The principles of the Illinois system of permanent soil fertility have been tested on more than fifty experiment fields over the state. These fields vary in size from about one acre to 40 acres or more. Several of the older fields have been in operation for nearly twenty-five years. Fields that have been discontinued are indicated by an open circle.
FIG. 1.—PROGRESS OF THE SOIL SURVEY

The shaded areas indicate the 92 counties that have been surveyed. Dark shading shows the counties for which soil reports have been published.
The Illinois System of Permanent Soil Fertility in the Light of Twenty-five Years of Investigation

BY LOUIE H. SMITH, Chief in Charge of Publications of the Soil Survey

Recognizing the fact that the soil of Illinois is her foremost natural resource, the people of this state twenty-five years ago made provision for a systematic and comprehensive investigation of that resource. It was in 1910, thru the leadership of the Illinois State Farmers' Institute, that the Forty-second General Assembly granted the first generous appropriation for the investigation of the soils of Illinois by the Agricultural Experiment Station. And it is the Farmers' Institute that has been sponsor, thru its Soils Advisory Committee, for the continuance of the work thru the intervening years.

Thus we celebrate, at this session of the Institute, the twenty-fifth anniversary of the launching of this great enterprise—the investigation of Illinois soils—and it is highly appropriate that special consideration be given to the progress made in these investigations as well as to the application of some of the principles that have been uncovered in their prosecution.

It was in the year 1900 that our revered Doctor Cyril G. Hopkins, then serving as chemist of the Experiment Station, was appointed to the chair of Agronomy. This was the beginning of his great life work in the study of soils, which led to his conception of the idea of a permanent system of soil fertility.

Soil Investigations Planned Along Three Lines

In taking up this investigation of the soils of the state, three main lines of procedure were inaugurated; namely, the soil survey, laboratory experiments (including greenhouse culture), and field experiments.

In the soil survey the various kinds of soils are classified and mapped in such manner as to furnish a complete inventory of the soils of the state. When it is finished, every landowner in the state will have a description of the soil on his farm, will know approximately its composition, and will have at hand information relating to its maintenance and improvement.

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1 Address before the Illinois State Farmers' Institute at Paris, Illinois, February 18, 1925.
What Has Been Accomplished

With more than 56,000 square miles to cover, this was a gigantic undertaking. The work has progressed steadily, however, thru the years, county by county, until about ninety-two have now been mapped. In this work samples representing each soil type are collected and subjected to chemical analysis, and well over half the state has been covered by this phase of the work. To date, twenty-eight County Soil Reports have been published.

The status of the soil survey at the present may be roughly summarized as follows:

- Proportion of state mapped: 90%
- Proportion of state covered by analysis: 60%
- Proportion of state covered by publications: 30%

According to the first report to the Farmers' Institute, after the soil investigations were started, fifteen experiment fields had been laid out. Some of these original fields are still in operation. Others have been discontinued; altogether more than fifty have been operated (see map on cover). At the present time there are thirty-five of these fields laid out in plots serving for investigation as well as for demonstration. Experiments on these fields are so planned as to give information on practical and permanent systems of farming, including matters relating to fertilizer requirements, proper systems of crop rotation, drainage, prevention of erosion, subsoiling, and dynamiting.

Idea of a System of Permanent Soil Fertility Develops

As the results of these investigations accumulated, there was gradually evolved a philosophy, or doctrine, of soil fertility intended to apply to the more common soils of Illinois and to similar areas. This body of ideas relating to the fertility of the soil was enunciated by Doctor Hopkins and it has come to be called the "Illinois System of Permanent Soil Fertility." I have been asked to outline on this occasion this "Illinois System," and I assure you that the task is undertaken with due appreciation of the honor involved. In presenting the subject I shall attempt to give, as nearly as I am able to interpret it, Doctor Hopkins' own conception of the matter, and I do this with no little misgiving, appreciating fully the difficulty of representing fairly and impartially the views and opinions of another.

Doctor Hopkins' Contribution

In speaking of the relation of Doctor Hopkins to the Illinois system, Doctor Robert Stewart well expressed the matter in Circular 245 of the Illinois Agricultural Experiment Station, in the following words:

"The great contribution made by the late Doctor Hopkins was the gathering together, studying, interpreting, classifying, and unifying of the known facts of agricul-
ture into a definite whole as practiced and taught by him in the 'Illinois System of Permanent Soil Fertility.'

"Many of the facts upon which the Illinois system is based have been known for years and even centuries, and have been developed by other men and other institutions in other times. It remained, however, for Doctor Hopkins to bring together and to unify these isolated facts into a definite, workable system and by his own investigations to demonstrate clearly that the system could be understood and used by the average farmer on his own fields with very profitable and satisfactory results. In his interpretation of the facts upon which the system is based, all men have not agreed and some even still do not agree with him. But the system rests upon the sure foundation of facts supported by an abundance of experimental data now available from the fields and laboratories operated under his direction."

In the speaker's opinion the foregoing statement by Stewart is very fair in explaining the great heritage that Doctor Hopkins has left us.

Twelve years ago at the annual convention of this organization Doctor Hopkins himself presented an address on this same subject. In the opening paragraph he said:

"I have been invited to speak upon the Illinois system of permanent fertility, but I wish to state in the beginning that in complying with this request I am speaking in a representative capacity. Many have contributed to the development of this system, including both able investigators in other states and countries, my own colleagues in the investigation of Illinois soils, and the truly scientific farmers of this state, some of whom have kept their own farm practice so close up to the work of the Experiment Station as to exert an influence upon the adoption of systems of permanent fertility."

Thus we find that Doctor Hopkins himself laid no claims for originality in connection with the fundamental principles upon which the idea of the Illinois system is based.

As the speaker understands it, Doctor Hopkins' dominant idea was to provide a system of soil fertility that would result in permanent agriculture. He recognized that the continual removal of crops from the land must finally lead to soil exhaustion unless the materials taken from the soil were restored. The common practice of applying commercial fertilizers means that some of the necessary elements of plant food are returned to the soil, but since these elements are not returned in amounts proportionate to the quantities removed by crops the effect is a stimulation of the soil rather than an actual enrichment in plant food. By restoring the plant-food elements to the soil somewhat in excess of the amounts in which they are removed by cropping and thru other natural processes, the soil is not only maintained in its natural fertility but is actually built up and made more productive. In order to accomplish this effect, the elements must be secured in the most economic form, which ordinarily calls for raw materials rather than those that are treated or manufactured.

Thus in ordinary cropping systems, raw rock phosphate should be used, and the natural biological process of the soil will make the phosphorus available. Nitrogen should be secured from the air thru the growth of legume crops. Potassium is abundant in most soils, and the

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problem of supplying this element is usually a matter of liberation from the minerals naturally present in the soil rather than the addition of potassium salts to the soil. In order that these natural biological processes may function properly, the soil must be kept supplied with sufficient basic material, and for this purpose natural crushed limestone serves best.

This is an attempt at a very brief statement of the fundamental or guiding principles of Dr. Hopkins' proposition of a permanent system of agriculture. There are hundreds of deviations in details, most of which are yet to be worked out. Such details will vary with different types of soil; they will vary with the kind of enterprise followed—whether grain farming, livestock farming, or fruit farming; they will vary with different economic situations, such, for example, as affect the accessibility and the cost of different forms of fertilizing materials. And so, while we may consider that the great idea of a permanent system of agriculture and the fundamental principles for carrying it out are established, in reality the work on this problem is only well begun. The foundation is laid, so to speak, but the great superstructure is yet to be erected before Illinois agriculture as a whole shall be actually upon a permanent basis.

**Soil Investigations Involve Many Complications**

In our constant strife to reduce all problems to the simplest formula, we are often prone to disregard complicating elements and there is danger in becoming dogmatic in our statements. If the problems of soil management could all be reduced to a few simple formulas there would be no need of the years and years of patient study of conflicting results with which we often have to deal. It seems worth while to consider for a moment some of the difficulties peculiar to soil investigation which are sometimes not fully appreciated.

In the first place the soil is to be regarded as a dynamic, ever-changing, exceedingly complex substance made up of organic and inorganic materials and teeming with life in the form of microorganisms. Because of these characteristics, the soil cannot be considered as a reservoir into which a given quantity of an element or elements of plant food can be poured with the assurance that it will respond with a given increase in crop yield. Likewise it cannot be expected to respond with perfect uniformity to a given set of management standards. To be productive a soil must be in such condition physically with respect to structure and moisture as to encourage root development, and in such condition chemically that injurious substances are not present in harmful amounts, that a sufficient supply of the elements of plant food will become usable during the growing season, and that lime materials are present in sufficient abundance for the growth of the higher plants and of the beneficial microorganisms. Good soil management under humid
conditions involves the adoption of those methods of tillage, cropping, and fertilizer treatment which will result in profitable and permanent crop production on the soil type concerned.

In the interpretation of field results all these complexities related to the fundamental nature of the soil are involved. Added to these complexities are the inevitable soil variations which occur in many fields. One plot may not be just like another and thus the response to the experimental treatment may be misinterpreted. Again, the seasonal effect of one year upon a certain treatment may not be the same as that of another year. For example, on the old "continuous-corn" plot of the Morrow series at the University the yield in 1916 was 11.2 bushels an acre and the very next year it was 40 bushels. Thus long years of trials are often necessary before final conclusions are warranted.

**Changing Economic Conditions Call for Adjustments**

But these natural complications are not enough; added to them are those of man-made origin found in the ever-changing economic conditions by which market prices are affected. For example, many farmers, when corn sold at $1 and even $2 a bushel, enjoyed a substantial profit in the use of rock phosphate purchased at $6 or $8 a ton. But when the price of rock phosphate went up to $15 a ton and corn sold at 40 cents a bushel, it was a common observation that phosphate was not being extensively purchased. Thus from the standpoint of financial profits, a practice perfectly recommendable today as a paying proposition may become unprofitable tomorrow, according to market prices of farm products and fertilizing materials; and, vice versa, a practice which is unprofitable today may become profitable tomorrow.

**Not a Subject for Hasty Conclusions**

These are only a few suggestions of the various complications with which we have to deal in interpreting the results of field experiments and recommending practices deduced therefrom, but they will serve to bring out the point I wish to make. My purpose in bringing before you some of these problems, with their complexities, is not to discourage you in the prosecution of field experiments nor to shake your confidence in them, but rather to warn against hasty conclusions based upon scanty experience or superficial observation, and perhaps to explain the action of the investigator when he hesitates to answer with confidence and directness some of the numerous legitimate questions put to him.

**Experiment Fields Reveal Variety of Results**

In spite of these various difficulties, our experiment fields have furnished, and will continue to furnish as the years go by, much information that is reliable and indeed invaluable. May we now turn to some
typical results from several of these fields, which have a direct bearing upon our discussion of the Illinois system of permanent soil fertility.

For the purpose in hand I will attempt to show only a section of the plots from each of the fields considered; namely, (1) a check plot receiving no fertilizer treatment; (2) a so-called "residues" plot, where stalks and straw and also legume crops are plowed down to furnish organic matter and nitrogen; (3) a plot to which, in addition to the residues treatment, limestone is applied; (4) a plot which receives residues, limestone, and phosphorus; and finally, (5) a plot receiving residues, limestone, phosphorus, and potassium.

These fields are all under a systematic program of crop rotation, the one most frequently used consisting of wheat, corn, oats, and legumes. For the purpose of making the following comparisons we have represented the values of the crops produced on an annual acre basis, and have assumed values corresponding to the average market price on December 1 for the past ten years, as follows:

- Corn ........... $ .78
- Barley ........... $ .80
- Oats .............. .48
- Rye .............. 1.10
- Wheat ........... 1.45
- Hay .............. 16.03

The principal point that I should like to bring out in this connection is that these fields show very different responses to different treatments.

Some Soils Show Special Response to the Application of Organic Matter

Let us first consider a group of fields that are especially responsive to the "residues" treatment, which supplies organic matter and nitrogen.

The Hartsburg field exhibits such a response (Fig. 2). With no soil treatment, the average annual value of the crops harvested is $33.11 an
acre, but under the residues system the value rises to $38.44. The data show no benefit of consequence for limestone, and rock phosphate in addition to limestone has not given sufficient increase to cover its cost. The addition of potassium shows negative results.

This striking effect of the simple addition of organic matter is found also in the results from the Minonk, Rockford, Union Grove, and other fields.

On Many Soils Limestone is the Foremost Requirement

Let us now turn to southern Illinois, where limestone is the foremost requirement. For a typical illustration, one that does not represent an extreme case, we may consider the results from the field at Oblong, in Crawford county. The use of limestone on this field has almost doubled the returns. Phosphate applied in addition to residues and limestone has increased it to some extent, and potassium has raised this increase a limited amount (Fig. 3). If time permitted, similar results might be shown from Newton, Ewing, Odin, Toledo, and other fields, where limestone is the key to productivity.

In this connection might be mentioned also the striking response where limestone has been applied on our sandy fields. At Oquawka, near the Mississippi river in Henderson county, where the land is almost barren sand, we have a crop value of $9.19 on the residues plot; but on the adjacent plot, where limestone has been added, the value rises to $23.35. (Fig. 4). The short-time experiments on the Palestine field, representing sandy land in the region of the Wabash river, exhibit a similar tendency.
Considering briefly the effect of limestone on land lying outside the very acid region of southern Illinois, we find at Mt. Morris a crop increase resulting from limestone treatment amounting to $6.49 an acre. In like manner very marked results have been produced from limestone used on the Carlinville, Carthage, and Urbana fields. On most of the fields, in fact, there has been some benefit from limestone, altho there are a few instances of an actual loss on the limestone plots, as found on the Hartsburg, Minonk, and Rockford fields.

**Phosphorus Hunger Strikingly Illustrated on Some Fields**

Speaking next of the fields where the soil has responded to phosphorus in a striking manner, may be mentioned the Joliet field, where the phosphorus plot shows an average annual increase in the value of crop yields amounting to $8.60 an acre, thus yielding a handsome profit with rock phosphate at its highest cost (Fig. 5). Other fields especially responsive to phosphorus treatment are those at Galesburg and Sidell, where rock phosphate has been applied; at Bloomington and Antioch, where bone meal has been the source of phosphorus; and at Urbana, where both of these phosphorus carriers have been used.

On the other hand, the fields at Lebanon, Minonk, Pana, and Oquawka have each returned a gross profit from phosphorus, applied in rock phosphate in the residues system, of less than a dollar an acre yearly. Between these extremes we have all gradations of economic profit or loss from phosphorus treatment.
Benefit from Potassium Salts Limited to a Few Areas

Potassium is an element required by peat soil, but we have found that the addition of potassium salts has produced a beneficial effect on certain fields not located on peat. Thus a marked result has been produced on the Odin field by the use of potassium sulfate (Fig. 6), and plots at Ewing as well as at Union Grove show considerable benefit from this material. The use of kainit has given good results at Ewing. Most of the fields, however, have not responded in a profitable way to the application of potassium.
Some Fields Exhibit No Conspicuous Contrasts

These few examples are sufficient to illustrate the statement made above that soils are unlike in their response to fertilizer treatment. The fields from which the foregoing results are presented have been selected in such manner as to bring out sharp distinctions. Such conspicuous contrasts, however, do not always occur. Another group of fields might be shown in which no certain treatment stands out in particular, but instead the results grade in step-like fashion from one plot to another. Obviously, a combination of factors is often more effective in increasing yields than a single factor.

“The Illinois System” a Philosophy of Soil Treatment—Not a Formula

Among the various ideas concerning the Illinois system of soil fertility, one of the prevalent notions is that the system prescribes the application to the soil of certain specific materials, and that the omission of, or substitution for, any of these materials represents a violation of the system.

It has been my purpose, in presenting these few typical cases of results from our field experiments, to illustrate the fact that soils differ tremendously in their response to various treatments, and therefore the building up of soil cannot be reduced to a single method of procedure. The deduction is that a system of soil fertility must be comprehensive and deal with fundamental principles. A workable system cannot be tied to a single formula nor to a single method of procedure. In the speaker’s opinion the Illinois system of permanent soil fertility is intended to be such a comprehensive system. Indeed, if it serves its purpose it must be a philosophy of soil fertility rather than a dogmatic formula of procedure.

With such complex problems to deal with it is inevitable that progress is slow, and it is also probable that occasionally mistakes will be made. In working with these problems a large stock of patience is required, and, above all, an open-minded attitude must be maintained, even to the extent of sometimes changing an opinion. We should maintain the spirit of our great teacher, Dr. Hopkins, who in the closing words of his address delivered to the Illinois Farmers’ Institute on the occasion of its 1916 annual convention, said: “We must always be open-minded and ready to change our opinion tomorrow, if justified by additional investigation with accumulated, trustworthy data.”