagerstown loam, Cumberland clay loam, and Memphis silt loam, are reported.

2. The tanks were made of heavy galvanized iron, and were 3.33 ft. in diameter, allowing 1/5000 acre of soil area. The tanks were of 4 depths: 1 foot, 2, 4, and 6 feet. In each case a constant amount of surface soil was used. The amount of subsoil varied from none to 5 feet in depth, depending on the depth of tank.

3. Records were obtained of the yields of 5 crops—oats, wheat, millet, tall oat grass, and alfalfa. The influence of tank depth was more marked in the case of wheat and tall oat grass than of the others. Millet was the least influenced by the depth of subsoil.

4. The influence of tank depth was appreciably less in evidence with the Memphis silt loam than with either of the others. With this

soil the 1-ft. tanks, which contained no subsoil, produced on the average 70.8 per cent as large a crop as the 4-ft. tanks containing the same amount of soil underlaid with 3 feet of subsoil. On the average for the Hagerstown and Cumberland loams 54.3 per cent as large a crop was produced in the 1-ft. tanks as in the 4-ft., 85.5 per cent in the 2-ft., and 126.1 per cent in the 6-ft.

5. In a trial with uncropped soils lasting 3.43 years 50.7 per cent of the rainfall leached through the Cumberland clay loam and 47.3 per cent through the Memphis silt loam.

6. The depth of subsoil had practically no effect on the amount of water leached through the Memphis silt loam. In the case of the Cumberland clay loam nearly the same amounts were leached through the 1-ft., 4-ft., and 6-ft. tanks, but with the 2-ft. tanks only 45.7 per cent of the rainfall leached through, or 87.2 per cent as much as the average for the other depths. This result is attributed to the greater pull exerted by the long columns of subsoil when saturated with water.

7. In the case of the Cumberland clay loam the subsoil not only greatly retarded outgo but prevented full recovery of applied nitrogen. On the basis of 100 per cent for the recovery from the 1-ft. tanks, the calculated total recoveries from the others in the course of 2.43 years from the time of the last application were as follows:

2-ft.	60.4 per cent
4-ft.	34.3 do
6-ft.	47.7 do

8. In the case of the Memphis silt loam the subsoil retarded the outgo of the applied nitrogen to an appreciable extent, but apparently did not prevent total recovery.

9. Charts are presented showing the progressive recovery of the applied nitrogen.

10. An additional series of experiments with the Cumberland clay loam was started in 1921, and continued for 5 years. In this series 6-ft. tanks of small diameter were used. Sodium, calcium, and magnesium nitrates were applied in the beginning, at the rate of 6000 pounds per acre of sodium nitrate, or its equivalent, and the periodic recovery of nitrogen was determined. At the close of the period the total recoveries were as follows:

Sodium nitrate	92.95 per cent
Calcium nitrate	83.08 do
Magnesium nitrate	81.19 do

11. Beginning in 1919, 14 of the large tanks were cropped in

alfalfa and the same number in tall oat grass. Record was kept of the crop nitrogen and the amount that leached during the following 5 years.

12. The alfalfa crops from the Cumberland loam contained 24.39 grams of nitrogen and the Memphis silt loam 20.72 grams. The grass crops removed only 5.34 grams of nitrogen from the Cumberland clay loam and 6.11 grams from the Memphis silt loam.

13. The amount of nitrogen in the drainage water from the alfalfa was much larger than that from the grass tanks; the average from the alfalfa of the Cumberland clay loam being 13.25 grams, and from the grass only 3.63 grams. Similarly 15.85 grams of nitrogen was found in the drainage from the alfalfa tanks of the Memphis silt loam and 6.49 grams from the grass tanks.

14. The falling off in nitrogen outgo from the grass tanks appeared suddenly and was sharply defined, but varied, according to depth of subsoil, from 287 to 1335 days after the crops were planted in the case of the Cumberland clay loam, and from 287 to 359 days in the case of the Memphis silt loam.

15. Total nitrogen determinations were made in the surface soils in 1915, 1919, and 1924.

16. The loss of nitrogen from November, 1915, to August, 1919, from uncropped soils was 10.4 per cent for each kind of soil.

17. Under cropping for 5 years in alfalfa the per cent of soil nitrogen was exactly maintained in the case of the Cumberland clay loam, but there was a loss of 10 per cent in the case of the Memphis silt loam.

18. Under cropping for 5 years in grass the Cumberland clay loam lost 3.1 per cent of its nitrogen and the Memphis silt loam 11.6 per cent.

19. Minor changes were noted in the nitrogen content of the soil as influenced by the presence or absence of subsoil. These changes are supposed to be due to small differences in the moisture content of the soil.

20. Rain and snow brought 0.31 gram of nitrogen per tank, or 3.4 pounds per acre per annum.

21. From the changes in the nitrogen content of the soils, and the amount of nitrogen found in the crops and drainage water, calculations were made of the nitrogen attributable to atmospheric sources.

22. There were indications of nitrogen fixation where the grass was grown, but the amount was small, if any. For the 5-year period the amount of nitrogen attributable to fixation in the case of the alfalfa was 30.26 grams for the Cumberland clay loam and 25.73 grams for the Memphis silt loam. These amounts are equivalent, respectively, to 66.8 and 56.7 pounds of nitrogen per acre per annum.

23. General conclusion: In the study of income and outgo of nitrogen from the surface soil, subsoil interferes to a serious extent by delaying the outgo, which may be so retarded as to be practically unrecoverable.