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Fertilizer Experiments

University of Tennessee Agricultural Experiment Station

Charles A. Mooers

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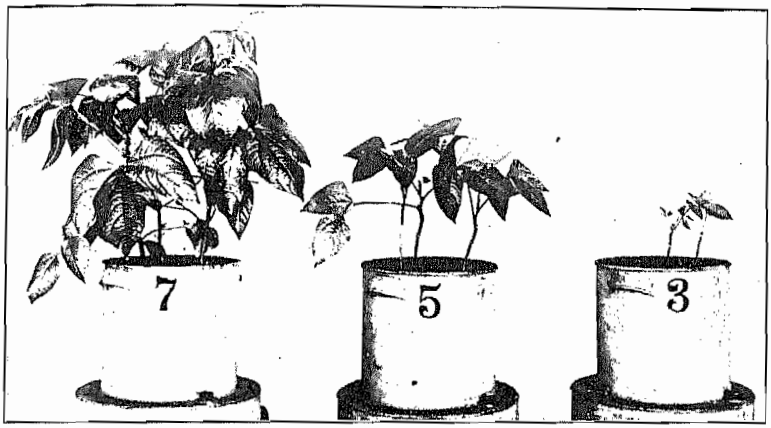
BULLETIN

OF THE

Agricultural Experiment Station

OF THE

UNIVERSITY OF TENNESSEE



7 Phosphoric acid from precipitated phosphate
5 Phosphoric acid from bone meal
3 Phosphoric acid from phosphate rock

COWPEAS GROWN IN SAND. ALL POTS FERTILIZED, ETC., THE SAME EXCEPT AS TO PHOSPHORIC ACID

VOL. XVI JANUARY 1903 No. 1

FERTILIZER EXPERIMENTS

BY

CHARLES A. MOOERS

KNOXVILLE, TENNESSEE

THE AGRICULTURAL EXPERIMENT STATION

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FERTILIZER EXPERIMENTS

INTRODUCTION

The chief objects of this bulletin are to give the results of some fertilizer experiments and to make a few suggestions in regard to the use of fertilizers on Tennessee soils. Both field experiments and laboratory work on the soils of this State are of more than ordinary value, on account of the uniform composition of each type. Those of most importance in East Tennessee repeat themselves in narrow strips, having a general direction from northeast to southwest. The typical soils of the other sections of the State are not so complicated and will require less investigation.

One of the main objects has been to determine for each type the elements which are most needed. For this purpose chemical analysis has been found especially valuable. In many instances the amounts of certain elements of plant food, phosphoric acid in particular, were so small that conclusive results were obtained in the laboratory. The soils found to be poorest in phosphoric acid are those of the Cumberland plateau and of the "barrens," the white soil of the Highland Rim in Middle Tennessee. Next to these are the "white gravelly" soils of the dolomite formation in East Tennessee. The better class of dolomite soils, shale (slate), the Lenoir or blue limestone, and the marble and iron limestone, all of East Tennessee, follow in the order given; that is, the shale soils are apt to be somewhat better supplied with phosphoric acid than the dolomite, etc. The red soils of the Highland Rim and the soils of the "flatwoods" region and of other parts of West Tennessee resemble in chemical composition the shale and limestone soils of East Tennessee. River bottom soils and the soils of the Central Basin of Middle Tennessee, both upland and bottom, have generally been found to be well supplied with phosphoric acid. With these exceptions, the results of both chemical analysis and field experiments show the need of phosphate on all the kinds mentioned. To such an extent is this true that when phosphoric acid in an available form to plants is omitted the other important elements, nitrogen and potash, are not effective. In other words, a phosphate is the basis of all efficient fertilizer mixtures.

Next to the fundamentally important phosphoric acid, nitrogen is most needed. The need is general on uplands in all parts of the State, but much less frequent on bottom lands. Both on account of the large amount of nitrogen required in the soil by all non-leguminous plants, and on account of its high price, it may well be considered the most important element of plant food. One object in some of the experiments has been to determine how much nitrogen could be used to advantage with a given amount of acid phosphate.

Without doubt the least needed element at present is potash. The soil analyses show in nearly every instance more potash than lime or any other important element of plant food. The soils which have analyzed the lowest

in potash are from the Cumberland plateau and from the cherty ("white gravelly") dolomite ridges. Those having the highest percentages are the heavy yellowish clay soils of the blue limestone formation, whether found in East or in Middle Tennessee.

From all the results obtained I conclude that the need of fertilizers is amply proved and that their use should be encouraged. The amounts which are generally used, however, or which could be used with profit for such crops as wheat, corn, grass, etc., are insufficient to replace more than a small part of the nitrogen (ammonia) removed by the crop. Hence the necessity of growing cowpeas, clover, and the like, to replace this loss, which is the natural result of grain farming. About the most serious general criticism which can be made in regard to the commercial fertilizer mixtures is the low nitrogen content of the so-called complete or ammoniated goods, and with this should be included the low availability of the nitrogen, the source of which as a rule is tankage, which is much inferior to nitrate of soda, ammonium sulphate, dried blood, or cotton-seed meal.

EXPERIMENTS ON SWEET POTATOES

One of the few general farm crops in Tennessee which can be heavily fertilized with profit is the sweet potato. Too often it is considered able to give good yields on almost any soil, so that no special effort is made either to manure or to fertilize it. This crop can also be made a means of soil improvement; for enough fertilizer can be profitably used to furnish more plant food than is removed, and the vines will serve as a green manure to increase the supply of vegetable matter, which is apt to be deficient in the soil.

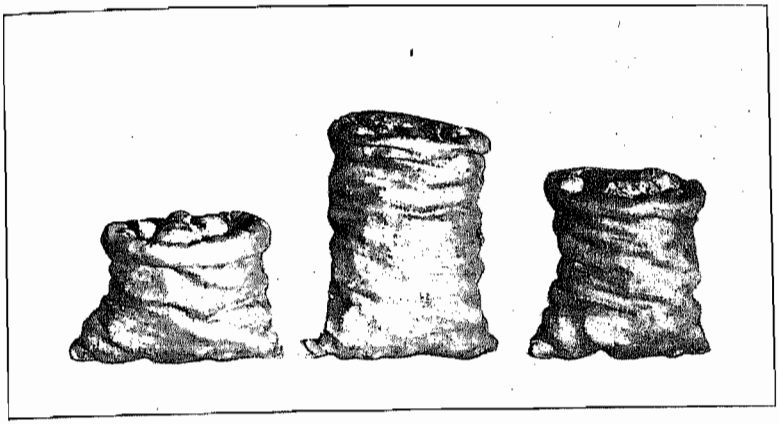
The experiments were undertaken with the objects both of getting some idea as to the most profitable amount of fertilizer and of testing different formulas—especially of trying varying quantities of cotton-seed meal with a standard amount—300 lbs. to the acre—of acid phosphate. The soil used was a sandy loam on a hillside in Woodlawn cemetery, near Knoxville. This kind of soil is characteristic of the iron limestone formation, and is considered first-class for market garden purposes. It is not naturally well supplied with plant food, however, so that unmanured it does not long produce paying crops. The preparation of the soil, setting of the plants, etc., were under the careful supervision of Mr. C. M. Ford, an experienced gardener.

FIRST SEASON

The plants for the first season's experiments (1901) were set out the middle of May. The fertilizers had been applied a few days earlier by scattering the various mixtures along the rows, which had been laid off with a shovel plow. The fertilizers were then mixed with the soil by running a shovel plow through them once. The low ridges in which the plants were to be set were then thrown over the fertilizer, which was buried under the ridge rather than mixed through it. This method of application is considered advisable for soils poor in the mineral elements, phosphoric acid and potash; for even when soluble in water at the time of application they soon become insoluble and "fixed" in the soil, so that their full effect

is not obtained if they are applied near the surface. Moreover, a large part of the available phosphoric acid is insoluble in water, and must be applied

126 bu. per acre | 230 bu. per acre | 182 bu. per acre

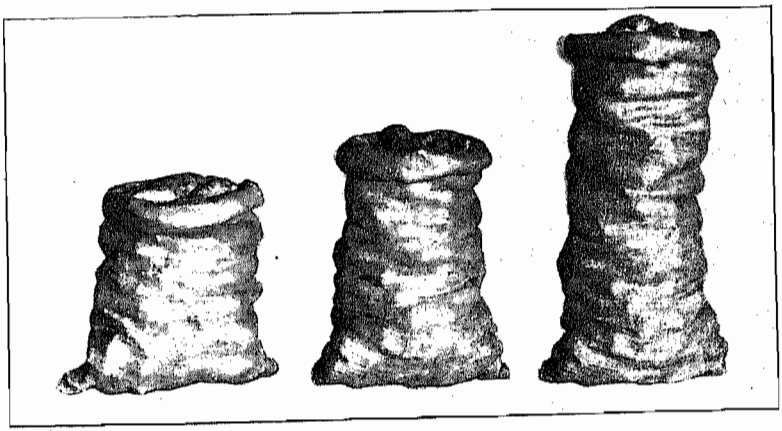


No fertilizer

Fertilized with
300 lbs. of acid phosphate
100 lbs. of muriate of potash
360 lbs. of cotton-seed meal
per acre

Fertilized with
15 tons of stable manure
per acre

170 bu. per acre | 218 bu. per acre | 322 bu. per acre



Fertilized with
300 lbs. of acid phosphate
100 lbs. of muriate of potash
per acre

Fertilized with
300 lbs. of acid phosphate
360 lbs. of cotton-seed meal
per acre

Fertilized with
600 lbs. of acid phosphate
200 lbs. of muriate of potash
720 lbs. of cotton-seed meal
per acre

SWEET POTATOES

deep in order that the roots may come in contact with it. So far as the nitrogen is concerned the fertilizers might have been mixed throughout the soil of the ridges to advantage, as the tendency of this element is to penetrate the soil, so that in wet weather it may even be lost by leaching.

Each plot was 1-40 of an acre and was 121 feet long and nine feet (three rows) wide. The same number of plants was set to each plot on the same date. Two varieties were grown, one-half of each plot being planted to Southern Queen and the other half to Kentucky White. These halves were harvested and weighed separately, the Kentucky White giving an average yield of about 25 bushels of salable potatoes to the acre more than the Southern Queen. This result, however, may not be of much value, for although the fertilizer was carefully weighed out for each row of each plot, it was not applied by weight to each half, and one end of the plot may therefore have received more fertilizer than the other. A different season, moreover, might have given different results.

The season was characterized by very dry weather throughout July and the early part of August, and the plants on all the plots suffered from drouth. Good cultivation was given, and after the vines covered the ground so as to prevent further working, the occasional weeds were removed by hand. Table I gives the yields and other data of interest.

TABLE I—*Results per acre from series 1 of fertilizer experiments on sweet potatoes*

Plot	Fertilizer mater als used	Amounts	Yields (a) Salable	Yields (b) Culls	Increase from fertilizer. Salable	Cost of fertilizer	Cost per bu. of increase	Profits from fertilizer at 40c per bu. for salable potatoes
		lbs.	bu.	bu.	bu.		cts.	
1	Acid phosphate	300	286	36	143	$12.00	8.4	$45.19
	Muriate of potash	100						
	Cotton-seed meal	540						
2	Acid phosphate	300	262	41	119	8.63	7.3	38.91
	Muriate of potash	100						
	Cotton-seed meal	270						
3	Acid phosphate	450	280	31	137	14.63	10.7	40.14
	Muriate of potash	150						
	Cotton-seed meal	540						
4	Acid phosphate	300	261	29	118	7.50	6.4	38.35
	Muriate of potash	100						
	Cotton-seed meal	180						
5	No fertilizer	.....	141	38	.....	.....	....	.....
6	Acid phosphate	300	226	25	83	5.25	6.3	10.11
	Muriate of potash	100						
7	Acid phosphate	300	266	34	123	9.75	7.9	39.48
	Muriate of potash	100						
	Cotton-seed meal	360						
8	Acid phosphate	300	284	27	141	6.75	4.8	49.63
	Cotton-seed meal	360						
9	No fertilizer	.....	145	33	.....	.....	....	.....
10	Acid phosphate	600	414	31	271	19.50	7.2	88.89
	Muriate of potash	200						
	Cotton-seed meal	720						

SECOND SEASON

The second season's experiments were much the same as the first, the chief difference being a trial of stable manure by itself and with acid phosphate. Both these plots had received a good dressing of a complete fertilizer the previous season. The season of 1902 though not marked by a long dry spell was generally considered unfavorable for sweet potatoes, and the yields on all the plots were less than those of 1901. With the exception of plot 10 the numbering of the plots was the same both years, but, necessitated by the field conditions, some changes were made in the location of the experiments. These changes were not thought, however, to lessen the value of the results.

TABLE II—*Results per acre from series 2 of fertilizer experiments on sweet potatoes*

Plot	Fertilizer materials used	Amounts	Yields of salable potatoes	Increase from fertilizer	Cost of fertilizer	Cost per bushel of increase	Profit from fertilizer at 40c per bu. for salable potatoes
		lbs.	bu.	bu.		cts.	
1	Stable manure	15 tons	195	69	$17.25	25.0	$10.35
	Acid phosphate	300					
2	Acid phosphate	300	202	76	12.00	15.8	18.40
	Muriate of potash	100					
	Cotton-seed meal	540					
3	Acid phosphate	450	230	104	14.63	14.1	26.97
	Muriate of potash	150					
	Cotton-seed meal	540					
4	Acid phosphate	300	201	75	7.50	10.0	22.50
	Muriate of potash	100					
	Cotton-seed meal	180					
5	No fertilizer	.....	126	.....	.....	.....	.....
6	Stable manure	15 tons	182	56	15.00	26.8	7.40
7	Acid phosphate	300	230	104	9.75	9.4	31.85
	Muriate of potash	100					
	Cotton-seed meal	360					
8	Acid phosphate	300	218	92	6.75	7.3	30.05
	Cotton-seed meal	360					
9	Acid phosphate	600	322	196	19.50	10.0	59.40
	Muriate of potash	200					
	Cotton-seed meal	720					
10	Acid phosphate	300	170	44	5.25	11.9	12.35
	Muriate of potash	100					

REMARKS ON THE RESULTS

Each year the most profit came from the plot receiving the most fertilizer—a mixture of 600 pounds of high-grade acid phosphate, 200 pounds of muriate of potash, and 720 pounds of cotton-seed meal. This result is all the more reliable because in the second season a change was made in the location of the experiment to a plot which had made a very poor yield the previous season, not having been fertilized with phosphate. Contrary to recommendations sometimes given, a large amount of cotton-seed meal was

used with decided profit; in fact, the poorest results from a fertilizer mixture were obtained each year from the plot receiving only acid phosphate and muriate of potash. The results were inconclusive as to the best proportion of meal to phosphate and as to the value of potash. Attention is called, however, to the fact that the plot receiving potash for the two seasons made a more profitable return the second season than the adjoining plot, which had received no potash in the same time. Though decidedly the least needed element, potash would sooner or later be required for market garden crops, unless stable manure were used.

The amount of nitrogen used was about equal to that removed by the tubers, so that the soil could not be said to have been built up in this element. More phosphoric acid and potash was applied than was removed, and there was a decided gain in phosphoric acid, of which the cotton-seed meal supplied almost as much as was removed. These residues are sufficient to be of marked value to the next crop, and consequently should not be ignored.

The plots receiving stable manure made a comparatively poor showing, although they did decidedly well the first season with fertilizer alone. The best quality of well-rotted manure, containing only a small amount of litter, was used. The addition of acid phosphate seemed to be an advantage, but more conclusive results are hoped for in the future. Without doubt some market garden crops can be more profitably fertilized with commercial fertilizers than with stable manure. Somewhat extensive experiments on the subject made both in England and in France have gone to show that under their conditions a judicious combination of manure and fertilizer gives most profit for the majority of garden crops.

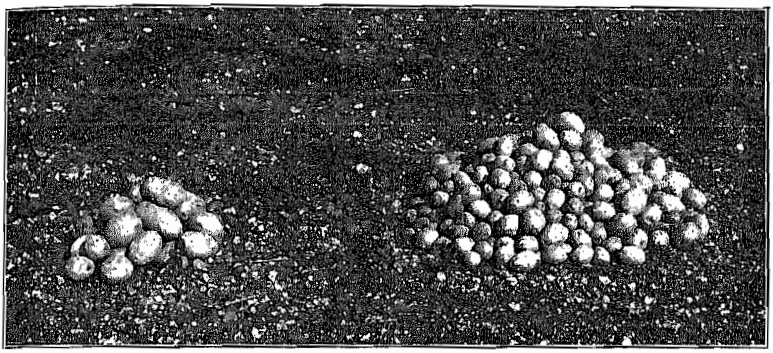
Judging from numerous investigations, acid phosphate by itself would be a highly profitable auxiliary to stable manure for general farm crops on soils naturally poor in phosphoric acid, as acid phosphate is almost unexcelled as a preservative for the nitrogen of manure. For this purpose it is recommended to be scattered daily over the fresh manure of the heap at the rate of 50 pounds to the ton of manure. For market garden purposes the use of nitrate of soda is advised in addition to acid phosphate. Moderate amounts to the acre are, 10 tons of manure, 300 pounds of acid phosphate, and 150 pounds of nitrate of soda. The nitrate, however, should not be mixed with the manure or with the phosphate, but applied as a surface dressing along the rows as soon as the plants are set out or appear above ground.

EXPERIMENTS ON IRISH POTATOES

SERIES ONE

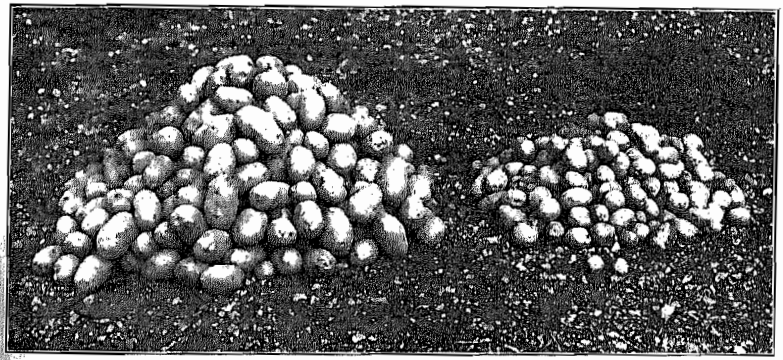
The chief objects in the first series were to test the special soil needs and to try different fertilizer formulas—in particular to test varying amounts of cotton-seed meal used with the standard amount of acid phosphate as in the sweet potato experiments. The soil used was very deficient in plant food. It came from a shale formation, but was somewhat lighter than the clay, which is characteristic of this type of soil. The fertilizers were applied in the row and mixed with the soil by running a shovel plow

through them once. The plots were 1-40 of an acre each. The preparation of the soil and the cultivation of the crop were about the same as are generally given by farmers in this vicinity. No special effort was made to put the soil into an unusually good condition or to give the crop the best possible attention, for a test under usual field conditions was sought. Each season the plants made a satisfactory growth until struck with a blight, which seems to be the most serious drawback to the successful growing of



3 bu. salable per acre 11.6 bu. culls per acre

No fertilizer



48.8 bu. salable per acre 14.5 bu. culls per acre

Fertilized with 500 lbs. of complete fertilizer per acre

Irish Potatoes

Irish potatoes in this climate. This blight generally occurs after wet weather which is followed by hot, dry weather, and seems to be more of a sun-scald than a fungous disease, for spraying with Bordeaux mixture has not been found to prevent it. The plants best supplied with moisture and plant food are the least apt to be affected, and plants from Southern-grown seed are less liable to injury than those from Northern-grown seed. While

the yields were short on account of this trouble, the results are of value, because they show the elements most needed by the soil and give an indication as to the best proportions of nitrogen and phosphoric acid to produce the earliest marketable potatoes. The following table gives the yields, etc., for the two seasons in which these experiments were carried out:

TABLE III—*Results per acre from series 1 of fertilizer experiments on Irish potatoes*

Plot	Fertilizer materials used	Amounts	Yields for season of 1901	Yields for season of 1902
		lbs.	bu.	bu.
1	Acid phosphate Sulphate of potash	300 100	15.3	17.3
2	Acid phosphate Cotton-seed meal	300 360	26.7	34.0
3	Acid phosphate Sulphate of potash Cotton-seed meal	300 100 360	34.0	30.0
4	No fertilizer	.....	8.0	12.0
5	Acid phosphate Sulphate of potash Cotton-seed meal	300 100 540	31.3	33.3
6	Acid phosphate Sulphate of potash Cotton-seed meal	300 100 720	36.7	.....
7	Acid phosphate Sulphate of potash Cotton-seed meal	600 200 720	50.0	50.0
8	Sulphate of potash Cotton-seed meal	100 360	20.0	.....
9	Stable manure	20 tons	26.7	.....
10	Acid phosphate Sulphate of potash Cotton-seed meal	300 50 360	.....	34.0

REMARKS ON THE RESULTS

An inspection of the table shows, first, that a mixture of cotton-seed meal and acid phosphate was highly beneficial, and, second, that no conclusion can be drawn as to the value of potash. The results indicate the proportion of 350 pounds of cotton-seed meal to 300 pounds of acid phosphate to be the most favorable to the production of early potatoes. But the results should not be taken as an indication of what the yields would have been had the plants lived out their full life, for until affected by the blight the plants of plots 5 and 6 (season of 1901), which received a much larger proportion of cotton-seed meal to acid phosphate than plots 2 and 3, were apparently most vigorous and gave greatest promise of a large yield. Increasing the total amount of fertilizer advanced the earliness of the potatoes and increased the total yield.

The stable manure used was the best quality of well-rotted farmyard manure, but at no period of growth did the plants of the manured plot thrive better than those of the plots which received the medium applica-

tions of fertilizer (Nos. 2 and 3), while the plot which received twice the standard amounts (No. 1) made a much superior growth and yield. As potash has been without profit not only on this soil but also on others which have been tested, a large amount is not advised for a potato formula, and if anyone desires to mix his own fertilizer and is unable to obtain potash salts conveniently they can be omitted without fear of any serious loss, at least for a season or two. The acid phosphate and the cotton-seed meal are the important constituents. Had these experiments been on a soil naturally better supplied with moisture, and had better preparation and cultivation been given, the results would without doubt have shown more profit.

SERIES TWO

The experiments of series 2 were carried out on an exceedingly poor "white gravelly" soil situated on a hilltop. For a number of years only the most meager crops had been harvested from this soil, and the experiment was undertaken with the idea of testing the profitableness of fertilizers under such adverse circumstances. About the only favorable condition was the rather loose and gravelly texture of the soil. No attempt was made to test the particular plant food deficiencies, as there was assumed to be the need of a complete fertilizer, which was used at different rates from 250 to 2000 pounds to the acre. The plots were each 1-50 of an acre. Only ordinary preparation and cultivation were given. The season was fairly favorable. The following table gives the yields and other data which may be of interest:

TABLE IV—*Results per acre from series 2 of fertilizer experiments on Irish potatoes*

Plot	Fertilized with	Yields		Increase from fertilizer. Salable	Cost of fertilizer †	Cost of 1 bu. of increase	Approx. amounts fertilizer residues		Values of residues
		(a) Salable	(b) Culls				Acid Phos.	Sulphate of potash	
		bu.	bu.	bu.		cts.	lbs.	lbs:	
1	250 lbs. of complete fertilizer*	33.3	17.5	30.3	$4.50	15	109	15	$1.27
2	500 lbs. of complete fertilizer	48.8	14.5	45.8	9.00	20	236	52	3.33
3	1000 lbs. of complete fertilizer	56.7	18.1	53.7	18.00	34	499	135	7.79
4	1500 lbs. of complete fertilizer	60.8	12.5	57.8	27.00	47	767	226	12.53
5	2000 lbs. of complete fertilizer	49.2	17.5	42.6	36.00	85	1039	320	17.39
6	No fertilizer	3.0	11.6	.....	.....	.....	....	....	.....

*The formula used was—
300 lbs. acid phosphate
100 lbs. sulphate of potash
160 lbs. nitrate of soda

†Calculated from high retail prices, as follows:
Acid phosphate, 75 cents per cwt.
Sulphate of potash, 3 cents per lb.
Nitrate of soda, 3 cents per lb.

REMARKS ON THE RESULTS

In spite of the poverty of the soil, fertilizers were highly profitable. The most profitable amount was 500 pounds to the acre, but the mixture is very concentrated, and had cotton-seed meal been used instead of nitrate of soda, the most profitable amount would have been about 680 pounds. The effect of the fertilizers on the yields of crab-grass from the different plots was very marked. That such increased yields should follow the application of purely mineral fertilizers indicates that this soil is more in need of plant food than of vegetable matter or of moisture in order to yield remunerative crops. This experiment and others have gone to show that however valuable an increased supply of humus might be to upland soils, it is not the first essential. That is, humus without plant food could hardly be expected to make greatly increased yields. On the other hand, although the two should go together, plant food without humus has given greatly increased yields.

POTATOES IN A ROTATION OF CROPS

These experiments were on a poor "white gravelly" soil but the location was more favorable for moisture than was the case for either of the other series. The unfertilized plot yielded 14 bushels of salable potatoes to the acre and the fertilized plots from 85 to 114 bushels. The plots were each 1-20 of an acre. They were kept free from weeds, and after the potato tops were dead crab-grass was allowed to grow up and cover the ground before the potatoes were dug. The yield of crab-grass from the fertilized plots was about 1500 pounds to the acre, from the unfertilized plots about 500 pounds. After the potatoes were dug the soil was turned and prepared for wheat, which was drilled about the middle of October. With the seed was drilled, on all the plots alike, 350 pounds of a high-grade complete fertilizer. The yield of wheat on the fertilized potato plots was about 20 bushels to the acre, on the unfertilized potato plots about 12 bushels. In March clover seed was sown on all the plots, but the plants died out where no fertilizer had been used for the potatoes. On the other hand, the plants on the fertilized plots grew well and withstood the exceedingly dry weather of that summer, but no cutting was made. In the season of 1902 there were three good cuttings, giving a total yield of about three tons of clover hay to the acre. Attention is called to these results to show how easily a poor soil can sometimes be profitably brought up to a good state of fertility, and largely by means of fertilizers.

EXPERIMENTS ON GRASS AND CLOVER

One season's experiments on orchard grass and clover were carried out on what had been a very poor and unproductive piece of land. To prepare this soil for grass a crop of cowpeas and a crop of rye had been turned under. Both the rye and the peas had been moderately fertilized and manured. The experiments were made the second season after seeding. Adjoining plots 1-100 of an acre each were carefully selected. The fertilizer was applied broadcast in March, before much if any spring growth had been made. The following table gives the amounts and kinds of fertilizers used, the yields, and other data which may be of interest:

TABLE V—*Results per acre from fertilizer experiments on a mixture of orchard-grass and clover*

Plot	Fertilizer materials used	Amounts	Yields of hay	Increase from fertilizer	Cost of fertilizer*	Cost of increase per 100 lbs.	Approximate amounts fertilizer residues		Values of residues
							Acid phosphate	Potash salts	
		lbs.	lbs.	lbs.			lbs.		
1	Acid phosphate...	300	3560	566	$2.25	$0.40	205	In each case more potash was removed than was applied	$1.54
2	Acid Phosphate ..	300	3625	631	5.25	0.83	203		1.52
	Muriate of potash.	100							
3	Acid phosphate...	300	3560	566	2.25	0.40	205		1.54
4	Acid phosphate...	300	3300	306	5.25	1.72	212		1.59
	Sulphate of potash	100							
5	No fertilizer.....	.....	2994	....	....	.....	.....		.....
6	Acid phosphate ..	300	3956	962	10.05	1.05	194		1.46
	Muriate of potash.	100							
	Nitrate of soda ...	160							
7	Acid phosphate...	600	4331	1337	20.10	1.50	184		1.38
	Muriate of potash.	200							
	Nitrate of soda ...	320							
8	Nitrate of soda ...	160	3269	275	4.80	1.74	.....		.....

*Calculated from high retail price, as follows:
Acid phosphate, 75 cents per cwt.
Potash salts, 3 cents per lb.
Nitrate of soda, 3 cents per lb.

REMARKS ON THE RESULTS

Acid phosphate was the only fertilizer material which was used with decided profit, although the need of nitrogen was fully demonstrated. Practically no increase resulted from an application of potash, whether in the form of a muriate or of a sulphate. The effects of the fertilizers on the clover and the grass were decidedly different. At the start all the plots had apparently about an equal stand of clover and of orchard-grass, but on the plots which received acid phosphate or a mixture of acid phosphate and potash salts the growth of clover predominated more and more as the season advanced. On the other hand, where the nitrate of soda was used alone or in a mixture with acid phosphate and potash the orchard-grass predominated; that is, the minerals enabled the clover to crowd the grass, while the nitrate of soda enabled the grass to crowd the clover. A rough but fairly reliable separation of clover and grass was made from samples of hay, with results as follows:

Plot	Fertilizer materials used	Per cent clover	Per cent orchard-grass
1	Acid phosphate	79	21
2	Acid phosphate and muriate of potash	63	37
3	Acid phosphate	70	30
4	Acid phosphate and sulphate of potash	61	39
5	No fertilizer	57	43
6	Acid phosphate, muriate of potash, and nitrate of soda	16	84
7	Acid phosphate, muriate of potash, and nitrate of soda (double quantity)	41	59

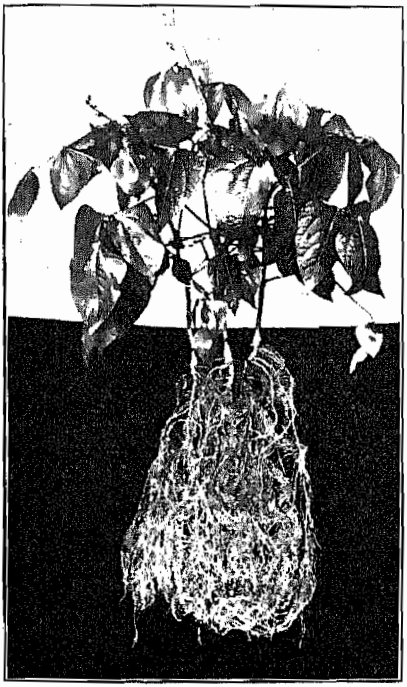
The explanation of these results is that the clover was able to gather nitrogen from the atmosphere, so that with acid phosphate as a fertilizer it was well supplied with all kinds of plant food. The orchard-grass, on the contrary, was in need of nitrogen and without it could not make a vigorous growth. When well supplied, however, it was more than able to hold its own against the clover. Similar results have often been noted and they may be said to be characteristic of the different fertilizer materials when used on leguminous and non-leguminous plants. On account of its high content of protein, clover hay is more nutritious and valuable than orchard-grass, so that the advantage in favor of the use of acid phosphate without nitrate of soda was greater than is indicated by the yields per acre. Moreover, the better the growth of clover the more favorable would be conditions for the following crop, for the clover roots and stubble would furnish no inconsiderable quantity of nitrogen and other forms of plant food. Attention is called to the large amount of potash removed by hay, which if sold off the farm would sooner or later make potash needed as well as phosphoric acid and nitrogen. Although profit was not obtained from the amounts of nitrate of soda used, the use of smaller amounts to give the grass a good start would probably be justifiable. The value of the residual phosphate was not large, but at least meant the building up of this soil with an element in which it was naturally deficient.

EXPERIMENTS ON COWPEAS

A number of fertilizer experiments have been made from year to year on cowpeas. This crop has been found to respond readily to the mineral fertilizers, in particular to acid phosphate. Numerous experiments have been made to test the value of nitrogen along with phosphoric acid, but thus far no increased growth has apparently resulted from nitrogen, even on the poorest land. If nitrate of soda, cotton-seed meal, etc., are with difficulty made profitable on such crops as corn and wheat, their profitable use for a leguminous crop, such as cowpeas or clover, which are known to be able to gather a large part of their nitrogen from the air, would naturally be much more difficult. Acid phosphate has been found to increase greatly the yields of both the hay and the peas, but especially the yield of peas. One of the most economical ways in which to improve a poor soil has been found to be the growing of cowpeas, fertilized with acid phosphate. A good plan in the case of a worn-out soil is to plant the peas in rows, using acid phosphate at the rate of 300 pounds to the acre. The peas should be cultivated at least twice. The seed can be picked or the crop can be pastured off to good advantage. In order to derive permanent benefit from this method of soil improvement it is not advisable to remove the crop as hay unless the equivalent in stable manure be returned to the land. The pea roots, stubble, and fallen leaves contain only about one-third of the total plant food gathered by the crop, and could be expected to give only temporary improvement.

On account of the cheapness with which ground raw phosphate rock can be obtained in the State, its value as a fertilizer is frequently asked. Pot experiments on peas and on turnips and field experiments on peas were

carried out during the past season to test this question. The results were not at all favorable to the use of the rock. The soil selected for the experiments was known to be poor in phosphoric acid and though the season was unfavorable a greatly increased yield resulted from the use of acid phosphate. As acid phosphate contains land plaster, the equivalent quantities of this substance were used with the rock phosphate, and in each case except where no fertilizer was used muriate of potash was added to supply any possible deficiency of potash. No apparent increase in yield resulted from any of the mixtures in which acid phosphate was not present. Tennessee soils have been found to be generally poor in lime, but over the greater



76.5 per cent of the total nitrogen and 72.6 per cent of the total dry matter were in the tops

COWPEA PLANTS

part of the State, outside of the Central Basin limestone soil, the need of phosphoric acid is so much greater than the need of lime that an application of lime alone is seldom attended with much profit.

The pot experiments were carried out under more satisfactory conditions than the field experiments, but the results were practically the same; that is, little increase was gotten from the untreated phosphate, which had been ground to the usual fineness for manufacture into acid phosphate. That raw phosphate ground to a much greater degree of fineness would

have given better returns is probable. That fine-ground phosphate rock can be used to advantage on decidedly acid soils—soils on which acid phosphate does not give good results—has been well established, but otherwise it is generally considered to be of doubtful value.

TABLE VI—*Results per acre of fertilizer experiments on cowpeas*

Plot	Fertilizer materials used	Amounts	Yields of shelled peas
		lbs.	bu.
1	Acid phosphate Muriate of potash	300 50	10.2
2	Phosphate rock Muriate of potash Land plaster	300 50 300	3.5
3	Phosphate rock Muriate of potash Land plaster	450 50 300	4.0
4	Muriate of potash Land plaster	50 300	3.5
5	No fertilizer	.....	3.5

The phosphoric acid from raw bone meal, which was ground so that the largest particles were about the size of pin heads, was found much more available than the phosphoric acid from the ground rock and about one-half as efficient as that from acid phosphate.

APPLICATION OF FERTILIZERS

The question as to how fertilizers should be applied is somewhat difficult to answer because it depends on a number of conditions, especially the kind of fertilizer and the amount to be used. Phosphoric acid and potash, even in water soluble forms, do not leach out of the soil to any appreciable extent. On the contrary, they do not distribute themselves well enough, and therefore should be applied to some depth. Nitrogen, on the other hand, finally leaches out of the soil unless taken up by the roots of plants. In some materials, however, it is much less readily soluble than in others. Tankage, for example, should be applied deep, and it is well to mix cotton-seed meal and blood with the soil; but nitrate of soda and ammonium sulphate should nearly always be applied as surface dressings. Only one application is advised for ammonium sulphate, but when large quantities, over 200 pounds to the acre, of nitrate are to be used, two applications of 100 pounds each are often made to advantage, one when the plants are first coming up and the other two or three weeks later. Potash salts when used in quantity, 100 pounds or more to the acre, are well applied in the fall, so that the winter rains may take out the chlorine, which when combined with either lime or magnesia acts in a detrimental manner to plant growth. Lime is also well applied in the fall. Acid phosphate when used as a top dressing may be applied either in the fall or in the early spring. When a small amount of fertilizer is to be used it is best applied as the seed is sown or as the plants are set out, in the row or in the hill or, when practicable,

drilled with crops which are drilled. As a general rule only a heavy application of a complete fertilizer, say 1000 pounds or more to the acre, is recommended to be applied broadcast and worked into the soil for crops which are planted in rows. The following table gives the results of experiments on corn to test two common methods of application, in the row and broadcast. The soil used was known to be deficient both in phosphoric acid and in nitrogen.

TABLE VII—*Results per acre from fertilizer experiments on field corn*

Plot	Fertilized with	Manner of application	Yields of corn	Yields of stover
			bu.	lbs.
1	250 lbs. of complete fertilizer*	Broadcast	25.6	1950
2	500 lbs. of complete fertilizer.	Broadcast	28.4	2050
3	1000 lbs. of complete fertilizer.	Broadcast	31.6	2450
4	250 lbs. of complete fertilizer.	In row	28.0	1850
5	500 lbs. of complete fertilizer.	In row	27.3	2200
6	1000 lbs. of complete fertilizer.	In row	29.5	2425
7	No fertilizer	.....	14.4	1680

*The formula used was—
300 lbs. acid phosphate
50 lbs. muriate of potash
180 lbs. cotton-seed meal

REMARKS ON THE RESULTS

The results of this one trial were that 250 pounds of fertilizer gave better returns applied in the row than applied broadcast, and that both 500 and 1000 pounds gave slightly larger returns applied broadcast than in the row. The season, however, was not favorable to the experiment, for dry weather, amounting almost to a drouth, lasted throughout July and a part of August. Before the dry weather the corn on all the plots fertilized in the row was looking much superior to that where the fertilizer was applied broadcast and harrowed into the soil, so that it is evident that these experiments should be continued over several seasons in order to give satisfactory results. Different crops have been found in the early part of their lives to store up plant food to be used later when fruit is being formed, which furnishes a good reason for putting the fertilizer in the row where the roots are sure of finding it early.

Experiments made at this Station in the season of 1900 showed that cotton-seed meal, dried blood, potash salts and nitrate of soda could not be used safely in direct contact with the seed, the germination of which was prevented to a greater or less extent. Acid phosphate was found to be one of the few materials which could be used safely in contact with the seed. Of the materials tried, cotton-seed meal, pound for pound of nitrogen, did the most serious damage. Under somewhat unfavorable conditions for the germination of wheat, 50 pounds of cotton-seed meal to the acre, drilled with the seed, was found to interfere seriously with the germination, and 100 pounds to the acre was found practically to prevent it. Under more favorable conditions, 150 pounds of meal to the acre was drilled with the

seed without very serious consequences, although the germination was evidently retarded. Were it not for this drawback much higher-grade fertilizer mixtures could be drilled with seed than are being used. If the high-grade mixtures which contain cotton-seed meal or blood in large proportion are to be used they should be drilled separate from the seed. A few experiments were made to test the value of cotton-seed meal for wheat when applied as a surface dressing. For comparison nitrate of soda furnishing equivalent quantities of nitrogen was used. The following table gives the amounts used per acre, the times of application, and the yields. The preceding crop was potatoes, which had been highly fertilized with a complete fertilizer, and the soil was considered to be fairly well supplied with the mineral elements, phosphoric acid and potash. The yield of potatoes was so uniform on these plots that the results are considered reliable.

TABLE VIII—*Results per acre from fertilizer experiments on wheat*

Plot	Sources of nitrogen	Amounts	Time of application	Yields		Increase from use of nitrogen	
				(a) Grain	(b) Straw	(a) Grain	(b) Straw
		lbs.		bu.	lbs.	bu.	lbs.
1	Nitrate of soda...	150	Spring	21.5	2235	5.4	623
2	Nitrate of soda...	150	$\frac{1}{3}$ Fall, $\frac{2}{3}$ Spring	20.2	2100	4.1	388
3	No nitrogen.....	.....	.....	16.1	1612	.....	.....
4	Cotton-seed meal.	338	Fall	22.3	2189	6.2	577
5	Cotton-seed meal.	169	Fall	22.1	2500	6.0	888
	Nitrate of soda...	75	Spring				
6	Cotton-seed meal.	85	Fall	20.1	1969	4.1	357
	Nitrate of soda...	37.5	Spring				

REMARKS ON THE RESULTS

Both nitrate of soda and cotton-seed meal gave a marked increase in yield, but in order to draw satisfactory conclusions the experiment should be continued for several years. If we judge by this one year's results, nitrate of soda is best applied in the spring. The cotton-seed meal was applied broadcast before the wheat was drilled and no evil effects could be detected. The nitrogen from the meal seemed to be more effective than that from the nitrate of soda. As can be calculated from the table, the increased yields from the amounts used either of nitrate of soda or of cotton-seed meal were unprofitable. From experiments continuing over several seasons at the Experiment Station farm, 75 pounds of nitrate of soda seems to be much nearer the limit of profit than 150 pounds.

SUMMARY OF RESULTS

SWEET POTATOES

1 Sweet potatoes gave greatly increased yields from a fertilizer mixture of cotton-seed meal and acid phosphate in the proportion of 350 pounds of meal to 300 pounds of phosphate.

2 Potash was not found of much value, and for all the soils tested has been found the least needed of the important elements of plant food.

3 The most profitable returns for the two seasons came where the most fertilizer had been used—1520 pounds to the acre. The mixture was made up of 720 pounds of cotton-seed meal, 600 pounds of acid phosphate, and 200 pounds of muriate of potash, and would analyze—

	Per cent
Available phosphoric acid	7.3
Potash	7.3
Nitrogen	3.3
or Ammonia	4.0

Judging from the other results, however, the amount of potash could have been reduced to advantage.

IRISH POTATOES

Irish potatoes were found to respond well to fertilizers, but on account of their lack of hardiness in this climate the use of large amounts of fertilizer is attended with more risk than is the case with sweet potatoes. 500 to 1000 pounds of the following mixture is recommended: 360 pounds of cotton-seed meal, 300 pounds of acid phosphate, and 50 pounds of muriate of potash. This mixture analyzes—

	Per cent
Available phosphoric acid	7.5
Potash	4.3
Nitrogen	3.5
or Ammonia	4.25

GRASS AND CLOVER

1 The yields of grass and clover were greatly increased by applications of acid phosphate and nitrate of soda. Acid phosphate used alone affected the clover more than the grass, while the mixture of acid phosphate and nitrate of soda resulted in a predominating growth of grass.

2 Acid phosphate, 300 pounds to the acre, used alone, greatly increased the yield of clover, and was by far the most profitable fertilizer.

COWPEAS

1 Acid phosphate used alone has given the most profitable returns. On very poor land good results have followed the use of potash along with the phosphate.

2 Fine-ground raw rock phosphate did not produce any marked in-

crease of growth on a soil known to be poor in phosphoric acid. A similar result was obtained in pot experiments on both cowpeas and turnips.

3 In pot experiments the phosphoric acid from fine-ground raw bone was found to be about one-half as efficient for both cowpeas and turnips as the phosphoric acid from acid phosphate.

APPLICATION OF FERTILIZERS

1 Better results followed the use of 250 pounds of a complete fertilizer for corn when applied in the row than when applied broadcast and harrowed into the soil. Slightly better yields came from the broadcast application of 500 to 1000 pounds to the acre than from the same amounts applied in the row, but the results should not be considered conclusive.

2 Cotton-seed meal was found to retard seriously the germination of seed with which it was applied in direct contact, and it should not therefore be drilled with wheat. When applied in the row for crops planted in rows it should be mixed with the soil before the seed is dropped.

3 Cotton-seed meal applied broadcast in the fall for wheat gave favorable returns as compared with nitrate of soda furnishing the same amount of nitrogen.