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## CIRCULAR NO. 123

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# PHOSPHATE AND LIMESTONE FOR KENTUCKY SOILS.

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By

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## Phosphate and Limestone for Kentucky Soils.

By S. C. JONES and R. E. STEPHENSON

Practically all soils in the state outside the thirty-five counties constituting the Bluegrass region are acid and are naturally deficient in phosphorus. More than half of the soils within the Bluegrass region respond profitably to phosphate treatment. Perhaps more than half of the Bluegrass soils would respond to limestone treatment when legumes, especially sweet clover and alfalfa, are grown.

On all the outlying experiment fields in the state, including the Lincoln Ridge experiment field, which is in western Shelby County on the edge of the Bluegrass region, phosphate, when properly used, has given highly profitable results.

The tables in this circular give the increases produced by phosphates and limestone and the average yields of the check plots; that is, those not treated with phosphate or limestone but otherwise managed in the same way. A four-year rotation of corn, soybeans, wheat and clover is used in most cases, with a rye cover crop between the corn and soybeans. Acid phosphate has been used at the rate of 800 pounds, rock phosphate at the rate of 1600 pounds, and limestone at the rate of 2 tons per acre per rotation, during the first two rounds of the rotation in the four-year rotations. After the first two rounds, limestone has been or will be left off for a time, perhaps two or three rounds of the rotation, and the applications of acid and rock phosphate will have been reduced at the same time to one-half of the previous applications. Bone meal and basic slag, where used, have supplied the same amount of phosphorus as in the acid phosphate applications with which they are compared.

In computing the value of crops, corn was priced at 50c per bushel, wheat at $1.00 per bushel, and hay from soybeans and clover at 50c per hundred. The acid phosphate was priced at $20.00 per ton, or $8.00 per acre for the 800 pounds; the rock phosphate at $10.00 per ton, or $8.00 per acre for the 1600 pounds, and the limestone at $2.50 per ton, or $5.00 per acre for the two tons per rotation.

For each treatment reported, the total value of the crop increases is given, the value of the increase less the cost of the treatment, and the net return per dollar invested. (By net return is meant the return per dollar invested after deducting the cost of the treatment.) Net returns are based upon the above prices of crops and fertilizers, and will vary with varying prices. No charge is made for labor in applying limestone and phosphate, but neither is any value assigned to the increase in the straw and stover. The cost of one should about offset the value of the other.

Beginning in 1916, manure was used at the rate of 6 tons per acre on the check plots and on the plots treated with limestone, phosphate and the combination of limestone and phosphate, on the Mayfield, Lone Oak, Russellville and Greenville Experiment fields. The manure was applied on the plots that were planted to corn.

This rate of application was continued on these fields for one round of the rotation, the manure being applied on the corn plots. Since then, manure has been applied on the Russellville and Mayfield fields at the rate of one ton of manure for each ton of produce (except the wheat grain) removed, except in 1920 when manure was left off of the Mayfield field, but that year the residues—cornstalks and wheat straw—were returned. After using manure one round of the rotation, it has been left off at Greenville and at Lone Oak, but the cornstalks and the wheat straw have been returned.

Six corn crops, five soybean crops, four wheat crops and three clover crops of the number reported in the averages have been affected by manure or crop residues. The increases shown

for limestone and phosphate are in addition to any increases produced by manure and residues.

The use of manure in the same way was begun on the Berea field in 1917.

No manure has been used on the Fariston field, but the ground on which corn has been planted has been plowed up the previous year as soon as the clover crop was harvested and has been planted to soybeans which have been turned under and followed by a rye cover crop which has been turned under the following spring.

The following abbreviations and symbols are used in the tables of results:

L = ground limestone; AP = acid phosphate; RP = rock phosphate; Inc. = increase.

## PURCHASE REGION SOILS

### Mayfield and Lone Oak Experiment Fields

Mayfield and Lone Oak (McCracken County) experiment fields represent the predominating upland soils of the Purchase region. Of the 2300 square miles comprising this area, approximately two-thirds is upland.

### RESULTS FROM MAYFIELD EXPERIMENT FIELD

Average Crop Increases Per Acre

| Treatment | Corn, bus., ave. 8 years. | Soybean hay, lbs., ave., 6 years. | Wheat, bus., ave., 7 yrs. | Clover hay, lbs., ave. 6 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 5.1 | 709 | 2.6 | 1707 | $17.22 | $12.22 | $2.44 |
| AP | 0.6 | 51 | 1.9 | 58 | 2.74 | —5.26 | Loss |
| RP | 3.4 | 392 | 2.1 | 706 | 9.29 | 1.29 | .16 |
| LAP | 12.1 | 1141 | 7.2 | 2739 | 32.65 | 19.65 | 1.51 |
| LRP | 12.0 | 1071 | 8.8 | 2664 | 33.47 | 20.47 | 1.56 |
| Ave. yield of check plots | 29.1 | 2049 | 8.1 | 806 | | | |

**RESULTS FROM LONE OAK EXPERIMENT FIELD**

**Average Crop Increases Per Acre**

| Treatment | Corn, bus., ave. 9 years. | Soybean hay, lbs., ave. 7 years. | Wheat bus., ave. 8 years. | Clover hay, lbs., ave. 6 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 4.3 | 205 | 0.0 | 831 | $7.32 | $2.32 | $0.46 |
| AP | 0.4 | 124 | 0.2 | 130 | 1.67 | —6.33 | Loss |
| RP | 0.6 | 87 | 1.7 | 607 | 5.47 | —2.53 | Loss |
| LRP | 4.5 | 733 | 6.8 | 1859 | 22.01 | 9.01 | 0.69 |
| LAP | 7.4 | 815 | 5.4 | 1472 | 20.54 | 7.54 | 0.58 |
| Ave. yield of check plots | 33.5 | 2642 | 11.3 | 1770 | | | |

At present prices for both crops and fertilizers, acid phosphate, when used alone on the four-year rotation, has been used at a loss on both the Mayfield and Lone Oak fields, while limestone alone has produced large increases at Mayfield and fair increases at Lone Oak.

On these fields, both acid phosphate and rock phosphate, when used with limestone, have produced large increases in yields, especially on the Mayfield field. The yield of corn has been increased practically one-third, that of soybean hay and wheat has been doubled and that of clover hay more than trebled.

At Mayfield, in a tobacco-wheat-clover rotation, acid phosphate has produced an increase of 152 pounds of tobacco, 6.9 bushels of wheat and 694 pounds of clover, a net return at present prices for these products of more than $4.00 for each dollar invested. On the other hand, a combination of limestone and acid phosphate has given an increase of 388 pounds of tobacco, 15 bushels of wheat and 2939 pounds of clover hay per acre, or more than $4.00 for each dollar invested in limestone and acid phosphate. This does not take into consideration the value of the residue of limestone and phosphate left in the soil, which will be effective for some time to come. It is very ap-


Fig. 1. Wheat on Mayfield Experiment Field. Unfertilized plot 3.8 bu. per acre; plot treated with limestone and acid phosphate 29.3 bu. per acre.

parent that limestone and phosphate should be used together on soils represented by these fields.

## WESTERN AND EASTERN COAL FIELDS SOILS

### Greenville and Fariston Experiment Fields

The Western Coal Field comprises 4500 square miles of territory, while the Eastern Coal Field comprises approximately 10,000 square miles.

The Greenville experiment field represents the upland soils of the Western Coal Field and the Fariston field (Laurel County) represents the soils of the Eastern Coal Field and especially the western half of the Eastern Coal Field. Altho the soils of the eastern half are decidedly richer in mineral elements than those of the western half, no doubt the results from the Fariston field will apply to the entire Eastern Coal Field.

Both acid phosphate and rock phosphate, when used alone on the Greenville field, in the four-year rotation, have produced very marked crop increases; in fact, the yields of corn, soybean hay and wheat have been increased more than one-fourth and the yields of clover hay have been more than doubled. However, of the two, rock phosphate has produced decidedly the larger increases.

**RESULTS FROM GREENVILLE EXPERIMENT FIELD**

**Average Crop Increases Per Acre**

| Treatment | Corn, bus., ave. 6 years. | Soybean hay, lbs., ave. 6 years. | Wheat, bus., ave. 6 yrs. | Clover hay, lbs., ave. 6 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 3.4 | 654 | 1.6 | 623 | $9.68 | $4.68 | $0.93 |
| AP | 7.4 | 736 | 3.3 | 1002 | 15.69 | 7.69 | 0.96 |
| RP | 7.6 | 1021 | 4.6 | 1315 | 20.08 | 12.08 | 1.51 |
| LAP | 15.7 | 1976 | 7.9 | 1869 | 34.97 | 21.97 | 1.69 |
| LRP | 13.3 | 1358 | 5.0 | 1408 | 25.48 | 12.48 | 0.96 |
| Ave. yield of check plots | 28.1 | 1768 | 6.3 | 758 | | | |

**RESULTS FROM FARISTON EXPERIMENT FIELD**

**Average Crop Increases Per Acre.**

| Treatment | Corn, bus., ave. 6 years. | Soybean hay, lbs., ave. 6 years. | Wheat, bus., ave. 3 years. | Clover hay, lbs., ave. 4 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 4.8 | 244 | 0.7 | 286 | $5.75 | $0.75 | $0.15 |
| AP | 19.6 | 677 | 4.3 | 663 | 20.80 | 12.80 | 1.60 |
| RP | 19.4 | 1112 | 3.0 | 494 | 20.98 | 12.78 | 1.60 |
| LAP | 31.6 | 2006 | 7.7 | 1638 | 41.57 | 28.57 | 2.20 |
| LRP | 14.3 | 987 | 2.8 | 743 | 18.60 | 5.60 | 0.43 |
| Bone Meal | 19.4 | 1007 | 6.8 | 505 | 24.05 | 16.05 | 2.00 |
| Ave. yield of check plots | 11.6 | 1165 | 3.2 | 134 | | | |

At Fariston, acid phosphate and rock phosphate, when all crops are considered, have considerably more than doubled the crop yields. However, bone meal has given slightly better results than either acid phosphate or rock phosphate. At present prices of both crops and fertilizers, either of the phosphates has

returned practically $3.00 for each dollar invested. It should be noted that on this field neither phosphate alone nor limestone alone has produced much clover. On both these fields limestone and acid phosphate have produced much greater increases than limestone and rock phosphate. At Greenville, limestone and acid phosphate have produced more than fifty per cent increase for corn and decidedly more than doubled the yield of soybean hay, wheat and clover hay. While the returns per dollar invested have not been quite so good as for rock phosphate alone, yet the returns per acre have been practically twice as great. This should be the basis for determining the treatment to be used. The use of limestone and acid phosphate on the Fariston field practically has trebled the yield of corn, doubled the yield of wheat and increased the yield of clover hay more than tenfold. However, the increase for limestone and rock phosphate on this field has fallen below that of rock phosphate alone. In fact, limestone when used with rock phosphate has barely paid its cost at Greenville, and has been used at a considerable loss at Fariston when compared with rock phosphate alone.

**RESULTS FROM THE THREE-YEAR ROTATION AT GREENVILLE**

**Average Crop Yields Per Acre**

| Treatment | Tobacco, lbs., ave. 7 years. | Wheat, bus., ave. 5 years. | Clover hay, lbs., ave. 7 years. | Value of inc. for 3 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|
| LAP | 1003 | 20.4 | 3560 | | | |
| 0 | 424 | 6.7 | 727 | | | |
| Increase | 579 | 13.7 | 2833 | $114.17* | $103.17 | $9.38 |

*Tobacco valued at 15c per pound.

At Greenville, in a three-year rotation of tobacco, wheat and clover, limestone and acid phosphate have more than doubled the yield of tobacco, trebled the yield of wheat, and quardrupled

Fig. 2. Clover on Greenville Experiment Field. Unfertilized plot 590 lbs. per acre; plot treated with limestone and acid phosphate 5360 lbs. per acre.

the yield of clover hay. In fact, the money invested in limestone and acid phosphate in this rotation, at present prices for these crops, has returned more than $9.00 net, for each dollar invested.

## THE ST. LOUIS LIMESTONE SOILS

### Russellville Experiment Field

The Russellville experiment field represents some 5000 square miles of territory in southern and western Kentucky whose soils have been derived from the St. Louis limestone.

It will be seen from a study of the table above that both acid phosphate and rock phosphate, when used alone in the four-year rotation on the Russellville field, have produced substantial increases on all crops. However, rock phosphate has made decidedly the better showing, due primarily to the effectiveness of the rock phosphate in increasing clover yields.

The reverse is true when the results from limestone and acid phosphate are compared with those from limestone and rock phosphate, the acid phosphate and limestone producing much the larger increases. The net return per dollar invested is practically the same from rock phosphate alone and limestone

## RESULTS FROM RUSSELLVILLE EXPERIMENT FIELD

### Average Crop Increases Per Acre

| Treatment | Corn, bus., ave. 8 years. | Soybean hay, lbs., ave. 8 years. | Wheat, bus., ave. 7 years. | Clover hay, lbs., ave. 7 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 5.2 | 595 | —0.2 | 1108 | $10.91 | $5.91 | $1.18 |
| AP | 5.6 | 454 | 3.2 | 721 | 11.87 | 3.87 | 0.48 |
| RP | 4.3 | 438 | 4.6 | 1213 | 15.01 | 7.01 | 0.88 |
| LAP | 8.2 | 638 | 7.5 | 1952 | 24.55 | 11.55 | 0.89 |
| LRP | 5.6 | 590 | 5.0 | 1855 | 20.03 | 7.03 | 0.54 |
| Ave. yield of check plots | 34.9 | 1979 | 12.1 | 1578 | | | |

and acid phosphate, but the returns per acre are much greater from limestone and acid phosphate combined.

Limestone used alone has been highly profitable, but when used with rock phosphate, it has barely paid its way when compared with the use of rock phosphate alone.

## FLAT LANDS BORDERING ON THE BLUEGRASS REGION

### The Berea Experiment Field*

The Berea experiment field represents thousands of acres of low, flat, poorly drained land adjacent to the knobs, extending in a large crescent from Vanceburg on the Ohio River around the border of the Bluegrass region, back to the Ohio River at Louisville.

In the four-year rotation on the Berea field both acid phosphate and rock phosphate have given fair increases on all crops. Limestone alone has given good increases, but the big increases have been obtained from both limestone and acid phosphate, and limestone and rock phosphate, the former combination, however, giving the larger increases when all crops are considered.

This soil was so poorly drained that clover and winter grain generally were "heaved out" during the winter. A tile drainage system was laid in the spring of 1917. Since then clover

## RESULTS FROM BEREA EXPERIMENT FIELD

### Average Crop Increases Per Acre

| Treatment | Corn, bus., ave. 9 years. | Soybean hay, lbs., ave. 8 years. | Wheat, bus., ave. 3 years. | Clover hay, lbs., ave. 4 years. | Value of inc. for 4 crops. | Value of inc. less cost of treatment. | Net return per dollar invested. |
|---|---|---|---|---|---|---|---|
| L | 8.4 | 620 | 5.7 | 382 | $14.91 | $9.91 | $1.98 |
| AP | 6.9 | 706 | 2.6 | 303 | 11.14 | 3.14 | 0.39 |
| R P | 5.8 | 556 | 2.3 | 261 | 9.28 | 1.28 | 0.16 |
| LAP | 13.8 | 1490 | 8.6 | 1909 | 32.50 | 19.50 | 1.50 |
| LRP | 15.0 | 1463 | 5.8 | 1797 | 29.60 | 16.60 | 1.28 |
| Ave. yield of check p- | 29.2 | 2634 | 5.2 | 285 | | | |

*The Berea experiment field is conducted in cooperation with Berea College on land belonging to the College.

has been grown. Wheat does not seem to be adapted to this soil and it will be dropped from the rotation and rye will be substituted for it. In farm practis, the rye could be pastured.

## WAVERLY LIMESTONE AND FREESTONE SOILS

### Results from the Campbellsville Experiment Field

Work on the Campbellsville field, in Taylor County, was begun in 1920. Results obtained on this field are applicable to the freestone and limestone soils bordering on the Bluegrass region. These soils comprise an area of about 4500 square miles.

The rotation used is corn, wheat and clover. Two corn crops, one wheat crop and one clover crop have been grown. Both acid phosphate and rock phosphate have given good results when used without limestone. Rock phosphate alone has given better results than acid phosphate alone.

It is interesting to note that rock phosphate alone has given 3 bushels of corn, 1.1 bushels of wheat and 1760 pounds of clover greater increases than rock phosphate used with limestone. Limestone and acid phosphate have given no greater increases of clover than rock phosphate alone. Limestone and acid phosphate have given profitable increases, however.

## MORE PHOSPHATE IS APPLIED THAN CROPS USE

Limestone and fertilizers in the amounts noted have been applied once each four years on the corn ground, but their effect is not exhausted completely in that time. In fact quite a large residue of the applications remains in the soil at the end of the rotation. When crop residues (straw, stalks, etc.) or manure are returned, quite an appreciable portion of the phosphorus used in the growing crops gets back to the soil.

Calculation of the phosphorus required for average yields produced shows that about two-thirds of the phosphorus applied in acid phosphate is used each rotation by the crops grown. This gives in round numbers 20 pounds of phosphorus in excess of the requirement, which is the equivalent of about 300 pounds of 16 per cent acid phosphate. With the application halved there would be still enough phosphorus to supply three-fourths of the total requirements and more than enough to supply the actual crop increase. If, then, three-fourths of the phosphorus used by the crops produced is turned back to the soil in the form of manure, phosphorus is being supplied in amounts approximately one and one-third times as great as taken out by crops, and a reserve is being stored up in the soil which will help to improve the soil each rotation, provided the proper use is made of legumes, manure and crop residues.

In the case of rock phosphate, four times as much phosphorus is applied to the soil in 1600 pounds of raw rock as in 800 pounds of acid phosphate. An excess of approximately 185 pounds of phosphorus is applied each rotation, or more than six times the actual crop demands. This reserve is equal to about 1400 pounds of average rock phosphate. With the application halved there would be still more than three times the amount of phosphorus required by the rotation. Add to this the phosphorus turned back to the soil in manure (approximately three-fourths of the amount used by the crops) and it is easy to see that the soil is being built up rapidly in phosphorus content. Applications at the smaller rate should double the phosphorus content of this soil in ten to fifteen years. When only residues instead of manure are returned, phosphorus does not accumulate

in the soil so rapidly because about three-fourths of the phosphorus used by crops is removed in the grain.

Thru the action of weathering agencies in the soil, the phosphorus in rock phosphate will gradually become available. Very little phosphorus is lost from the soil by leaching; much may be lost if the soil is allowed to wash. The soil should be occupied by crops all the time to prevent washing.

## POOR SOILS NEED ORGANIC MATTER

A few soils of the state are so poorly supplied with nitrogen and organic matter that phosphates give little return when used on grains or grasses. On these soils, if limestone is used, legumes will respond to phosphate because they can take their nitrogen from the air. By growing legumes to plow under, any soil may be built up to a state of fertility such that phosphates can be used profitably on the non-leguminous crops.

## SOURCES OF PHOSPHORUS

The common sources of phosphorus are acid phosphate, basic slag, bone meal and ground rock phosphate. The form of phosphate to use depends both upon the cost of the phosphate and upon the returns it will give.

Rock phosphate is by far the cheapest source of phosphorus, but acid phosphate is much more commonly used. The studies made on the Kentucky soil experiment fields have been made principally with these two forms of phosphorus.

Acid phosphate is made by treating a given weight of rock phosphate with an equal weight of sulfuric acid to change the phosphate of the rock into a more soluble form of higher availability to crops. A ton of raw rock phosphate of the grade generally used contains, therefore, twice as much phosphorus (12 to 14 per cent of the element) as a ton of standard acid phosphate. The phosphorus of the raw rock will become available gradually, the only question being whether it will act rapidly enough to give profitable returns.

## GENERAL RECOMMENDATIONS

It will be seen from a study of the results on the various fields that a knowledge of the soils and the crop rotation practist,

as well as a knowledge of the system of farming in use, is necessary before recommendations can be made in regard to the use of fertilizer.

Acid phosphate alone has given satisfactory results on all the experiment fields except those of the Purchase region. Anywhere that phosphate fertilizer is needed, therefore, acid phosphate has proved a profitable source of phosphorus. Notwithstanding the results to the contrary on the experiment fields in the Purchase region, many farmers in Marshall, Carlisle, Graves and Fulton Counties of that section have found acid phosphate profitable. Lighter applications of phosphate have been made by the farmers than were used on the experiment fields, which may account for their more profitable results. When used with limestone, acid phosphate has been highly profitable on the soils of the Purchase region.

Most soils that give satisfactory results with acid phosphate will give satisfactory results from rock phosphate where no limestone is used. In most cases rock phosphate has been more profitable than acid phosphate on unlimed soil. When limestone is used with rock phosphate, on the other hand, satisfactory results have been obtained only on the Mayfield, Lone Oak and Berea experiment fields. On the other fields the use of limestone with rock phosphate renders the rock phosphate less satisfactory with each succeeding application of limestone.

No soil can be built up to a high state of productiveness by the use of limestone and phosphate alone. Legumes must be grown to supply the nitrogen and organic matter. The poorest soils need legumes most. To start a poor soil quickly one or two legume crops should be plowed under. On soils in a good state of fertility the legume may be grown as a part of the regular rotation, fed to live stock and the manure and residues carefully returned to the soil. For pasture lands, legumes should form a part of the pasture crop mixture. If much grain and tobacco is sold and little live stock is kept, it will be necessary to turn under legumes regularly to maintain the supply of nitrogen. For a fuller discussion of the nitrogen problem, see Bulletin No. 228, which will be sent on request.

## WHERE THE RESULTS ARE APPLICABLE

The results obtained on the Berea field will apply to the knob regions of Bath, Bullitt, Estill, Fleming, Garrard, Jefferson, Lewis, Madison, Marion, Nelson, Oldham and Powell counties.

Those of the Russellville field will apply to the limestone region of southwestern Kentucky, which includes parts of Adair, Allen, Barren, Breckenridge, Bullitt, Caldwell, Casey, Christian, Clinton, Crittenden, Cumberland, Edmonson, Grayson, Green, Hardin, Hart, Larue, Livingston, Logan, Lyon, Meade, Metcalfe, Monroe, Pulaski, Rockcastle, Russell, Simpson, Taylor, Todd, Trigg, Warren, and Wayne counties.

Those of the Mayfield and Lone Oak fields will apply to the soils of Ballard, Calloway, Carlisle, Fulton, Graves, Hickman, Marshall and McCracken counties.

The results from the Greenville field will apply to the Western Coal Field which includes parts of Butler, Caldwell, Christian, Daviess, Edmonson, Grayson, Hancock, Henderson, Todd and Union counties and all of Hopkins, McLean, Muhlenberg, Ohio and Webster counties.

Those from the Fariston field will apply to the western part of the Eastern Coal Field and the worn lands of the eastern half of the Eastern Coal Field in the counties of Bell, Breathitt, Boyd, Carter, Clay, Elliott, Floyd, Greenup, Harlan, Jackson, Johnson, Knott, Knox, Laurel, Lawrence, Lee, Leslie, Letcher, McCreary, Magoffin, Martin, Menifee, Morgan, Owsley, Perry, Pike, Pulaski, Rockcastle, Rowan, Wayne, Whitley and Wolfe.

Those from the Campbellsville field will apply to the freestone and limestone soils of southern and eastern Kentucky, which includes parts of Adair, Allen, Barren, Boyle, Bullitt, Casey, Clinton, Cumberland, Estill, Green, Jefferson, Larue, Lewis, Lincoln, Madison, Marion, Menifee, Metcalfe, Monroe, Nelson, Powell, Pulaski, Rockcastle, Russell, Rowan, Taylor and Wayne.

## DIRECTIONS FOR THE USE OF PHOSPHATES

### Acid Phosphate

In farm practis probably the most economical way to use acid phosphate is to drill 300 to 400 pounds per acre when

wheat or other small grain is sown. This will be sufficient for the wheat and for the clover or grass crop which usually follows wheat. If this practis is followed regularly with each rotation and manure is used on the land on which tobacco or corn is grown following the clover and grass, it will not be necessary to use additional phosphate, provided the manure has been saved carefully, and as much as six to eight tons per acre has been used.

If it is desired to use acid phosphate in connection with manure for corn, tobacco, or other crops, it may be applied when the manure is being spread. When loading the spreader, place a layer of manure and sprinkle over it uniformly some acid phosphate. Two layers of manure and phosphate should give an even spread of the phosphate on the land. The amount of phosphate for each load of manure is determined by dividing the application of phosphate desired per acre by the number of loads of manure used per acre.

For inter-tilled crops, such as corn, tobacco and beans planted in rows, it is best to apply the acid phosphate broadcast, or drill it with the fertilizer attachment of a grain drill. Without doubt, it is more effective applied this way than in the row, for the feeding roots have a better opportunity to come in contact with the phosphate thruout the growing season. Broadcast applications should be made on the broken ground so that it may be thoroly distributed in the soil in the preparation of the seed bed. Where an application of as much as 600 pounds or more per acre is used, to last for a period of three or four years or more, the phosphate may be applied broadcast on the unbroken ground and disked in before breaking.

Only with very small amounts of acid phosphate, say 100 pounds per acre or less, would we recommend drilling in the row. But we do not believe it advisable to use such small applications.

Experiments on some of the Kentucky experiment fields indicate that it makes very little difference in yields whether large amounts of acid phosphate are applied at once for a rotation, or the same amount is divided into annual applications for

the same period of time. Very little phosphate is lost by leaching.

These directions will apply to the use of bone meal and basic slag.

When acid phosphate is to be used on land where lime is used, either the lime should be applied first and worked into the soil, or the lime and acid phosphate may be applied together, provided they are worked into the soil before it rains.

Where lime is badly needed and is difficult to obtain because of long haul or other reasons, it is suggested that 250 pounds of acid phosphate be mixed with 500 to 750 pounds of finely ground limestone, and that as large an application of the mixture as can be run thru the fertilizer attachment of the grain drill be applied when wheat or other small grain is sown. The materials should be applied *immediately,* preferably the day they are mixed. Experimental results indicate that this treatment will aid greatly in getting a crop of clover following the grain.

### Rock Phosphate

Rock phosphate should not be used in small annual applications. One thousand to 1500 pounds per acre, sufficient for three to five years, should be applied broadcast on the unbroken ground and should be disked in before breaking. It may be applied with a lime spreader, thru the fertilizer attachment of a grain drill, or when manure is being spread, in the manner already indicated for acid phosphate.

A good way to use rock phosphate is to apply it in the stalls as the manure accumulates, using 2 or 3 pounds per day for an animal weighing 1000 pounds. A pint of rock phosphate weighs about 1¼ pounds. It is doubtful if mixing with manure adds materially to the availability of the phosphate over what it would be were the phosphate and manure applied separately, but it is a saving of time to apply them together.

Contrary to much that has been written on the subject, it has been found on the Kentucky experiment fields that rock phosphate gives good results on thin land the first year before animal manure or green manure crops have been used. Of

course much larger yields will be obtained by the use of manures than without them.

When the price of acid phosphate is twice as much per ton as rock phosphate, or more, farmers well may consider the use of rock phosphate, altho it is more bulky and trublesome to handle. The excess of phosphorus that is stored in the soil by its use is an important consideration. After using rock phosphate two rotations at the rate above recommended, the amount may be reduced by half. Especially is this true where manure is being returned to the soil.