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The Rational Improvement of Highland Rim Soils: Conclusions from six years of field experiments with various farm crops

University of Tennessee Agricultural Experiment Station

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THE RATIONAL IMPROVEMENT OF HIGHLAND RIM SOILS

CONCLUSIONS FROM SIX YEARS OF FIELD EXPERIMENTS WITH VARIOUS FARM CROPS

BY

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KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

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

PREFACE

The Highland Rim, which completely surrounds the Central Basin of Middle Tennessee, has an approximate area of 9300 square miles and an elevation of about 1000 feet above sea level. The average annual rainfall of nearly 50 inches is well distributed throughout the year. The average date of the last killing frost in the spring varies, according to the locality, from April 8 to April 20. In a similar manner, the average date of the first killing frost in the fall varies from October 8 to October 26.

The soils may be roughly divided into two large groups, one on the outside of the Rim, consisting of those derived from the decomposition of limestone, and the other those derived from a siliceous or "freestone" formation. Over large areas the former are readily distinguished by their very dark red, or "mulatto," color. They are heavy silt loams, which are recognized as much more fertile and valuable than the gray-colored light silt loams of siliceous origin. Other areas of limestone origin consist of grayish or brownish loams which have red subsoils. The siliceous soils can be subdivided into several closely related classes, which may be distinguished by differences in both texture and color, the latter being especially pronounced in the subsoil, which varies from light red to yellow and gray. The investigation of these various soils has not progressed far enough to permit of accurate distinctions in all respects, but if the dark red soils be placed first in value, then the gray soils with red subsoils come next, followed by those with yellowish subsoil, while the least valuable and the most difficult to handle are the light gray, silty soils, which are known as "crawfishy" and which are apt to be in need of drainage.

In regard to adaptability to different crops: The dark red areas are especially well suited to wheat, corn, and various forage crops, including clover, grass and alfalfa. The gray soils are excellent for tobacco, peanuts, and various trucking crops; also for corn, wheat and other general farm crops, although clover and grass are satisfactorily obtained with some difficulty.

The experimental work on which this bulletin is founded has extended over a period of six years. Special credit should be given, for the conduct of the experiments, to the following assistants: Mr. J. E. Converse, Mr. W. N. Rudd, Mr. L. R. Neel, and Mr. J. E. Hite.

Numerous experimental results with various crops have been reported in detail in Bulletins 86 and 92 of this Station, which may be obtained upon request.

The experimental data obtained on the Rim soils are considered by the writer to be applicable in a large measure to the soils of East Tennessee. Both the gray-colored, gravelly dolomitic soils and the gray-colored slate or shale soils of East Tennessee are very similar in plant-food requirements to the gray soils of the Rim. The dark red, or mulatto, soils derived from limestone in East Tennessee are similar in appearance, origin, and crop adaptability to the mulatto soils of the Rim, but the former soils are somewhat better supplied with phosphoric acid than the latter. The Chickamauga, or "rotten," limestone soils, though different in color and mechanical composition, have plant food and lime needs similar to those of the limestone soils of the Rim.

THE RATIONAL IMPROVEMENT OF HIGHLAND RIM SOILS

Conclusions from Six Years of Field Experiments with Various Farm Crops

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PRINCIPLES OF SOIL FERTILITY WITH SPECIAL REFERENCE TO THE HIGHLAND RIM

THE PLANT-FOOD ELEMENTS

Plants need food of different kinds, very much as do animals. That is, a plant will starve if deprived of any one of several substances in the soil, just as a man will starve if he tries to live on fat meat alone, or on starch alone, or on sugar alone, or, for that matter, on all three of these articles of food, because they lack the element that makes blood and lean meat and which is found in eggs, milk, beans, and the like. To state the case another way, a person to be well fed, must get not only food enough to satisfy his hunger, but also food that contains in proper amount the elements needed to renew all parts of the body. In like manner, plants, to be well nourished, require an abundance of each of a number of elements.

The elements necessary

The elements found in the soil which are necessary to plants are nitrogen, phosphorus, calcium, potassium, magnesium, sulphur, and iron. Those that come wholly from air and water are carbon, hydrogen, and oxygen. The latter group makes up the bulk of the dry substance of plants, or 90 to 99 parts out of 100. The element nitrogen can be given an intermediate place between the two groups, because the original source of the soil nitrogen is the air. Also certain kinds of plants, the legumes, are able to utilize atmospheric nitrogen, though this is done indirectly, through the nodule-forming bacteria found in their roots.

To the farmer the discovery of the elements that plants must have meant much, for as long as they were unknown there was no way to tell exactly what could be used to help make poor land rich. Since this knowledge was obtained the world has been searched for minerals and refuse that supply these elements; soils have been analyzed to find out how much of each they contain; and it is now possible to take almost any soil and make it fertile.

The four elements of most importance

Of the seven soil elements mentioned, only four have been found to be especially important in practical farming. That is, they are the only ones which are apt to be deficient in the soil, and which generally make the difference between a rich and a poor soil, so far as plant food is concerned. These four elements are nitrogen, phosphorus, calcium, and potassium. The last three are sometimes called the "minerals" and are generally referred to under the names of "phosphoric acid," "lime," and "potash."

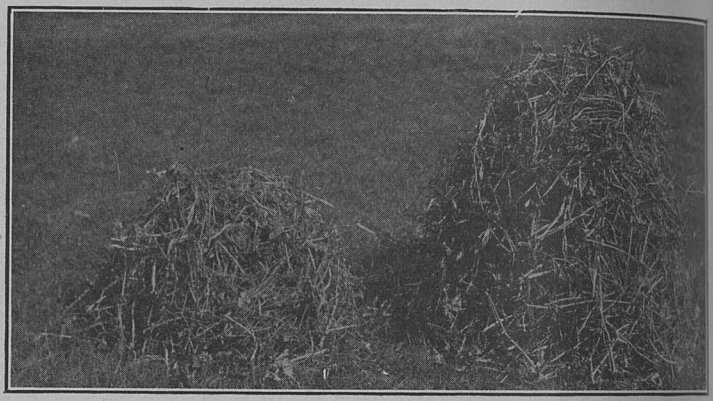
Main object of bulletin

One of the main objects of this bulletin is to show the special plant-food needs of the Highland Rim soils, what fertilizers to buy, and, as far as possible, how much to use on different crops in order to get the best practical results.

THE MINERALS

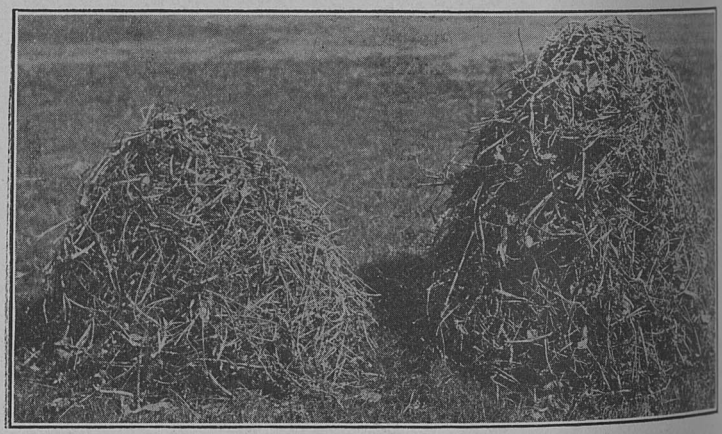
Chemical analysis tells much about a soil's supply of plant food, and if the evidence furnished by the analysis is supported by the results of field trials there can be little doubt as to the correctness of the conclusions. In the case of the gray soils of the Barrens type we have both kinds of evidence to prove that they are naturally very poor in two important mineral substances, phosphoric acid and lime, and that they are not well supplied with a third one, potash. According to the chemical analyses made at this Station, an average acre of Barrens soil to the depth of one foot contains only 1500 pounds of phosphoric acid, 3100 pounds of lime, and 5300 pounds of potash that can be dissolved out by the aid of strong, hot hydrochloric acid, as compared with 8000 pounds of phosphoric acid, 11000 pounds of lime, and 13600 pounds of potash in the rich Central Basin soil. The red-colored limestone soils of the Rim are appreciably better supplied with these elements than the gray soils, a foot-acre containing, by analysis, 2500 pounds of phosphoric acid, 5600 pounds of lime, and 9600 pounds of potash. The results of field experiments conducted in several different counties have demonstrated repeatedly that phosphoric acid is greatly needed by all the Rim soils, that liming is nearly always profitable, and that potash is often needed by the gray soils. In fact, in the case of the latter soils the need of all these substances is so great that there is no occasion for surprise that in the past many farmers have become discouraged and failed in the attempt to get satisfactory crops from such a soil. Fortunately, these substances are easily obtained, and can be profitably used from the outset. Also the writer will add that the soils of the greater portion of the eastern United States are deficient in these same elements, and that little more will be found to be required by the Plateau soils than should be used elsewhere outside of a few favored localities.

COWPEA HAY—FROM EXPERIMENTS ON HIGHLAND RIM SOIL



NO FERTILIZER AND NO LIME
0.46 ton per acre

PHOSPHATE AND POTASH
1.22 ton per acre



LIME BUT NO FERTILIZER
0.80 ton per acre

PHOSPHATE, POTASH AND LIME
1.66 ton per acre

HOW MUCH AND WHAT KIND OF LIME TO USE

Ground limestone, fresh burnt lime, air-slaked lime, and wood ashes may be used for liming the land. Any one of them will "sweeten" the soil; and the Rim soils are often "sour," a condition that is unfavorable to most farm crops. A reasonable application of ground limestone is 2 tons per acre; and if it be evenly distributed this amount will probably be ample for 5, or perhaps 10, years. One ton of burnt lime is equal to

2 tons of the ground limestone, and may be used to advantage where the hauling is an important item. About 1 1-3 ton of air-slaked lime is equal to 1 ton when fresh-burnt, and about 3 tons of wood ashes are required to equal 2 tons of the ground limestone. Any of these materials can be advantageously applied for almost any crop except cotton, peanuts and possibly tobacco. The crops most benefited are the legumes, such as clovers, cowpeas, etc., but according to our field experiments corn, sorghum, millet, oats, and the like are nearly always helped to a marked extent, so that the expense of liming is often more than met the first year by the increased yields.

Why has liming been neglected?

The question may now arise, If lime is highly beneficial to Rim soils, why has it not been extensively used? There are, doubtless, several reasons, such as the expense and labor of hauling and applying, but in particular a lack of knowledge in regard to its true value. The fact must be remembered that in addition to making "sour" land "sweet" lime adds only one element of plant food to the soil, and that it does not take the place of phosphoric acid, or potash, or nitrogen. The writer has little doubt that if lime were the only necessity it would have been extensively used long ago, but the fact that other things were needed complicated the matter and obscured its true value. Therefore, lime the land, but do not expect it to take entirely the place of phosphate, of manure, of soil-improving crops, or any good method of soil improvement. For further details and experimental data of different kinds, reference may be had to Bulletin 97 of this Station, "Liming for Tennessee Soils."

PHOSPHATES

Phosphoric acid is the valuable constituent of a number of commercial materials which are known as phosphates. Some kind of phosphate is a necessity in order to lay a firm foundation for a fertile and durable Rim soil; and acid phosphate is now advised as the most profitable for general use. Either Thomas slag phosphate or bone meal might be used, but they are too expensive. Raw phosphate rock is recommended by some, but, according to numerous experiments by the Station, its effect is uncertain and, if the land be limed, acid phosphate is apt to surpass it in profitableness. Unlike lime, which need be applied only once in several years, acid phosphate should be used in small quantity and applied for almost every crop. Two to three hundred pounds per acre is a practical amount for a common farm crop, such as corn, sorghum, millet, cowpeas, etc., and will more than replace the phosphoric acid which the crop removes.

Composition and grades of acid phosphate

Since acid phosphate is the basis material of the commercial fertilizer mixtures, its composition and properties should be understood by every farmer. Briefly stated, acid phosphate is made by mixing about equal parts by weight of ground phosphate rock and sulphuric acid. The acid unites with the lime of the rock phosphate and forms the sulphate of lime, or land plaster, which makes up about one-half of the acid phosphate. In addition, the phosphoric acid is changed from insoluble to soluble forms, so that plants can readily make use of it. Fertilizer dealers generally handle two grades of acid phosphate. One is guaranteed to contain 16 per cent of available phosphoric acid, and the other is of lower grade, guaranteed to contain 14 per cent of available phosphoric acid. The "high-grade," with 16 per cent guarantee, is nearly always the most economical to buy. In fact, the 14 per cent goods is apt to be made, in response to a demand for a cheap fertilizer, by mixing sand, soil, or some such material, with a high-grade goods to reduce it to a low-grade. Any such reduction costs something to make, and the freight on the material added must be paid, so that for these, as well as other reasons that may be thought of, the really dear and least profitable kind is the low-grade phosphate.

Some properties of acid phosphate

If kept under cover acid phosphate can be held over for any length of time, as it does not lose strength on standing. It should not be mixed with either lime or ashes, but even then its value is by no means destroyed. It is not lost from the soil by leaching, but in the course of a little time combines with lime, iron, or other bases in the soil, which reduce the readiness with which plants can make use of it, and hence one reason for the advice to make a light dressing to suit each crop. Wherever needed the effect of an application of acid phosphate is especially noticeable in the increased production of grain and fruit, though an increase of stem and leaf growth is also marked. Only a relatively small quantity of phosphoric acid is needed even by a large crop, but where a great deficiency exists, such as is the case with the Barrens soil in particular, successful farming will be almost impossible until the deficiency is remedied.

Not enough manure

At this point some one is sure to think of a vegetable garden or other piece of land which was made highly productive by the application of manure and where neither commercial phosphate nor lime had ever been used. Manure is a complete fertilizer, containing lime, phosphoric acid, potash, and nitrogen. It is also an alkaline substance, and tends, therefore, to "sweeten" a soil. The great value of manure is unquestioned. If every farmer had all he was willing to haul, say, four or five miles, the soil fertility prob-

lem would be solved; but unfortunately nothing of the kind is the case, either here or anywhere else, except in the neighborhood of some town or city. Furthermore, if the manure could be gotten, a good liming of the land and an application of phosphate would be profitable at the outset of the soil upbuilding, for the manure would give better returns and clover could be grown at once. The writer recalls a very successful farmer who years ago bought some poor Barrens land and brought it up to a high state of productiveness in the course of his lifetime by buying corn from his neighbors and feeding it, along with whatever else he could raise, to cattle. He considered the manure as about the chief profit, and thereby succeeded in enriching his land. In this case the necessary phosphoric acid was obtained in the corn which grew on other lands, which were therefore impoverished. All the manure is needed that can be gotten, but to get the crops that can be fed to make the manure both lime and phosphate are very important.

POTASH

Potash is little needed by the red-colored soils, so that if the major part of the crops grown be fed on the farm and the manure returned to the land, little attention need be given to this element. The Barrens soils, however, are at best only moderately well supplied, and if large crops, by the aid of liming, phosphating, and good methods of culture, be grown, and especially if crops like Irish potatoes be raised for shipment, then potash salts should be used in moderate quantity along with acid phosphate.

Muriate of potash The cheapest of the commercial salts is the muriate of potash, which retails at nearly 3 cents per pound. It contains about 50 pounds of potash to the 100, so that potash is one of the cheap elements which can be profitably supplied whenever needed.

Wood ashes Wood ashes contain about 5 pounds of potash to the 100, but if kept dry and unleached may contain twice this amount. Of course, in addition they contain a large amount of lime—to which the writer would attribute their chief value—some phosphoric acid, and, in fact, all of the mineral elements of plant food.

NITROGEN

As a rule the most marked difference between rich and poor land or between "new" and "old" land lies in the content of nitrogen and humus, which are abundant in the rich soil but deficient in the poor soil.

The high cost of nitrogen

Nitrogen is by far the most expensive to buy of the plant food elements. A pound of available phosphoric acid costs at the present time about 4½ cents; a pound of potash costs nearly 6 cents; but a pound of nitrogen costs in the neighborhood of 20 cents. Moreover, plants require two or three times as much nitrogen as they do of phosphoric acid. For example, the nitrogen needed in the production of a bushel of corn would cost about 33½ cents; while the phosphoric acid would cost only 2½ cents and the potash 7½ cents. This high cost of nitrogen prohibits the use of more than a small amount for field crops and limits the amount that can be used profitably on even high-priced garden crops. It is this high cost of nitrogen that prevents the so-called "complete fertilizer" from being well balanced and containing its due proportion of nitrogen. In fact, 100 pounds of the average complete fertilizer, as commonly sold on the market, contains enough phosphoric acid for 18 bushels of corn, but only enough nitrogen for one bushel. With these facts before us, and also in view of the poverty in nitrogen of nearly all long-cultivated soils, not only on the Rim but everywhere in the Eastern States, it is evident that the problem of really building up the soil in this element must be solved in some way other than by buying it in commercial fertilizer form. To understand that fertilizers in and of themselves must fail to keep up soil fertility, because they do not furnish enough nitrogen, is very important and explains why they have so often fallen into disrepute.

Nitrogenous materials

There are a number of nitrogenous materials which are much used for fertilizer purposes, such as ammonium sulphate, dried blood, and tankage, but the two that are at this time the most easily obtained and are in other respects best adapted to general use are nitrate of soda and cotton-seed meal. Nitrate of soda contains 15 pounds and "prime" cotton-seed meal about 6¼ pounds of nitrogen per 100. For Rim soils neither is advised to be used alone, but only in connection with an application of acid phosphate.

Legumes as a source of nitrogen

Fortunately there is a family of plants that is able to get nitrogen from the air through the aid of bacteria which live in their roots. This family is known as legumes. Those of most importance are as follows: Red clover, alsike clover, white clover, crimson clover, Japan clover, alfalfa, sweet clover, cowpeas, soy beans, garden beans and peas, and vetches.

Complete fertilizer for legumes

A complete fertilizer for these crops need not contain nitrogen; hence, the usual recommendation is, after the land has been limed, to use a mixture of only acid phosphate and muriate of potash. For Rim soils the following is a moderate application for an acre of land:

200 lbs. high-grade acid phosphate
20 lbs. muriate of potash

The two ingredients should be well mixed by being shoveled together so that both may be applied at the same time.

SOIL INOCULATION

On the roots of all kinds of legumes are normally found small growths resembling warts, which are called "nodules." These nodules are produced by exceedingly small forms of plant life, the nodule-forming bacteria, which can be seen only by the aid of a powerful microscope. These bacteria take plant food of the various kinds needed from the root sap of the plants in which they live and in turn they supply the plant with more or less nitrogen, which they have the power to get from the air. If a legume be grown in a soil which does not contain these bacteria it can make use only of the soil supply of nitrogen, like other plants, such as corn or wheat. Clover, for instance, can enrich a soil in nitrogen only when the proper bacteria are present because the latter are the true nitrogen gatherers from the inexhaustible supply of the air. It has been found that widely different kinds of legumes require different bacteria. For example, cowpeas may thrive on a certain soil, the nodules proving that the right kind of bacteria are present, but alfalfa sown on the same soil may produce only yellow looking and unhealthy plants and no nodules, even though the soil be limed and well fertilized. In such a case the proper bacteria must be supplied before alfalfa can be grown successfully. This is usually done by scattering 200 or 300 pounds of earth per acre, taken from some field where alfalfa was grown successfully and was well inoculated. Also, inoculation usually follows the repeated seeding of the legume desired, and for this reason a small amount of alfalfa or of sweet clover seed is sometimes advised to be sown with clover and grass.

Some precautions

In this connection there are a few precautions which should be mentioned. First, it is not worth while to inoculate soil in great need of lime and phosphate until these substances have been supplied. Second, direct rays of the sun can kill the germs, so that the best results are obtained if the inoculating soil be either drilled into the ground or scattered broadcast on a cloudy day and then harrowed in. Third, undesirable weed seeds may be brought to the land along with the de-

sirable bacteria. It may also be mentioned that after a soil has once become thoroughly inoculated a second inoculation is seldom if ever needed.

Crops that may need inoculation

The Barrens soils have proven rather poorly supplied with bacteria, and if any of the following crops be grown, soil inoculation may be required at first in order to get the best results: Vetch, crimson clover, soy beans, sweet clover, and alfalfa. For the last two crops in particular inoculation should always precede the first seeding.

AZOTOBACTER

There is another and very important group of bacteria, which appear to be nearly everywhere, and which supply the soil with nitrogen from the air. They are called azotobacter. Unlike the nodule-forming kinds, azotobacter are independent of the higher forms of living plant life. The conditions favorable to their best development are abundant supplies of lime, phosphoric acid, air, and some kind of organic matter, such as would be furnished by manure, rye or other green crop turned under, the carbon of which they use as a source of energy. Meadow land conditions seem to be favorable to them, for meadows are found to gain in nitrogen even when no legumes are present.

HUMUS

One of the soil constituents which are well known to decrease under usual cultivation is humus, as the dark-colored organic substances which result from the decay of vegetable matter, etc., are called. The value of vegetable matter in the soil is not apt to be overestimated, for the humus produced from it increases the water-holding capacity of the soil and improves the texture, so that the soil is less inclined to bake and be cloddy. Also its importance in connection with different kinds of necessary bacteria is very great.

GREEN-MANURE FARMING

The growing of a legume, to be turned under and followed with a money crop, is known as green-manure farming and has been practiced very successfully both in some parts of Europe and in this country. New Jersey farmers have grown crimson clover to be turned under and followed with either potatoes or corn, not only getting large crops, but also building up the soil at the same time. Crimson clover is being grown to advantage in various parts of Tennessee and should receive special attention as a means of soil improvement. Many soils, however, are too poor in vegetable matter for any of the clovers, in which case cowpeas and rye may be used as green-manure crops at the outset.

CROP ROTATION

A proper rotation, or change of crops, has much to do with soil fertility. In the most prosperous and longest organized farm communities definite crop rotations are followed year after year with little variation. The kind of crops grown must of course be suitable to the climate, the soil, and the market conditions, but there are certain essentials to be kept in mind.

1. Leguminous crops are necessary to bring nitrogen from the air. For this purpose cowpeas are the most easily gown, but in order to be of most benefit to the soil the crop must be either pastured off or turned under. Soy beans resemble cowpeas as soil improvers, but neither is equal to either crimson or red clover, with which alsike may be included. The clovers should be especially sought, for once the conditions for their satisfactory growth have been gotten, the solution of the soil fertility problem is not difficult.

2. There should be one or more cultivated crops so that weeds may be kept in check or eradicated. Good crops for this purpose are Irish potatoes, cowpeas or soy beans planted in rows, sorghum, and corn.

3. To put vegetable matter into the soil and increase its water-holding capacity, a grass crop is very important.

Generally speaking a long rotation, covering a period of five or more years, is better than a short two-or-three-year rotation. The following is given as an example of a good, practical rotation:

1st year—Corn, followed by cover crop of rye sown at last working.

2d year—Cowpeas or soy beans.

3d year—Wheat or other small grain.

4th year—Clover and grass (chiefly clover).

5th year—Clover and grass (chiefly grass).

This means that the cultivated part of the farm is divided into five fields and that each year, as soon as the rotation is fully established there is one field in corn, one in cowpeas or soy beans, one in a small grain, one in first-year clover and grass, and one in second-year clover and grass. For a complete scheme of the crops that may be grown in order to reach this rotation, and the fetilizers, etc., suggested, see page 42.

SOME RESULTS OF FIELD EXPERIMENTS

FERTILIZERS FOR IRISH POTATOES

QUANTITY OF COMPLETE FERTILIZER

Table I gives the results obtained in nine series of experiments conducted on as many different soils of varying fertility. The fertilizer used consisted of the following mixture:

300 lbs. high-grade acid phosphate
50 " muriate of potash
400 " cotton-seed meal

The approximate cost of 750 pounds of the mixture was $9.90. In one-third of the trials this amount per acre proved more profitable than twice the quantity, and is recommended as a conservative application. 1,500 pounds per acre proved, however, to be on the average the more profitable, and would, of course, leave a larger residue for the benefit of the succeeding crop. The results were obtained in different seasons, but probably represent rather favorable conditions for this crop.

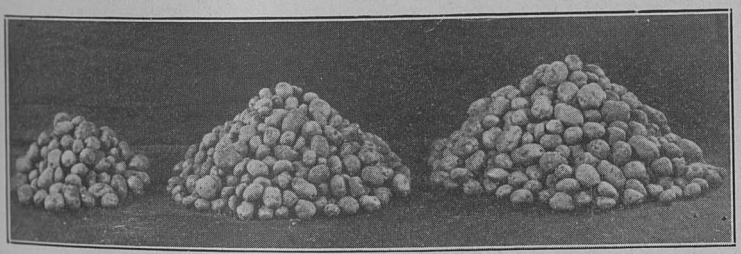
TABLE I—*Fertilizer experiments with Irish potatoes, testing two rates of application, 750 and 1500 pounds per acre, of a complete fertilizer—results of nine series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with 750 lbs. complete fertilizer		Yield per acre with 1500 complete fertilizer	
	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	61	52	104	81	136	120
2	57	36	101	80	109	90
3	37	17	96	76	108	88
4	24	4	109	54	158	91
5	32	20	142	131	191	180
6	73	63	123	110	136	121
7	54	46	164	147	198	177
8	155	139	193	180	221	205
9	110	90	167	151	228	199
Average	67	52	133	112	165	142

COTTON-SEED MEAL VERSUS NITRATE OF SODA FOR POTATOES

Table II gives the results obtained on seven different farms where experiments were made to compare the effect of nitrogen from cotton-seed meal with that from nitrate of soda for Irish potatoes. 400 pounds of the meal was assumed to contain the same amount of nitrogen as 160 pounds of the nitrate. Acid phosphate and muriate of potash were used in every case in sufficient quantity to make the nitrogen fully effective. The averages of the series show that nitrate of soda was only slightly more efficient than the cotton-seed meal, the average total yield being 145 bushels where the nitrate was used, as compared with 140 bushels where meal was used; but the average quantity of salable potatoes was the same for each. Nitrate of soda has the advantage of being somewhat cheaper than cotton-seed meal, but the disadvantages that it cannot be so generally obtained, is apt to be lumpy and need pulverizing, and is preferably applied separately from the phosphate and potash as a surface dressing.

TYPICAL RESULTS FROM EXPERIMENTS WITH POTATOES



No Fertilizer	12 Tons Manure Per Acre	12 Tons Manure and 600 Lbs. Acid Phosphate Per Acre
44 Bu. per acre	130 Bu. per acre	179 Bu. per acre

FARMYARD MANURE ALONE AND REINFORCED WITH FERTILIZERS

Farmyard manure can be used with extra good chance of profit on the Irish potato crop. According to the results of Table III, 12 tons of manure per acre gave, as the average of six series of experiments, an increase of 92 bushels of salable potatoes, or 7 2-3 bushels per ton of manure. Farmyard manure is considered to be a complete and well-balanced fertilizer for a soil that is fairly well supplied with the mineral elements, phosphoric acid and potash, but for Rim soils an additional supply of phosphoric acid in particular is needed in order to make manure most efficient. The average of five series of

TABLE II—*Fertilizer experiments with Irish potatoes, with special reference to a comparison between cotton-seed meal and nitrate of soda as sources of nitrogen—results of seven series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with phosphoric acid and potash No nitrogen		Yield per acre with phosphoric acid, potash and nitrogen from cotton-seed meal		Yield per acre with phosphoric acid, potash and nitrogen from nitrate of soda		Notes
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
1	24	4	(33)	(6)	82	71	105	59	400 lbs. meal vs. 160 lbs. nitrate
2	32	20	93	82	162	150	156	146	400 " " 160 "
3	81	64	150	127	164	150	157	148	600 " " 240 "
4	73	63	96	84	130	115	129	116	450 " " 180 "
5	89	79	93	83	85	74	102	89	300 " " 120 "
6	155	137	167	152	179	164	190	177	800 " " 320 "
7	110	90	(153)	(131)	181	162	173	153	400 " " 160 "
Average	81	65	112	95	140	127	145	127	480 " " 192 "

TABLE III—*Fertilizer experiments with Irish potatoes. Manure alone vs. manure reinforced with commercial fertilizers—six series conducted on six different farms*

Series	Yield per acre without fertilizer		Yield per acre with 12 tons manure		Yield per acre with 12 tons manure and 600 lbs. acid phosphate		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, 100 lbs. muriate of potash, and 320 lbs. nitrate of soda		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, and 320 lbs. nitrate of soda	
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	50	45	153	126	212	179	...	...	...	...
2	42	22	195	150	...	...	315	266	...	...
3	24	4	196	140	248	208	286	251	286	254
4	32	20	128	116	209	201	215	206	...	...
5	110	90	212	193	237	213	244	228	242	223
6	83	62	109	76	139	111	159	127	145	114
Series 1-6 averaged	57	41	166	133	...	...	...	...	...	...
Series 1, 3-6 averaged	60	44	160	130	209	182	...	...	...	...
Series 2-6 averaged	58	40	168	135	...	...	244	216	...	...
Series 3, 5, 6 averaged	72	52	172	136	208	177	230	202	224	197

experiments gives an increase of 138 bushels of salable potatoes from an application of 12 tons of manure, reinforced with 600 pounds of acid phosphate, as compared with an increase of only 86 bushels from 12 tons of manure alone. As the average of three trials, the application of 320 pounds per acre of nitrate of soda, in addition to 12 tons of manure and 600 pounds of acid phosphate, resulted in a further increase of 20 bushels of salable potatoes per acre. The results of the experiments in which 100 pounds of muriate of potash per acre were used in connection with 600 pounds of acid phosphate and 320 pounds of muriate of potash as a supplement to the manure, are not favorable to the use of the potash salt.

VARIETY TRIALS OF IRISH POTATOES

Several variety trials were made with Irish potatoes, but they were neither as extensive nor as long continued as is necessary in order to get conclusive results. According to the results obtained, Burbank and Green Mountain were the best late varieties, and Early Rose and Irish Cobbler the best medium-early. Bliss Triumph was found to be one of the lowest yielders, but its earliness is ample reason for its popularity. "Second-crop" seed of the Triumph variety are justly given first place over Northern-grown seed, but mention should be made of the fact that the continued planting of small seed is very apt to cause the variety to "run out," so that a very inferior strain is the result. On the other hand, the selection of good-sized seed potatoes from productive hills will have a strong tendency to improve the crop.

TIME OF APPLICATION OF NITRATE OF SODA

Nitrate of soda—value and properties

Nitrate of soda furnishes nitrogen in its most available form for plant-food purposes, especially for cereal crops. It is also about the cheapest commercial source of fertilizer nitrogen. These two reasons are sufficient to warrant the study on the part of every farmer of the most important principles concerning its use. Nitrate of soda is very readily soluble in water and may be lost from the soil by leaching, but this chance of loss is much less than might be supposed, as the results of Table IV show. It may be decomposed and nitrogen be lost into the air by being mixed with acid phosphate, but in practice such loss is apt to be small. Nitrate takes up moisture from the air in considerable quantity, and the mixture with acid phosphate will, if sufficient nitrate be present, soon become sticky, so that there are two reasons against mixing acid phosphate and nitrate of soda. Fertilizer manufacturers have found, however, that they could add a small amount to their mixture without bad results,

and this is not an uncommon practice. Because of the chance of loss by leaching and of the possible bad results from mixing with other fertilizer materials, nitrate of soda is usually applied by itself as a top-dressing. The generally accepted rules in regard to its use are as follows:

Rules for use of nitrate

1. If the soil be poor in either phosphoric acid or potash, nitrate should not be used until the deficiency in these mineral elements be supplied. According to numerous trials on Highland Rim soils, 300 pounds of acid phosphate and 50 pounds of muriate of potash are ample to reinforce 160 pounds of nitrate.

2. For fall-sown small grains, a very light application—say 40 pounds per acre—may be made at the time of seeding, provided the soil be poor and there be some danger of the crop's freezing out; otherwise all of the nitrate is applied as soon as spring growth starts, or sometime in March. For spring and summer crops the nitrate is applied as a top-dressing when the plants are small.

3. Nitrate should not be applied when the leaves of the plants are wet with rain or dew, as burning is apt to follow.

4. With light applications, up to, say, 200 pounds per acre, all the nitrate may be applied at one time, but with heavy applications one-half is often advised to be applied at an early stage of growth and the balance in ten days or two weeks.

EXPERIMENTAL EVIDENCE

For the reason that there is at the present time a wide difference between the recommendations of some writers in regard to the time at which nitrate should be applied, experiments were undertaken on this subject with two crops, corn and Irish potatoes. The soils used were, of course, deficient in nitrogen in each case, and phosphate and potash were applied in ample quantity to make the nitrate effective. Table IV gives the schemes followed and the results obtained as an average of several trials for each crop.

DISCUSSION OF THE RESULTS

Early application best for corn

The results with the corn point very definitely to the application of the nitrate at an early stage of growth, the gain being greatest when the plants were from 3 inches to 2 feet high. Of special interest were the results following the application made at tasseling time, for in none of the three series from which the averages were obtained did any increase in yield of grain result from this time of application, the only apparent effect being a deeper green foliage.

TABLE IV—*Experimental results relating to time of application of nitrate of soda*

Crop	Exp. No.	Amount of nitrate applied per acre	Time of application of nitrate	Yield per acre		Remarks
				Grain Bu.	Stover Ton	
Corn	1	None	.....	25.7	1.19	CORN
	2	100 lbs.	When plants about 3 in. high	31.2	1.39	The average of three complete sets conducted on three different farms, each in a different section of the State.
	3	"	" " " 2 ft. "	31.4	1.32	
	4	"	" " " 3½ "	30.0	1.25	Phosphate and potash used on all plots alike.
	5	"	As soon as in tassel	24.8	1.26	
				Salable tubers Bu.	Culls Bu.	
Irish potatoes	1	None	.....	78	14	POTATOES
	2	320 lbs.	Mixed in row before planting	145	22	Average of four sets on four different farms, three on Cumberland Plateau and one on Highland Rim.
	3	"	In one application as soon as plants came up	150	16	
	4	"	In two applications, ½ as soon as plants up and ½ about 12 days later.....	133	20	Phosphate and potash used in ample amount to balance nitrate.

Early application best for potatoes

The results of the experiments on Irish potatoes are of special interest, as three of the four sets were made on the fine sandy loams of the Plateau, which might be expected to suffer from leaching. In practically every one of the four sets nearly as good results as any were obtained when the nitrate was mixed with the phosphate and potash applied in the row before planting. This was rather unexpected, for the rainfall at this time of the year is heavy, so that loss of nitrate would be looked for. The results from applying one-half of the nitrate as a top-dressing when the plants were just coming up, and the balance in ten days or two weeks, were unfavorable to this method. As with the corn, the results are, therefore, decidedly in favor of an early application.

FERTILIZERS FOR CORN

PHOSPHATE AND POTASH

Corn is a very important crop, but one that is low-priced, so that the question as to the most profitable fertilizer is not always easy to answer. Fertilizer experiments covering every condition have not been possible, but considerable evidence has been obtained. With regard to phosphate, acid phosphate in moderate quantity, say 200 pounds to the acre, is recommended, and may be used by itself with as good a chance for profit as any other material or combination of materials of equal money value; it may even give greater profit, especially in the case of freshly cleared land. If a light dressing of manure can be made, then the plain acid phosphate is highly advisable as a supplement to the manure, which, as demonstrated in the potato experiments, is strengthened in its weakest point for soils like these. In a similar manner acid phosphate is recommended for a green-manure or pasture crop which is to be followed by corn, the one application in that case answering fairly well for the two crops.

The experimental results do not warrant anything more than a very light application of a potash salt, say, 10 pounds per acre of muriate of potash mixed with the acid phosphate.

CAN NITRATE OF SODA BE USED PROFITABLY FOR CORN?

We have now to consider the value of nitrogenous materials when used in combination with acid phosphate and muriate of potash. In particular, the question arises, Can nitrate of soda be used profitably for corn?

In order to answer this question field experiments have been conducted at various places in the State. In some instances the experiments have been rather extensive, embracing 25, and even 30, plots, some of which received no fertilizers, some only phosphate and potash, others

only nitrate, and a fourth set receiving phosphate, potash, and nitrate. Such a series was conducted in Warren County for each of three seasons, 1908, 1911 and 1912. In Table V are presented the fertilizer scheme and the results of the series conducted in 1912 on the farm of A. P. Titsworth, in Warren County. This series is given by itself for the reason that the results are characteristic of those obtained from nitrating under very favorable seasonal and soil conditions. According to these experiments, the cost of nitrate for each bushel of increase produced by it was 32 cents for the 40-pound application for an acre, 31 cents for the 80-pound application, 37 cents for the 160-pound, and 46 cents for the 240-pound. Under less favorable conditions the increased yield proved insufficient to pay for the nitrate, and in very unfavorable seasons no increase in grain production was obtained. Evidently there is considerable risk run. All things considered, the margin of profit appears at the present time to be too small to permit the recommendation of nitrate of soda for the corn crop, except possibly a very light application under special conditions of nitrogen deficiency.

A COMPLETE FERTILIZER FOR VERY POOR SOILS

In order to get additional data with regard to a practical formula for corn, experiments were undertaken with three different mixtures, each of which was tested at three different rates. Table VI gives the average results of six sets of these trials, which were conducted in the seasons of 1907, 1910, and 1911. Each set was conducted on a different farm, and the unfertilized plots gave yields ranging from 6.3 to 24.1 bushels per acre, the average being 15.5 bushels per acre. The experiments were made, therefore, under strictly poor-land conditions, but such as are of common occurrence.

The three formulas used were as follows:

FORMULA 1

1200 lbs. high-grade acid phosphate
100 " muriate of potash
480 " cotton-seed meal
This mixture analyzes approximately—
11 per cent available phosphoric acid
1¾ " " nitrogen
3 " " potash

FORMULA 2

1200 lbs. high-grade acid phosphate
100 " muriate of potash
720 " cotton-seed meal
This mixture analyzes approximately—
10 per cent available phosphoric acid
2½ " " nitrogen
3 " " potash

TABLE V—*Fertilizer experiments on corn, with special reference to nitrate of soda—experiments conducted on farm of A. P. Titsworth, Warren County*

Series	Phosphate and potash per acre	Application of nitrate and increased yields per acre											
		No nitrate		40 lbs. nitrate		80 lbs. nitrate		160 lbs. nitrate		240 lbs. nitrate		Average	
		Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
		Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton
1	No phosphate; no potash....	*	*	2.4	0.16	0.0	0.14	0.6	0.12	5.1	0.20	2.0	0.16
2	300 lbs. acid phosphate.....	11.4	0.66	12.6	0.58	15.5	0.64	21.5	0.62	21.7	0.78	16.5	0.66
3	300 lbs. acid phosphate.. 100 lbs. muriat of potash	6.4	0.50	9.9	0.62	.....	.....	20.6	0.78	20.8	0.86	14.4	0.69
4	150 lbs. acid phosphate.. 100 lbs. muriate of potash	6.2	0.36	12.1	0.46	12.6	0.44	16.9	0.24	.....	.....	12.0	0.38
5	600 lbs. acid phosphate.. 100 lbs. muriate of potash	8.9	0.56	13.5	0.72	19.6	0.76	25.8	0.84	26.5	0.74	18.9	0.72
	Average of series 2, 3, and 5	8.2	0.52	12.0	0.60	15.9	0.61	21.2	0.62	23.0	0.79	.....	.....

*Average of five unfertilized plots, 36.5 bushels grain and 1.08 ton stover per acre.

FORMULA 3

1200 lbs. high-grade acid phosphate
100 " muriate of potash
1440 " cotton-seed meal
This mixture analyzes approximately—
8 per cent available phosphoric acid
3½ " " nitrogen
2½ " " potash

OBJECTS IN VIEW

Attention is called to the fact that in the experiments the low rate for each formula—135 pounds of Formula 1, 150 pounds of Formula 2, and 200 pounds of Formula 3—contains the same quantity of acid phosphate, or about 90 pounds per acre; also each contains about 6¾ pounds of muriate of potash per acre; so that the differences are due entirely to a variation in the amount of cotton-seed meal used. In a similar manner, the medium rates of 202, 225, and 308 pounds each contained the same amounts of acid phosphate and muriate of potash; namely, 134 pounds of the former and 11 pounds of the latter per acre. In the heavy rates of 404, 450, and 617 pounds per acre the amount of acid phosphate for each was 270 pounds and of muriate of potash 22.5 pounds per acre. The experiments, therefore, resolve themselves into only two distinct objects; one to determine the proportion of cotton-seed meal which would be the most profitable to use with a given amount of the acid phosphate and muriate of potash, and the other to determine the quantity of the complete mixture which would be the most advisable to use. In all the trials the fertilizer was applied in the row and mixed with the soil by running a shovel plow through it before planting.

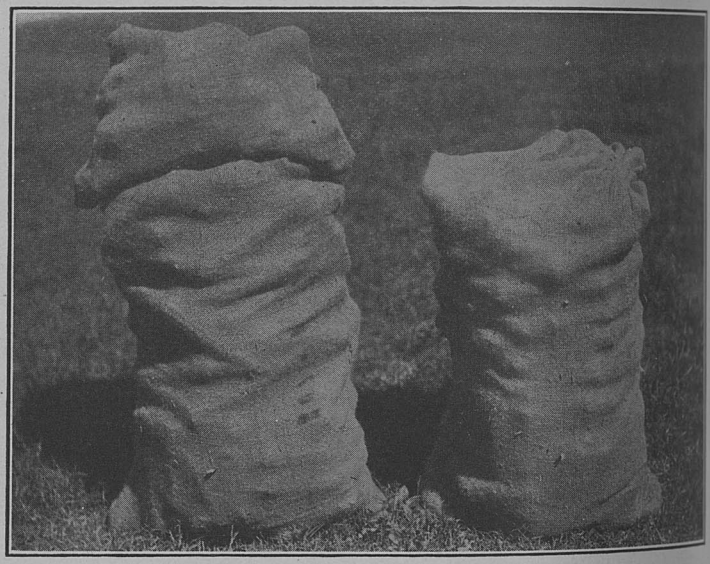
RESULTS OF EXPERIMENTS

The results of these experiments seem to justify the use of a complete fertilizer for corn on very poor soils like these. The largest gross profit was obtained where a medium application of 308 pounds per acre of Formula 3 was made. The second largest gross profit was obtained where the medium application of 225 pounds of Formula 2 was used. If the average gross profit of the three formulas be calculated, then Formula 3 ranks highest, with $4.32 per acre; Formula 2 ranks second, with $3.92 per acre; and Formula 1 ranks lowest, with an average profit of only $2.74 per acre. The question arises, however, Do the results justify the recommendation of Formula 3, which gave both highest yield and largest gross profits. In the writer's opinion they do not, for the reason that the margin of profit which can be attributed to the large proportion of cotton-seed meal in Formula 3 is too small to warrant the risks incurred. The moderate application of 225 pounds per acre of Formula 2 is, therefore, advised as both conservative and practicable. According to these

TABLE VI—*Trials of three different fertilizer mixtures for corn—seasons of* 1907-1912—*average of six sets—four on Highland Rim and two on Cumberland Plateau*

Fertilizer used per acre	Yield per acre		Increase over unfertilized plots		Value of increase @ 60c per bu.	Cost of fertilizer	Cost of increase per bu.	Profit per acre from fertilizer
	Grain	Stover	Grain	Stover				
	Bu.	Ton	Bu.	Ton				
135 lbs. Fomula I.....	21.0	0.98	5.5	None	$3.30	$1.51	$0.27	$1.79
202 " " ".....	23.7	1.18	8.2	0.10	4.92	2.26	.27	2.66
404 " " ".....	29.3	1.40	13.8	0.32	8.28	4.52	.33	3.76
150 " " II.....	24.7	1.28	9.2	0.20	5.52	1.72	.19	3.80
225 " " ".....	27.6	1.29	12.1	0.21	7.26	2.59	.21	4.67
450 " " ".....	29.6	1.41	14.1	0.33	8.46	5.18	.37	3.28
206 " " III.....	25.2	1.27	9.7	0.19	5.82	2.50	.26	3.32
308 " " "	30.1	1.37	14.6	0.29	8.76	3.74	.26	5.02
617 " " "	35.7	1.49	20.2	0.41	12.12	7.50	.37	4.62
No fertilizer	15.5	1.08						

experiments it raised the average yield of corn from 15.5 bushels to 27.6 bushels per acre, at a cost of only $2.59. It may be of interest to note that 225 pounds of Formula 2 contains as much phosphoric acid as is removed by the grain and stover of a 40-bushel crop, enough potash to replace that removed by 5½ bushels and nitrogen to equal that removed by only 3 bushels, the stover being included with the grain in each case.



LIMED
53.7 Bu. per acre

UNLIMED
44 Bu. per acre

CORN

VARIETIES OF CORN

In the variety experiments on corn perhaps nothing was developed in a more pronounced manner than the adaptability of certain varieties to definite soil conditions. For example, Hickory King proved itself to be a superior poor-land variety and was followed closely in this respect by Leaming and Iowa Silver Mine, both of which appear to be well suited to the Highland Rim. They are also the best early varieties of field corn discovered in the Station trials. Boone County White was found to be early, but adapted only to rich land. Varieties like the well-known Huffman, Webb's Improved W tson, and the ensilage corns, Albermarle Prolific and Cocke's Prolific, are strictly adapted to rich lands, for which they out-class Hickory King, etc. Red-cob corn is not one variety, but consists of many varieties with various lengths of season and wide adaptabilities, but agree in pos-

sessing white grains and red cobs, although usually white cobs are to be found, which shows that the types are not standardized. In general these red-cob corns were not found to equal the pure varieties, such as Hickory King, etc. According to trials at both the Knoxville and the Jackson Station, the Looney variety, a white corn with a white cob, which is grown in the vicinity of Winchester, is fully the equal of Hickory King in grain production.

For rich land

The following table, which is based on data obtained at the Experiment Station farm, at Knoxville, gives dates when the best varieties may be planted on rich land to get a succession of crops for hog pasture or the like:

Variety	Date of planting	Date of maturity
Reid's Yellow Dent	Apr. 15	Aug. 25
Hickory King	" 15	Sep. 4
Webb's Improved Watson	" 15	Sep. 10
Huffman	" 15	Sep. 19

For poor lands only Hickory King, Looney, Leaming and Iowa Silver Mine are recommended. The question as to what is meant by "rich" and what by "poor" lands naturally arises at this point. From numerous results obtained over a series of about ten years at the Experiment Station the conclusion is drawn that up to about 50 bushels per acre Hickory King is unsurpassed. On lands which produce 50 or more bushels of corn, Webb's Watson and Huffman are apt to yield better.

FERTILITY EXPERIMENTS ON A VERY POOR GRAY-COLORED SOIL OF THE HIGHLAND RIM

During the seasons of 1910, 1911 and 1912 a valuable series of fertility experiments were conducted on a very poor gray-colored silt loam on the farm of D. T. Allison, near Baxter, in Putnam County. The soil was known to be very deficient in both phosphoric acid and nitrogen, and field corn without fertilizer or other manurial treatment yielded only 8 to 15 bushels per acre. The experimental tract was divided into four sections, and the crops grown on each section, and their disposal are indicated as follows:

Section A	1910	Corn	Hogged off
	1911	Soy beans	"
	1912	Corn	For grain
Section B	1910	Soy beans	Hogged off
	1911	Corn	"
	1912	Corn	For grain
Section C	1910	Cowpeas	Hogged off
	1911	"	"
	1912	Corn	For grain
Section D	1910	Cowpeas	Turned under
	1911	"	"
	1912	Corn	For grain

Each section was divided into several plots for the purpose of getting the effects of acid phosphate and of liming under each of the four conditions of cropping. The plots of all the ranges were of course handled alike with regard to preparation, time of planting, etc. The treatment of each of three plots of every section is reported in Table VII, which gives the yield of corn obtained the third year, 1912.

DISCUSSION OF RESULTS

The experiments afford a striking demonstration of the rapidity with which even a poor soil responds to proper treatment. The results show both the marked increase in yield which may be brought about by the pasturing off of legumes, such as cowpeas and soy beans, and the great value of acid phosphate rightly used. Liming appears profitable for these crops and would probably be a necessity in order to get clover. It should be noted in this connection that in the season of 1912 corn in neighboring fields and on the same character of soil as that used in the experiments produced less than 10 bushels to the acre.

ALFALFA

Suitable soils

The dark-red soil of the Rim is, as previously stated, well suited to general farm crops. Under good management clover and grass are grown profitably, and within the last few years alfalfa has been successfully grown in different places, but particularly in the vicinity of Belvidere, Franklin County, where the writer has seen excellent fields of 30 or more acres, which had been cut from one to five years. This success has been had chiefly on farms where live stock has played an important part in the improvement of the soil and where first-class methods of management have been followed for a number of years, but is by no means limited to this condition, for excellent crops have been obtained by many farmers on relatively poor land and without the aid of farmyard manure.

Several series of cooperative experiments were conducted on both the red and the gray soils, none of which were of more than ordinary fertility. The results proved that with attention to its special requirements alfalfa could be grown with at least moderate success on either type, although the dark red soil is, as would be expected, considerably better adapted to it than the gray soils.

Liming necessary

Liming proved to be a necessity, and rather extensive experiments were made in order to determine the most rational amount. The results proved that very heavy liming was not needed. In fact, 2 tons appeared to do as well as any larger quantity. In order to be on the safe side, 3 tons per acre is recommended as ample, and, according

TABLE VII—*Experimental results with corn following pasture and green-manure crops on very poor gray-colored soil of the Highland Rim—season of 1912—experiments conducted on farm of D. T. Allison, Putnam County*

Section	Plot	Previous crops	Fertilizer per acre	Yield per acre of corn
				Bu.
A	1	Corn, 1910—pastured; Soy beans, 1911—pastured	300 lbs. acid phosphate in both 1910 and 1911.	37.7
	2	" "	2 tons ground limestone in 1910; 300 lbs. acid phosphate in both 1910 and 1911.	39.2
	3	" "	No phosphate and no lime.	29.4
B	1	Soy beans, 1910—pastured; Corn, 1911—pastured	Same as Section A, Plot 1	31.0
	2	" "	" A, " 2	36.0
	3	" "	" A, " 3	27.1
C	1	Cowpeas, 1910—pastured; Cowpeas, 1911—pastured	" A, " 1	45.9
	2	" "	" A, " 2	49.0
	3	" "	" A, " 3	26.2
D	1	Cowpeas, 1910—turned under; Cowpeas, 1911—turned under	" A, " 1	49.0
	2	" "	" A, " 2	44.1
	3	" "	" A, " 3	31.9

to trials at the Knoxville Station, would be expected to be sufficient for eight or ten years. In order to get the limestone thoroughly mixed throughout the soil, one-half may be applied before plowing and well disked into the soil, and one-half after plowing.

Phosphates important

An abundant supply of phosphate is of very great importance. In the experimental work 500 pounds of acid phosphate and 500 pounds of bone meal were used per acre as a supplement to the manure. This is heavy phosphating, but furnishes no more phosphoric acid than would be removed by four tons of alfalfa hay per annum in five years. The thor ugh mixing of the phosphate with the soil is essential to the best results. At least in the case of a heavy application one-half may well be applied and disked into the soil before plowing and the other half afterward.

Potash may be of value

Potash did not always prove necessary—perhaps due to the amount of manure used—but 100 pounds per acre of muriate of potash is advised, and may be applied along with the acid phosphate.

Manure of much value

Farmyard manure is a great help in getting a stand of alfalfa, even on rich land, and on very poor land should be considered a necessity. 12 tons per acre were found to be ample. It is well to make the application early in the season, so that weed seeds may have a chance to sprout and be killed before the alfalfa is sown. Undoubtedly the manure may be reduced in quantity or even omitted if green-manure crops, such as crimson clover, sweet clover, etc., are grown in preparation.

Inoculation necessary

At the Knoxville Station, and occasionally elsewhere, soil inoculation is not required, but in the majority of instances it is a necessity. Certainly the risk of failure is too great for inoculation to be omitted the first time that a field is sown. The most certain plan is to use, say, 300 pounds per acre of soil from an old alfalfa field where the nodules were abundant on the roots of the plants. The inoculating soil may be screened and drilled in like fertilizer to advantage, but if scattered broadcast a cloudy day should be selected and the application should be harrowed into the ground.

Late summer or early fall seeding best

The best time of seeding is the latter half of August or early in September—early enough so that the plants will go through the winter without being frozen out. Wheat or other small grain, or Irish potatoes, may precede alfalfa, but a summer crop is apt to leave the ground so dry that the necessary fall growth can not be made. The best plan, therefore, is to

turn the land in June, or as early in July as possible, and keep well harrowed in order to destroy weeds and to provide a moist and mellow seed-bed.

Amount of seed

24 pounds of seed per acre—12 pounds sown each way—is advised unless the soil and seasonal conditions be very favorable. A heavy seeding is necessary in order both to crowd out weeds and to allow for the thinning of the stand, which always takes place, due to disease, weeds, losses by harrowing, etc.

Nurse crops and reseeding

Nothing in the way of a "nurse crop" should be used, the results of the experiments showing that the greater the "nurse crop" the less was the alfalfa. Spring seeding is justifiable, and can be recommended for one purpose only, and that is, to thicken a

MANURE ONLY MANURE, PHOSPHATE, POTASH AND LIME

ALFALFA HAY

poor stand obtained the previous fall. Attempts to thicken a stand two or more years old have, in our trials, always failed.

Harrowing necessary

Two weeds have proven to be especially troublesome in alfalfa culture; one is crab-grass, which flourishes only in the summer, and the other is chickweed, which is dangerous only in the winter. In either case, harrowing with a specially constructed alfalfa harrow is the remedy. Harrowing should be done after every cutting, beginning with the first one in the spring. In this way alfalfa at the Station farm has been kept free of crab-grass for the past five years.

Time of cutting

Cutting is recommended as soon as the new shoots at the base of the plants are two to three inches long. In very dry weather the yellowing of the leaves may indicate that cutting is advisable even though the growth be very small.

Top-dressing

In order to maintain a stand on average upland, a top-dressing of manure or fertilizer, or both, may be necessary about the third season. Eight or ten tons of manure per acre may be applied in late winter or in early spring. Preferably the manure from cattle fed on silage and cotton-seed meal should be used both because of its richness and because of its freedom from weed seeds. Six tons of manure and 200 pounds of acid phosphate per acre would also be a fair application. If fertilizer alone be used, a mixture of 300 pounds of acid phosphate and 100 pounds of muriate of potash is recommended, to be applied at the same season as advised for the manure.

"CLOVERS"

RED CLOVER

Of all the legumes red clover may well be considered as the most valuable for soil-improvement purposes, and although much of the Rim may not be naturally adapted to this crop, the aim of every farmer should be to get his soil into the proper condition for its profitable production. In the case of freshly cleared land liming and phosphating are the main requirements. For old land there must usually be given, in addition, at least a light dressing of manure, or there may be turned under for one or more seasons beforehand such green-manure crops as can be grown to most advantage. According to common farm practice, seeding is nearly always done in the early spring, with some nurse crop, such as wheat or oats, but the Station's experimental results have demonstrated that where the success of clover is rather uncertain, seeding without a nurse crop in the latter part of August or early in September is advisable. Indeed, in this way the best crops can be obtained on almost any soil. The land should be plowed early in the summer and kept well harrowed to destroy weeds and conserve the moisture supply, so that a stand can be obtained at the proper time.

ALSIKE

Alsike clover is not as robust as red clover, and is, therefore, not so well suited to poor land. It has, however, done very well in our experiments, and has some advantages over red clover, especially in that it is completely resistant to the common red clover disease, which has done great damage throughout the State during the past

twenty or more years. Only about two-thirds as much seed is required as for red clover.

WHITE CLOVER

White clover, like red and alsike, responds to liming and phosphating, and should not be overlooked as an addition to the pasture and a means of soil improvement. 1½ pound of seed per acre is suggested to be mixed with the clover and grass wherever the land is to be used for pasture purposes.

CRIMSON CLOVER

Crimson clover is a valuable green-manure crop, but only rather fertile soils are well adapted to it. To get best results it should be sown by itself in middle or late summer, but under favorable conditions it may be sown in September. According to the Station's experiments seeding in corn at the last working is not apt to be successful.

LESPEDEZA

Lespedeza, or Japan clover, is not a true clover, but may be included with the others for practical purposes. Although found growing almost everywhere, it responds well to liming and phosphating, as was demonstrated at the West Tennessee Station. Under some conditions it may even be worth while to sow the seed. This may be done the middle of April. About 25 pounds per acre is required for a full stand the first year. Ten pounds, however, will be sufficient to give it a good start.

MELILOTUS

Melilotus, or sweet clover, is a legume but not a true clover. This plant requires, like alfalfa, a soil well supplied with lime; also soil inoculation with the same kind of bacteria required by alfalfa is apt to be necessary. It is probable that with attention to liming, phosphating, and inoculation, sweet clover can be used to some advantage as a green-manure crop. 25 or 30 pounds of seed per acre are recommended and the seeding may be done either in the spring, with oats, or in late summer without a nurse crop. The white-flowering variety rather than the yellow-flowering is preferred.

COWPEAS AND SOY BEANS.

The cowpea fruits extra well on Rim soils and is a seed crop of much promise for this section, especially as satisfactory threshers are now on the market. The standard variety is the Whippoorwill, but the late Black and the Clay variety are much used.

Soy beans and inoculation

Soy beans may be grown to advantage both for hay and for grain, and have greater capacity for making heavy yields than the cowpeas. The writer has sometimes observed that soy beans when grown for the first time do not appear to be well inoculated, as indicated both by the light color of the foliage and also by the sparsity of the nodules on the roots. Continued growing of the beans on the same land would be expected to remedy the trouble, but soil inoculation may occasionally be advisable.

Soy-bean varieties

On soils of average fertility only the late and vigorous varieties, such as Mammoth Yellow, Tokio, and Acme, are advised. The early varieties, such as Ito San and Haberlandt, which have done extra well at the Knoxville Station, are advised only for soils of rather high fertility. On poor land their growth is too dwarfed and meager.

For a more complete comparison between the cowpea and the soy bean, reference may be had to Bulletin 82 of this Station.

Fertilizers

The fertilizer recommended for the red-colored limestone soils is 200 or 300 pounds of high-grade acid phosphate per acre. For the gray-colored soils of the Barrens type 200 or 300 pounds of the acid phosphate, together with 25 pounds per acre of muriate of potash, is advised.

GRASSES

The growing of grass should be considered one of the essentials to the most successful farming on Rim lands. Red-top is the common and generally most profitable grass, especially on the gray soils, but a mixture with Timothy is often sown. A number of experimental trials were made with other grasses, and both orchard and tall-oat were found to do well, the latter variety in particular having a great capacity for hay production. The best results were obtained from late August or early September seeding, and without a nurse crop. For hay a mixture of 33 pounds of tall-oat grass and either 12 pounds of red clover or 8 pounds of alsike per acre is recommended. Both lime and phosphate are generally essential for best results, and a light top-dressing of manure is very helpful. Clover not only adds to the yield but nourishes the grass. In the event of a failure of the clover, or after it has run out, a seeding of Japan clover may prove advantageous. For a thick stand the first season, 25 pounds of the Japan clover seed per acre is required, but 10 pounds will give it a good start for pasture purposes and is advisable in order to get a uniform stand as early as possible. In the absence of both clover and manure, the grass may be top-dressed with 80 or

100 pounds of nitrate of soda per acre, and this light application has sometimes been found to make the difference between success and failure.

Although the fall seeding of Timothy and red-top along with the wheat is a common practice, at least in some counties, spring seeding has given decidedly the best results in the Station's trials.

THE SMALL GRAINS

WHEAT

Wheat enters very nicely into most systems of crop rotation, and both the climatic and soil conditions of the Rim are favorable to it. The placing of this crop after corn should as a rule be avoided, although this may be done on soils of good fertility, especially if the corn be cut and shocked or removed for silage. Either cowpeas or soy beans, if removed early for hay, makes an excellent preceding crop.

Best varieties

According to Station trials, which have been continued for 10 or more years, the best varieties of wheat for average upland are Fulcaster, Mediterranean, and Poole. Currell's Prolific and Fultz have also done well. For rich land, where the other varieties are apt to lodge, Fultzo-Mediterranean has proven superior to any other.

Fertilizers

If the wheat be preceded by cowpeas, soy beans, or one of the clovers, or if a dressing or farmyard manure be made, then only acid phosphate at the rate of, say, 200 pounds per acre is advised as a fertilizer. Otherwise a complete fertilizer, such as recommended for corn, may be used. Under some circumstances a light dressing of, say, 40 pounds per acre of nitrate of soda may be profitably made in the fall, especially if the seeding be unduly delayed. Under usual conditions 60 to 100 pounds of nitrate may be applied in the spring, as soon as early growth starts, but the margin of profit is not great. Cotton-seed meal, dried blood, nitrate of soda, and other active forms of nitrogenous fertilizer are detrimental to the germination of seed with which they come into direct contact, and the later and more unfavorable the season the more pronounced is this effect. If any one of these materials be used, therefore, it should be drilled in separate from the seed. Acid phosphate, however, does not injure the germination, so that when used alone no precaution is necessary.

OATS

Both spring oats and winter oats are grown successfully on the Rim, but whenever possible winter oats rather than spring oats are advised. The winter or Gray Turf oat is the standard variety in common use. The Station found that the Culberson variety had some very desirable qualities, and has obtained from it a short-strawed selection which rarely lodges even on extra rich land, matures nearly two weeks earlier than the Turf oat, and is equally productive of grain.

Best varieties — The Burt and the Kherson, or 60-Day Russian, are the best spring varieties. The latter is two or three days later than the former, produces somewhat more foliage, and has given a yield of grain fully equal to the Burt.

Time of seeding — Winter oats should be sown earlier in the fall than any other small grain, or about the middle of September. Spring oats should be sown as early in the season as possible.

Oats and clover for hay — A mixture of Culberson oats and either red or alsike clover for hay has been tried experimentally at a number of places with excellent results. A full seeding of each is advised, and the seeding should be done the latter part of August or early in September.

Fertilizers — The same kind of fertilizers as recommended for wheat may be used for oats.

BARLEY

Winter barley is a rich-land crop, which does extra well on land too fertile for wheat. It is not, therefore, suited to average Rim soils. However, on account of its ready response to manuring, and its great capacity for grain production, it should receive more attention than it has received in the past. Seeding should be done the latter part of September in order to get the best results.

Spring barley is of little value, and has not proven equal to spring oats.

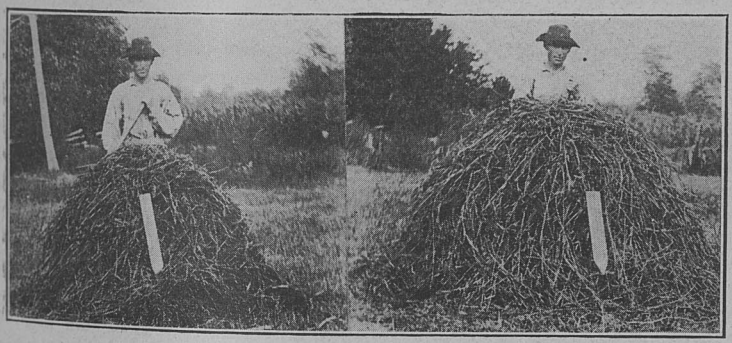
RYE

Rye is valuable chiefly as a grazing and cover crop, and also as a green-manure crop on very poor land. It can be sown with good results later than any other small grain, November and even December seedings being successful. October is probably the best month for seeding, but it is often sown in late August and September for pasture purposes.

MILLET HAY—FROM EXPERIMENTS ON HIGHLAND RIM SOIL

NO FERTILIZER

PHOSPHATE AND POTASH



NITRATE OF SODA

PHOSPHATE, POTASH AND NITRATE OF SODA

MILLET FOR HAY

German millet, which is sown either alone or, better, with cowpeas for hay, responds well to rather heavy fertilization. Table VIII gives the average results obtained from five complete series of experiments, two conducted in different seasons on one farm, and each of the other three on different farms.

According to these and other trials on old land, 300 pounds of acid phosphate and from 80 to 160 pounds of nitrate of soda may be used per acre with fair assurance of profit. Also a small amount of muriate of potash may be used along with the acid phosphate—say 50 pounds for Barrens soil and 25 pounds for red lands—the two being mixed and well worked into the ground before seeding. The nitrate is advised to be applied broadcast as a top-dressing

soon after the plants come up. In the case of recently cleared land only acid phosphate is advised. Also it should be noted that in a mixture of millet and peas the phosphate and potash will encourage the growth of cowpeas in particular, but that the nitrate increases the growth of the millet much more markedly than that of the peas.

SORGHUM

The saccharine, or sweet, sorghums have long been grown on the Rim both for forage and for syrup. The Red Top variety is in common use for forage purposes, but the juice is too dark to make the best syrup. Tennessee-grown seed has proven to be superior to Western-grown seed. Amber, Orange, and other varieties are often grown for syrup-making purposes. Recent experiments by the Station have indicated, however, that the Honey variety, which is equally adapted to forage and to syrup making, is not only a far better yielder than any of the other varieties mentioned, but also is the least liable to lodge. It is therefore recommended as especially worthy of trial.

Sorghum may be planted either in rows and cultivated like corn or sown broadcast like millet. In either case cowpeas may be planted with it to advantage. For planting in rows, 6 to 8 pounds of seed are used for forage and about 4 pounds for syrup. A good mixture for broadcast seeding is 1¼ bushel of peas and ¾ bushel of sorghum. If sown in rows, ½ bushel of peas is ample.

The same kind of fertilizers recommended for corn may be used for sorghum.

The most serious trouble with sorghum sown broadcast is the difficulty of curing; and for this reason millet is often preferred, especially on fertile land. When planted in rows sorghum may be put into the silo with the best of results; otherwise it is cut and shocked before frost and will make excellent feed up to about New Year's. The planting in rows is advised for soil of good fertility, while broadcast seeding is adapted to the poor land where the sorghum does not grow too rank.

PEANUTS

An important crop

Peanut growing is an important industry in some counties of the Highland Rim and could be greatly extended. Gray-colored and easily tilled silt loams, both bottom and upland, are used. The low lands give the largest yields, but the rather common practice of raising peanuts on the same land year after year has greatly reduced their fertility. Undoubtedly a judicious crop rotation would do much to improve this condition, and either manure or crops like grass and clover will be needed to replenish the soil with vegetable matter. At present fertilizers are little used and liming is seldom if ever practiced.

Liming of little value to peanuts

The experimental results agree with respect to the direct effect of liming, which proved detrimental to the production of nuts, but appreciably increased the growth of tops. This does not exclude the possibility that lime will either act beneficially on other types of soil or be of much indirect value in peanut culture through its favorable effect on other crops, such as clover and grass.

Acid phosphate profitable

Acid phosphate was found to be highly profitable in various localities on Rim soils, but the addition of either a potash salt or a nitrogenous fertilizer was apparently not needed. The peanut is a leguminous plant, which gets much of the needed nitrogen from the air, but on extra poor soils, a little cotton-seed meal or nitrate of soda may possibly be used to advantage to give the plants a quick start. From 200 to 300 pounds of acid phosphate per acre is advised.

Varieties

Several tests have been made of the common varieties, such as Virginia White, both spreading and bunch types, Spanish and two kinds of Reds. The Spanish is the most productive and is strongly recommended for forage-crop purposes and also for home use, the flavor being superior to that of the other sorts. Favorable results have been obtained by the Station in the way of getting improved strains of several varieties by means of individual plant selection. In particular a stronger-hulled and slightly larger type of Spanish nut than that commonly grown has been gotten, and has been used in the cooperative trials.

TOBACCO

For the past six years fertilizer experiments have been conducted in Montgomery County in cooperation with successful tobacco growers. From twenty-five to thirty separate experimental plots were generally used at each place, so that valuable data were gotten. Much difficulty was experienced, however, in finding uniform soils adapted to experimental purposes, so that mention will be made here of only the following simple conclusions, which appeared to be well established:

1. The results obtained in eight out of nine series of experiments, in which six different farms were respresented, showed that the following mixture was used at a satisfactory profit:

300 lbs. high-grade acid phosphate.
100 " sulphate of potash.
400 " cotton-seed meal.

This mixture analyzes—

6 per cent available phosphoric acid
3¼ " nitrogen
6 " potash

The average for the nine series of the tobacco fertilized with the 800 pounds per acre was 1096 pounds of leaf, as compared with 748 pounds where no fertilizer was applied.

2. The results from seven series of experiments in which 160 pounds of nitrate of soda was compared with 400 pounds of cotton-seed meal indicated that there was little choice between these two sources of nitrogen for the tobacco crop. An ample supply of both phosphate and potash was used on all plots in order to make the nitrogenous material effective. Also the soils used were poor in nitrogen.

3. As the average of five series of experiments there was found to be a gain of only 34.4 pounds of leaf tobacco per acre for each ton of farmyard manure used. In two of the series 12 tons of manure were used per acre, and in three series only 6 tons. Under the most favorable conditions there was an increase of 60.5 pounds of leaf for each ton of manure used.

4. Six tons of manure per acre, together with 800 pounds of the complete fertilizer mentioned, proved more profitable than either used alone.

5. Liming was tested on several farms, and at each place under a variety of fertilizer conditions, but no general conclusions can be drawn from the results, except that tobacco does not appear to be very responsive to liming. However, the indirect effect of liming, through the increased production of clover or other legume preceding tobacco, could not be other than beneficial.

CROP ROTATIONS

LIST OF ROTATIONS

A—GENERAL FARMING—FIVE-YEAR ROTATION

1st year—Corn, followed by winter cover crop for pasture and green manure.

2d year—Cowpeas or soy beans.

3d year—Wheat or other small grain.

4th year—Clover and grass.

5th year—Clover and grass.

B—GREEN MANURE AND GRAIN—THREE-YEAR ROTATION

1st year—Corn, followed by winter cover crop for pasture and green manure.

2d year—Cowpeas or soy beans.

3d year—Wheat, followed by crimson clover for green manure.

Note—A most excellent rotation wherever crimson clover does well.

C—GENERAL FARMING—THREE-YEAR ROTATION (OR LONGER IF DESIRED)

1st year—Corn.

2d year—Wheat.

3d year—Clover, or clover and grass for two or more years.

Note—This is a well-known rotation, which has been followed successfully in many instances, but under average conditions Rotation A is considered to be decidedly preferable.

D—PASTURE FOR HOGS—TWO-YEAR ROTATION

1st year—Corn and cowpeas.

2d year—Rye, sown in fall, and alsike or red clover, sown in spring.

E—PASTURE FOR HOGS—TWO-YEAR ROTATION

1st year—Red or alsike clover and barley.

2d year—Soy beans or cowpeas.

GUIDE IN THE ESTABLISHMENT OF A ROTATION

The writer has prepared Table IX with the view of furnishing a practical guide during the establishment of the five-year general farming rotation. The spring of the year 1914 is taken as the commencement of the project and it is assumed that the land is in an ordinary state of fertility. According to this plan the rotation will not be in full operation until 1916; at least two years being required to accomplish this result.

TABLE IX—*Five-year crop rotation (No. 1), showing crops, amount per acre of fertilizers, etc., suggested for each field during the establishment of the rotation—based on experiments conducted on gray-colored soils of Highland Rim—all operations assumed to begin in spring of* 1914

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5
1914 — Corn—followed with winter cover crop Acid phosphate 200 lbs., muriate of potash 20 lbs., cotton-seed meal 100 lbs.	1914—Cowpeas. Acid phosphate 300 lbs., muriate of potash, 50 lbs.	1914—Soy beans. Acid phosphate 300 lbs., muriate of potash 50 lbs.	1914—Spring oats. Acid phosphate 200 lbs., muriate of potash 20 lbs., nitrate of soda 100 lbs.	1914—Spring oats. Acid phosphate 200 lbs., muriate of potash, 20 lbs., nitrate of soda, 100 lbs.
1915—Soy beans. Acid phosphate 300 lbs., muriate of potash, 50 lbs.	1915—Wheat. (Sown in Oct., 1914). Ground limestone 2 tons, acid phosphate 200 lbs. in fall and manure 6-10 tons top-dressed during the winter.	1915—Corn — followed with a winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs., cotton-seed meal 100 lbs.	1915—Red clover. (Sown late in Aug. or early in Sept., 1914.) Ground limestone 2 tons, acid phosphate 300 lbs., muriate of potash 50 lbs.	1915—Clover and grass. (Sown late in Aug. or early in Sept., 1914.) Ground limestone 2 tons. acid phosphate 300 lbs., muriate of potash 50 lbs.
1916—Wheat. (Sown in Oct., 1915). Ground limestone 2 tons, acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during the winter.	1916—Clover and grass (Sown in spring, 1915.)	1916—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.	1916—Corn. Acid phosphate 200 lbs., muriate of potash 20 lbs. Follow with winter cover crop.	1916—Clover and grass (for hay and pasture.)
1917—Clover and grass. (Sown in spring, 1916.)	1917—Clover and grass (for hay and pasture).	1917—Wheat. (Sown in Oct., 1916.) Ground limestone 2 tons. acid phosphate 200 lbs. in fall, manure 6-10 tons, top dressed during winter.	1917—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.	1917—Corn — followed with winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs.
1918—Clover and grass (for hay and pasture.)	1918—Corn — followed with winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs.	1918—Clover and grass. Sown in spring, 1917.	1918—Wheat. (Sown in Oct., 1917.) Acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during winter.	1918—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.

It may be noted that after the establishment of the rotation—1916 and later—a change is made in the commercial fertilizers, both for corn and for the small-grain crop. This change consists in the omission of both the cotton-seed meal and the muriate of potash. In the case of the rye, the manure would much more than replace these two ingredients and the residues from the clover and grass would be expected to furnish an appreciable supply of nitrogen for the corn which follows. Also in case of freshly cleared land neither meal or potash salt is advised from the outset.

NOTES ON TABLE IX

1. The liming may be done sooner than directed in the table. In fact, although especially beneficial to clover, liming is apt to increase the yield of any of the crops to an appreciable extent. According to our experimental evidence, two tons of ground limestone will be ample for at least five years, and possibly for twice that length of time.

2. The acid phosphate and muriate of potash should always be applied before planting the crop for which they are especially intended, and give best results when applied in the row for crops planted in rows. For broadcast-sown crops these materials may be applied broadcast before the land is turned, or may either be drilled in afterward or scattered broadcast and well harrowed into the soil.

3. As a cover crop after corn, to prevent loss during the winter, choice may be had of wheat, rye, crimson clover, and hairy vetch. Crimson clover is an ideal crop in some respects, but requires a rather fertile soil in order to thrive. Even then, when sown in corn at the last working, it is apt to be killed before winter by dry, hot weather. Rye would help to hold the crimson clover from freezing out during the winter, and the mixture may be sown considerably later than crimson clover alone. Hairy vetch can be sown later than crimson clover and any time during September is favorable, provided the soil-moisture supply be good. If sown in early October it is apt to go through the winter. Like crimson clover it may be sown with either rye or wheat. Rye can be sown later than wheat and makes the earliest spring growth.

The cover crop should be turned under at a rather early stage of growth—in the case of rye and wheat not later than when in boot; but for crimson clover and vetch when in early bloom. Attention is called to the fact that vetch makes only a small growth during the fall, winter, and early spring, and is a vigorous grower only after warm weather comes in the spring; so that to get the most good out of this crop for green-manure purposes it must remain on the land later by several weeks than either of the others, or until about the middle of May. This would not, however, be a serious objection, as either cowpeas or soy beans can be planted to advantage after this date.

4. The manure is advised as a top-dressing on the wheat for the special purpose of getting a good stand of clover and grass from a spring seeding. If the land is of such quality that the manure is not needed for this purpose it may well be applied for the corn crop, which offers a greater possible increase in grain than the wheat.

In the absence of manure an extra amount of both the phosphate and potash is advised.

5. Either red or alsike clover may be used, and a mixture of the two is sometimes advisable. Alsike when sown in late summer or early fall would be expected to produce an appreciable part of the hay crop of the next two years, but red clover is apt to disappear after the first year. When spring-sown, one lasts about as long as the other, provided the red clover disease, which does not affect the alsike, is not serious.

In the case of a failure of clover, in the spring following the seeding an application of 100 pounds per acre of nitrate of soda may be made to advantage for the grass, and should be applied as early in March as the spring growth begins.

In case of a poor stand of both clover and grass at the beginning of the second year a seeding of 25 pounds per acre of Japanese clover (Lespedeza) about the first of April is recommended.

6. For the red-colored soils of limestone origin the same fertilizers, etc., may be used, except that the potash can be reduced by one-half.