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## THE ILLINOIS SYSTEM OF PERMANENT FERTILITY[1]

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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 great influence upon the adoption of systems of permanent fertility.

It is more than fifty years since Liebig wrote the following words:

> "Agriculture is, of all industrial pursuits, the richest in facts, and the poorest in their comprehension. Facts are like grains of sand which are moved by the wind, but principles are these same grains cemented into rocks."

An important part of the work performed in Illinois has consisted in assembling the facts the world affords and cementing these into concrete forms that serve as a firm foundation upon which to build systems of permanent agriculture.

[1] Address before the Illinois State Farmers' Institute at Sterling, February 19, 1913.

The main problem of permanent fertility is simple. It consists, in a word, in making sure that every essential element of plant food is continuously provided to meet the needs of maximum crops; and of course any elements which are not so provided by nature must be provided by man. The whole subject has been greatly and unnecessarily complicated, not only by erroneous theories commonly held by farmers and sometimes advocated by falsely so-called scientists holding official positions, such as the theory that crop rotation will maintain the fertility of the soil, but also by the ruinous policy of most commercial fertilizer interests in urging and often persuading farmers to use small amounts of high-priced so-called "complete" fertilizers, which add to the soil only a fraction of the plant food actually required by the crops removed, with the inevitable result that the land itself is steadily impoverished.

The more rational system makes use of abundant quantities of all essentials but at a cost low enough to be within reasonable reach. Those materials which are naturally contained in the soil in inexhaustible amounts are liberated from the soil and thus made available for crop production; those contained in the air are likewise drawn upon as needed; while those materials which must be purchased are bought and applied in liberal quantities, but in low-priced forms, and then made available on the farm by economic natural methods.

## Four Fundamental Facts

Nearly 150 years ago Sénébier of Switzerland found that the carbon of plants is derived from the carbon dioxid of the air, and it is more than a century since DeSaussure of France first gave to the world a correct and almost complete statement concerning the essential mineral food of plants. Later, Lawes and Gilbert of England established the fact that for most plants the soil must furnish the nitrogen as well as the mineral elements; and more than a quarter-century has passed since Hellriegel of Germany discovered that bacteria living in symbiotic relationship with legume plants have power to gather nitrogen from the inexhaustible atmospheric supply.

These are the four great fundamental facts upon which the science of plant growth and permanent fertility must be based, and they were all discovered before the Illinois Experiment Station was established.

## Illinois Contributions

There remained, however, two very important general problems, and in the solution of these Illinois has made some contributions. One of these relates to the amount of nitrogen taken from the air by legumes under normal field conditions; and the other concerns the liberation of mineral plant food from insoluble materials.

It is not enough to know that clover has power to secure nitrogen from the air; we should know how much nitrogen is thus secured in order that we may plan intelligently to provide nitrogen for the production of corn, oats, wheat, and other nonlegumes, instead of using clover merely as a soil stimulant in systems of ultimate land ruin, as is still the most common practice.

It is also a matter of the greatest economic importance that definite information should be secured in regard to the practical means of utilizing mineral plant food from the abundant natural supplies nearest at hand, such as Tennessee phosphate rock, Illinois limestone, and the potassium minerals already present in our normal soils.

## Plant-food Elements

In brief, there are ten elementary substances that bear the same relation to the making of crops as brick and mortar bear to a wall of masonry. If any one of these ten elements is entirely lacking, it is impossible to produce a grain of corn or wheat, a spear of grass, or a leaf of clover.

Two elements, carbon and oxygen, are taken into the plant from the air thru the leaves; hydrogen is secured from water absorbed by the roots; and iron and sulfur are also supplied by nature in abundance. But the other five elements require careful consideration if lands are to be kept fertile. These are potassium magnesium, calcium, phosphorus, and nitrogen; and every landowner ought to be as well acquainted with these five elements as he is with his five nearest neighbors.

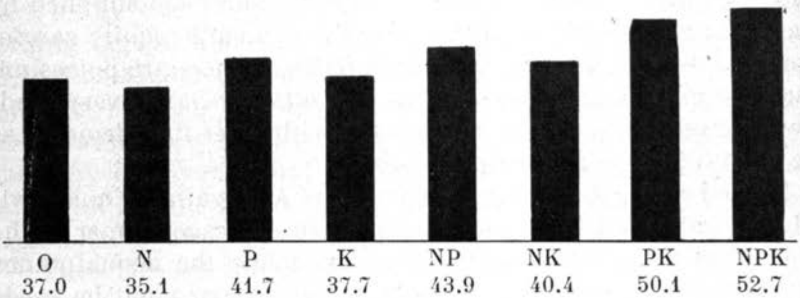
Instead of making this acquaintance and gaining a knowledge of important facts and principles, the average farmer in the older states, with failing fertility, has made the acquaintance of the fertilizer agent; and instead of purchasing what he needs for the permanent improvement of his soil, he buys what the agent wants to sell, with the common result that the seller is enriched while the soil is merely stimulated to greater poverty.

*Potassium.*—A careful study of the facts shows that potassium is one of the abundant elements in nature; that the average crust of the earth contains 2½ percent of this element; and that normal soils bear some relation in composition to the average of the earth's crust.

If normal soil had the same percentage, then the plowed soil of an acre 6⅔ inches deep (corresponding to 2 million pounds of soil) would contain 50,000 pounds of potassium. In Illinois, the normal soils actually do contain from 25,000 to 45,000 pounds per acre of this plant-food element in the first 6⅔ inches, while less than 4 pounds of potassium would be added in an application of 200 pounds of the most common commercial fertilizer. The Illinois system of permanent fertility does not provide for the purchase of potassium for normal soils, but it does provide for the liberation of an abundance of that element from the practically inexhaustible supply in the soil. This liberation is accomplished by the action of decaying organic matter plowed under in the form of farm manure or crop residues, including clover or other legumes.

Only where the soil is positively deficient in potassium susceptible of liberation, as is the case with some sand soils and with most peaty swamp lands, need potassium be purchased in permanent systems of either grain farming or live-stock farming; but in market gardening, or in raising timothy hay for the market, commercial potassium may be required, and, on some worn soils especially deficient in decaying organic matter, the temporary use of kainit is often advisable.

*Magnesium and Calcium.*—As a general average, the normal




Bloomington Experiment Field, 1902: Corn, Bushels

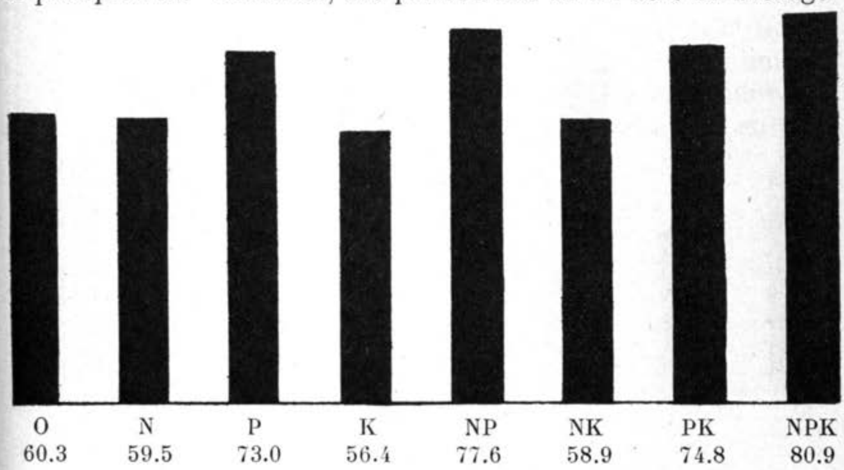
soils of Illinois contain more than four times as much potassium as magnesium, while the loss by leaching and cropping in rational systems of grain or live-stock farming may be actually greater for magnesium than for potassium, so that magnesium is more likely to become deficient in soils than is potassium.

The calcium supply in normal soils is also only one-fourth that of potassium, while the average loss by cropping and leaching is four times as great, so that 16 to 1 expresses the relative importance of calcium and potassium in the problem of permanent fertility on normal Illinois soils.

All limestones contain calcium; and the common dolomitic limestone in the almost measureless deposits of northern Illinois contains both calcium and magnesium in very suitable form both for plant food and for correcting or preventing soil acidity.

In the Illinois system of permanent fertility, ground natural limestone is applied, where needed, at the rate of about 2 tons per acre every four years. With the same price and purity, probably the dolomite is preferable to the high calcium stone of southern Illinois, altho both kinds have been used with very good results. Further data from investigations now in progress are expected to furnish definite information as to the relative value of these materials.

*Phosphorus.*—Attention was called to the fact that 2 million pounds of the average crust of the earth contains 50,000 pounds of potassium; but compared with this we find only 2,000 pounds of phosphorus. Likewise, the plowed soil of an acre of average



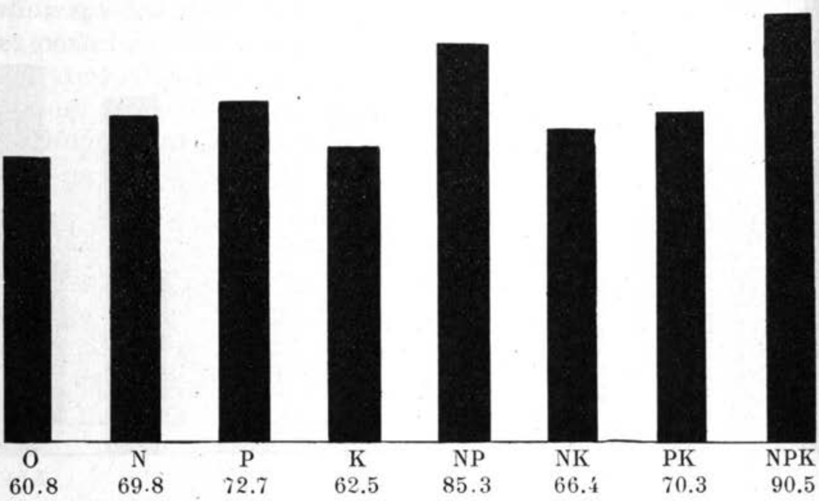

BLOOMINGTON EXPERIMENT FIELD, 1903: CORN, BUSHELS

Illinois land contains about 35,000 pounds of potassium but less than 1,200 pounds of phosphorus. When grain is sold from the farm, about equal amounts of phosphorus and potassium are carried away, while in independent systems of live-stock farming much more phosphorus than potassium leaves the farm.

With phosphorus at 3 cents a pound, one can double the amount of that element contained in the plowed soil of our $200-land at a cost of $35 an acre, while to double the potassium in the same stratum would cost more than $1000 an acre.

Phosphorus can be purchased delivered at the farmer's railroad station in Illinois, for about 3 cents a pound in the form of fine-ground natural rock phosphate, for 10 to 12 cents a pound in steamed bone meal, or for 12 to 15 cents in acid phosphate. It can be used with profit in any of these forms, but the data thus far secured in comparative experiments plainly indicate that, with equal amounts of money invested, the natural rock phosphate will give the greatest profit in rational permanent systems. At least 1,000 pounds per acre every four years should be applied, and for the first application even 3 or 4 tons per acre is not considered too much phosphate by those who best understand the the need and value of phosphorus on normal Illinois land.

*Nitrogen and Organic Matter.*—There is a rather common opinion that the growing of clover enriches the soil in nitrogen, and many people even believe that clover in crop rotation will

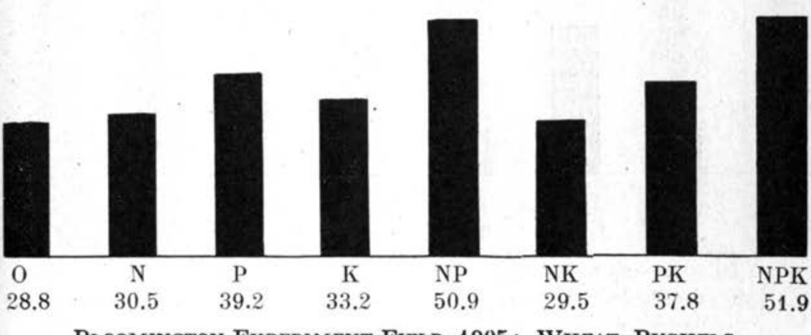



Bloomington Experiment Field, 1904: Oats, Bushels maintain the fertility of the soil. These same people are likely to think that the application of limestone and phosphate involves much expense and work, and that the returns are much less certain than those from other labor and money investments.

Such opinions are largely erroneous. The mere growing of clover on normal land does not enrich it. Even the nitrogen is not increased unless the clover crop is returned to the soil either directly or in farm manure. Rotation with such crops as corn, oats, and clover depletes the soil of all important elements of fertility, and on normal soils always results ultimately in land ruin unless some system of restoration is practiced. Clover takes large amounts of calcium and phosphorus from the soil, and does not increase the nitrogen content if only the roots and stubble are left because they contain no more nitrogen than the clover itself will take from soils of normal productive power.

To increase or maintain the nitrogen and organic matter of the soil is the greatest practical problem in American agriculture. In an hour's time one can spread enough limestone or phosphate on an acre of land to provide for large crops of wheat, corn, oats, and clover for ten or twenty years, while to supply the nitrogen for the same length of time would require from 20 to 40 tons of clover or from 80 to 160 tons of farm manure to be added to the same acre of land even tho one of the four crops harvested secured its nitrogen from the air.

Certainly we are making no such additions to the soil in average Illinois agriculture, and one may well ask, How then is it possible to grow the crops now produced in this state? In the simplest language the answer to this question is: By "skinning" the soil,— by working the land for all that's in it,— by following the example of our ancestors, who brought agricultural ruin to




Bloomington Experiment Field, 1905: Wheat, Bushels millions of acres of once fertile farm land in the original thirteen states.

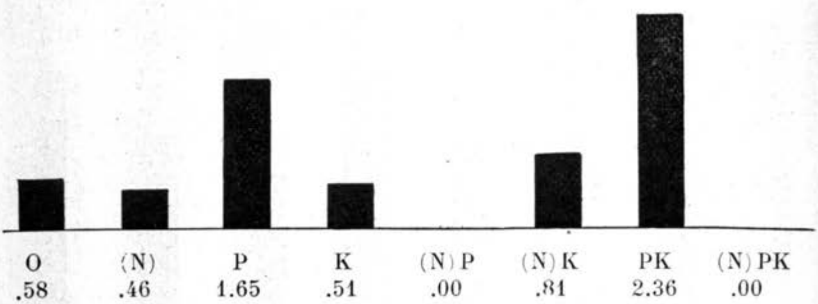
To provide nitrogen in the Illinois system of permanent agriculture requires the use of common sense and positive knowledge, the same as in providing limestone and phosphorus.

For the live-stock farmer I would suggest a five-field system, —a four-year rotation of corn, corn, oats, and clover grown upon four fields for five years, while the fifth field is kept in alfalfa. At the end of the fifth year the alfalfa field is brought into the rotation and one of the other four fields seeded to alfalfa for another five-year period, and so on.

If the crop yields are 50 bushels each of corn and oats, 2 tons of clover, and 3 tons of alfalfa; if the straw and half the corn stalks are used for bedding and all other produce for feed, and if 60 percent of the nitrogen in the manure is used for the production of crops; then a system is provided which will permanently maintain the supply of nitrogen.

For the farmer who sells grain and hay, a 25-bushel wheat crop may well be substituted for the first corn crop, clover being seeded on the wheat for plowing under the next year before planting corn. If the fall and spring growths of this clover aggregate 1½ tons, and if only the grain and clover seed and the alfalfa hay are sold, all clover, stalks, and straw being returned to the land, this also provides a system for the permanent maintenance of nitrogen.

If the crop yields are all increased by 50 percent, or even by 100 percent, these systems still provide for the nitrogen supply, unless with the larger yields on richer land a somewhat greater




Bloomington Experiment Field, 1906: Clover, Tons
"(N)" *means nitrogen applied for previous crops.* (Where the wheat "lodged" in 1905, the clover was smothered.)

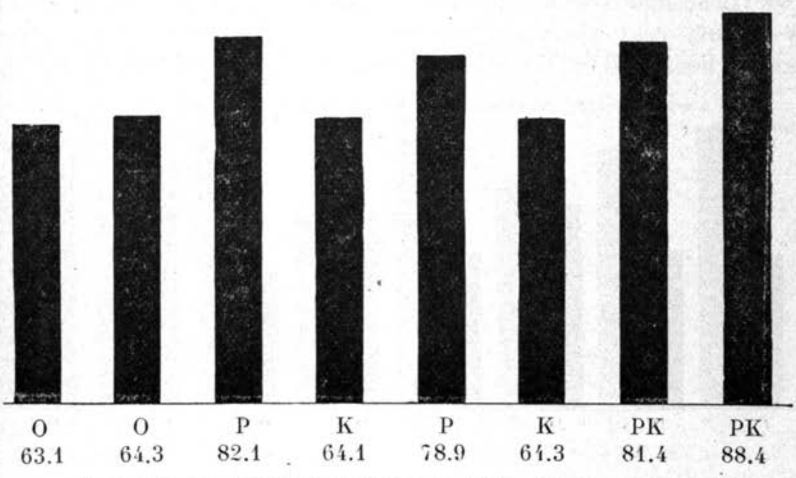
amount is likely to be lost by leaching than is added in the rain and by the azotobacter and other non-symbiotic bacteria.

While these systems are distinctly for live-stock farming or for grain and hay farming, they should be considered as only suggesting the basis for solving the nitrogen problem. In diversified farming a combination of these systems will often be preferred to either one alone. The important point is that the landowner should know the essential facts and base his practice upon them in order to provide for permanent fertility with respect to the three elements nitrogen, phosphorus, and limestone.

## Application of Principles Established

From the definite information already secured in the investigation of Illinois soils, including the general soil survey of the entire state and the detailed survey of more than forty counties, it is safe to say that at least two-thirds, and probably three-fourths, of all the cultivated soils of Illinois are already in need of phosphorus and organic manures, and most of this vast area is also deficient in limestone.

The facts thus far presented are derived chiefly from the investigations relating to the formation of soils, the requirements of crops, and the composition and possible supply of natural fertilizing materials, such as limestones, phosphates, and organic




Bloomington Experiment Field, 1907: Corn, Bushels

manures, including animal excrements, legume crops, and crop residues. I wish now to cite some typical illustrations giving the proofs or results from the actual application of these principles in the production of field crops in the most rational and trustworthy field investigations in the world's record of agricultural science.

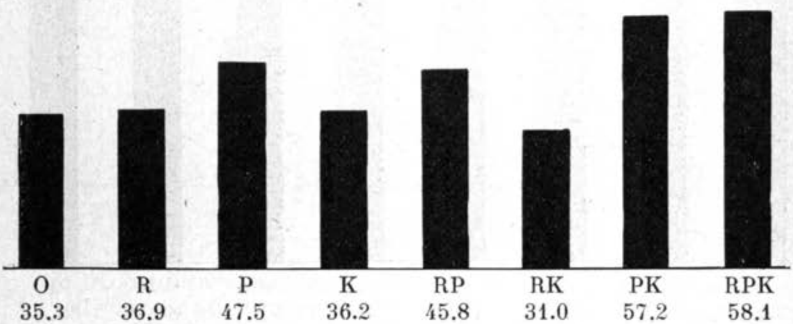
*Rothamsted Experiments.*— At Rothamsted, England, a four-year rotation of turnips, barley, clover, and wheat has been practiced for sixty-four years. In order to reduce the results to the simplest terms, I have computed the value of the four crops at conservative prices[1] for Illinois farm conditions.

On the unfertilized land, the value per acre of the four crops amounted to $74.84 for the years 1848 to 1851, and to $28.50 for 1908 to 1911, sixty years later. Bear in mind that these data represent no mere opinion or theory: they represent the facts from the first and last four-year periods in sixty-four years of farming on normal soil where the crops were rotated, where clover was grown (with beans substituted whenever clover failed), and where half of the turnips were fed on the land, thus supplying a limited amount of farm manure. This soil was also abundantly supplied with limestone.

On another part of the same field, the treatment of which differed from the unfertilized part only by the addition of mineral plant food, the crop values were $74.57 for the years 1848 to 1851, and $77.57 for 1908 to 1911.

These are indeed remarkable facts, but they are supported by twenty-year averages, the average values of the four crops having been $70.06 for the first twenty years and $76.83 for the

[1] $1.40 a ton for turnips, 50 cents a bushel for barley, $6 a ton for hay, and 70 cents a bushel for wheat.



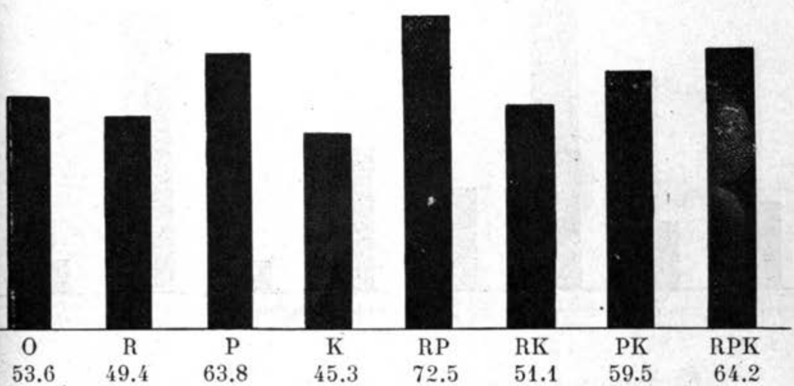

BLOOMINGTON EXPERIMENT FIELD, 1908: CORN, BUSHELS

third twenty-year period, where mineral plant food was applied. Barley, which is grown three years after clover, is the only one of the four crops to show actual decrease in yield, and the increase of clover and of the crops which follow soon after the clover is still more than sufficient to counterbalance the decrease in barley. Of course this system is perfect and permanent, so far as clover is concerned, because the clover bacteria have power to secure nitrogen from the air; while in the case of wheat and turnips, sufficient nitrogen to maintain the yields has been provided thus far by some growth of clover not harvested for hay, the leguminous weeds which grow in both barley and wheat, the manure from the turnips, and the depletion of the soil's supply.

Where additional supplies of nitrogen were provided together with the mineral plant food, the crop values per acre were $77.21 for the years 1848 to 1851, and $93.79 for 1908 to 1911. Thus the crop values from the best fertilized land have been more than three times as great as those from the unfertilized land during the last rotation of this sixty-four-year period.

*Louisiana Experiments.*—The longest record of a rational permanent system of agriculture conducted in America is furnished by the Louisiana Experiment Station. As an average of nineteen years, the values per acre of three crops were $29.79 from unfertilized land, and $92.04 where organic manures and phosphorus were regularly applied[1] in a three-year rotation of (1) cotton, (2) corn and cowpeas, (3) oats and cowpeas. Here

[1] In addition, 5 pounds per acre of potassium were applied every three years.

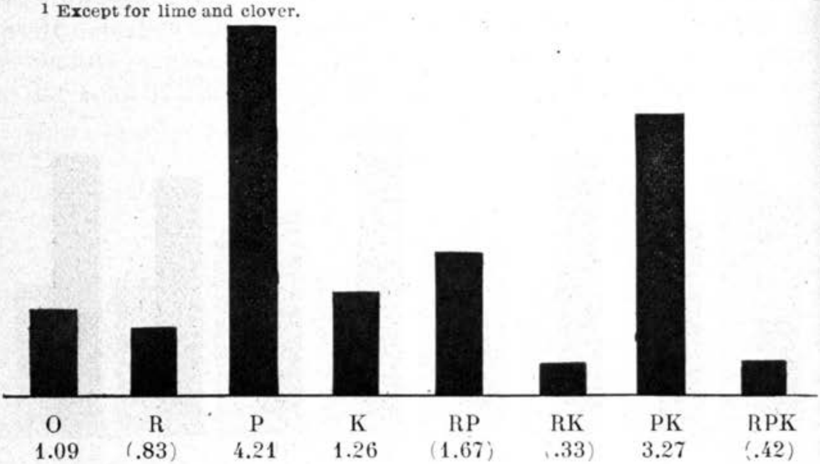



BLOOMINGTON EXPERIMENT FIELD, 1909: OATS, BUSHELS the crop values from the well-fertilized land average more than three times as great as those from the unfertilized land under the same rotation and with two legume cover crops grown every three years.

*Ohio Experiments.*—The Ohio Experiment Station has reported sixteen years' results from a three-year rotation of corn, wheat, and clover, both from unfertilized land and from land treated with farm manure and phosphorus. As a general average, the values per acre of the three crops at Illinois prices were $27.07 on untreated[1] land, $44.65 where farm manure was applied, $53.82 where manure and rock phosphate were used, and $53.61 where manure and acid phosphate were applied, practically the same yields having been secured whether the phosphorus was applied in raw rock phosphate or in acid phosphate, costing twice as much. The well-fertilized land has produced nearly twice as much as the land where no manure and phosphate were used, altho clover was grown every third year in the rotation and all the land was limed.

On the basis of these figures, 8 tons of manure were worth $17.58, or $2.20 per ton; and the rock phosphate, costing about $7.50 or $8 per ton, was worth $57.31; or, if we use the Ohio methods of computing the amount and value of the increase produced, each ton of raw phosphate was worth $65.63; and it may well be added that to obtain the same amount of phosphorus in the

[1] Except for lime and clover.

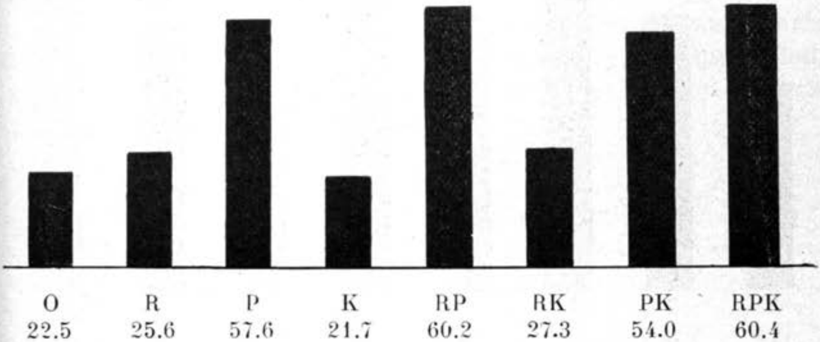



BLOOMINGTON EXPERIMENT FIELD, 1910: CLOVER, TONS OF HAY (OR BUSHELS OF SEED) common high-priced mixed manufactured commercial fertilizer, such as farmers are advised by the fertilizer manufacturers and advertising agencies to use, would cost about $75.

*Illinois Experiments.*—At the last annual meeting of the Illinois Farmers' Institute at Centralia, I presented the averages from many of the Illinois soil experiments, especially the results from our southern Illinois experiment fields, where limestone is the material of first importance in the beginning of systems of permanent soil improvement; and I also reported the average results from the oldest experiments in the state where raw rock phosphate has been used.[1] These results show, for example, that as an average of 318 tests conducted in southern Illinois during a period of eight years, two tons of ground limestone, applied once in four years at a cost of about $2.50 per acre, has produced an increase of 5 bushels of corn, 6½ bushels of oats, 4 bushels of wheat, and ½ ton of hay. They also show that where one ton per acre of fine-ground rock phosphate was applied on the common corn-belt land on the University farm at Urbana in a rotation of wheat, corn, oats, and clover, the value of the increase produced paid back more than 100 percent for the first crop rotation and nearly 200 percent for the second four-year period, and in addition to this the soil has grown 25 percent richer in phosphorus, while the untreated land has grown poorer.

Two years ago I gave a summarized report of all the Illinois soil investigations that have been conducted since this organization secured from the Illinois legislature the first appropriation to the state experiment station for this work. Thus the general plans and progress of the Illinois soil investigations, and many

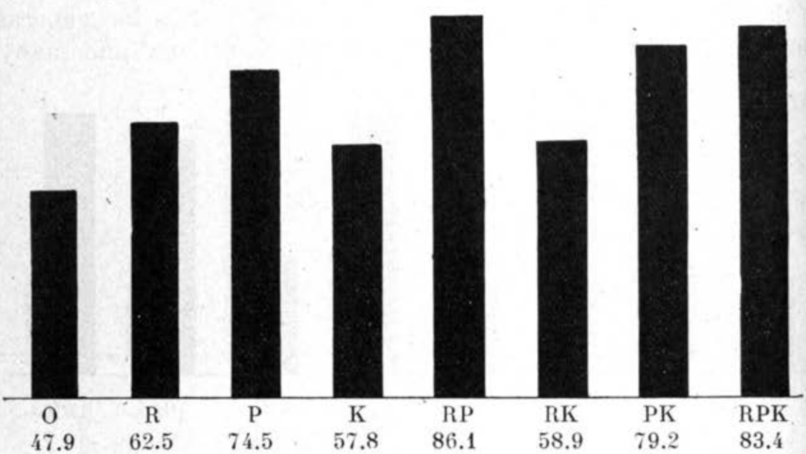
[1] See Circular 157.




BLOOMINGTON EXPERIMENT FIELD, 1911: WHEAT, BUSHELS of the details, are already contained in your annual reports, and more complete data are easily available in the bulletins and soil reports from the Illinois Experiment Station. (See also Circulars 110, 127, and 165).

In closing this paper I shall direct your special attention only to the detailed data and illustrations from one of our oldest experiment fields on the typical prairie soil of the corn belt, where phosphorus is usually the element of first importance in the beginning of soil improvement, especially where clover and manure have been used in the past in a way to maintain in the soil a fair supply of decaying organic matter. It should be stated, however, that on some farms on the same type of soil, where corn has been grown almost continuously for many years, with perhaps an occasional crop of oats and with little or no use of clover or manure (not even by pasturing), the active organic matter may already be so reduced as to be the first factor which limits the crop yields. Under such conditions clover is the only crop which phosphorus is likely to benefit.

This soil experiment field was established near Bloomington, McLean county, in the fall of 1901, soon after the first state appropriation for soil investigations became available; and the results presented are from eight contiguous and very uniform plots of ground. A five-year rotation is practiced, including two crops of corn and one each of oats, clover, and wheat. All these plots received one small uniform application of lime at the beginning of the experiment, so that the treatment of the plots has differed




BLOOMINGTON EXPERIMENT FIELD, 1912: CORN, BUSHELS

only as indicated in the foregoing diagrams, with the exception that during the first four years, commercial nitrogen ("N") was applied to the four plots which have subsequently received nitrogen additions only in crop residues, as indicated by "R" in the diagrams. Phosphorus is indicated by "P"; and its total cost in steamed bone meal is indicated by that part of the last diagram (see page 20) which stands above the four short cross marks. Potassium is represented by "K"; and its cost was the same as the cost of phosphorus.

In computing the values shown in the diagram on page 20, corn is figured at 35 cents per bushel, oats at 30 cents, wheat at 70 cents, hay at $6 per ton, and clover seed at $6 per bushel. These are very conservative prices, but they are probably as high as it is safe to use for the value of the increase from the soil treatment, because of the additional expense for harvesting, shocking, stacking, threshing, husking, and marketing. Computation will show that during the last four years the value of the produce from the land receiving phosphorus has been twice as much as that from the untreated land. In other words, $2.50 invested in phosphorus has brought the same gross income as $250 invested in land; and even the interest on the land investment is five times the annual cost of the phosphorus. Furthermore, the addition of phosphorus tends toward enrichment and consequently toward the protection of the capital invested in the land. Another very important point is that up to the time of harvest, practically no extra work is required to produce the increase from phosphorus.

The effect of the crop residues ("R") in 1911 and 1912 indicates that the value of clover plowed under may ultimately reappear in subsequent grain crops.

Finally, the fact should be emphasized that ordinary farming is not a very profitable business financially, but that intelligent permanent soil improvement is both the safest and the most profitable investment that farmers can make.

# NOTES

## Natural Rock Phosphate

Fine-ground raw rock phosphate, containing from 10 to 14 percent of phosphorus, can be obtained from the following companies, delivered in bulk on board cars at the mines in Tennessee for \$2.50 to \$5.00 per ton, the price varying with the quality. The freight rate from Tennessee per ton of 2000 pounds in carload lots varies from \$2.50 to points in southern Illinois, to \$3.58 to northern Illinois points. Of course, these addresses are given solely as a matter of information, and the Experiment Station makes no recommendations or guarantees as to reliability.

Mt. Pleasant Fertilizer Co., Mt. Pleasant, Tenn.
Robin Jones Phosphate Co., Nashville, Tenn.
Natural Phosphate Co., Nashville, Tenn.
Farmers Ground Rock Phosphate Co., Mt. Pleasant, Tenn.
Ruhm Phosphate Mining Co., Mt. Pleasant, Tenn.
Blue Grass Phosphate Co., Mt. Pleasant, Tenn.
Southern Lime & Phosphate Co., Birmingham, Ala.
Federal Chemical Co., Columbia, Tenn.
Central Phosphate Co., Mt. Pleasant, Tenn.
Central Kentucky Phosphate Co., Wallace, Ky.
American Fertilizer Co., Santa Fé, Tenn.

It should be borne in mind that rock phosphate varies much in quality. Consequently, it should always be purchased upon a guaranteed analysis, and it is advisable for the purchaser to take an average sample of the carload when received and have it analyzed both for phosphorus and for fineness, even tho the analysis cost him \$2 or \$3. To collect an average sample, take a small teaspoonful from about fifty different places in the car, not only from the surface but also from different depths. These fifty spoonfuls well mixed together will make a trustworthy sample, and about one pound of this should be sent to some commercial chemist for analysis.

If 12½-percent rock, containing 250 pounds of phosphorus per ton, costs \$7.50 (including freight), then 10-percent rock, containing 200 pounds of the element per ton, is worth \$6, a difference in value of \$1.50 per ton, which, on a 30-ton car, amounts to \$45.

The important phosphorus compound in rock phosphate is calcium phosphate, $Ca_3(PO_4)_2$. The percentage of this compound in the rock phosphate marks the purity of the rock. Thus, if the rock phosphate contains 60 percent of calcium phosphate, it is 60 percent pure, with 40 percent of impurities.

Sometimes the guarantee is given as "phosphoric acid," meaning phosphoric oxid, $P_2O_5$. This also is a definite compound and always contains 43⅔ percent of the element phosphorus. Thus it will be seen that the same sample of rock phosphate may be guaranteed to contain 62 percent of calcium phosphate, $Ca_3(PO_4)_2$, or 28.4 percent of "phosphoric acid" ($P_2O_5$), or 12.4 percent of phosphorus (P).

Raw rock phosphate should be very finely ground, so that at least 90 percent of the material can be washed thru a sieve with 100 meshes to the linear inch, or with 10,000 meshes to the square inch. Of course anyone can test for fineness by sifting ten ounces and then drying and weighing what will not wash thru the sieve.

As a rule, it is more satisfactory to purchase in bulk rather than in bags (see page 15 of Circular 110).

## Bone Meal

A good grade of steamed bone meal (about 12½ percent phosphorus) can be obtained delivered in Illinois for about $25 a ton, from the local agents of Morris & Co., Swift & Co., Armour & Co., the American Glue Co., or the American Fertilizer Co., Chicago, Ill., or from the Empire Carbon Works, National Stock Yards, East St. Louis, Ill.

### Potassium Salts

Potassium chlorid (so-called "muriate of potash"), containing about 42 percent of potassium, can be obtained for about $45 a ton from Armour & Co., Swift & Co., or Darling & Co., Union Stock Yards, Chicago, Ill., from the German Kali Works or the Nitrate Agencies Co., Chicago, Ill., from A. Smith & Bro., Tampico, Ill., or from the American Agricultural Chemical Co., New York, N. Y.; and kainit, containing about 10 percent of potassium, together with some magnesium sulfate, magnesium chlorid, and sodium chlorid, can also be obtained from Armour & Co., Darling & Co., Swift & Co., Hirsch, Stein & Co., the Chicago Fertilizer Works, or the German Kali Works, Chicago, Ill., for about $13 a ton.

### Ground Limestone

Ground limestone can now be obtained at 60 cents a ton ($1 in bags, to be returned at purchaser's expense and risk) from the Southern Illinois Penitentiary, Menard, Ill., and at different prices from the following companies.

Casper Stolle Quarry & Contracting Co., East St. Louis, Ill. (Quarry at Stolle, Ill.)
Southwestern Contracting & Engineering Co., East St. Louis, Ill.
Ellis Bros., Elsberry, Mo.
Carthage Superior Limestone Co., Carthage, Mo.
Mitchell Lime Co., Mitchell, Ind.
John Armstrong Lime & Quarry Co., Alton, Ill.
Lehigh Stone Co., Kankakee, Ill.
Elmhurst-Chicago Stone Co., Elmhurst, Ill.
East St. Louis Stone Co., East St. Louis, Ill.
Columbia Quarry Co., St. Louis, Mo. (Quarry at Columbia, Ill.)
McLaughlin-Mateer Co., Kankakee, Ill.
Lockyer Quarry Co., Alton, Ill.
Western Whiting & Mfg. Co., Elsah, Ill.
Eldred Stone Co., Eldred, Ill.
Marblehead Lime Co., Masonic Temple, Chicago, Ill. (Quarries at Quincy, Ill.)
United States Crushed Stone Co., 108 S. LaSalle St., Chicago, Ill.
Dolese & Shepard Co., 108 S. LaSalle St., Chicago, Ill.
Fruitgrowers Refrigerating & Power Co., Anna, Ill.
Biggsville Crushed Stone Co., Biggsville, Ill.
Hart & Page, Rockford, Ill.
McManus & Tucker, Keokuk, Iowa.
Moline Stone Co., Moline, Ill.
John Markman, Gladstone, Ill.
Superior Stone Co., 218 Hearst Bldg., Chicago, Ill.
Brownell Improvement Co., 1220 Chamber of Commerce, Chicago, Ill.
Dolese Bros. Co., 10 S. LaSalle St., Chicago, Ill.
Ohio & Indiana Stone Co., Indianapolis, Ind. (Quarry at Greencastle, Ind.)
C. F. Gill & Co., 6709 Lakewood Av., Chicago, Ill. (Quarry at Joliet, Ill.)

Some of these companies furnish fine-ground limestone and some furnish limestone screenings, which include both very fine dust and some coarse particles even as large as corn kernels. In carload lots the price on board cars at the plant varies from 50 cents to $1 a ton according to fineness. The freight charges are one-half cent per ton per mile, with a minimum charge of 25 cents per ton by each railroad handling the car, and with a minimum carload of 30 tons. At most points in Illinois the cost delivered in bulk in box cars should be between $1 and $2 a ton. Sometimes one can get one and one-half tons of material containing one ton of fine dust and half a ton of coarser particles, varying in size from less than pinheads to corn kernels, at no greater expense than would be required for one ton of fine-ground stone containing no coarser particles. The coarser particles will last in the soil longer than the finer material, which is rapidly lost by leaching, and a product that will all pass thru a sieve with 8 or 10 meshes to the linear inch, and that contains all the fine dust produced in the process of crushing or grinding is very satisfactory.

### Machines for Grinding Limestone

Portable machines for crushing and grinding limestone, using threshing engines for power, can be obtained from—

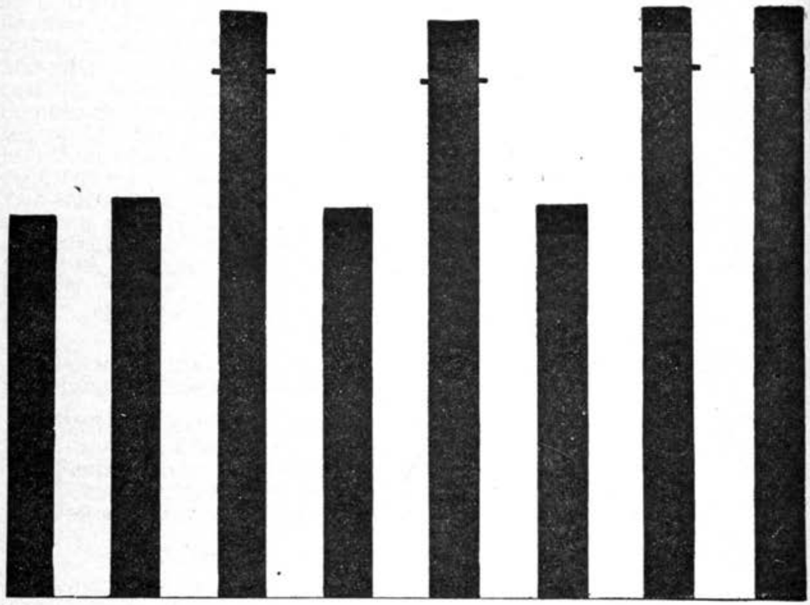
Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.
Universal Crusher Co., Cedar Rapids, Iowa.
Pennsylvania Crusher Co., Pittsburgh, Pa.
Wheeling Mold & Foundry Co., Wheeling, W. Va.
Jeffrey Manufacturing Co., Columbus, Ohio.

### Machine for Spreading Limestone and Phosphate

Directions for making a machine for spreading ground limestone and ground rock phosphate are given in Circular 110, which will be sent to anyone upon request. This is a homemade machine, using the wheels of an old mower, and it can be made by any good blacksmith or carpenter.

There is no regular manufactured machine on the market that has given as satisfactory service in our experience as these homemade machines. They are made upon order by many blacksmiths in different parts of the state, and the following business houses usually keep machines in stock for sale:

George Kubacki, DuBois, Ill.
Pana Enterprise Manufacturing Co., Pana, Ill.



O $165.52 R $173.17 P $255.44 K $169.66 RP $251.43 RK $170.57 PK $256.92 RPK $254.76

BLOOMINGTON EXPERIMENT FIELD: CROP VALUES FOR ELEVEN YEARS

"R" means residues of crops (corn stalks, straw, and clover) plowed under to maintain nitrogen and organic matter.

"P" means phosphorus, the cost of which is represented by that part of the diagram above the short cross marks. It has paid back $3 for each dollar invested.

"K" means potassium, which has paid back 6 cents for each dollar spent for it.