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A SOIL FERTILITY TEST

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A SOIL FERTILITY TEST

The Palouse country has long been famous for its wheat crops, the yields of fifty, sixty, and even more bushels per acre seeming well nigh incredible to the Eastern man. These remarkable yields are due primarily to the wonderful fertility of the soil, which is eminently adapted to the culture of wheat. This adaptability is the result of the bounteous supply of plant food elements contained in the soil; and of its physical constitution, whereby it is exceedingly retentive of moisture received from the winter rains.

In a publication praising the wonderful resources of Idaho, an authority on agricultural matters is quoted as saying that the volcanic ash soils of this region are inexhaustible, the inference being, evidently, that the wonderful crop yields would continue indefinitely. While it is doubtless true that no agricultural soil can be *entirely* exhausted of all its plant food elements, is it not possible that the stock of available plant food in even the most fertile soil may be so depleted as to seriously affect the crop yields and make the farming of such soils unprofitable? If the plant food elements in the soil are removed more rapidly by cropping than the dormant elements are rendered available to the succeeding crops, the time will inevitably come, sooner or later, when the supply is not equal to the demand, and the yield must of necessity become less. The more fertile the soil, the greater the excess of available plant food and the farther away is the time when the supply will become less than the demand; but, nevertheless, this time must come. Are there any indications that anything of this nature is in progress in the Palouse soils?

The writer, in conversation with one who had been engaged in wheat farming in the vicinity of Moscow for fifteen or more years, asked him if his wheat yielded as heavily as when he first began farming here. He at once said that it did not. The next question was as to the color of the soil as compared with that of fifteen years before. The answer was that it is lighter in color than then. As the dark color of soils is usually due to the humus or disintegrated organic matter in the soil, and as the nitrogen compounds of the soil are almost entirely derived from the humus, it seemed very probable that the diminished yield might be due to a lack of soil nitrogen. Further inquiry and thought upon the matter convinced the writer that it would be well to make a test of the available fertility of a typical soil of this region for the purpose of determining whether or not any essential plant food elements were insufficient in quanity.

Of the chemical elements essential to plant growth, long experience has shown that three elements are all that are apt to become sufficiently scarce to affect crop yields. These three elements are *nitrogen, phosphorus,* and *potassium.* In some some sections, *lime* may be insufficient in quantity, but it is generally plentiful enough for the needs of most crops. It was therefore decided to test for the three elements first mentioned.

While a chemical analysis will enable one to determine the exact amount of the various chemical elements in a soil, it does not satisfactorily show what use a plant can make of them under the various conditions that may exist in the soil. Neither can a mechanical analysis solve the problem; nor, indeed, can the two analyses combined do more than hazard a guess at what may be the probable result. It has been found to be the most satisfactory to test the soil by making an actual growing test upon it, varying the soil conditions under which the crop is grown.

A growing test for soil fertility may be made in the greenhouse or in the field, each method having its advantages. In the greenhouse test, the conditions may be controlled so that comparable results may be expected from the first test. In addition, samples of soils may be brought in from localities where it would not be feasible to carry out the test. As it is the soil, and not the climatic conditions, that is to be tested, soils from various sections may all be conveniently tested at once. The advantages of a field test are that larger areas may be tested and results obtained comparable with those in the surrounding community. A complete test should include both methods.

In the spring of 1906 the writer collected soil for a greenhouse test. The soil was the common upland wheat soil as found in the vicinity of Moscow. It was collected about a mile west of Moscow on the farm of Mr. John Riley. Two samples were taken within about fifty yards of each other. One was soil that had never been cropped, so far as could be ascertained; the other had been cropped to small grain, principally wheat, ever since it had been placed under cultivation, the bare fallow system being practiced.

The soils were placed in four-gallon earthenware jars, two series of ten jars each being prepared. "Series A" contained the virgin or uncropped soil, "Series B" the cropped soil. The two series were treated the same in every respect so far as possible in order that the results might be comparable. Below is given the general plan of the experiment.

Dried blood was used as a source of nitrogen. It is a slaughter house product and contains about twelve per cent of nitrogen. *Fifteen grams* of the blood was applied to each jar of soil in which a nitrogen fertilizer was desired.

Steamed bone meal was used as a source of phosphorus. It is also a slaughter house product and contains about twelve per cent of phosphorus. Instead of giving the per cent of phosphorus in a fertilizer, it is the usual custom to give the per cent in terms of a compound of phosphorus and oygen (P_2O_5) of which phosphorus constitutes about three-sevenths (43 per cent). This compound is usually termed "phosphoric acid," although, in reality, phosphoric acid is a different compound. According to this method the bone meal would contain about twenty-eight per cent of "phosphoric acid'" *Six grams* of this bone meal was applied to each jar of soil in which a phosphorus fertilizer was desired.

Potassium chloride, commonly called "muriate of potash," was used as a source of potassium. This fertilizer comes from the potash mines of Germany. The commercial form of potassium chloride used as a fertilizer contains about forty per cent of potassium. Here, as in phosphorus fertilizers, it has become customary to express the fertility content in terms of a compound. This compound, called potash, is composed of potassium and oxygen (K_2O) and is about four-fifths (83 per cent) potassium. The fertility content of this fertilizer is therefore given as fifty per cent of potash. *Three grams* of this fertilizer was applied to each jar of soil in which a potassium fertilizer was wanted.

Below is given the general plan of the experiment, showing what treatment was given to the soil in each jar. The meanings of the symbols used are N—nitrogen; P—phosphorus; K—potassium; Man'r—manure; Legm—legume.

No.	Symbols.	Treatment.
1	Check	No fertilizer added.
2	N	Dried blood, 15 grams.
3	P	Bone meal, 6 grams.
4	K	Potasium chloride, 3 grams.
5	NP	Dried blood, 15 grams; bone meal, 6 grams.
6	NK	Dried blood, 15 grams; potassium chloride, 3 grams.
7	PK	Bone meal, 6 grams; potassium chloride, 3 grams.
8	NPK	Dried blood; 15 grams; bone meal, 6 grams; potassium chloride, 3 grams.
9	Manr.	Fresh horse manure, 1 pint.
10	Legm.	Clover grown and turned under.

In carrying out this experiment, a deviation from the general plan was necessary. As the series were prepared just before planting, it was thought best not to risk using fresh manure, and manure from a compost heap was used, so that the results do not fully represent what manure is capable of doing. Furthermore, as the clover had not yet been grown, no results were possible from the tenth jar the first season. However, the first eight jars of the series are the only ones necessary in making the test.

A spring wheat was selected for planting, a durum or macaroni wheat, the Kubanka, being used. The planting was done April 6, 1906. Thirty grains were planted in each jar, and these, when well started were thinned to ten. Notes were kept; measurements were made, and photographs were taken at different stages of growth. When fully mature the crop in each jar was carefully harvested, and weighed. The detailed results are given in the following table:

	Series A—Uncropped.					Series B—Cropped.			
Jar No.	Treatment.	Yield in Grams. Total	Straw	Grain	Jar No.	Treatment.	Yield in Grams. Total	Straw	Grain
1	Check	49.5	34.7	14.8	1	Check	27.0	18.7	8.3
2	N	169.0	115.3	53.7	2	N	103.5	77.5	26.0
3	P	51.0	34.0	17.0	3	P	37.5	26.0	11.0
4	K	50.0	34.5	15.5	4	K	28.0	18.5	9.5
5	NP	177.5	117.3	60.2	5	NP	137.0	90.3	46.7
6	NK	162.5	110.3	52.2	6	NK	157.5	104.0	53.5
7	PK	48.0	33.0	15.0	7	PK	40.0	27.5	12.5
8	NPK	183.5	122.3	61.2	8	NPK	122.5	83.0	39.5
9	Manr	60.0	41.2	18.8	9	Manr	42.0	28.7	13.3
10	Legm	— -	— -	— -	10	Legm	— -	— -	— -

(For a photographic representation of the results at different stages see Figs. 1-4.)

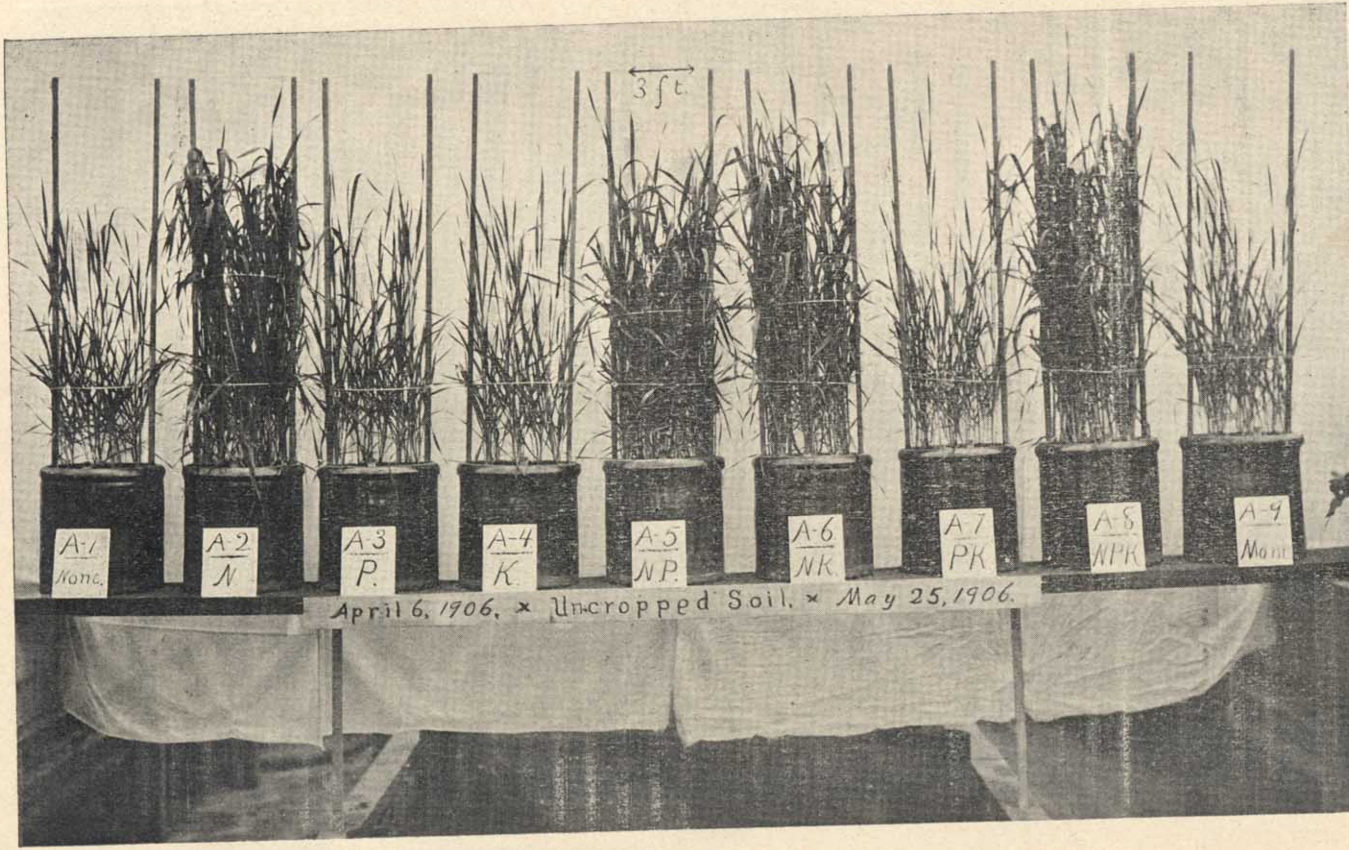
3 ft.
A-1
None.
A-2
N
A-3
P.
A-4
K.
A-5
NP.
A-6
NK.
A-7
PK
A-8
NPK
A-9
April 6, 1906. × Uncropped Soil. × May 25, 1906.

FIGURE 1


3 ft.
B-1 None
B-2 N.
B-3 P.
B-4 K.
B-5 NP.
B-6 NK
B-7 PK
B-8 NPK
B-9 Manr
April 6, 1906. × Cropped Soil. × May 25, 1906.

FIGURE 2

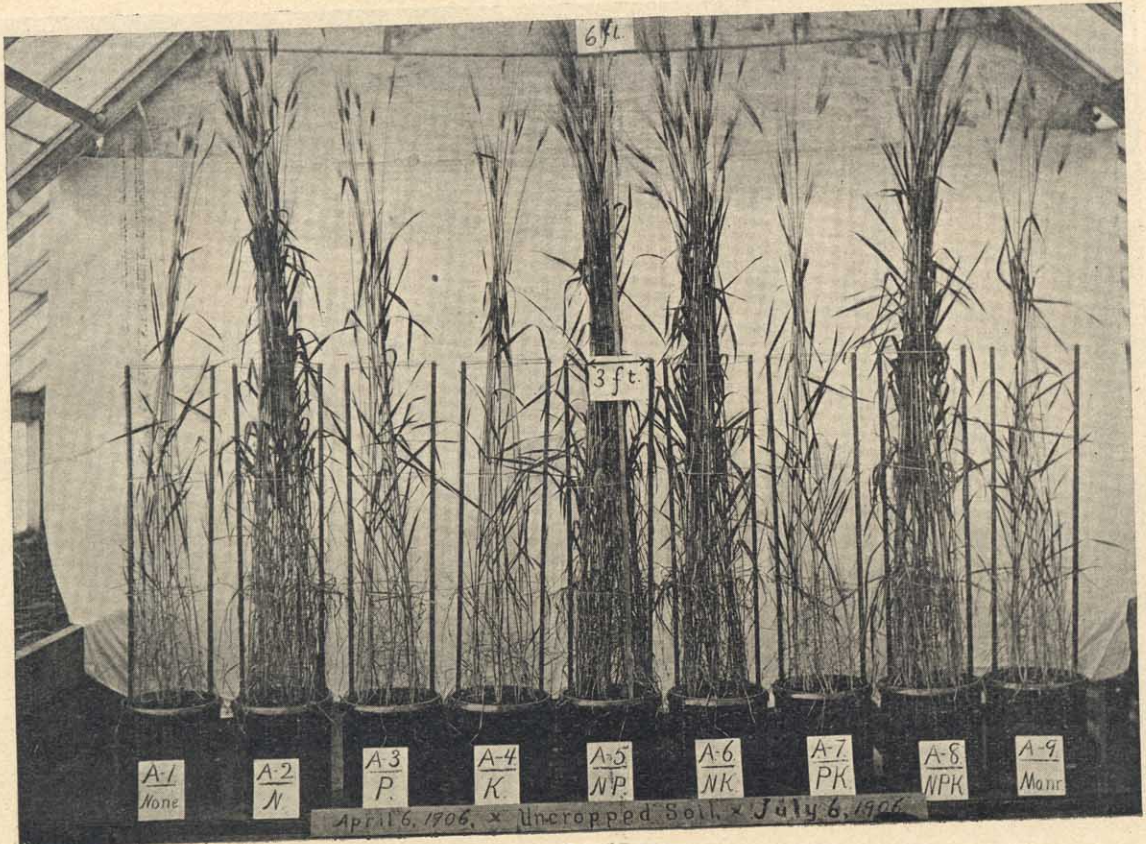
6 ft.
3 ft.
A-1 None
A-2 N
A-3 P.
A-4 K.
A-5 NP.
A-6 NK.
A-7 PK.
A-8 NPK
A-9 Manr.
April 6, 1906, × Uncropped Soil, × July 6, 1906.

FIGURE 3

FIGURE 4

An examination of the above table shows that wherever nitrogen was added there was a very decided increase in yield. The only possible conclusion, therefore, is that the store of available nitrogen in the soil is deficient. This is seen to be true even of the virgin soil. As indicative of the effect of long-continued wheat growing upon the soil, No. 1 in each series should be carefully noticed. The total yield has decreased from 49.5 to 27.0 and the yield of grain from 14.8 to 8.3. No. 2 shows that the addition of nitrogen has not only increased the yield in each series, but that it has increased the yield in "Series B" above that of the untreated soil in No. 1 of "Series A," the yield of the former being over 75 per cent greater than that of the latter.

A consideration of the results in No. 3 in each series shows a very satisfactory increase in each case as a result of the phosphorus added, the per cent of increase being considerably greater, however, in "Series B," indicating that the supply of available phosphorus had been very appreciably depleted.

Number 4 in each series shows an increase because of the potassium added, although not so great as that resulting from the use of phosphorus.

No. 5 in each series shows a greater increase from the addition of both *nitrogen* and *phosphorus* than would be expected, judging from the increase when they were applied alone. This was no doubt due to chemical reaction between the two fertilizers, by which they were made more readily available.

No. 6 in each series shows the result of applying both *nitrogen* and potassium. In "Series A" there is no increase in favor of the combination above that of nitrogen alone, the result being slightly less, in fact. In "Series B," however, result is very much in favor of the combination.

In neither series did No. 7 give a result favoring the combination of *phosphorus* and *potassium*.

In No. 8 of each series the use of the three elements gave results better than when nitrogen alone was applied, but only very little better in "Series A" and considerably less in "Series B" than when nitrogen and potassium were both used.

In No. 9 of each series the use of *manure* gave a better result than did the use of either phosphorus or potassium but the result was considerably less than when nitrogen was added. As has been stated, however, the manure used was not so rich in fertility as that usually used in such experiments, much of the nitrogen having no doubt escaped.

As clover was being grown in No. 10 of each series, no wheat was grown in them. The clover made a good growth in each series, being somewhat better, however, in "Series A." Some difficulty was experienced in getting a "catch" of clover in "Series B." After a second failure, the soil was tested with litmus paper and found to be slightly acid. A little carbonate of lime (air slacked lime) was then applied and the clover germinated and grew very satisfactorily. The clover in each jar has since been turned under. (In March, 1907.)

Allowing for unavoidably variations that will occur in experiments of this nature, it is nevertheless very evident that nitrogen should be restored to the soil in some way. If field tests should give as great a per cent of increase as is shown above, it might pay to use a commercial nitrogen fertilizer upon the land. Nitrogen fertilizers are so expensive, however, that the advisability of using them in general farming is very doubtful. Fortunately, however, the farmer has at hand the means whereby he may obtain an abundance of nitrogen at very little cost to himself.

The legumes or pod plants, such as beans, peas, clover, alfalfa, vetch, soy beans, and cow peas, are, through the agency of certain bacteria living in nodules upon their roots, able to extract nitrogen from the inexhaustible supply in the air. All that is necessary to maintain the needed amount of nitrogen in the soil is to grow one of these crops occasionally. No further experiment is needed to establish this, as it has long been proved to be true.

In growing legumes there is one condition that must be carefully looked after. It was stated above that legumes extracted nitrogen from the air through the agency of bacteria. These bacteria are not present in all soils, however, and in case they are absent the legume takes its nitrogen from the soil just as other crops do. Different kinds of these soil bacteria work upon different legumes, each legume having its own particular kind, which can not live upon the roots of other legumes. (It has recently been proved that the same bacterium may, in some cases, work upon the roots of closely related plants, as was proved by Hopkins of Illinois to be true of alfalfa and white sweet clover.) A soil that will successfully grow clover as a nitrogen-gathering crop may fail in this particular if alfalfa is grown, because of the absence of alfalfa bacteria. The presence of the proper bacteria in a soil may be determined by an examination of the roots of the legume in the spring or early summer. The presence of the little nodules or tubercles on the roots shows that the bacteria are present. (See Fig. 5)

If the desired bacteria are not present in the soil, they must be placed there in some way, if the stock of soil nitrogen is to be increased. A very simple method of doing this, when a successful field of the desired legume is accessible, is to transfer soil from that field to the field where the same legume is desired, and to scatter it over that field. As the surface layers of an inoculated soil contain countless numbers of bacteria, their transferrence is thus assured. The scattered soil should be well mixed with the other soil by harrowing or disking, as the bacteria do not thrive except where it is moist and dark. The amount of soil applied per acre will depend upon the ease of procuring it, but at least one hundred pounds should be used. A wagon load would of course be better, as the more soil, the more bacteria.

Another method of getting the desired bacteria into the soil has been worked and is giving more or less satisfaction. Pure cultures of the bacteria are sent out by mail, and by carefully following the directions sent an abundance of bacteria may be easily applied to the soil. This method has not given universal satisfaction, but enough has been accomplished to indicate that it will no doubt become a feasible method of applying bacteria, especially when no inocculated soil is accessible. It is claimed that inocculation by scattering soil may bring in weeds, insects, or fungi injurious to crops, which is no doubt possible. The Department of Agriculture of the United States sends out liquid cultures of bacteria of the various legumes. The Bacteriological Department of the Ontario Agricultural College prepares a culture also, which is very easily applied. The writer tested cultures from these two sources in 1906 and obtained good results in some cases. Anyone desiring to try this method of inocculaton should *carefully follow the directions sent.* He should remember, however, that the method is still in the experimental stage and should be prepared for failure. The won-

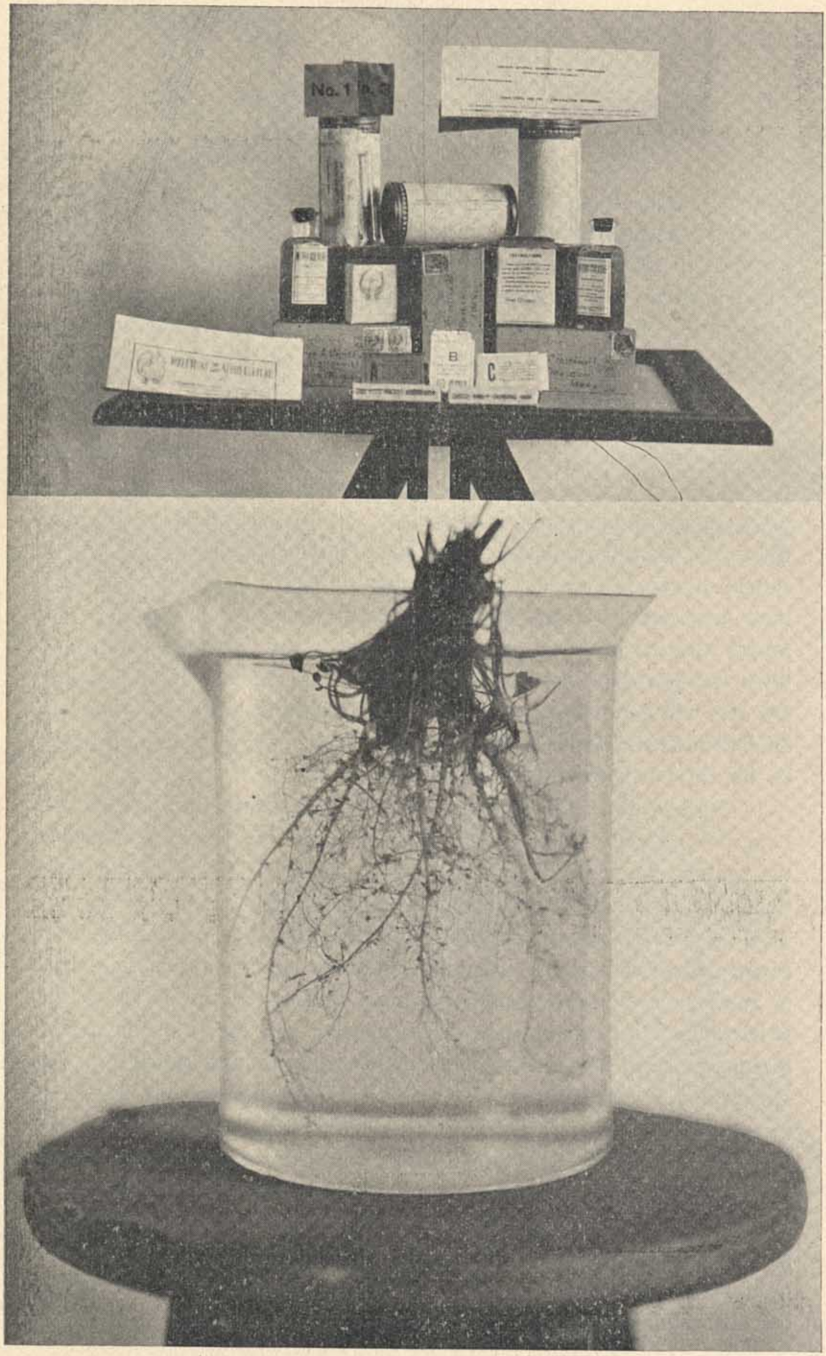

FIGURE 5

derful claims made by some writers and by some firms having cultures to sell should be received with the proverbial "grain of salt." (See fig. 6.)

Medium red clover is one of the best legumes for soil renovation and will probably grow almost anywhere in the wheat district, as the soil seems to be generally well supplied with clover bacteria. It should therefore be grown now and then, to keep up the stock of nitrogen in the soil. Any other legume may be grown if the conditions are favorable. The field pea is one of the best soil renovators, and has the advantage of being an annual, thereby occupying the soil but a short time, which is sometimes desirable. Alfalfa should be used only when it can be left a number of years, as a rule.

At the present time (May, 1907) the clover turned under in "Series A" and "Series B" is showing the effect of nitrogen taken from the air last year. The wheat in these jars is already far ahead of that in the jars of untreated soil and compares quite favorably with that in the jars where the nitrogen fertilizer was applied. If a soil is sour or acid, the bacteria that work on the legumes cannot exist. The soil should be sweetened by the addition of some form of lime. Air-slacked lime is one of the best forms, although any form may be used. The amount depends upon the acidity of the soil. It would be well to apply different amounts on small areas as a test before liming a large field, using it at the rate of several hundred pounds per acre. In very sour soils 1000 fo 4000 pounds per acre may be necessary. To test a soil for acidity, moisten a small quantity of it and press a piece of moist *blue litmus paper* firmly upon it. If the soil is acid, the paper will turn red after some minutes, perhaps half an hour or more.

In regard to the application of a phosphorous fertilizer, it would seem that it would be practicable if applied in conjunction with the growing of a legume and the entire crop turned under. However, more tests must be made before a positive statement can be published.

It is not evident as yet that the application of a potassium fertilizer would be profitable.

The writer advises every farmer to make a test of his own soil as was done above. Boxes, cans, or jars may be used. The necessary fertilizers will cost but a few cents.

It would be well to carry on the above experiment in small field plats, applying the fertilizers at the following rates per acre: Dried blood, 800 pounds; bone meal 600 pounds, and potassium chloride 300 pounds. Eight plats would be necessary to show what elements were not sufficiently plentiful. Plats 9 and 10 could be added to test the effect of manure and legumes. In order that there may be uniformity among those who may make this test, we advise the use of 20 large loads of manure per acre and recommend the use of the field pea for plat 10. Plat 10 might well be duplicated with red clover and any other legume desired. The experiment should be conducted several years. Dried blood should be applied each year, preferably a short time before the crop is planted, as the nitrogen is apt to waste if in the soil a con iderable time before the crop is present to use it. The other fertilizers, including the manure, are slower in action and need be applied less frequently, say once in three years for the sake of uniformity. Because of their slow action it is well to apply them some time before planting is done. The field pea may of course be turned under a few months after planting, but clover should usually be allowed to stand the second year.

Plats should be laid out long and narrow and care should be taken that the fertilizers intended for one plat are not scattered upon the edges of an adjoining plat. A strip several feet wide should be left between plats.

The fertilizers may be scattered broadcast by hand if one is careful to scatter it evenly, To facilitate this, the plat may be divided into a number of equal parts and a like part of the fertilizer applied to each division. A wheat drill may often be used to advantage. Where several fertilizers are applied to a plat they should be scattered separately. The fertilizers are best applied when there is no wind.

Either wheat or oats may be used in this test, but wheat is recommended, either fall or spring varieties. The writer has begun a field test with corn, wheat, and oats, using one-tenth acre plats.

The Experiment Station chemist, J. Shirley Jones, has just completed a determination of the protein content of the wheat grown in Nos. 1 and 2 of "Series B." He finds the wheat from No 1 to contain 16.06 percent of protein, and that from No. 2 to contain 18.30 per cent. This is of interest as indicating the probability of being able, by the increase of the amount of available nitrogen in the soil, to increase the gluten content of wheat, as the gluten depends upon the proportion of protein present. This is of particular interest to the miller, as the superior qualities of wheat flour for bread-making are largely due to the gluten in the wheat. Mr. Jones will further investigate this problem both with grain grown in the greenhouse and with that grown in the fertility plats in the field.

In conclusion, we wish to emphasize the fact that we are not as yet recommending the purchase of commercial fertilizers except in a small way to be used in testing the soil.