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A Comparative Study of the Nitrogen Economy of Certain Tennessee Soils

University of Tennessee Agricultural Experiment Station

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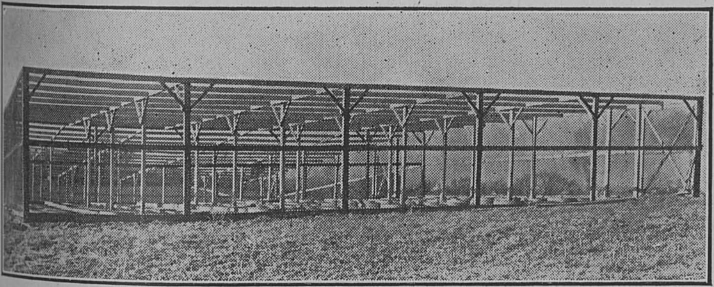
A COMPARATIVE STUDY OF THE NITROGEN ECONOMY OF CERTAIN TENNESSEE SOILS

By
C. A. MOOERS



THE PLANT
CYLINDERS IN SCREENED CAGE

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

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

A COMPARATIVE STUDY OF THE NITROGEN ECONOMY OF CERTAIN TENNESSEE SOILS

INTRODUCTION

The supply of nitrogen in the soil is more or less deficient throughout the State of Tennessee. This deficiency is most marked in the uplands which have been long under cultivation. If only virgin soils be considered a great variation is found, running from those which are rich in nitrogen, and which would remain highly productive for many years when cultivated, to those having only a scant natural supply, which would soon become exhausted so far as profitable crop production is concerned. The depletion of the nitrogen supply of the soil is greatly facilitated by the State's climatic conditions, which are favorable to both nitrification and loss by leaching throughout a large part of the year. In addition, the loss by erosion of cultivated land is severe. The best farmers make good use of the farmyard manure, and attach much importance to clover and other legumes, but according to the writer's observations they are unable, without feeding much cottonseed meal, or the like, to maintain more than a moderate state of fertility, even on naturally rich soils. For the poorer classes of soils the situation is serious, and the seriousness is increased by the fact that not only do crops remove from two to three times the amount of nitrogen as of the much-discussed phosphoric acid, but also that the cost per pound of readily available nitrogen is high—about four times that of phosphoric acid. The result is that under usual conditions very little commercial nitrogenous material can be used profitably for most of the common farm crops. Even in the case of high-priced market garden crops, only a small fraction of the nitrogen required to maintain an adequate soil supply can be profitably used.

As is well known, soil nitrogen can be not only lost in several ways, but also gained in several ways, in particular through bacteriological processes both with and without the intervention of legumes. Nitrogen is therefore prominent as the plant-food element and soil constituent which is most affected by all the conditions which arise in farm practice, such as kind and yield of crop, liming, manuring, soil drainage, tillage, and moisture supply.

There are also excellent reasons for thinking not only that different kinds of soil even under the same climatic conditions differ with regard to the availability of the nitrogen naturally present, but also that nitrogen applied in fertilizers and manures will be utilized better by the crops on one soil than on another.

The main object in undertaking the experiments discussed in this bulletin was to study what has been termed the "nitrogen economy" of the soil. The principal subjects considered are: (1) the comparative utilization of nitrogen by crops on different soils with regard to both the nitrogen naturally present and that supplied by nitrate of soda and farm manure; (2) the losses of both soil and subsoil nitrogen under various conditions, such as cropped and uncropped, limed and unlimed, manured and unmanured; and (3) indications of nitrogen assimilation from the atmosphere independent of legumes. In these experiments, therefore, only non-legumes were grown.

PRELIMINARY CONSIDERATIONS

DESCRIPTION OF SOIL TYPES USED IN THE EXPERIMENTS

As subjects for study, four types of soil were selected. These differ materially in character, but are representative of large areas in the State. Ample quantities were brought to the Station farm at Knoxville to fill 100 cylinders, as described later. These four types are as follows:

The Cookeville Soil. This is a poor, gray-colored sandy loam from the "Barrens" of the Highland Rim of Middle Tennessee.

The Crossville Soil. This is a poor loam of excellent physical make-up, such as is characteristic of the Cumberland Plateau, where it was obtained.

The Gallatin Soil. This is a fertile, brown-colored silt loam, a representative of the rich Central Basin section of Tennessee, but was taken from a field which was considered to be somewhat reduced in fertility.

The Jackson Soil. This is a gray-colored silt loam from West Tennessee, very high in silt, with poor drainage qualities, and considered to be troublesome to handle.

THE CHEMICAL COMPOSITION OF THE SOILS

Chemical analyses of the soils were made according to the methods of the American Association of Official Agricultural Chemists, hydrochloric acid of 1.115 Sp. Gr.* being used.

Judged by generally accepted standards, the Cookeville soil is poor in all the important elements of plant food. The Crossville soil has a considerably higher content of potash and a considerably lower content of calcium oxide than the Cookeville soil, but would be classed with the latter as poor in all the important elements of plant food. The Gallatin soil has a high content of phosporic acid and a good content of both potash and nitrogen. The calcium oxid supply is low when judged by common standards, but is good as compared

*Bu. Chem., U. S. Dept. Agr., Bul. No. 107 (Rev.), pp. 13-20.

with limestone soils of this State. The Jackson soil is low in phosphoric acid and potash, but somewhat better supplied with calcium oxide than even the Gallatin soil. The content of nitrogen is very low, and distinctly lower than that of any other soils.

TABLE I—*The chemical composition of the soils—analyses made by the official method, HCl of 1.115 Sp. Gr. being used. Results on moisture-free basis*

CONSTITUENT	Soil			
	Cookeville	Crossville	Gallatin	Jackson
	Per cent	Per cent	Per cent	Per cent
Insoluble matter and soluble silica	93.150	89.260	84.340	92.460
Potash (K_2O)	0.077	0.138	0.420	0.150
Soda (Na_2O)	0.220	0.270	0.270	0.300
Lime (CaO)	0.093	0.051	0.275	0.330
Magnesia (MgO)	0.105	0.243	0.370	0.244
Manganese oxid (Mn_3O_4)	0.050	0.097	0.265	0.093
Ferric oxid (Fe_2O_3)	0.887	1.740	3.215	0.890
Alumina (Al_2O_3)	2.353	4.290	5.525	3.130
Phosphorus pentoxid (P_2O_5)	0.032	0.035	0.342	0.048
Sulphur trioxid (SO_3)	0.025	0.034	0.075	0.025
Carbon dioxid (CO_2)	0.028	0.046	0.085	0.058
Volatile matter	2.992	3.694	5.015	2.462
Total	100.012	99.898	100.197	100.190
Humus	0.880	0.730	1.520	0.500
Nitrogen (total)	0.0742	0.0784	0.1463	0.0593
Organic carbon	1.135	1.234	1.494	0.590
Acidity by Veitch method	0.099	0.182	0.205	Alkaline

As judged by the Veitch test the Cookeville, Crossville, and Gallatin soils were acid and the Jackson soil was slightly alkaline.

PHYSICAL CHARACTERISTICS OF THE SOILS

Mechanical analyses were made of the several soils by the method of the Bureau of Soils.* These analyses, as given in Table II, do not, however, give a good indication of the comparative textures of the soils. According to the analyses, there is considerable similarity between the Cookeville and Crossville soils. Marked differences, however, exist between them. The Cookeville soil puddles readily when wet, so that drainage is greatly retarded, and the soil heaves little

*Bu. Soils, U. S. Dept. Agr., Bul. No. 24.

during the cold months. The Crossville soil, on the other hand, is open and porous and heaves badly during the winter. The Gallatin soil, like the Crossville, heaves badly in the winter. It is darker-colored and "heavier" than the Crossville soil, and, like the latter, drains well. The Jackson soil rather closely resembles, in its physical properties, the Cookeville soil, but it drains less readily, especially when uncropped, due, evidently, to its very high content of silt.

TABLE II—*Mechanical analyses of the soils*

SOIL	Fine gravel 2-1 mm	Coarse sand 1-.5 mm	Medium sand .5-.25 mm	Fine sand .25-.1 mm	Very fine sand .1-.05 mm	Silt .05-.005 mm	Clay .005-0 mm
Cookeville	1.37	2.72	3.32	21.98	20.75	43.40	6.46
Crossville	0.75	2.24	2.85	19.02	16.57	46.38	12.19
Gallatin	1.54	2.03	1.32	2.79	9.92	65.59	16.81
Jackson	0.14	2.30	2.53	2.76	4.22	79.06	8.97

SIZE OF CYLINDERS, AMOUNTS OF SOIL USED, ETC.

The four soils described, together with their subsoils to a depth of 4 feet, were brought, in 1908, to the Experiment Station farm at Knoxville in sufficient quantity to fill 100 cylinders, each 4 feet deep and 2.225 feet in diameter. The exposed, or surface, area of soil in each cylinder was, therefore, 1/10,000 acre. Each lot of soil had been kept to itself and the corresponding subsoil had been removed in layers, as determined by color, so that they might be placed in the cylinders in the order in which they occurred in the field. The changes in color were sufficient to enable the line of demarcation between any two layers to be distinguished with little difficulty. The depth of the surface soil used for each type varied with the degree of compaction, but was in the neighborhood of from 5 to 6 inches. The weights of the water-free fine earth (particles not over .5 mm in diameter) of (1) the surface soil and (2) the first 6 inches of subsoil per cylinder were as follows:

	Soil Grams	Subsoil Grams
Cookeville soil	52,753	75,000
Crossville soil	53,343	75,000
Gallatin soil	51,982	65,000
Jackson soil	50,757	73,000

CLIMATIC CONDITIONS

From September 1, 1909, to September 1, 1914, practically the five-year period of the experiments, the daily mean temperature and the average rainfall per season were, according to the U. S. Weather Bureau observations, as follows:

	Mean temperature	Rainfall
	Degrees F.	Inches
Spring	57	13.92
Summer	75	12.39
Fall	58	9.03
Winter	39	11.04

Lysimeter experiments at the Station farm, with cans 4 feet deep and 1/5,000 acre in surface area, from which both a crop of wheat and a crop of millet were harvested each year, gave the data of Table III for the two-year period, November 1, 1912, to November 1, 1914.

TABLE III—*Results of lysimeter experiments for two-year period Nov. 1, 1912, to Nov. 1, 1914*

SOIL	Liters of precipitation	Water leached through soil	
		Liters	Per cent
Cookeville	1685.8	726.9	43.12
Crossville	1685.8	857.4	50.86
Gallatin	1685.8	716.4	42.50

The data indicate the heavy leaching which cropped soils undergo.

MANURIAL TREATMENTS

Figure 1 shows the numbering and arrangement of the cylinders, and Table V gives the manurial treatment of each cylinder for the five years, 1909 to 1914, inclusive. The ground limestone contained no particles larger than 2 mm in diameter and analyzed 90.46 per cent of carbonates, less than one per cent of which was magnesium carbonate. The farmyard manure was freed from straw as far as practicable, thoroughly air-dried, ground to pass through a 2-mm sieve, and thoroughly mixed before being weighed out for the cylinders. Each application of 300 grams was mixed throughout the surface 5 inches of soil, about one inch of soil next to the subsoil being left as an absorbent layer. The straw was cut into pieces about one inch in length previous to application. The acid phosphate was of a standard make, analyzing about 16 per cent of available P_2O_5. Commercial muriate of potash, analyzing about 50 per cent K_2O, was used.

All the materials were carefully worked into the surface soil previous to a planting, except the nitrate of soda, which was applied as a surface dressing to the cereal crop in early spring, generally about the middle of March.

The composition of nitrogenous materials and the total amount of nitrogen furnished by each for the five-year period are given in Table IV.

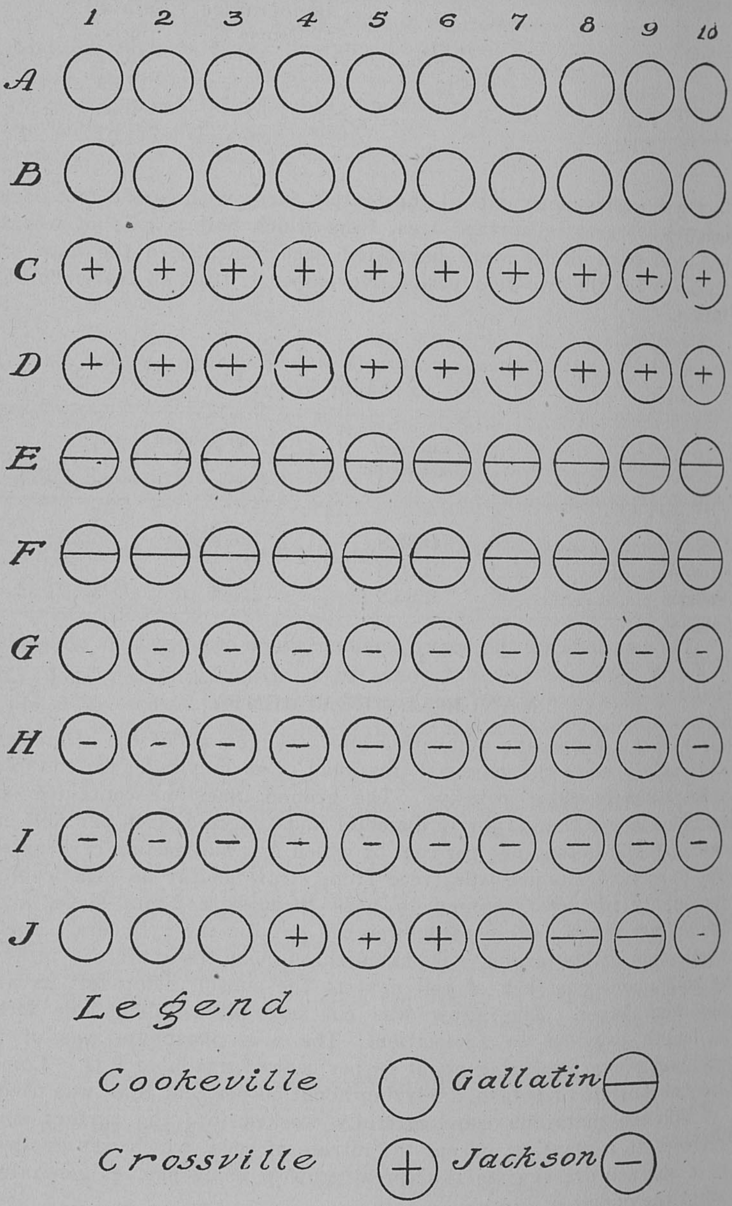

FIG. 1—ARRANGEMENT OF CYLINDERS IN FIELD

TABLE IV—*Composition of nitrogenous materials and nitrogen furnished by each material in the five-year period*

MATERIAL	Nitrogen content (air-dry substance)	Nitrogen furnished per cylinder
	Per cent	Grams
Nitrate of soda	16.080	5.8370
Manure—		
(1) 1909	1.490	4.4700
(2) 1911	1.840	5.5200
Straw—		
(1) 1909	0.530	0.9616
(2) 1911	0.404	0.7330

SYMBOLS

For the sake of brevity the following symbols are used in Table V and others which follow:

L—An application of 181.44 grams of ground limestone per cylinder, equivalent to 2 tons per acre. This application was made only once, and at the outset of the experiments, to each cylinder where indicated.

F—An application of 300 grams of air-dried farmyard manure, practically free from straw and equivalent to about 12 tons of fresh manure per acre. This amount was applied in 1909 and again in 1911, after the removal of the fourth crop.

S—An application of 181.44 grams of chopped straw per cylinder, or at the rate of 2 tons per acre. This application was made at the outset and was repeated in 1911 as for the manure.

N—An annual application of 7.26 grams of nitrate of soda, or at the rate of about 160 pounds per acre.

PK—An annual application of 13.60 grams of acid phosphate and 4.54 grams of muriate of potash per cylinder, or 300 pounds and 100 pounds per acre, respectively.

THE CROPS GROWN

Two crops were harvested each year on the cropped cylinders, as follows:

1910—Oats, German millet
1911—Wheat, German millet
1912—Wheat, German millet
1913—Wheat, German millet
1914—Wheat, German millet

The uncropped cylinders were kept clean of weeds or bare throughout the five years, but received the same tillage as the cropped.

TABLE V—*List of experiments and manurial treatment of cylinders*

Exp. No.	Treatment	Cylinders to which applied	Cropping
1	L	A1, C1, E1, G1	Cropped
2	F	A2, C2, E2, G2	Cropped
3	LF	A3, C3, E3, G3	Cropped
4	O	A4, C4, E4, G4	Cropped
5	LFS	A5, C5, E5, G5	Cropped
6	LFSPK	A6, C6, E6, G6	Cropped
7	PK	A7, C7, E7, G7	Cropped
8	LPK	A8, C8, E8, G8	Cropped
9	PKN	A9, C9, E9, G9	Cropped
10	LPKN	A10, C10, E10, G10	Cropped
11	SPK	B1, D1, F1, H1	Cropped
12	LSPK	B2, D2, F2, H2	Cropped
13	SPKN	B3, D3, F3, H3	Cropped
14	LSPKN	B4, D4, F4, H4	Cropped
15	S	B5, D5, F5, H5	Cropped
16	LS	B6, D6, F6, H6	Cropped
17	LFSPKN	B7, D7, F7, H7	Cropped
18	LPK	B8, D8, F8, H8	Uncropped
19	LFPK	B9, D9, F9, H9	Uncropped
20	LSPK	B10, D10, F10, H10	Uncropped
21	LFSPK	J1, 4, 7, 10	Uncropped
22	LPKN	J2, 5, 8, and I9	Uncropped
23	LSPKN	J3, 6, 9, and I10	Uncropped
24	O	I1	Uncropped
25	L	I2	Uncropped
26	PK	I3	Uncropped
27	FSPK	I4	Uncropped
28	FS	I5	Uncropped
29	LFS	I6	Uncropped
30	FeFS	I8	Uncropped

OTHER CONDITIONS AFFECTING THE CROP YIELDS

Seventeen cylinders for each kind of soil were planted annually to the crops mentioned. No artificial watering was given, and the cylinders were fully exposed to the weather the year round. When practically matured, the crops were harvested, placed in paper bags, and thoroughly air-dried in the laboratory, so that the moisture content, as found by a number of determinations, was very nearly 10 per cent. The crops were then weighed, ground and analyzed for nitrogen.

Since there is the possibility of a stimulating action on crop production at the outset, due to the aeration, etc., of the soils in handling, emphasis may be placed on the facts that the subsoils were placed in 1908, about a year and a half previous to the cropping here recorded, and that the surface soils used in 1908 and 1909 were replaced by fresh lots in the early fall of 1909. The first crop, oats, was planted in March, 1910. There was therefore an interval of about six months between the placing of the surface soils and the planting of the oats, during which there were heavy, leaching rains, which would be expected to carry away any abnormal accumulation of nitrates. Also neither the soils nor the subsoils were dried out at any time previous to placement beyond a moisture content of from 12 to 15 per cent, or such as is common in the field.

CROP RESULTS

YIELDS AND AMOUNTS OF NITROGEN REMOVED

Table VI (see Appendix) gives the yields of both air-dry substance and nitrogen obtained from each cylinder. This table shows that only

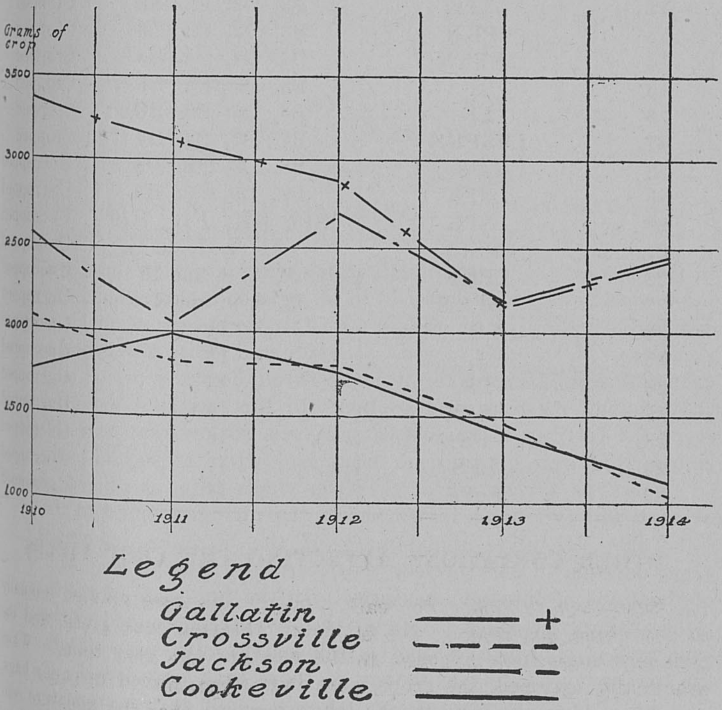

FIG. 2—CROP YIELDS OF EACH OF THE FOUR SOIL TYPES—AVERAGE YIELDS OF LIMED CYLINDERS ONLY

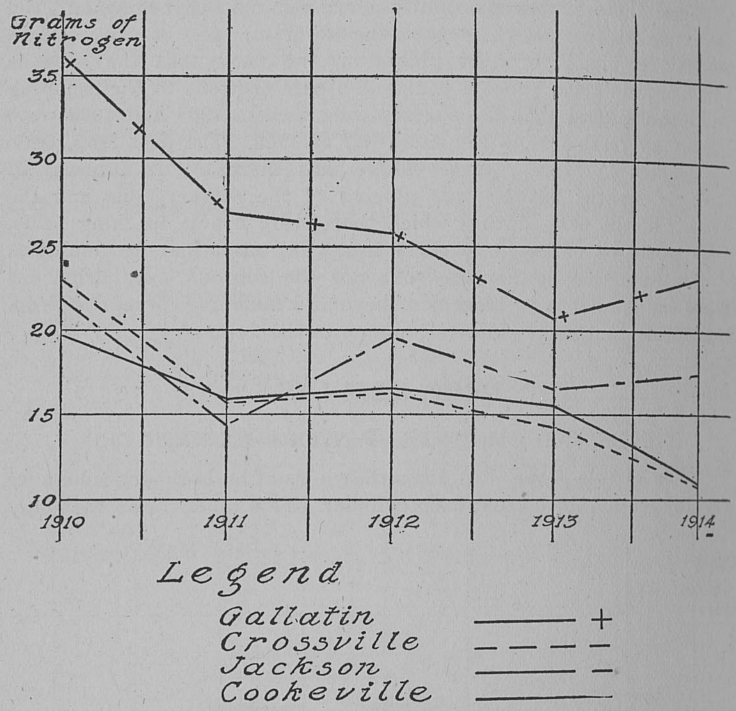

FIG. 3—NITROGEN FOUND IN CROPS FROM EACH OF THE FOUR SOIL TYPES —AVERAGE RESULTS FROM THE LIMED CYLINDERS ONLY

in the case of the Jackson soil, which was naturally slightly alkaline, were consistent yields obtained in all cylinders throughout the period. The Gallatin soil comes second, with fair regularity of yields for most cylinders. In the case of the Cookeville and Crossville cylinders, however, unbroken yields were obtained throughout the period only where the ground limestone was applied. In fact, without manurial treatment the fertility of these two soils was so low that scarcely appreciable crops were obtained on either soil after the second year.

Fig. 2 is a diagram of the crop yields from the limed cylinders of each soil type, and Fig. 3 shows the nitrogen found in the crops.

Table VII gives a summary of the nitrogen removed by the crops in each of two periods as determined by the first and second applications of manure and straw. In the first half of the table the total nitrogen removed by all of the seventeen cropped cylinders for each soil is shown, and this is followed by a similar statement for the ten best-producing cylinders, or those that were limed.

Fig. 4 is a diagram of the nitrogen found in the crops from the limed cylinders of each soil type for each of the two periods mentioned.

TABLE VII—*Summary of nitrogen removed by crops in each of two periods*

SOIL	Nitrogen removed by crops in period 1909-1911	Nitrogen removed by crops in period 1911-1914, or after second manure and straw treatment	Gain (+) or loss (—) of nitrogen in three-year as compared with two-year period
1. All cropped cylinders—17 for each soil			
	Grams	Grams	Grams
Cookeville	53.7518	43.7168	—10.0350
Crossville	52.2290	43.3868	— 8.8422
Gallatin	100.8784	96.2351	— 4.6433
Jackson	58.8274	80.8399	+22.0125
2. The ten limed cylinders for each soil			
Cookeville	37.4945	40.3167	+ 2.8222
Crossville	38.7757	41.2112	+ 2.4355
Gallatin	64.0098	68.3251	+ 4.3153
Jackson	36.3485	53.0711	+16.7226

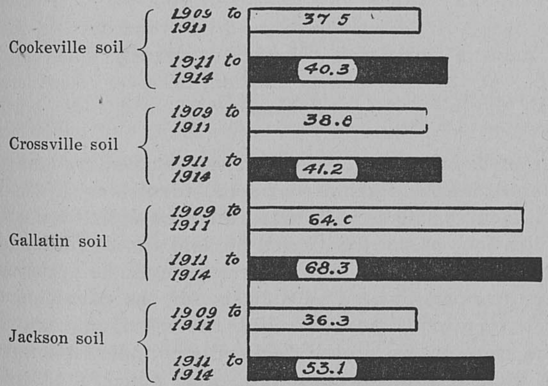

FIG. 4—GRAMS OF NITROGEN REMOVED BY CROPS FROM THE LIMED CYLINDERS IN EACH OF TWO PERIODS

From the data of the seventeen cylinders it may be seen that less nitrogen was removed by the crops in the last three years, or after the second application of manure and straw, than in the first two years for each of the three soils, Cookeville, Crossville, and Gallatin. In the case of the Jackson soil, however, there was an increase of nearly 37 per cent. If the limed, or ten highest-yielding, cylinders

be compared, the differences between the soils are somewhat reduced. In round numbers there were removed in the crops of the first two years 37 grams of nitrogen from the Cookeville cylinders, 39 grams from the Crossville, 64 grams from the Gallatin, and only 36 grams from the Jackson cylinders. In the next three years there were removed from the same cylinders 40 grams of nitrogen from the Cookeville, 41 grams from the Crossville, 68 grams from the Gallatin, and 53 grams from the Jackson cylinders. The Jackson soil, therefore, ranked fourth in nitrogen production for the first two years, yielding only 56 per cent as much as the rich Gallatin soil and 95 per cent as much as the average of the Cookeville and Crossville soils, but ranked second in the succeeding three years, yielding 78 per cent as much as the Gallatin soil and 30 per cent more than the average of the Cookeville and Crossville soils. These results show the decidedly superior capacity of the Jackson soil to maintain the supply of available nitrogen.

RECOVERY OF NITROGEN FROM NITRATE OF SODA

Nitrate of soda furnishes nitrogen in a most available form for plants. The ready solubility of this salt leads to the conclusion that it would be more readily leached from one soil than another. On the other hand, the nitrate might be broken down and converted by microorganisms into organic forms, and so be retained longer in one soil than in another. In fact, there are several reasons for expecting that the availability would vary with different soils. Determinations of the percentage of nitrogen recovered by crops dressed with nitrate have been made at numerous places, but usually with only a single type of soil. At the New Jersey Station, however, considerable work of this kind has been done in comparative study of eight different soils.*

Five cropped cylinders in every series received annually, in early spring, a top-dressing of nitrate of soda, furnishing 1.1674 grams of nitrogen to each cylinder. All these nitrated cylinders had received annual applications of phosphate and potash, and the other treatments as indicated in Table V. Similarly treated cylinders, but unnitrated, are used for comparison and as a basis for the usual calculation of the nitrogen recovery. For example, the nitrogen removed in five years by the crops grown on the Cookeville cylinder, A8, which received ground limestone, acid phosphate, and muriate of potash, was 5.9994 grams. The crops from A10, which received ground limestone, acid phosphate, and muriate of potash in the same amount as A8, but was nitrated each year in addition, yielded 8.7653 grams of nitrogen. The difference between these two amounts, 2.7659 grams, is assumed to come from the nitrate, and is 47.38 per cent of the total nitrogen contained in the nitrate of soda applied. Table VIII gives the calcu-

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*N. J. Exp. Sta. Bul. 289, Cylinder Experiments Relative to the Utilization and Accumulation of Nitrogen, by Jacob G. Lipman and A. W. Blair. See also Report of the Soil Chemist and Bacteriologist of the N. J. Sta., by Jacob G. Lipman and Augustine W. Blair, for the year 1914.

lated percentage recovery for all four soils under various experimental conditions.

TABLE VIII—*Recovery of nitrogen from nitrate of soda—comparative data for five-year period*

SOIL	LPK vs. LPKN Per cent recovery	LSPK vs. LSPKN Per cent recovery	LSFPK vs. LSFPKN Per cent recovery	PK vs. PKN Per cent recovery	SPK vs. SPKN Per cent recovery	Average per cent recovery
Cookeville	47.38	44.97	43.80	--------	--------	45.38
Crossville	*55.29	46.78	59.05	--------	--------	53.71
Gallatin	--------	92.56	†88.45	91.38	75.93	87.08
Jackson	70.94	65.19	--------	74.29	78.40	72.21

*Last four years only.
†Last three years only.

DISCUSSION OF THE RESULTS

In the case of both the Cookeville and the Crossville soil the limed cylinders were the only ones to produce crops throughout the five-year period, so that the data from the others must be considered of little or no value so far as the present object is concerned. The data from the Gallatin soil varied considerably, but the four results given in the table are considered to be the best index for this soil, the crops on which, from every point of view, appear to have been able to take up more of the nitrate nitrogen than was the case for any other soil. One estimation was also omitted for the Jackson soil because considerably out of harmony with the other four results. Inspection of the average per cent of recovery obtained, as outlined, shows a wide variation among the different soils. The Gallatin soil easily comes first, with a recovery of 87.00 per cent; the Jackson soil is second, with an average recovery of 72.21 per cent; the Crossville soil ranks third, with a recovery of 53.71 per cent; and the Cookeville soil comes last, with a recovery of only 45.38 per cent.

There seems to be little correlation between these results and the physical nature of the soil. The Gallatin soil is of excellent texture and structure, but so is the Crossville, which ranks next to the lowest in nitrogen recovery. The Jackson soil, which easily ranks second in recovery, is considered to have decidedly the poorest texture of all the soils, but resembles in this particular the Cookeville soil more than any other. The latter, however, gave the lowest recovery, which was only a little more than half that of the Gallatin soil, and not two-thirds that of the Jackson soil. The only important correlating factor noticeable to the writer is crop yield; that is, the percentage of nitrogen recovery is in harmony with the natural productiveness of the soils, being greatest for the fertile Gallatin soil and least for the very poor Cookeville soil. It should be borne in mind, however, that all four soils proved to be in considerable need of available nitrogen. Of course with an excessive supply naturally present in the Gallatin

soil, for example, other and even opposite conclusions would be expected, as was found by Lipman and Blair* in the case of rich garden soil so abundantly supplied with nitrogen as to give the lowest response to the applications of nitrate.

RECOVERY OF ORGANIC NITROGEN

The availability of the nitrogen of farm manures applied to the soil is very different from that of nitrate of soda. The latter is ready for immediate use by plants and, as just indicated, seems to be taken up most nearly completely where there is the greatest mass of roots to come into contact with the salt as it is carried through the soil in water solution. On the other hand, insoluble organic nitrogen must undergo a complete change, and for the most part is probably converted into the nitrate form before being taken up by plants. The conversion, due almost entirely to bacteria, which are dependent, among other things, on a good supply of air, goes on slowly in farm manures, and this accounts for their reputation for "lasting" effects. For several reasons, such as variation in air and moisture supplies, different soils would be expected to show in the crop returns different percentages of recovery of the organic nitrogen applied.

Five cylinders in each series received manure, one application at the outset, in 1909, and another in 1911, at the close of the second year. To three of each set of five, an application of straw was made along with the manure; or these three may be said to have received applications of "strawy" manure. Since the Cookeville and Crossville soils produced crops regularly throughout the five-year period only where limed, the cylinders which received manure without lime are omitted from the calculations for all four soils. There are left, then, for each kind of soil four cylinders which are suitable to the purpose. Since there were corresponding cylinders similarly treated, except that neither straw nor manure was used, the percentage recovery of the organic nitrogen can be calculated as in the case of the nitrate nitrogen. Table IX gives the data thus obtained.

TABLE IX—*Recovery of organic nitrogen—comparative data for five-year period*

SOIL	L vs. LF Per cent recovery	L vs. LSF Per cent recovery	LPK vs. LSFPK Per cent recovery	LPKN vs. LSFPKN Per cent recovery	Average per cent recovery
Cookeville	34.13	34.18	26.12	24.84	29.82
Crossville	41.92	37.78	32.58	25.81	34.52
Gallatin	50.83	38.36	29.88	31.25	37.58
Jackson	19.34	20.94	22.06	33.18	23.88

*N. J. Exp. Sta. Bul. 289.

DISCUSSION OF RESULTS

Table IX shows that the soils differed widely with respect to their influence upon the recovery of organic nitrogen. The Gallatin soil gave the highest recovery, 37.58 per cent; the Crossville soil is a close second, with a recovery of 34.52 per cent; the Cookeville soil ranks third, with a recovery of 29.82 per cent; and the Jackson soil comes last, with a recovery of only 23.88 per cent. It is worthy of note that the soils which were most alike in physical condition gave similar recoveries, the open and porous Gallatin and Crossville soils ranking highest on the one hand, and the close, silty Jackson and Cookeville soils ranking lowest on the other.

Fig. 5 shows the comparative recoveries of both the organic and the inorganic nitrogen applied to each soil type.

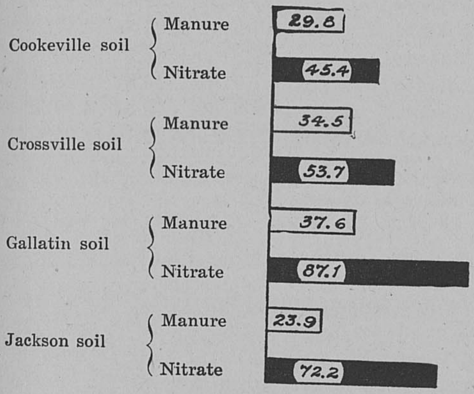

FIG. 5—PERCENTAGE RECOVERY OF ORGANIC AND INORGANIC NITROGEN IN FIVE-YEAR PERIOD

THE RATIO BETWEEN CROP NITROGEN AND CROP YIELD

The ratio between the nitrogen content of the crops and the total yield of dry substance proved of interest because, as shown in

TABLE X—*Utilization of nitrogen by crops grown on different soils—comparative data for five-year period from the ten limed cylinders of each type*

SOIL	Crop yield (air-dry substance)	Nitrogen in crops	Air-dry crop per gram of nitrogen	Dry substance per gram of nitrogen
	Grams	Grams	Grams	Grams
Cookeville	7926.99	77.8112	101.88	91.69
Crossville	8221.02	79.9869	102.78	92.50
Gallatin	13990.28	132.3349	105.72	95.15
Jackson	11922.78	89.4196	133.34	120.01

TABLE XI—*Utilization of nitrogen from (1) manure and (2) nitrate of soda—comparative data for five-year period*

SOIL	Fertilizer source of nitrogen	Nitrogen applied	Air-dry crop increase	Nitrogen increase	Nitrogen recovery	Calculated increase of dry substance per gram of nitrogen utilized
		Grams	Grams	Grams	Per cent	Grams
Cookeville	Manure*	29.9700	1126.29	9.8746	32.95	102.65
Cookeville	Nitrate of soda†	17.5110	812.60	7.9479	45.39	92.02
Crossville	Manure*	29.9700	1269.74	10.6259	35.45	107.54
Crossville	Nitrate of soda†	17.5110	1122.85	10.4167	59.49	97.01
Gallatin	Manure*	29.9700	1389.21	12.0049	40.05	104.15
Gallatin	Nitrate of soda‡	21.0132	1840.47	18.2664	86.93	90.68
Jackson	Manure*	29.9700	672.54	4.9763	16.61	121.63
Jackson	Nitrate of soda§	23.3480	2429.19	16.8585	72.21	129.68

*Experiment Nos. 1, 16, 12, and 3, 5, 6.

†Experiment Nos. 6, 8, 12, and 17, 10, 14.

‡Experiment Nos. 6, 7, 11, 12, and 17, 9, 13, 14, but only last three years of 6 and 17.

§Experiment Nos. 7, 8, 11, 12, and 9, 10, 13, and 14.

Table X, the Jackson soil produced nearly a third more crop per gram of nitrogen utilized than did the other kinds of soil. The average for the Cookeville, Crossville, and Gallatin soils is only 93.11 grams of dry crop per gram of nitrogen, while for the Jackson soil there were produced 120.01 grams of dry crop per gram of nitrogen.

In Table XI is shown the calculated dry matter per gram of nitrogen utilized from both nitrate of soda and manure for each type. The figures show, on the average, for the Cookeville, Crossville, and Gallatin soils that one gram of nitrogen utilized from nitrate of soda produced 93.24 grams of dry substance, and that one gram of nitrogen utilized from the manure produced 104.78 grams of dry substance. In the case of the Jackson soil, however, one gram of utilized nitrogen from nitrate of soda produced 129.68 grams of dry substance, and one gram of nitrogen utilized from manure produced a gain of 121.63 grams of dry substance.

The grain and straw of the wheat crops grown in both 1912 and 1913 were analyzed separately, and Table XII gives the nitrogen content of these parts for each type of soil. Also there is given the average nitrogen content of the whole wheat crop for the four years grown and of the millet hay for five years. From these data it is evident that both the grain and the straw of the wheat crops from the Jackson soil are appreciably and consistently lower in nitrogen than the same products from any of the other three soils. Similarly the nitrogen content of the millet hay is consistently the lowest for the

Jackson soil. The close accord of the results for the Crookeville, Crossville, and Gallatin soils is noticeable. All the data show that the Jackson soil is quite different from the others; and the conclusion is drawn that the nature of the soil may have an important effect on the composition of the crop. However, in view of the results obtained by others,* as well as the close agreement in the composition of the crops from three of the four soils investigated here, it is evident that the Jackson soil is exceptional in this respect.

TABLE XII—*Nitrogen content of wheat and millet crops when grown on different soils—data from air-dry crops grown in experiments Nos. 3, 5, 6, 8, 10, 12, 14, and 17*

SOIL	Wheat				Wheat—whole crop—four year averages	Millet hay—five year averages
	Harvest of 1912		Harvest of 1913			
	Grain	Straw	Grain	Straw		
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Cookeville	1.81	0.34	2.13	0.54	0.958	1.034
Crossville	1.82	0.42	2.05	0.51	0.996	0.951
Gallatin	1.82	0.31	2.07	0.44	0.949	0.894
Jackson	1.59	0.21	1.93	0.34	0.782	0.744

SOIL NITROGEN RESULTS

CONSIDERATIONS LEADING TO THE ANALYTICAL DATA

At the outset of the experiments both surface-soil and subsoil samples, the latter at different depths, were taken from each type for analysis. The subsoils were laid down in 1908 and the samples were taken at that time. The surface-soil samples were taken in 1909, previous to the manurial treatment, and, as in the case of the subsoil, each was supposed to represent the average of the mixture for that type. A better plan of procedure would have been to analyze for nitrogen the soil of each cylinder separately, and so avoid errors which can easily follow from a single sampling and analysis. For this reason the writer can not lay the stress he would like to on the absolute results which might be calculated from the early sampling, but he wishes to emphasize in particular only such conclusions as can be brought out by comparative data.

In 1911, previous to the second application of manure and straw, surface-soil samples were taken from each cylinder. In 1914, after the harvest of the millet crop, samples were taken not only from the surface soil of each cylinder, but also from the subsoil at both the

*See "Environmental Influence on the Physical and Chemical Characteristics of Wheat," by J. A. LeClerc and P. A. Yoder, Jour. of Agr. Research, Vol. 1, No. 4, pp. 275-291. Their results "emphasize the relatively small role played by the soil in influencing the protein content of wheat." A similar conclusion was also reached by Lipman and Blair, N. J. Sta. Bul. 289, p. 45.

6-to-12-inch depth (first six inches of subsoil) and the 12-to-24-inch depth, with the exception of the estimations summarized in Table XVII for the 12-to-24-inch depth. All the nitrogen estimations calculated to a moisture-free basis are given in Tables XIII and XIV (see Appendix). These estimations were made with special care by the Kjeldahl method as modified by Gunning. Ten-gram samples were always used, and pains were taken to insure throughout the period the same actual strength of standard acid used as a basis for the titrations. Owing, however, to errors, apparently unavoidable in both sampling and analysis—errors which are appreciable where an effort is made to determine the nitrogen to the fourth decimal—too much value can easily be put upon a single result. It is, therefore, important to draw conclusions only where the results from several cylinders can be averaged; in fact, the larger the number the better.

THE LOSS OF NITROGEN FROM THE SURFACE SOIL UNDER VARIOUS CONDITIONS

In Table XV is given the nitrogen found in each type of soil under several different conditions, which will be considered as follows:

1. CROPPING VERSUS BARE FALLOW

In this comparison there are for each of the four types of soil five cropped cylinders which received the same manurial treatment as five of the bare-fallow cylinders. The results given in Table XV show that without exception the soils lost decidedly more nitrogen under bare fallow than where the two crops, a small grain and millet, were removed each year. The losses under bare fallow varied from about one and one-half times the loss under cropping for the Gallatin soil to about six times for the Crossville soil.

In reviewing the investigations at Rothamsted, Dyer called particular attention to the correlation between increased crop production and increase in nitrogen content of the soil, but attributed the increase solely to the increase in crop residues.* This explanation will account for only a part, perhaps one-third, of the nitrogen found to be conserved in the cylinder experiments. An additional reason for this result is, therefore, suggested, as follows: Under cropping the average moisture content of the soils was observed to be considerably less than where no crops were grown. The higher moisture content of the uncropped cylinders results in a longer period favorable to nitrification, and consequently increased total production. Furthermore, with a higher moisture content less rain would be required to produce leaching. There would, therefore, not only be more nitrate produced, but a greater chance for loss by leaching under bare fallow than under cropping.

Figure 6 shows the comparative losses of soil nitrogen suffered by each type of soil in the five-year period under both cropped and uncropped conditions.

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*Bernard Dyer, Results of Investigations on Rothamsted Soils, Office of Exp. Stas. Bul. 106, p. 48.

TABLE XV—*Loss of nitrogen from the surface soil under various conditions—all cropped except Series B*

SOIL	Per cent nitrogen 1909*	Per cent nitrogen 1914	Loss in grams per cylinder for five-year period
A. Cropped. Experiment Nos. 6, 8, 10, 12, and 14. Treatments comparable to those in Series B			
Cookeville	0.0799	0.0759	2.1108
Crossville	0.0841	0.0819	1.1735
Gallatin	0.1521	0.1282	12.4268
Jackson	0.0652	0.0660	+ 0.4060
Average	0.0953	0.0880	3.8263
B. Uncropped. Experiment Nos. 18, 20, 21, 22, and 23. Treatments comparable to those in Series A			
Cookeville	0.0799	0.0671	6.7547
Crossville	0.0841	0.0725	6.1873
Gallatin	0.1521	0.1171	18.1983
Jackson	0.0652	0.0569	4.2118
Average	0.0953	0.0784	8.8380
C. Phosphate and potash applied. Experiment Nos. 6, 7, 8, 11, and 12. Treatments comparable to those in Series D			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0813	1.4936
Gallatin	0.1521	0.1270	13.0474
Jackson	0.0652	0.0641	0.5583
Average	0.0953	0.0870	4.3683
D. Neither phosphate nor potash applied. Experiment Nos. 1, 4. 5, 15, and 16. Treatments comparable to those in Series C			
Cookeville	0.0799	0.0745	2.8487
Crossville	0.0841	0.0827	0.7468
Gallatin	0.1521	0.1265	13.3074
Jackson	0.0652	0.0639	.6598
Average	0.0953	0.0869	4.3907

*Nitrogen applied in manure and straw in 1909 and 1911 included.

TABLE XV (*Continued*)

SOIL	Per cent nitrogen		Loss in grams per cylinder for five-year period
	1909*	1914	
E. Limed. Experiment Nos. 1, 3, 8, 10, 12, 14, and 16. Treatments comparable to those in Series F			
Cookeville	0.0784	0.0729	2.9024
Crossville	0.0826	0.0819	0.3734
Gallatin	0.1506	0.1282	11.6469
Jackson	0.0637	0.0660	+ 1.1671
Average	0.0938	0.0873	3.4389
F. Unlimed. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those in Series E			
Cookeville	0.0784	0.0736	2.5330
Crossville	0.0826	0.0816	0.5334
Gallatin	0.1506	0.1253	13.1547
Jackson	0.0637	0.0605	1.1164
Average	0.0938	0.0853	4.3344
G. Nitrated. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those in Series H			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0821	1.0669
Gallatin	0.1521	0.1273	12.8915
Jackson	0.0652	0.0660	+ 0.4061
Average	0.0953	0.0877	3.9816
H. Unnitrated. Experiment Nos. 6, 7, 8, 11, and 12. Treatments comparable to those in Series G			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0813	1.4936
Gallatin	0.1521	0.1270	13.0474
Jackson	0.0652	0.0641	0.5583
Average	0.0953	0.0870	4.3683

*Nitrogen applied in manure and straw in 1909 and 1911 included.

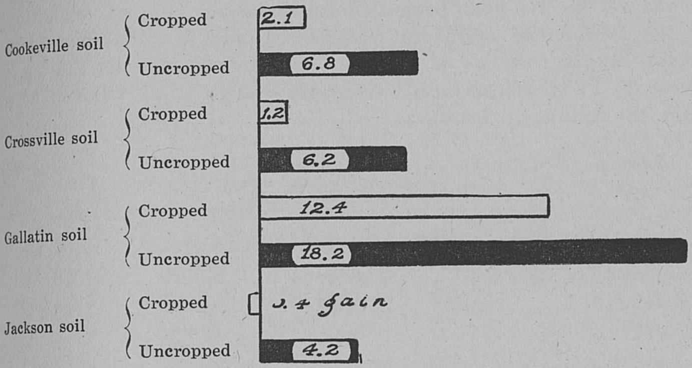

FIG. 6—LOSSES OF NITROGEN FROM SURFACE SOIL IN GRAMS PER CYLINDER IN FIVE-YEAR PERIOD UNDER BOTH CROPPED AND UNCROPPED CONDITIONS

2. THE EFFECT OF ACID PHOSPHATE AND MURIATE OF POTASH

The complaint is sometimes made by farmers that commercial fertilizers have a "burning" effect on the soil, much as lime is said to have. Complete experiments to test this possibility, so far as acid phosphate and muriate of potash are concerned, would include a series without crops, but unfortunately this was omitted from the plans.

An annual application of both acid phosphate and muriate of potash was made to five cropped cylinders (Exp. Nos. 6, 7, 8, 11, and 12) for each type of soil. Five other cylinders (Exp. Nos. 1, 4, 5, 15, and 16) received none, but otherwise the treatments were the same as for those receiving the phosphate and potash. For both the Cookeville and the Crossville soil this mixture produced an increased yield of nearly 25 per cent, but for the Gallatin soil the increase was only 5 per cent, while no increase is noted for the Jackson soil.

The results show that under cropping the nitrogen content of the soils treated with phosphate and potash was at the end of the five-year period practically the same, on the average, as that of the untreated soils.

3. THE EFFECT OF GROUND LIMESTONE

Liming is generally considered to accelerate oxidation, including nitrification, in the soil. Conclusive data with regard to the extent of this action are, however, not abundant. In order to eliminate the crop factor, experiments without cropping are necessary. Unfortunately only in the case of the Jackson soil are there uncropped cylinders furnishing this kind of comparison. These are Experiment Nos. 18, 21, 25, and 29, which included the application of ground limestone, and Nos. 24, 26, 27, and 28, without the application. At

the end of the five-year period the average per cent of soil nitrogen for the four limed cylinders was 0.0600, and for the four unlimed 0.0587. Another series of open-air experiments at this Station, experiments in which no crops were grown, gave, at the end of two years, the following results:

SERIES	CaO applied per acre in form of ground limestone	Total nitrogen Per cent
1	2 tons	.1127
2	8 tons	.1076
3	None	.1135

The soil used was a Cumberland loam from the Station farm at Knoxville. Each series gives the average result from four cylinders each of 1-10,000 acre surface area. The data obtained from both the Jackson soil and the Cumberland loam agree, therefore, in indicating that where no crop is grown, ground limestone produces a small but measurable decrease in soil nitrogen.

As given in Table XV, under cropping three of the four soils at the end of the five-year period show an increase of soil nitrogen where the ground limestone was applied, the average per cent of nitrogen for the four soils being 0.0873 for the limed as compared with 0.0853 for the unlimed. In short, the slight loss of soil nitrogen induced by the ground limestone per se was more than offset by the conservation brought about by increased crop production.

4. THE EFFECT OF NITRATE OF SODA

To determine the effect of nitrate of soda per se on the content of soil nitrogen, Experiment Nos. 22 and 23 (see Table V), which received an annual top-dressing of nitrate, can be compared with Nos. 18 and 20, which received none. There are, therefore, eight nitrated and uncropped cylinders, two for each kind of soil, which can be compared with eight others that were unnitrated. At the end of the five-year period, the average nitrogen content of the eight nitrated cylinders was 0.0773 per cent and of the eight unnitrated 0.0762 per cent. The results show, therefore, a loss of soil nitrogen attributable to the applications of the nitrate.

In the summary of the results obtained under cropping, none of the soils shows less nitrogen, on the average, where nitrated than where unnitrated, but the difference is small, only 0.0007 per cent, on the average, for the four types. This difference, however, allows the conclusion to be drawn that in these experiments any loss caused by the nitrate per se was somewhat more than offset by the conservation of soil nitrogen brought about by increased crop production.

TABLE XVI—*Loss of nitrogen from first six inches of subsoil under various conditions*

SOIL	Per cent nitrogen 1908	Per cent nitrogen 1914	Calculated loss in grams per cylinder in five-year period
A. Cropped. Experiment Nos. 3, 6, 8, 10, 12, and 14. Treatments comparable to those in Series B			
Cookeville	0.0300	0.0281	1.1883
Crossville	0.0607	0.0599	.5000
Gallatin	------	0.0736	------
Jackson	0.0324	0.0293	1.8858
Average		0.0477	
B. Uncropped. Experiment Nos. 18 to 23, inclusive. Treatments comparable to those in Series A			
Cookeville	0.0300	0.0261	2.4375
Crossville	0.0607	0.0561	2.8750
Gallatin	------	0.0668	------
Jackson	0.0324	0.0309	.9125
Average		0.0450	
C. Nitrated, cropped. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those of Series D			
Cookeville	0.0300	0.0276	1.5000
Crossville	0.0607	0.0584	1.4375
Gallatin	------	0.0747	------
Jackson	0.0324	0.0312	0.7300
Average		0.0480	
D. Unnitrated, cropped. Experiment Nos. 6, 7, 8,* 11, and 12. Treatments comparable to those of Series C			
Cookeville	0.0300	0.0271	1.8125
Crossville	0.0607	0.0585	1.3750
Gallatin	------	0.0725	------
Jackson	0.0324	0.0289	2.1292
Average		0.0468	

*No. 8 omitted from both Cookeville and Crossville calculations.

TABLE XVI (*Continued*)

SOIL	Per cent nitrogen 1908	Per cent nitrogen 1914	Calculated loss in grams per cylinder in five-year period
E. Manured, uncropped. Experiment Nos. 19 and 20. Treatments comparable to those in Series F			
Cookeville	0.0300	0.0262	2.3750
Crossville	0.0607	0.0552	3.4375
Gallatin	------	0.0698	------
Jackson	0.0324	0.0295	1.7642
Average		0.0452	
F. Unmanured, uncropped. Experiment Nos. 18 and 21. Treatments comparable to those in Series E			
Cookeville	0.0300	0.0254	2.8750
Crossville	0.0607	0.0578	1.8125
Gallatin	------	0.0691	------
Jackson	0.0324	0.0310	0.9517
Average		0.0458	
G. Manured, cropped. Experiment Nos. 2, 3, 5, 6, and 7. Treatments comparable to those in Series H			
Cookeville	0.0300	0.0273	1.6875
Crossville	0.0607	0.0592	0.9375
Gallatin	------	0.0746	------
Jackson	0.0324	0.0294	1.8140
Average		0.0476	
H. Unmanured, cropped. Experiment Nos. 1, 4, 7, 8, 9, and 10. Treatments comparable to those in Series G			
Cookeville	0.0300	0.0274	1.6250
Crossville	0.0607	0.0583	1.5000
Gallatin	------	0.0714	------
Jackson	0.0324	0.0285	2.3725
Average		0.0464	

LOSSES OF NITROGEN FROM THE SUBSOIL AT DIFFERENT DEPTHS

THE 6-TO-12-INCH DEPTH

Table XIV gives the nitrogen content of the subsoil from the 6-to-12-inch depth of each cylinder six years after being laid down. Also there is given the nitrogen content of an average sample for each type at the outset of the experiments, except for the Gallatin, which was, unfortunately, lost. The results for the Cookeville, Crossville, and Jackson soils all agree in indicating an appreciable loss of nitrogen at this depth. Table XVI shows the subsoil losses sustained under various conditions, which may be discussed briefly as follows:

CROPPING VERSUS BARE FALLOW

The effect of cropping on the loss of nitrogen from the subsoils resembles that from the surface soils, except that the losses from the latter are more pronounced than from the former. The average per cent of subsoil nitrogen from twenty-four cropped cylinders, six from each type of soil, was 0.0477, while the average per cent for the corresponding uncropped cylinders was 0.0450. Cropping, therefore, appreciably conserved the nitrogen supply of the subsoil.

THE EFFECT OF NITRATING

Comparison can be made under cropped conditions between five nitrated and five unnitrated cylinders for each type of soil. The results—C and D of Table XVI—show a higher nitrogen content in the subsoil of the nitrated cylinders for three of the four soil types. The average per cent of nitrogen for all four subsoils at the end of the five-year period was 0.0480 for the nitrated cylinders and 0.0468 for the unnitrated.

The higher percentage of the nitrated cylinders is attributed, as previously, to a conservation of nitrogen in the subsoil through increased crop production.

THE EFFECT OF MANURING

The effect of manure applied to the surface soil on the nitrogen content of the subsoil is shown by the results obtained under both cropped and uncropped conditions. Where no crops were grown—E and F of Table XVI—little appreciable difference, as the average for all four types, was found between the nitrogen content of the subsoil of the manured and unmanured cylinders, the manured cylinders giving an average percentage of 0.0452, as compared with 0.0458 for the unmanured. Since for two of the soil types there is a slightly higher nitrogen content under manuring, and for two others a slightly lower content, no special stress can be placed on the average difference, which is favorable to the unmanured cylinders. It is possible, however, that the period of nitrification and consequent increased loss by leaching would be greater for the manured cylinders than for the unmanur-

ed, due to the slightly higher moisture content, which would be expected in the former.

Under cropping—G and H of Table XVI—the average nitrogen content of the subsoil of all four soil types was found to be 0.0476 per cent for the manured cylinders and 0.0464 per cent for the unmanured. This result is in harmony with the others obtained; that is, subsoil as well as surface-soil nitrogen is conserved through increased crop production.

THE 12-TO-24-INCH DEPTH

Table XVII gives a summary of the analytical data from the second foot of each soil type. The results indicate a small probable loss from this depth, but owing to the uncertainty arising from the analysis of a single composite sample of each type of soil, as was the case for the 1908 determinations, no further conclusions seem warranted to the writer.

TABLE XVII—*Loss of nitrogen from second foot (all cylinders, regardless of treatment)*

SOIL	Total nitrogen		
	1908	1912	1914
	Per cent	Per cent	Per cent
Cookeville	0.0214	------	0.0186
Crossville	0.0421	------	0.0416
Gallatin*	0.0662	0.0654	0.0650
Jackson	0.0247	------	0.0249
Average	0.0386		0.0375

*The figures used for the Gallatin soil were obtained in another series of similar experiments with eight cylinders of this soil. Only the 1912 and 1914 results are available, the per cent for 1908 being calculated on the assumption that the loss of nitrogen was constant throughout the period.

QUANTITATIVE RELATIONSHIP BETWEEN CROP YIELD AND TOTAL NITROGEN CONSERVED IN SOIL AND SUBSOIL

There appears to be throughout the experiments a direct relationship between the size of the crop and the quantity of nitrogen conserved, so that, with other factors constant, the greater the crop, the greater will be the conservation. In Table XVIII there are given for each soil type the data showing the saving of nitrogen in the surface soil and the first six inches of subsoil combined per gram of crop harvested. The average for the four types is 7 mgs of nitrogen per gram of air-dry crop. The results from the Cookeville, Crossville, and Gallatin types are in very close accord, and probably represent the average expectancy much more than the results from the Jackson type. With the latter eliminated, the average combined saving of soil

TABLE XVIII—*The conservation of nitrogen through cropping. Calculations based on the changes in nitrogen content of surface soil and first six inches of subsoil in the five-year period*

SOIL	Average air-dry crop per cylinder for five-year period. Exp. Nos. 6, 8, 10, 12, and 14	Increased loss of nitrogen per cylinder where no crops were grown. Exp. Nos. 18 to 23, inclusive	Nitrogen conserved per gram of air-dry crop harvested
	Grams	Grams	Grams
Cookeville	796.57	6.3689	0.0080
Crossville	826.94	7.7389	0.0094
Gallatin	1379.56	10.5814	0.0077
Jackson	1171.53	3.5227	0.0030
Average			0.0070

and subsoil nitrogen becomes 8.4 mgs per gram of air-dry crop, or 9.3 mgs per gram of dry substance.

CONSERVATION OF SOIL NITROGEN AS A FACTOR IN THE INTERPRETATION OF PLOT AND CYLINDER EXPERIMENTAL RESULTS

Definite figures in regard to the amount of soil nitrogen conserved by cropping are of importance both to the practical farmer who has long been advised to grow winter cover crops to prevent waste of soil nitrogen, and to the scientific worker in the interpretation of both plot and cylinder experiments in the field. In fact, the extent to which an increase in crop conserves the soil supply of nitrogen seems not to have been sufficiently stressed, if realized, in the past. In a recent bulletin by Lipman and Blair* the higher nitrogen content of the soils of the green manure cylinders was attributed solely to the leguminous green manure crops. In view, however, of the findings reported in this bulletin, the higher content can be accounted for in large part through the conservation of the soil nitrogen induced by the increased crop production.

The importance of this suggestion causes the writer to consider in some detail the interpretation of certain of the results obtained with the eight different soils used in their experiments.

In 1907, at the outset of the experiments the average per cent of nitrogen in the eight soils was 0.0945. In 1912 the average for the "check" cylinders was 0.0712 per cent and for the "green manure" cylinders 0.0817 per cent. Since 200 pounds or 90,720 grams of soil were used per cylinder, 9.5256 grams of soil nitrogen per cylinder need to be accounted for. The authors state†: "Since no nitrogen has been ap-

*Lipman and Blair, Cylinder Experiments Relative to the Utilization and Accumulation of Nitrogen. N. J. Exp. Sta. Bul. 289 (1916).

†N. J. Exp. Sta. Bul. 289, p. 37.

plied to these cylinders it must be admitted that this extra amount has been accumulated by the leguminous crops grown on these cylinders." In the consideration of this subject the fact should be kept in mind that under both sets of experimental conditions all the soils, with one exception, were lower in nitrogen at the end of the six years than at the outset. To the 9.5256 grams of soil nitrogen must be added the gain in nitrogen found in the increased crops of the green manure cylinders, or 3.3173 grams on the average per cylinder for the eight soils. The total nitrogen to be accounted for, therefore, is 12.8429 grams. To account for this amount without regard to the conservation of soil nitrogen through increased crop production, either large green manure crops are required, or the assumption must be made that nitrogen was somehow deposited in the soil in excess of that which would be expected from the leguminous green manure crops obtained. The general opinion,* however, among agricultural authorities is that only a fraction of the nitrogen found in a leguminous field crop can be credited to the atmosphere and that perhaps the larger part is furnished by the initial nitrogen stores of the soil. Also there is reason to believe that the richer the soil in available nitrogen the less will the legume take from the air. If the assumptions be made, however, that in the experiments of Lipman and Blair one-half the total nitrogen of the green manure crops come from the air and that none was lost by leaching, how large crops are required to meet the conditions found? With one-half the nitrogen coming from the soil and one-half from the air the total nitrogen in the tops and roots of the green manure crops would amount to 25.6858 grams per cylinder for the five-year period, or 5.1372 grams per cylinder per annum. Two-thirds of this nitrogen, or 3.4248 grams, may be allowed to the harvestable part. Since the dry matter of an immature crop is considerably higher in nitrogen than the averages published for common hay crops a nitrogen content of 3 per cent is assumed.† On this basis there are required green manure crops furnishing 114.16 grams of dry matter per cylinder per annum, or 3655 pounds per acre, an amount which could not be described as "small, moderate" and "none large."‡

The question may now be asked, if the conservation factor be taken into consideration how large crops will be required?

Assuming that all the crops of the first six years should be included, the writer has calculated from the data of the bulletin that on the average for all eight soils there were produced in this period 471 grams more of dry matter per cylinder by the "green manure" cylinders than by the "check" cylinders. Using the factor found by the writer, the soil nitrogen conserved by 471 grams of dry matter

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*See, for example, the statements by various station workers, as recently compiled by Henry G. Bell, Agronomist, Middle West Soil Improvement Committee of the National Fertilizer Association, Chicago, Ill.

†See The Growth of Crimson Clover, by Charles L. Penny. Del. Exp. Sta. Bul. 67.

‡N. J. Exp. Sta. Bul. 289, p. 59.

would be 471 x 9.3 mgs, or 4.3803 grams.* This leaves 5.1453 grams of soil nitrogen and 3.3171 grams of crop nitrogen to be accounted for by two factors: (1) the further conservation of the soil supply by the green manure crops, and (2) the addition of nitrogen through fixation of atmospheric nitrogen by the green manure crops. Assuming as before that two-thirds of the nitrogen would be found in the harvestable part and that one-half the nitrogen of the total crop came from the air, the writer has calculated that an average annual crop of 1,800 lbs. per acre would be ample to meet the conditions. If, however, a gram of dry matter in the crops grown would under their conditions conserve more than 9.3 mgs the necessary green manure crop would be further reduced. Also more than 3 per cent nitrogen might be found in the dry matter of the green manure crops and this would cause another reduction in the crop required. At all events the writer feels justified in the conclusion that only a moderate utilization of atmospheric nitrogen by the leguminous crops grown may have been required in order to explain the New Jersey results.

THE COMPARATIVE LOSSES OF NITROGEN FOR THE DIFFERENT TYPES OF SOIL

The comparative losses of nitrogen suffered by each type of soil can be most satisfactorily studied from the data obtained in the last three years of the experiments. The reason for this is that only in 1911 and 1914 were nitrogen determinations made for each cylinder. Also if the calculations be limited to cropped and limed cylinders, which alone produced crops consistently throughout the period, a comparative study can be made with regard to the relationship between the loss of soil nitrogen and the nitrogen found in the crops produced. Table XIX has been prepared, therefore, to show for each type of soil (1) the average amount of nitrogen in the surface soil of the ten limed and cropped cylinders immediately after the manurial treatments of the fall of 1911; (2) the amount of nitrogen in the same soil at the end of three years; and (3) the nitrogen found in the crops for the same period after both the nitrogen contained in the seed sown and that calculated to be recovered from the surface dressing of nitrate of soda is deducted.

The calculations of Table XIX show that for all four types of soil, more nitrogen was found in the crops than can be accounted for by loss from the surface soil. If the losses of nitrogen from the subsoil be included, more nitrogen was lost from the Cookeville, Crossville and Gallatin cylinders than can be accounted for in the crops grown; that is, there were material losses by leaching, in spite of the fact that both winter and summer crops were grown. In the case of the Jackson soil, however, the remarkable result is obtained of an actual increase of surface-soil nitrogen, with only moderate losses from the

*In the experiments by Lipman and Blair 200 lbs. of surface soil were used per cylinder of 1-14,520 acre surface area. This rate is practically the same as the sum of the surface soil and first six inches of subsoil in the writer's experiments; that is, in each series there would be a little less than 3,000,000 lbs. per acre.

TABLE XIX—*The amount of nitrogen lost from the surface soil and the amount recovered by crops in the three-year period* 1911-1914. *Results from the aggregate of the ten limed and cropped cylinders for each soil type*

SOIL	Nitrogen in surface soil 1911	Nitrogen in surface soil 1914	Soil loss	Nitrogen found in crops (N in seed sown and that recovered from nitrate of soda deducted)
	Grams	Grams	Grams	Grams
Cookeville	434.5036	404.6478	29.8558	32.5655
Crossville	467.8582	450.3412	17.5170	32.3176
Gallatin	719.0515	670.1063	49.9452	55.6300
Jackson	345.6812	347.3935	+ 1.7123	42.2610

subsoil—losses entirely insufficient to account for the nitrogen found in the crops.

Possible sources of nitrogen, such as nitrogenous materials gathered by ants and other insects from sources outside the cylinders, were considered by the writer, but he was unable to discover anything which would not apply with equal or more force to the other soil types. Small red ants were occasionally observed in the cage, both inside and outside the cylinders of all the soils, but they were apparently in small numbers. The soil outside of the cylinders was kept bare and was quite poor, and there were no known sources near by from which ants could get special supplies of food. In addition the close, silty nature of the Jackson soil, with its poor drainage qualities, seemed unfavorable to animal life as compared with either the Crossville or Gallatin type, in particular. Since there is nothing to suggest capillary action as being responsible for the augmentation of nitrogen, the conclusion appears warranted that considerable atmospheric nitrogen was "fixed" in the Jackson soil and became available to the crops grown.

The peculiarities of this soil with regard to physical character and chemical composition have been referred to previously, but it may be of interest to note again that this was the only soil to give a slightly alkaline reaction by the Veitch test, all the others showing "acidity."

SUMMARY

GENERAL CONSIDERATIONS

1. Four distinct types of soil, designated as Cookeville, Crossville, Gallatin and Jackson, were selected for a study of nitrogen economy.

2. Each soil was removed in layers as found in the field, transported to Knoxville, and placed in cylinders sunk four feet in the ground. Each cylinder enclosed a surface area of 1/10,000 acre. Full

exposure to the weather was permitted, but protection was provided from birds, etc. No artificial watering was given.

3. Ten successive crops were planted in each of 69 cylinders, while 31 were kept bare. The crops were oats the first season, wheat four seasons, and millet grown in the summer after each of the five small-grain crops.

4. The amount of ground limestone applied and the other manurial treatments as given were moderate and well within the limits of farm practice.

CROP RESULTS

5. The largest crops were produced by the Gallatin soil, which had decidedly the highest content of total nitrogen, but the yields decreased very rapidly in the course of the five years. The second largest yields were obtained from the Jackson soil, which had the lowest nitrogen content—only a little more than one-third of that of the Gallatin soil. The Jackson soil, however, maintained a more constant yield than any other, and in the last two years the crop equalled those from the Gallatin soil. The Cookeville and Crossville soils proved to be the least productive, and were practically on an equality in this respect.

6. For the Cookeville and Crossville soils constancy of yield was obtained only on the limed cylinders. The results given by the ten limed and cropped cylinders of each of the four types were used, therefore, in determining the percentage of nitrogen recovery from manurial applications and in certain other calculations.

7. The recovery by crops of the nitrogen applied in the form of sodium nitrate varied with the kind of soil as follows:

Cookeville	45.38 per cent
Crossville	53.71 per cent
Gallatin	87.08 per cent
Jackson	72.21 per cent

The results are correlated with the productiveness of the soils; that is, the more productive the soil the greater the root development to intercept the nitrate—the greater the percentage of nitrate nitrogen recovered.

8. The recovery by crops of nitrogen from the organic materials —manure and manure plus straw—varied with the kind of soil as follows:

Cookeville	29.82 per cent
Crossville	34.52 per cent
Gallatin	37.58 per cent
Jackson	23.88 per cent

The results are correlated with the physical nature of the soils; that is, the more open and porous soils show the highest recovery.

9. The ratio between the nitrogen content and the dry matter of the crops varied little in the three soils, Cookeville, Crossville, and Gallatin, which averaged 93.11 grams of dry substance per gram of nitrogen. The crops from the Jackson soil, however, gave a ratio of 120.01 grams of dry substance per gram of nitrogen. A low nitrogen content was found to characterize alike the grain and the straw of the wheat, also the millet hay from the Jackson soil.

SOIL RESULTS

10. In every instance the cropped soils maintained a decidedly higher nitrogen content than the uncropped. This difference was noticeable both in the surface soil and in the first six inches of the subsoil, but the results from the 12-to-24-inch depth were inconclusive.

The losses of nitrogen from the surface soils under comparable conditions were as follows:

	Cropped	Uncropped
Cookeville ----------	2.1 per cent	6.8 per cent
Crossville ----------	1.2 per cent	6.2 per cent
Gallatin ------------	12.4 per cent	18.2 per cent
Jackson --------	plus 0.4 per cent	4.2 per cent

11. The average combined saving in surface soil and subsoil nitrogen for the three most representative types, Cookeville, Crossville, and Gallatin, was 8.4 mgs per gram of air-dry crop, or 9.3 mgs per gram of dry substance harvested.

12. In uncropped experiments surface soil treated with ground limestone showed appreciable loss of nitrogen as compared with untreated. Under cropping, however, three of the four soils showed more nitrogen at the end of the five-year period in the limed cylinders than in the unlimed. This result is attributed to the offsetting of the direct loss through liming by the conservation of nitrogen brought about through increased crop production.

13. The effect of applications of acid phosphate and muriate of potash on the content of soil nitrogen was not appreciable under cropping. No experiments were made under uncropped conditions.

14. Where no crops were grown, top-dressings of nitrate of soda resulted in a small but evident loss of soil nitrogen.

Under cropping the nitrated cylinders showed a greater supply of both soil and subsoil nitrogen than the unnitrated, the difference being slight for the soil, but more pronounced for the subsoil. This result, as in the case of the ground limestone, is attributed to the more than balancing of the direct loss through nitrating by the conservation of nitrogen brought about through increased crop production.

15. Manure applied to the surface soil of uncropped cylinders did not increase the nitrogen content of the subsoil.

Under cropping the nitrogen content of the subsoils from the manured cylinders averaged somewhat higher than that from the unmanured; that is, manure applied to the surface soil conserved the supply of nitrogen in the subsoil.

16. If the loss of nitrogen from both the soil and subsoil be considered, the loss from the Cookeville, Crossville, and Gallatin soils was in each case greater than can be accounted for in the crops removed. In the case of the Jackson soil, however, this was not so, the subsoil showing a moderate loss but the surface soil of the cropped cylinders a slight gain.

17. The Jackson soil, which gave in many respects decidedly different results from any other, is noted as the only one to give evidence of the fixation of atmospheric nitrogen to a marked extent. To attribute this nitrogen accumulation to other exterior sources was considered untenable.

18. The general conclusion is drawn that not only the cropping, but also the manurial treatments conserved both the soil and the subsoil nitrogen to a total depth of about one foot, directly in proportion to the crop increase. This conservation does not, of course, prevent a loss of soil nitrogen through either chemical or biological processes induced per se by an applied substance such as ground limestone. In such a case the two opposing factors may or may not balance each other.

Since cover crops are often advocated because they catch soluble nitrogen that would otherwise be lost by leaching, attention may be called to the fact that the conservation referred to is not limited to the nitrogen utilized by the crops and conserved in the crop residues, but is an additional and actual conservation of soil nitrogen which may be utilized by farm crops.

ACKNOWLEDGMENTS

The writer takes pleasure in expressing his indebtedness to Dr. J. G. Lipman, Director of the New Jersey Agricultural Experiment Station, for valuable criticism of the plans at the outset of the experiments herein reported. The writer also wishes to express his appreciation of the assistance rendered by Dr. W. H. MacIntire, Mr. L. G. Willis, and Mr. J. I. Hardy, in making the major part of the nitrogen determinations on both soils and crops.

APPENDIX

TABLES

Tables VI, XIII, and XIV are, on account of their length, appended here in order not to interfere with the pages of the bulletin proper.

TABLE VI—*Yields of crops and their nitrogen content*

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Cookeville	A1	L (1909)	1910	Oats	53.95	1.570	.8470
			1910	Millet	66.28	1.220	.8086
			1911	Wheat	46.88	1.100	.5157
			1911	Millet	79.43	0.910	.7228
			1912	Wheat	39.80	1.065	.4239
			1912	Millet	19.39	2.020	.3917
			1913	Wheat	24.13	0.914	.2205
			1913	Millet	35.50	1.510	.5361
			1914	Wheat	39.03	0.965	.3766
			1914	Millet	4.10	2.065	.0847
		Total			408.49		4.9276
Cookeville	A2	F (1909 & 1911)	1910	Oats	78.06	1.030	.8040
			1910	Millet	60.43	1.400	.8460
			1911	Wheat	47.67	1.220	.5816
			1911	Millet	88.34	0.770	.6802
			1912	Wheat	130.86	0.960	1.2563
			1912	Millet	12.71	1.695	.2154
			1913	Wheat	31.70	0.989	.3135
			1913	Millet	1.21	1.310	.0159
			1914	Wheat			
			1914	Millet			
		Total			450.98		4.7129
Cookeville	A3	L (1909)	1910	Oats	111.00	0.950	1.0545
		F (1909 & 1911)	1910	Millet	76.81	1.230	.9448

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1911	Wheat	65.01	0.970	.6306
			1911	Millet	115.01	0.720	.8281
			1912	Wheat	114.39	1.005	1.1496
			1912	Millet	94.68	1.013	.9591
			1913	Wheat	41.91	1.066	.4468
			1913	Millet	84.96	1.280	1.0875
			1914	Wheat	62.69	0.972	.6093
			1914	Millet	67.23	0.933	.6273
		Total			833.69		8.3376
Cookeville	A4	None	1910	Oats	25.30	1.590	.4023
			1910	Millet	27.02	1.500	.4053
			1911	Wheat	27.05	1.200	.3246
			1911	Millet	63.07	0.950	.5992
			1912	Wheat	3.21	1.152	.0370
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			145.65		1.7684
Cookeville	A5	L (1909)	1910	Oats	84.85	1.210	1.0267
		F (1909 & 1911)	1910	Millet	103.66	1.090	1.1299
		S (1909 & 1911)	1911	Wheat	68.23	0.970	.6618
			1911	Millet	138.40	0.690	.9550
			1912	Wheat	123.39	0.984	1.2142
			1912	Millet	119.55	0.833	.9959
			1913	Wheat	61.42	0.999	.6136
			1913	Millet	99.21	1.100	1.0913
			1914	Wheat	88.70	0.805	.7140
			1914	Millet	57.64	0.900	.5188
		Total			945.05		8.9212
Cookeville	A6	L (1909)	1910	Oats	94.90	1.150	1.0914
		F (1909 & 1911)	1910	Millet	95.86	1.330	1.2749
		S (1909 & 1911)	1911	Wheat	81.75	0.910	.7439

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Millet	135.45	0.640	.8669
			1912	Wheat	122.86	0.965	1.1856
			1912	Millet	130.33	0.868	1.1313
			1913	Wheat	76.90	0.954	.7336
			1913	Millet	86.00	1.200	1.0320
			1914	Wheat	74.51	0.813	.6058
			1914	Millet	36.95	1.043	.3854
		Total			935.51		9.0508
Cookeville	A7	PK (annual)	1910	Oats	48.73	1.000	.4873
			1910	Millet	27.34	1.130	.3089
			1911	Wheat	45.57	1.040	.4739
			1911	Millet	55.20	0.870	.4802
			1912	Wheat	23.24	0.856	.1989
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			200.08		1.9492
Cookeville	A8	L (1909)	1910	Oats	75.05	1.080	.8105
		PK (annual)	1910	Millet	60.33	1.220	.7360
			1911	Wheat	55.61	0.980	.5450
			1911	Millet	97.93	0.740	.7247
			1912	Wheat	65.65	0.813	.5337
			1912	Millet	61.71	0.920	.5677
			1913	Wheat	55.95	1.147	.6417
			1913	Millet	53.20	1.200	.6384
			1914	Wheat	57.31	0.866	.4963
			1914	Millet	22.74	1.343	.3054
		Total			605.48		5.9994
Cookeville	A9	PK (annual)	1910	Oats	154.80	0.910	1.4087
		N (annual)	1910	Millet	43.56	1.180	.5140
			1911	Wheat	81.79	1.150	.9406
			1911	Millet	86.20	0.790	.6810

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Wheat	38.67	0.872	.3372
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			405.02		3.8815
Cookeville	A10	L (1909)	1910	Oats	174.51	0.980	1.7102
		PK (annual)	1910	Millet	49.23	1.380	.6794
		N (annual)	1911	Wheat	97.66	1.050	1.0254
			1911	Millet	104.40	0.730	.7621
			1912	Wheat	112.25	0.797	.8946
			1912	Millet	41.52	1.073	.4455
			1913	Wheat	92.90	1.076	.9996
			1913	Millet	51.20	1.430	.7322
			1914	Wheat	94.74	1.255	1.1890
			1914	Millet	20.14	1.625	.3273
		Total			838.55		8.7653
Cookeville	B1	S (1909 & 1911)	1910	Oats	22.20	1.420	.3152
		PK (annual)	1910	Millet	44.74	1.190	.5324
			1911	Wheat	49.83	1.000	.4983
			1911	Millet	68.82	0.710	.4886
			1912	Wheat	21.55	0.842	.1815
			1912	Millet			
			1913	Wheat	1.75	0.560	.0098
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			208.89		2.0258
Cookeville	B2	L (1909)	1910	Oats	41.83	1.360	.5689
		S (1909 & 1911)	1910	Millet	90.53	1.100	.9958
		PK (annual)	1911	Wheat	60.00	0.930	.5580
			1911	Millet	110.20	0.630	.6943
			1912	Wheat	62.51	1.044	.6526

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Millet	51.96	0.885	.4598
			1913	Wheat	56.08	0.914	.5126
			1913	Millet	66.55	1.030	.6855
			1914	Wheat	63.24	0.765	.4838
			1914	Millet	62.71	0.730	.4578
		Total			665.71		6.0691
Cookeville	B3	S (1909 & 1911)	1910	Oats	106.29	1.000	1.0629
		PK (annual)	1910	Millet	48.83	1.240	.6055
		N (annual)	1911	Wheat	65.67	1.220	.8012
			1911	Millet	99.55	0.760	.7566
			1912	Wheat	84.30	0.785	.6618
			1912	Millet			
			1913	Wheat	3.25	1.271	.0413
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			407.89		3.9293
Cookeville	B4	L (1909)	1910	Oats	130.23	0.870	1.1330
		S (1909 & 1911)	1910	Millet	53.70	1.180	.6337
		PK (annual)	1911	Wheat	117.36	1.020	1.1971
		N (annual)	1911	Millet	123.15	0.730	.8990
			1912	Wheat	144.71	0.704	1.0188
			1912	Millet	51.11	0.930	.4753
			1913	Wheat	125.46	0.960	1.2044
			1913	Millet	75.43	1.020	.7694
			1914	Wheat	95.69	1.170	1.1196
			1914	Millet	20.77	1.175	.2440
		Total			937.61		8.6943
Cookeville	B5	S (1909 & 1911)	1910	Oats	13.80	1.770	.2443
			1910	Millet	5.05	1.640	.0828
			1911	Wheat	43.23	1.010	.4366
			1911	Millet	65.14	0.760	.4951
			1912	Wheat	13.86	0.949	.1315
			1912	Millet			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			141.08		1.3903
Cookeville	B6	L (1909)	1910	Oats	35.53	1.410	.5010
		S (1909 & 1911)	1910	Millet	76.34	1.290	.9848
			1911	Wheat	58.21	0.980	.5705
			1911	Millet	100.05	0.720	.7204
			1912	Wheat	33.68	1.142	.3846
			1912	Millet	36.88	1.330	.4905
			1913	Wheat	27.57	1.032	.2845
			1913	Millet	70.22	1.110	.7794
			1914	Wheat	48.17	0.930	.4480
			1914	Millet	27.11	1.013	.2746
		Total			513.76		5.4383
Cookeville	B7	L (1909)	1910	Oats	188.71	0.830	1.5663
		F (1909 & 1911)	1910	Millet	99.63	1.220	1.2155
		S (1909 & 1911)	1911	Wheat	101.08	0.980	.9906
		PK (annual)	1911	Millet	141.74	0.670	.9497
		N (annual)	1912	Wheat	214.72	0.882	1.8938
			1912	Millet	111.01	0.948	1.0524
			1913	Wheat	152.20	0.959	1.4596
			1913	Millet	64.11	1.220	.7821
			1914	Wheat	144.50	0.938	1.3554
			1914	Millet	25.44	1.345	.3422
		Total			1243.14		11.6076
Crossville	C1	L (1909)	1910	Oats	58.43	1.450	.8472
			1910	Millet	65.89	1.370	.9027
			1911	Wheat	41.24	1.190	.4908
			1911	Millet	65.65	1.100	.7222
			1912	Wheat	24.73	1.161	.2871
			1912	Millet	33.86	1.318	.4463
			1913	Wheat	35.51	0.488	.1733

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Millet	26.51	1.400	.3711
			1914	Wheat	11.83	1.120	.1325
			1914	Millet	8.92	1.400	.1249
		Total			372.57		4.4981
Crossville	C2	F (1909 & 1911)	1910	Oats	95.78	1.100	1.0536
			1910	Millet	75.96	1.150	.8735
			1911	Wheat	19.92	1.260	.2510
			1911	Millet	94.55	0.900	.8510
			1912	Wheat	121.47	0.875	1.0629
			1912	Millet	45.71	1.345	.6148
			1913	Wheat			
			1913	Millet	1.04	1.170	.0122
			1914	Wheat			
			1914	Millet			
		Total			454.43		4.7190
Crossville	C3	L (1909)	1910	Oats	114.11	1.000	1.1411
		F (1909 & 1911)	1910	Millet	112.48	1.150	1.2935
			1911	Wheat	61.20	1.110	.6793
			1911	Millet	115.47	0.810	.9353
			1912	Wheat	120.35	0.935	1.1253
			1912	Millet	124.05	0.730	.9056
			1913	Wheat	43.18	1.066	.4603
			1913	Millet	108.31	1.000	1.0831
			1914	Wheat	60.63	0.953	.5778
			1914	Millet	47.76	1.015	.4848
		Total			907.54		8.6861
Crossville	C4	None	1910	Oats	29.03	1.620	.4703
			1910	Millet	14.15	1.650	.2335
			1911	Wheat			
			1911	Millet			
			1912	Wheat			
			1912	Millet			
			1913	Wheat			
			1913	Millet			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Wheat			
			1914	Millet			
		Total			43.18		.7038
Crossville	C5	L (1909)	1910	Oats	88.63	1.220	1.0813
		F (1909 & 1911)	1910	Millet	132.39	1.210	1.6019
		S (1909 & 1911)	1911	Wheat	65.41	0.940	.6149
			1911	Millet	119.30	0.770	.9186
			1912	Wheat	84.52	1.277	1.0793
			1912	Millet	143.95	0.800	1.1516
			1913	Wheat	50.38	0.949	.4781
			1913	Millet	104.37	1.030	1.0750
			1914	Wheat	56.48	0.888	.5015
			1914	Millet	37.27	1.100	.4100
		Total			882.70		8.9122
Crossville	C6	L (1909)	1910	Oats	101.53	1.150	1.1676
		F (1909 & 1911)	1910	Millet	137.40	1.150	1.5801
		S (1909 & 1911)	1911	Wheat	69.20	0.890	.6159
		PK (annual)	1911	Millet	127.39	0.600	.7643
			1912	Wheat	100.22	0.936	.9381
			1912	Millet	127.16	0.768	.9766
			1913	Wheat	55.30	0.956	.5287
			1913	Millet	129.76	0.890	1.1549
			1914	Wheat	77.00	0.862	.6637
			1914	Millet	78.90	1.050	.8285
		Total			1003.86		9.2184
Crossville	C7	PK (annual)	1910	Oats	53.48	1.120	.5990
			1910	Millet	36.84	1.380	.5084
			1911	Wheat			
			1911	Millet	13.43	1.570	.2109
			1912	Wheat	0.36	1.861	.0067
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Millet			
		Total			104.11		1.3250
Crossville	C8	L (1909)	1910	Oats	85.25	1.020	.8696
		PK (annual)	1910	Millet	78.70	0.940	.7398
			1911	Wheat	48.48	1.100	.5333
			1911	Millet	99.08	0.750	.7431
			1912	Wheat	49.53	0.915	.4532
			1912	Millet	59.58	0.910	.5422
			1913	Wheat	34.74	0.978	.3398
			1913	Millet	57.70	1.040	.6001
			1914	Wheat	24.00	0.990	.2376
			1914	Millet	27.71	1.273	.3527
		Total			564.77		5.4114
Crossville	C9	PK (annual)	1910	Oats	137.39	1.310	1.7998
		N (annual)	1910	Millet	44.20	1.260	.5569
			1911	Wheat			
			1911	Millet	28.97	1.610	.4664
			1912	Wheat			
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			210.56		2.8231
Crossville	C10	L (1909)	1910	Oats	219.62	1.140	2.5037
		PK (annual)	1910	Millet	64.11	1.190	.7629
		N (annual)	1911	Wheat	85.40	1.090	.9309
			1911	Millet	131.15	0.720	.9443
			1912	Wheat	117.63	0.860	1.0116
			1912	Millet	68.30	0.808	.5519
			1913	Wheat	100.61	1.068	1.0745
			1913	Millet	55.98	1.150	.6438
			1914	Wheat	50.84	1.315	.6685
			1914	Millet	45.07	1.238	.5580
		Total			938.71		9.6501

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Crossville	D1	S (1909 & 1911)	1910	Oats	44.44	1.450	.6444
		PK (annual)	1910	Millet	64.20	1.120	.7190
			1911	Wheat			
			1911	Millet	47.92	1.120	.5367
			1912	Wheat	8.95	1.165	.1043
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			165.51		2.0044
Crossville	D2	L (1909)	1910	Oats	54.57	1.240	.6767
		S (1909 & 1911)	1910	Millet	94.08	1.180	1.1101
		PK (annual)	1911	Wheat	63.49	0.910	.5778
			1911	Millet	100.84	0.820	.8269
			1912	Wheat	41.55	0.914	.3798
			1912	Millet	71.14	0.870	.6189
			1913	Wheat	23.33	1.034	.2412
			1913	Millet	94.38	1.000	.9438
			1914	Wheat	47.83	1.195	.5716
			1914	Millet	55.10	1.043	.5747
		Total			646.31		6.5215
Crossville	D3	S (1909 & 1911)	1910	Oats	104.17	1.150	1.1980
		PK (annual)	1910	Millet	53.43	1.150	.6144
		N (annual)	1911	Wheat	19.43	1.590	.3089
			1911	Millet	54.03	0.820	.4430
			1912	Wheat	6.14	1.103	.0687
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			237.20		2.6330
Crossville	D4	L (1909)	1910	Oats	160.30	0.940	1.5068

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		S (1909 & 1911)	1910	Millet	84.97	0.980	.8327
		PK (annual)	1911	Wheat	111.44	1.050	1.1701
		N (annual)	1911	Millet	103.73	0.720	.7469
			1912	Wheat	123.43	0.833	1.0282
			1912	Millet	75.68	0.915	.6925
			1913	Wheat	120.60	0.924	1.1143
			1913	Millet	75.46	1.020	.7697
			1914	Wheat	62.74	1.213	.7610
			1914	Millet	62.70	1.005	.6301
		Total			981.05		9.2523
Crossville	D5	S (1909 & 1911)	1910	Oats	17.10	1.570	.2685
			1910	Millet	33.72	1.480	.4991
			1911	Wheat			
			1911	Millet	35.41	0.980	.3470
			1912	Wheat	5.30	0.975	.0517
			1912	Millet	1.69	1.505	.2543
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			93.22		1.4206
Crossville	D6	L (1909)	1910	Oats	41.71	1.390	.5798
		S (1909 & 1911)	1910	Millet	68.02	1.250	.8503
			1911	Wheat	47.41	1.070	.5073
			1911	Millet	91.27	0.790	.7210
			1912	Wheat	37.75	1.061	.4005
			1912	Millet	68.86	0.770	.5302
			1913	Wheat	24.96	1.158	.2890
			1913	Millet	63.56	1.060	.6737
			1914	Wheat	26.04	0.968	.2521
			1914	Millet	35.90	1.023	.3673
		Total			505.48		5.1712
Crossville	D7	L (1909)	1910	Oats	194.55	0.940	1.8288
		F (1909 & 1911)	1910	Millet	124.59	1.030	1.2833

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		S (1909 & 1911)	1911	Wheat	131.97	1.000	1.3197
		PK (annual)	1911	Millet	137.62	0.620	.8532
		N (annual)	1912	Wheat	202.91	0.817	1.6578
			1912	Millet	161.78	0.805	1.3023
			1913	Wheat	130.97	0.969	1.2694
			1913	Millet	122.48	0.880	1.0778
			1914	Wheat	138.86	0.949	1.3178
			1914	Millet	72.30	1.045	.7555
		Total			1418.03		12.6656
Gallatin	E1	L (1909)	1910	Oats	184.80	1.190	2.1991
			1910	Millet	84.34	1.040	.8771
			1911	Wheat	133.14	0.880	1.1716
			1911	Millet	108.76	0.710	.7722
			1912	Wheat	99.21	0.980	.9723
			1912	Millet	37.43	0.775	.2901
			1913	Wheat	89.83	0.875	.7860
			1913	Millet	73.00	1.080	.7884
			1914	Wheat	133.27	0.830	1.1061
			1914	Millet	3.20	1.625	.0520
		Total			946.98		9.0149
Gallatin	E2	F (1909)	1910	Oats	280.95	0.970	2.7252
			1910	Millet	110.96	0.970	1.0763
			1911	Wheat	160.64	0.940	1.5100
			1911	Millet	122.85	0.660	.8108
			1912	Wheat	252.09	0.852	2.1478
			1912	Millet	103.51	0.822	.8509
			1913	Wheat	152.03	0.860	1.3075
			1913	Millet	22.08	1.650	.3643
			1914	Wheat	163.10	0.940	1.5331
			1914	Millet			
		Total			1368.21		12.3259
Gallatin	E3	L (1909)	1910	Oats	267.03	1.160	3.0975
		F (1909 & 1911)	1910	Millet	125.68	0.930	1.1688
			1911	Wheat	195.32	1.110	2.1681

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Millet	17.07	1.400	.2390
			1913	Wheat	83.74	1.148	.9613
			1913	Millet	.63	1.590	.0100
			1914	Wheat	174.50	1.264	2.2057
			1914	Millet			
		Total			1204.41		11.8306
Gallatin	E10	L (1909)	1910	Oats	359.24	1.230	4.4187
		PK (annual)	1910	Millet	76.63	1.150	.8812
		N (annual)	1911	Wheat	231.01	0.990	2.2870
			1911	Millet	138.23	0.590	.8156
			1912	Wheat	264.37	0.832	2.1996
			1912	Millet	48.48	0.788	.3820
			1913	Wheat	212.00	0.965	2.0458
			1913	Millet	70.74	1.080	.7640
			1914	Wheat	234.18	1.310	3.0678
			1914	Millet	27.64	1.633	.4514
		Total			1662.52		17.3131
Gallatin	F1	S (1909 & 1911)	1910	Oats	160.15	1.250	2.0019
		PK (annual)	1910	Millet	64.80	1.530	.9914
			1911	Wheat	103.48	0.870	9003
			1911	Millet	109.38	0.660	.7219
			1912	Wheat	81.89	0.881	.7215
			1912	Millet	56.46	0.845	.4771
			1913	Wheat	67.75	0.888	.6016
			1913	Millet	22.92	1.530	.3507
			1914	Wheat	184.97	0.825	1.5260
			1914	Millet			
		Total			851.80		8.2924
Gallatin	F2	L (1909)	1910	Oats	167.00	1.180	1.9706
		S (1909 & 1911)	1910	Millet	81.38	1.120	.9115
		PK (annual)	1911	Wheat	119.16	0.910	1.0844
			1911	Millet	122.00	0.670	.8174
			1912	Wheat	96.69	0.972	.9398
			1912	Millet	80.41	0.684	.5500

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Wheat	60.53	0.999	.6047
			1913	Millet	100.75	0.860	.8665
			1914	Wheat	145.49	0.800	1.1639
			1914	Millet	100.99	0.808	.8160
		Total			1074.40		9.7248
Gallatin	F3	S (1909 & 1911)	1910	Oats	298.36	0.990	2.9538
		PK (annual)	1910	Millet	70.05	1.080	.7565
		N (annual)	1911	Wheat	230.65	0.810	1.8683
			1911	Millet	104.72	0.730	.7645
			1912	Wheat	219.30	0.761	1.6689
			1912	Millet	57.64	0.835	.4813
			1913	Wheat	128.72	0.967	1.2447
			1913	Millet	22.04	1.560	.3438
			1914	Wheat	261.63	1.010	2.6425
			1914	Millet			
		Total			1393.11		12.7243
Gallatin	F4	L (1909)	1910	Oats	281.37	0.960	2.7011
		S (1909 & 1911)	1910	Millet	95.95	1.040	.9979
		PK (annual)	1911	Wheat	233.17	0.940	2.1918
		N (annual)	1911	Millet	126.82	0.680	.8624
			1912	Wheat	224.05	0.805	1.8036
			1912	Millet	98.47	0.713	.7021
			1913	Wheat	163.50	0.875	1.4306
			1913	Millet	100.69	0.850	.8559
			1914	Wheat	250.79	1.053	2.6408
			1914	Millet	68.49	1.375	.9417
		Total			1643.30		15.1279
Gallatin	F5	S (1909 & 1911)	1910	Oats	103.47	1.400	1.4486
			1910	Millet	33.77	1.870	.6315
			1911	Wheat	179.00	0.940	1.6826
			1911	Millet	123.90	0.630	.7806
			1912	Wheat	81.64	0.848	.6923
			1912	Millet	51.99	0.830	.4315
			1913	Wheat	54.65	0.839	.4585

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Millet	0.74	1.570	.0116
			1914	Wheat	123.63	0.873	1.0793
			1914	Millet			
		Total			752.79		7.2165
Gallatin	F6	L (1909)	1910	Oats	169.37	1.120	1.8969
		S (1909 & 1911)	1910	Millet	98.77	1.050	1.0371
			1911	Wheat	152.87	1.010	1.5440
			1911	Millet	107.95	0.710	.7664
			1912	Wheat	93.81	0.970	.9100
			1912	Millet	107.56	0.705	.7583
			1913	Wheat	41.49	0.972	.4033
			1913	Millet	110.90	0.930	1.0314
			1914	Wheat	140.33	0.798	1.1198
			1914	Millet	29.45	1.563	.4603
		Total			1052.50		9.9275
Gallatin	F7	L (1909)	1910	Oats	340.88	1.210	4.1246
		F (1909 & 1911)	1910	Millet	126.91	1.000	1.2691
		S (1909 & 1911)	1911	Wheat	354.33	1.040	3.6850
		PK (annual)	1911	Millet	159.28	0.630	1.0035
		N (annual)	1912	Wheat	324.16	0.998	3.2351
			1912	Millet	161.16	0.790	1.2732
			1913	Wheat	161.56	1.062	1.7158
			1913	Millet	128.64	0.960	1.2349
			1914	Wheat	331.40	0.853	2.8268
			1914	Millet	29.95	1.990	.5960
		Total			2118.27		20.9640
Jackson	G1	L (1909)	1910	Oats	109.17	0.840	.9170
			1910	Millet	54.12	1.160	.6278
			1911	Wheat	69.22	0.800	.5538
			1911	Millet	81.08	0.660	.5351
			1912	Wheat	117.10	0.725	.8490
			1912	Millet	68.49	0.783	.5363
			1913	Wheat	84.90	0.789	.6699
			1913	Millet	80.50	0.620	.4991

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Wheat	96.41	0.735	.7086
			1914	Millet	85.78	0.653	.5601
		Total			846.77		6.4567
Jackson	G2	F (1909 & 1911)	1910	Oats	159.70	0.870	1.3894
			1910	Millet	76.09	1.130	.8598
			1911	Wheat	90.16	0.780	.7032
			1911	Millet	90.88	0.610	.5544
			1912	Wheat	202.46	0.686	1.3889
			1912	Millet	108.12	0.750	.8109
			1913	Wheat	55.39	1.040	.5761
			1913	Millet	115.03	0.630	.7247
			1914	Wheat	89.37	0.775	.6926
			1914	Millet	94.60	0.700	.6622
		Total			1081.80		8.3622
Jackson	G3	L (1909)	1910	Oats	177.56	0.780	1.3850
		F (1909 & 1911)	1910	Millet	67.60	1.150	.7774
			1911	Wheat	87.66	0.700	.6136
			1911	Millet	84.75	0.620	.5255
			1912	Wheat	201.72	0.707	1.4262
			1912	Millet	108.65	0.738	.8018
			1913	Wheat	68.02	0.995	.6768
			1913	Millet	111.84	0.660	.7381
			1914	Wheat	89.07	0.833	.7420
			1914	Millet	123.18	0.570	.7021
		Total			1120.05		8.3885
Jackson	G4	None	1910	Oats	99.69	0.770	.7676
			1910	Millet	41.12	1.250	.5140
			1911	Wheat	72.40	0.790	.5720
			1911	Millet	76.42	0.560	.4280
			1912	Wheat	83.28	0.692	.5757
			1912	Millet	42.12	0.800	.3370
			1913	Wheat	43.62	0.843	.3677
			1913	Millet	32.06	1.000	.3206
			1914	Wheat	74.21	0.703	.5217

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Millet	15.27	1.685	.2573
		Total			580.19		4.6616
Jackson	G5	L (1909)	1910	Oats	132.05	0.800	1.0564
		F (1909 & 1911)	1910	Millet	87.21	1.040	90.70
		S (1909 & 1911)	1911	Wheat	93.88	0.720	.6759
			1911	Millet	99.19	0.660	.6547
			1912	Wheat	168.79	0.794	1.3402
			1912	Millet	120.50	0.745	.8977
			1913	Wheat	115.91	0.849	.9841
			1913	Millet	117.08	0.640	.7493
			1914	Wheat	112.75	0.805	.9076
			1914	Millet	108.85	0.670	.7293
		Total			1156.21		8.9030
Jackson	G6	L (1909)	1910	Oats	125.67	0.950	1.1939
		F (1909 & 1911)	1910	Millet	88.88	1.010	.8977
		S (1909 & 1911)	1911	Wheat	103.97	0.760	.7902
		PK (annual)	1911	Millet	92.88	0.660	.6130
			1912	Wheat	172.16	0.807	1.3893
			1912	Millet	130.84	0.710	.9290
			1913	Wheat	79.74	0.875	.6977
			1913	Millet	127.76	0.630	.8049
			1914	Wheat	100.93	0.800	.8074
			1914	Millet	140.65	0.543	.7637
		Total			1163.48		8.8868
Jackson	G7	PK (annual)	1910	Oats	148.33	0.700	1.0383
			1910	Millet	42.77	1.220	.5218
			1911	Wheat	79.01	0.720	.5689
			1911	Millet	62.86	0.670	.4212
			1912	Wheat	100.30	0.698	.7001
			1912	Millet	31.20	0.783	.2443
			1913	Wheat	37.97	0.839	.3186
			1913	Millet	72.69	0.650	.4725
			1914	Wheat	65.28	0.785	.5124
			1914	Millet	52.76	0.885	.4669
		Total			693.17		5.2650

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Jackson	G8	L (1909)	1910	Oats	116.68	0.740	.8634
		PK (annual)	1910	Millet	59.29	1.050	.6225
			1911	Wheat	63.12	0.860	.5428
			1911	Millet	81.64	0.660	.5388
			1912	Wheat	109.81	0.724	.7950
			1912	Millet	74.78	0.773	.5780
			1913	Wheat	80.97	0.822	.6657
			1913	Millet	74.05	0.600	.4443
			1914	Wheat	87.83	0.738	.6482
			1914	Millet	99.50	0.613	.6099
		Total			847.67		6.3086
Jackson	G9	PK (annual)	1910	Oats	280.11	0.680	1.9047
		N (annual)	1910	Millet	39.80	1.230	.4895
			1911	Wheat	180.50	0.810	1.4621
			1911	Millet	78.82	0.620	.4887
			1912	Wheat	234.50	0.597	1.4000
			1912	Millet	57.50	0.793	.4560
			1913	Wheat	167.03	0.689	1.1509
			1913	Millet	57.04	0.800	.4563
			1914	Wheat	167.60	0.810	1.3576
			1914	Millet	55.97	0.778	.4354
		Total			1318.87		9.6012
Jackson	G10	L (1909)	1910	Oats	291.70	0.770	2.2461
		PK (annual)	1910	Millet	60.84	1.080	.6571
		N (annual)	1911	Wheat	156.31	0.690	1.0785
			1911	Millet	75.05	0.700	.5254
			1912	Wheat	248.19	0.614	1.5239
			1912	Millet	57.68	0.837	.4829
			1913	Wheat	177.45	0.766	1.3593
			1913	Millet	73.58	0.640	.4709
			1914	Wheat	170.47	0.858	1.4626
			1914	Millet	104.53	0.615	.6429
		Total			1415.80		10.4496
Jackson	H1	S (1909 & 1911)	1910	Oats	118.56	0.830	.9840

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1910	Millet	8.35	1.050	.0877
			1911	Wheat	86.07	0.730	.6283
			1911	Millet	92.23	0.630	.5810
			1912	Wheat	78.52	0.831	.6525
			1912	Millet	62.30	0.813	.5065
			1913	Wheat	50.97	1.021	.5204
			1913	Millet	85.04	0.620	.5272
			1914	Wheat	73.80	0.800	.5904
			1914	Millet	83.43	0.720	.6007
		Total			739.27		5.6787
Jackson	H2	L (1909)	1910	Oats	140.62	0.810	1.1390
		S (1909 & 1911)	1910	Millet	72.92	1.120	.8167
		PK (annual)	1911	Wheat	91.30	0.690	.6300
			1911	Millet	90.50	0.630	.5702
			1912	Wheat	87.21	0.827	.7212
			1912	Millet	80.31	0.768	.6168
			1913	Wheat	72.70	0.944	.6863
			1913	Millet	90.59	0.650	.5888
			1914	Wheat	97.24	0.763	.7419
			1914	Millet	109.20	0.585	.6388
		Total			932.59		7.1497
Jackson	H3	S (1909 & 1911)	1910	Oats	298.74	0.660	1.9717
		PK (annual)	1910	Millet	61.62	1.010	.6224
		N (annual)	1911	Wheat	200.86	0.680	1.3658
			1911	Millet	62.36	0.770	.4802
			1912	Wheat	193.48	0.659	1.2750
			1912	Millet	73.95	0.778	.5753
			1913	Wheat	169.64	0.755	1.2808
			1913	Millet	84.23	0.640	.5391
			1914	Wheat	154.47	0.955	1.4752
			1914	Millet	109.74	0.610	.6694
		Total			1409.09		10.2549
Jackson	H4	L (1909)	1910	Oats	268.40	0.670	1.7982
		S (1909 & 1911)	1910	Millet	66.15	1.120	.7409

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Wheat	197.44	0.720	1.4216
		N (annual)	1911	Millet	81.30	0.640	.5203
			1912	Wheat	215.33	0.643	1.3846
			1912	Millet	77.68	0.768	.5966
			1913	Wheat	174.95	0.879	1.5378
			1913	Millet	92.13	0.630	.5804
			1914	Wheat	202.80	0.810	1.6427
			1914	Millet	121.95	0.600	.7317
		Total			1498.13		10.9548
Jackson	H5	S (1909 & 1911)	1910	Oats	145.38	0.800	1.1630
			1910	Millet	71.48	1.000	.7148
			1911	Wheat	81.95	0.750	.6146
			1911	Millet	92.35	0.630	.5818
			1912	Wheat	79.92	0.774	.6186
			1912	Millet	60.91	0.768	.4678
			1913	Wheat	44.02	0.977	.4301
			1913	Millet	90.75	0.700	.6353
			1914	Wheat	73.10	0.825	.6031
			1914	Millet	80.95	0.735	.5950
		Total			820.81		6.4241
Jackson	H6	L (1909)	1910	Oats	135.29	0.750	1.0147
		S (1909 & 1911)	1910	Millet	80.74	1.040	.8397
			1911	Wheat	89.92	0.740	.6654
			1911	Millet	95.85	0.660	.6326
			1912	Wheat	94.81	0.822	.7793
			1912	Millet	82.19	0.810	.6657
			1913	Wheat	75.38	0.977	.7365
			1913	Millet	113.98	0.660	.7523
			1914	Wheat	106.40	0.750	.7980
			1914	Millet	113.28	0.628	.7114
		Total			987.84		7.5956
Jackson	H7	L (1909)	1910	Oats	317.33	0.730	2.3165
		F (1909 & 1911)	1910	Millet	108.91	1.000	1.0891
		S (1909 & 1911)	1911	Wheat	226.31	0.740	1.6747

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Millet	106.30	0.640	.6803
		N (annual)	1912	Wheat	312.04	0.686	2.1406
			1912	Millet	147.25	0.685	1.0087
			1913	Wheat	221.03	0.800	1.7682
			1913	Millet	123.68	0.730	.9029
			1914	Wheat	226.98	0.793	1.7999
			1914	Millet	164.41	0.575	.9454
		Total			1954.24		14.3263
Jackson	I8	D (1909)	1910	Oats	194.00	0.810	1.5714
		F (1909 & 1911)	1910	Millet	102.41	1.090	1.1163
		S (1909 & 1911)	1911	Wheat	122.07	0.750	.9155
		PK (annual)	1911	Millet	118.15	0.640	.7562
			1912	Wheat	177.16	0.808	1.4315
			1912	Millet	90.32	0.913	.8246
			1913	Wheat	128.95	0.860	1.1090
			1913	Millet	143.92	0.680	.9787
			1914	Wheat	117.77	0.735	.8656
			1914	Millet	154.60	0.540	.8348
		Total			1349.35		10.4036

TABLE XIII—*The nitrogen content of the surface soils at different periods. Estimations calculated to moisture-free basis*

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
"Average" samples of untreated soils taken in 1909, at the outset of the experiments									
Cookeville	1096	-----	-----------	0.0742	Gallatin	1267	-----	-----------	0.1463
Crossville	1101	-----	-----------	0.0784	Jackson	1266	-----	-----------	0.0593

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Samples taken in 1911, at the end of the two-year period									
Cookeville	1874	A 1	L	0.0745	Crossville	1911	8	LPK	0.0727
"	1875	2	F	0.0751	"	1912	9	LFPK	0.0768
"	1876	3	LF	0.0805	"	1913	10	LSPK	0.0762
"	1877	4	O	0.0760	"	1967	J 4	LSFPK	0.0794
"	1878	5	LSF	0.0846	"	1968	5	LPKN	0.0731
"	1879	6	LSFPK	0.0854	"	1969	6	LSPKN	0.0763
"	1880	7	PK	0.0738	Gallatin	1914	E 1	L	0.1264
"	1881	8	LPK	0.0710	"	1915	2	F	0.1346
"	1882	9	PKN	0.0797	"	1916	3	LF	0.1347
"	1883	10	LPKN	0.0720	"	1917	4	O	0.1294
"	1884	B 1	SPK	0.0740	"	1918	5	LSF	0.1364
"	1885	2	LSPK	0.0723	"	1919	6	LSFPK	0.1381
"	1886	3	SPKN	0.0782	"	1920	7	PK	0.1376
"	1887	4	LSPKN	0.0747	"	1921	8	LPK	0.1304
"	1888	5	S	0.0760	"	1922	9	PKN	0.1311
"	1889	6	LS	0.0760	"	1923	10	LPKN	0.1297
"	1890	7	LSFPKN	0.0823	"	1924	F 1	SPK	0.1320
"	1891	8	LPK	0.0698	"	1925	2	LSPK	0.1306
"	1892	9	LFPK	0.0752	"	1926	3	SPKN	0.1306
"	1893	10	LSPK	0.0695	"	1927	4	LSPKN	0.1318
"	1964	J 1	LSFPK	0.0740	"	1928	5	S	0.1306
"	1965	2	LPKN	0.0664	"	1929	6	LS	0.1348
"	1966	3	LSPKN	0.0699	"	1930	7	LSFPKN	0.1393
Crossville	1894	C 1	L	0.0817	"	1931	8	LPK	0.1247
"	1895	2	F	0.0897	"	1932	9	LFPK	0.1318
"	1896	3	LF	0.0874	"	1933	10	LSPK	0.1291
"	1897	4	O	0.0817	"	1970	J 7	LSFPK	0.1350
"	1898	5	LSF	0.0868	"	1971	8	LPKN	0.1247
"	1899	6	LSFPK	0.0848	"	1972	9	LSPKN	0.1298
"	1900	7	PK	0.0788	Jackson	1934	G 1	L	0.0620
"	1901	8	LPK	0.0759	"	1935	2	F	0.0674
"	1902	9	PKN	0.0774	"	1936	3	LF	0.0656
"	1903	10	LPKN	0.0776	"	1937	4	O	0.0568
"	1904	D 1	SPK	0.0871	"	1938	5	LSF	0.0725
"	1905	2	LSPK	0.0835	"	1939	6	LSFPK	0.0664
"	1906	3	SPKN	0.0869	"	1940	7	PK	0.0568
"	1907	4	LSPKN	0.0837	"	1941	8	LPK	0.0569
"	1908	5	S	0.0815	"	1942	9	PKN	0.0561
"	1909	6	LS	0.0800	"	1943	10	LPKN	0.0572
	1910	7	LSFPKN	0.0860	"	1944	H 1	SPK	0.0598

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Jackson	1945	2	LSPK	0.0649	Jackson	1955	2	L	0.0544
"	1946	3	SPKN	0.0626	"	1956	3	PK	0.0525
"	1947	4	LSPKN	0.0631	"	1957	4	SFPK	0.0654
"	1948	5	S	0.0624	"	1958	5	SF	0.0654
"	1949	6	LS	0.0610	"	1959	6	LSF	0.0643
"	1950	7	LSFPKN	0.0694	"	1960	7	FeSF	0.0644
"	1951	8	LPK	0.0524	"	1961	8	LSFPK	0.0718
"	1952	9	LFPK	0.0586	"	1962	9	LPKN	0.0557
"	1953	10	LSPK	0.0567	"	1963	10	LSPKN	0.0569
"	1954	I 1	O	0.0562	"	1973	J10	LSFPK	0.0648
Samples taken in 1914, at the end of the five-year period									
Cookeville	3799	A 1	L	0.0684	Crossville	3825	7	PK	0.0742
"	3800	2	F	0.0759	"	3826	8	LPK	0.0737
"	3801	3	LF	0.0795	"	3827	9	PKN	0.0762
"	3802	4	O	0.0741	"	3828	10	LPKN	0.0763
"	3803	5	LSF	0.0828	"	3829	D 1	SPK	0.0838
"	3804	6	LSFPK	0.0896	"	3830	2	LSPK	0.0845
"	3805	7	PK	0.0709	"	3831	3	SPKN	0.0824
"	3806	8	LPK	0.0724	"	3832	4	LSPKN	0.0846
"	3807	9	PKN	0.0714	"	3833	5	S	0.0821
"	3808	10	LPKN	0.0724	"	3834	6	LS	0.0783
"	3809	B 1	SPK	0.0731	"	3835	7	LSFPKN	0.0911
"	3810	2	LSPK	0.0711	"	3836	8	LPK	0.0704
"	3811	3	SPKN	0.0755	"	3837	9	LFPK	0.0763
"	3812	4	LSPKN	0.0740	"	3838	10	LSPK	0.0707
"	3813	5	S	0.0746	"	3892	J 4	LSFPK	0.0784
"	3814	6	LS	0.0726	"	3893	5	LPKN	0.0693
"	3815	7	LSFPKN	0.0838	"	3894	6	LSPKN	0.0739
"	3816	8	LPK	0.0646	Gallatin	3839	E 1	L	0.1184
"	3817	9	LFPK	0.0750	"	3840	2	F	0.1290
"	3818	10	LSPK	0.0681	"	3841	3	LF	0.1325
"	3889	J 1	LSFPK	0.0749	"	3842	4	O	0.1217
"	3890	2	LPKN	0.0619	"	3843	5	LSF	0.1394
"	3891	3	LSPKN	0.0658	"	3844	6	LSFPK	0.1367
Crossville	3819	C 1	L	0.0796	"	3845	7	PK	0.1219
"	3820	2	F	0.0904	"	3846	8	LPK	0.1245
"	3821	3	LF	0.0943	"	3847	9	PKN	0.1281
"	3822	4	O	0.0820	"	3848	10	LPKN	0.1270
"	3823	5	LSF	0.0915	"	3849	F 1	SPK	0.1272
"	3824	6	LSFPK	0.0904	"	3850	2	LSPK	0.1247

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Gallatin	3851	3	SPKN	0.1251	Jackson	3869	H 1	SPK	0.0625
"	3852	4	LSPKN	0.1283	"	3870	2	LSPK	0.0672
"	3853	5	S	0.1242	"	3871	3	SPKN	0.0625
"	3854	6	LS	0.1290	"	3872	4	LSPKN	0.0670
"	3855	7	LSFPKN	0.1283	"	3873	5	S	0.0598
"	3856	8	LPK	0.1146	"	3874	6	LS	0.0689
"	3857	9	LFPK	0.1211	"	3875	7	LSFPKN	0.0791
"	3858	10	LSPK	0.1201	"	3876	8	LPK	0.0539
"	3895	J 7	LSFPK	0.1228	"	3877	9	LFPK	0.0610
"	3896	8	LPKN	0.1123	"	3878	10	LSPK	0.0560
"	3897	9	LSPKN	0.1157	"	3879	I 1	O	0.0544
Jackson	3859	G 1	L	0.0615	"	3880	2	L	0.0534
"	3860	2	F	0.0669	"	3881	3	PK	0.0524
"	3861	3	LF	0.0711	"	3882	4	SFPK	0.0645
"	3862	4	O	0.0555	"	3883	5	SF	0.0688
"	3863	5	LSF	0.0739	"	3884	6	LSF	0.0635
"	3864	6	LSFPK	0.0739	"	3885	7	FeSF	0.0689
"	3865	7	PK	0.0565	"	3887	9	LPKN	0.0542
"	3866	8	LPK	0.0603	"	3888	10	LSPKN	0.0564
"	3867	9	PKN	0.0595	"	3898	J10	LSFPK	0.0640
"	3868	10	LPKN	0.0617					

TABLE XIV—*The nitrogen content of the subsoils at different periods. Estimations calculated to moisture-free basis*

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
"Average" samples of "6-to-12-inch" subsoils taken in 1908, at time of placing in cylinders									
Cookeville	1097	-----	-----------	0.0300	Gallatin	----	-----	-----------	------
Crossville	1107	-----	-----------	0.0607	Jackson	1280	-----	-----------	0.0324
Samples of "6-to-12-inch" subsoils, taken in 1914									
Cookeville	3899	A 1	L	0.0261	Cookeville	3902	4	O	0.0261
"	3900	2	F	0.0274	"	3903	5	LSF	0.0270
"	3901	3	LF	0.0274	"	3904	6	LSFPK	0.0277

TABLE XIV (*Continued*)

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
"	3905	7	PK	0.0265	Gallatin	3940	2	F	0.0770
"	3906	8	LPK	0.0307	"	3941	3	LF	0.0735
"	3907	9	PKN	0.0276	"	3942	4	O	0.0681
"	3908	10	LPKN	0.0274	"	3943	5	LSF	0.0768
"	3909	B 1	SPK	0.0275	"	3944	6	LSFPK	0.0736
"	3910	2	LSPK	0.0266	"	3945	7	PK	0.0691
"	3911	3	SPKN	0.0269	"	3946	8	LPK	0.0702
"	3912	4	LSPKN	0.0289	"	3947	9	PKN	0.0775
"	3913	5	S	0.0259	"	3948	10	LPKN	0.0752
"	3914	6	LS	0.0256	"	3949	F 1	SPK	0.0746
"	3915	7	LSFPKN	0.0272	"	3950	2	LSPK	0.0750
"	3916	8	LPK	0.0234	"	3951	3	SPKN	0.0743
"	3917	9	LFPK	0.0267	"	3952	4	LSPKN	0.0740
"	3918	10	LSPK	0.0257	"	3953	5	S	0.0719
"	3989	J 1	LSFPK	0.0274	"	3954	6	LS	0.0733
"	3990	2	LPKN	0.0262	"	3955	7	LSFPKN	0.0723
"	3991	3	LSPKN	0.0274	"	3956	8	LPK	0.0684
Crossville	3919	C 1	L	0.0569	"	3957	9	LFPK	0.0699
"	3920	2	F	0.0578	"	3958	10	LSPK	0.0697
"	3921	3	LF	0.0610	"	3995	J 7	LSFPK	0.0698
"	3922	4	O	0.0571	"	3996	8	LPKN	0.0605
"	3923	5	LSF	0.0589	"	3997	9	LSPKN	0.0624
"	3924	6	LSFPK	0.0609	Jackson	3959	G 1	L	0.0286
"	3925	7	PK	0.0608	"	3960	2	F	0.0284
"	3926	8	LPK	0.0444	"	3961	3	LF	0.0274
"	3927	9	PKN	0.0563	"	3962	4	O	0.0254
"	3928	10	LPKN	0.0604	"	3963	5	LSF	0.0297
"	3929	D 1	SPK	0.0548	"	3964	6	LSFPK	0.0274
"	3930	2	LSPK	0.0576	"	3965	7	PK	0.0285
"	3931	3	SPKN	0.0584	"	3966	8	LPK	0.0282
"	3932	4	LSPKN	0.0595	"	3967	9	PKN	0.0287
"	3933	5	S	0.0564	"	3968	10	LPKN	0.0317
"	3934	6	LS	0.0526	"	3969	H 1	SPK	0.0299
"	3935	7	LSFPKN	0.0574	"	3970	2	LSPK	0.0306
"	3936	8	LPK	0.0593	"	3971	3	SPKN	0.0311
"	3937	9	LFPK	0.0576	"	3972	4	LSPKN	0.0306
"	3938	10	LSPK	0.0528	"	3973	5	S	0.0306
"	3992	J 4	LSFPK	0.0563	"	3974	6	LS	0.0329
"	3993	5	LPKN	0.0542	"	3975	7	LSFPKN	0.0339
"	3994	6	LSPKN	0.0562	"	3976	8	LPK	0.0292
Gallatin	3939	E 1	L	0.0684	"	3977	9	LFPK	0.0292

TABLE XIV (*Continued*)

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
Jackson	3978	10	LSPK	0.0297	Jackson	3984	6	LSF	0.0319
"	3979	I 1	O	0.0312	"	3985	7	FeSF	0.0327
"	3980	2	L	0.0318	"	3986	8	LSFPK	0.0347
"	3981	3	PK	0.0312	"	3987	9	LPKN	0.0319
"	3982	4	SFPK	0.0323	"	3988	10	LSPKN	0.0324
"	3983	5	SF	0.0312	"	3998	J10	LSFPK	0.0327