# Using Phosphate Fertilizers For Better Crops

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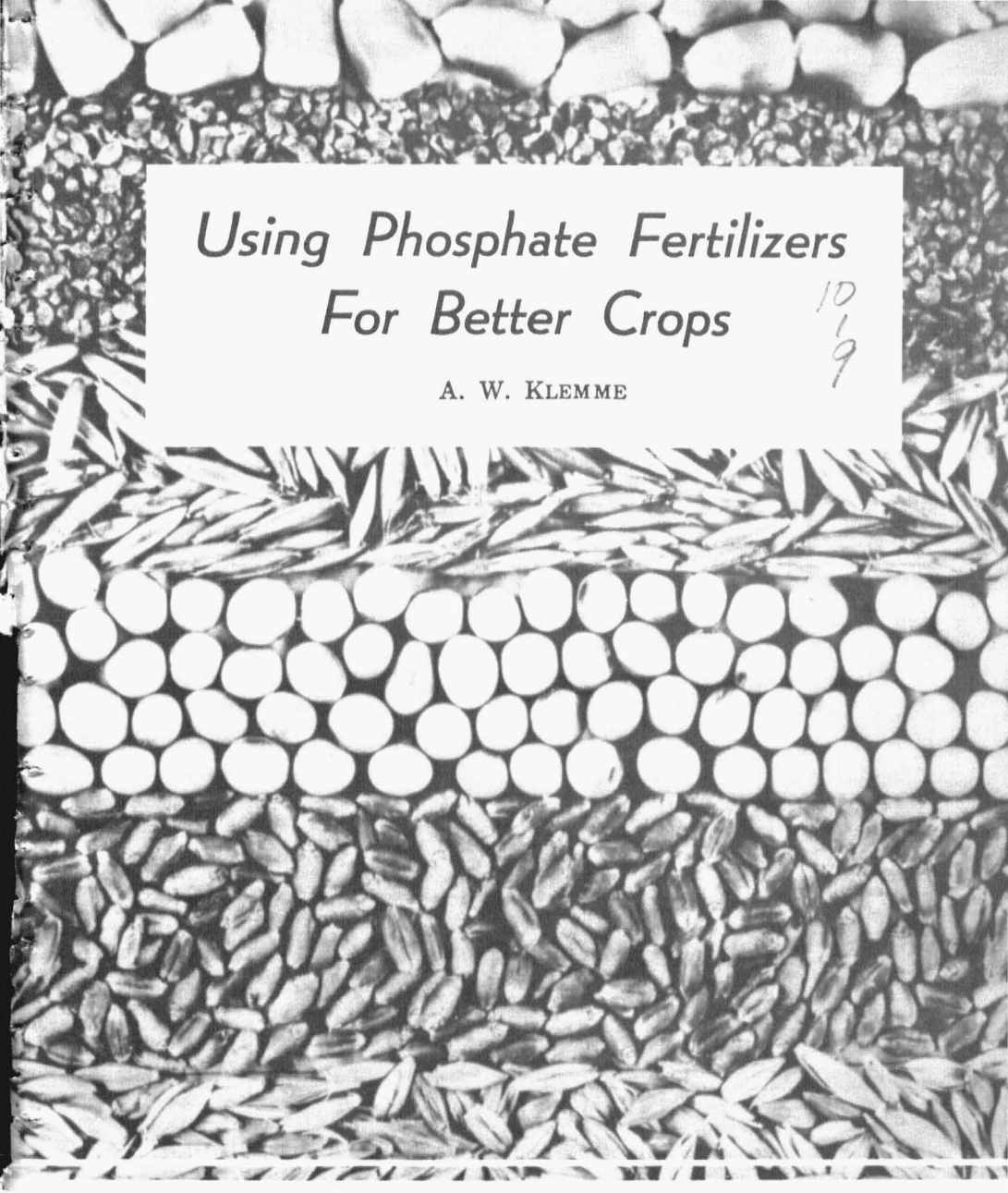
A. W. KLEMME



UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

Agricultural Experiment Station

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## FOREWORD

Gradually our farm folks are coming to realize that the major object of agriculture production is the provision of food. Food for lower life forms may be relatively simple. For plants it is as simple as limestone and other fertilizer. For the higher life forms, like man and the animals which he uses to assemble some of his food, this must be much more complex. Plants and animals are helps in putting together the elements and more simple compounds into those highly complicated ones required for him if he is to be healthy and survive. Our food is the result of the help of all the assembling and creative forces below us coming up from soil, to microbe, to plant, to animal and to man. If any one of these is not healthy and functioning fully, man at the top cannot be well fed nor healthy.

Phosphorus in the soil is one element at the starting point in the above assembly line of creating. Just what it does, how it serves, and other phases of its behavior are still not fully known. It serves in our getting energy from our foods. More pronounced is the influence on the final phases of reproduction like the size of the seed crop, or the fecundity, and the origin of the offspring—its effects are not spectacular in production of bulk but decisive in guarantee of survival.

Our soils as the foundation of reproduction must be built back. We must plow to put back fertility in the future rather than plow only to take it out as we have in the past. Phosphorus is one of the elements that must go back. There is no more favorable time to get back than now while supplies are self adequate. This circular is intended to bring about our fuller appreciation of the soil as a dwindling force in our assembly lines of agriculture production unless we provide the essentials that keep them going.

W. A. ALBRECHT, *Chairman*
Department of Soils

# Using Phosphate Fertilizers For Better Crops

A. W. KLEMME

Soil productivity is the power by which agriculture creates the materials for our food and clothing. Yet this creative power is not proof against depletion. It cannot renew itself while subjected to cultivation and the annual removal of its fertility in the form of crops, livestock and livestock products.

Having cleared the land, torn up its covering of sod, and subjected it to cropping and erosion, we must accept declining crop yields or renew the soil's productivity by adding fertilizers, along with animal manure and other organic matter.

In the fertilizers used for this purpose in Missouri, the element applied in greatest tonnage is phosphorus. And it is used mainly in the form of calcium phosphate.

## Importance of Phosphorus

Phosphorus is found in the living cells of all plants and animals. Seeds and legume crops are especially rich in this chemical. Along with calcium, phosphorus is the chief constituent of the skeleton of man and animal. It is essential for the synthesis of proteins. The soil needs enough phosphorus for rapid plant growth giving high yields of grain and seed. Phosphorus is needed for the production of nutritious forage and pasture crops.

Phosphorus exists in the soil in different combinations, namely; calcium and magnesium phosphates, iron and aluminum phosphate, within the rock from which the soil was formed, in organic matter, and in the clay complex itself. The amount of phosphate in the soil available to the plant at any given time is very small. As the plant uses this supply more becomes available. Unless the soil has ample phosphate in the less available forms, it cannot release enough to meet the full needs of the soil micro-organisms, which have first chance at it, and also of the growing crops. Without an adequate available supply, plant growth is slow, yields low and quality poor. Poor forage shows up through livestock troubles, such as lower reproduction rate, slower gains and less production in general.

Fig. 1.—The flow of life through plants, seeds and animals requires phosphorus.

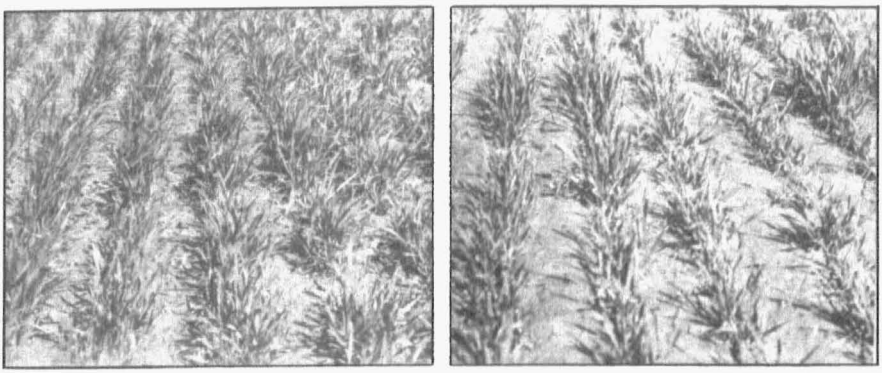
Many Missouri soils in their virgin state, though relatively low in total phosphorus, provided a sufficient amount of available phosphate for fair crop yields for some time. This was done by a more rapid release of phosphorus from the soil's accumulated organic matter. Long years of cropping with the sale of grain, livestock and livestock products have depleted the soil organic matter causing widespread phosphate deficiencies.

Even a livestock farming system depletes the phosphate in the soil. Each 1000 pounds of cattle raised and sold from the farm takes with it about 16 pounds of phosphate. Each 10,000 pounds of milk sold from feed raised on the farm takes a like amount. This is equivalent to the phosphate in an 80-pound bag of 20 per cent phosphate. Every ton of pork produced and sold from the farm takes about 7 pounds of phosphate or nearly one-half the plant food in an 80-pound bag of 20 per cent phosphate. Because of this constant removal, phosphate must be replaced on both crop and pasture lands.

**Some Factors Influencing the Availability of Phosphorus in the Soil**

There are numerous factors which influence the available phosphorus in the soil. On a strongly acid soil the phosphorus release to the plant is less than on soils only slightly acid or just under neutral in reaction. A poorly drained and thereby poorly aerated soil retards

the activity of soil micro-organisms which ordinarily help release the phosphorus from the soil organic matter. The use of limestone on calcium deficient soils not only reduces soil acidity and thus increases the availability of soil phosphates but also supplies calcium and magnesium which are thought to aid in mobilizing phosphorus into the plant. Increasing the turnover of organic matter in the soil improves aeration. It also increases decomposition thus making more phosphorus available to the plant. Drainage where needed acts similarly.



Phosphate at Seeding No Phosphate

Fig. 2.—Wheat like other plants needs phosphate for rapid growth.

## Why Phosphate Deficiencies Occur

Phosphorus deficiencies can be eliminated only through the application of phosphatic plant food materials. Because of phosphate depletion many Missouri soils low in organic matter need relatively heavy initial applications to supply phosphorus needed for abundant plant growth. Here this need is increased because our silt and clay loams are highly absorbent.

This absorbing characteristic of a soil is similar to that of a sponge. When moistened with only a small amount of water it is difficult to squeeze any water out. When moistened with much more, the water is brought out much more easily. A similar condition prevails with respect to applied phosphate. Small applications are absorbed so firmly by the soil that the plant can obtain only a relatively small part of the phosphate. Increased applications meets this absorbing capacity along with that used by soil micro-organisms and increase the phosphate available for the plants.

## Determining Phosphate Needs of the Soil

When vegetation of high feed value, like the clovers, no longer grows, and when that coming in naturally is not eaten by livestock, it may be that the crop is not synthesizing or compounding enough good food to tempt even a cow. This food compounding process by the plant is failing because the help from enough soil fertility is not coming to this "invading" crop. Such "symptoms" suggest that the soil should be tested for possible deficiencies in phosphorus and other nutrient elements which make the feeds more nutritious, at least, according to choice of the livestock.

The kind of vegetation which naturally grows in pastures and meadows is an indicator of the phosphate supply of the soil. For example, broom sedge (*Andropogon virginicus*) will make considerable growth of bulk, but this bulk is not eaten by the cattle. Chemical studies show that on soils very deficient in phosphorus, this plant may contain only 0.10 per cent phosphorus as compared to 0.25 per cent in clover. Likewise, tickle grass (*Aristida*) which will grow where red clover fails may contain only .07 per cent phosphorus when grown on phosphate deficient soils. Other crops and their low concentration of phosphorus might be added as additional testimony of low nutrient contents of crops on phosphorus deficient soils.

A chemical inventory of the soils of all the fields on the farm to find their phosphate levels will serve as a guide to find the amount needed to supply enough phosphorus for plant growth. Instructions for taking soil samples and obtaining soil tests for phosphate and other nutrient elements can be obtained from any county agent's office or by writing the College of Agriculture.

## Kinds of Phosphate Available

Several phosphate materials can be used to build back the phosphate reserves and to correct such soil deficiencies. A list of materials which can be used to supply phosphate are given in Table 1. As shown in this table, these materials include the regular processed phosphates, such as superphosphate, triple superphosphate, mixed fertilizers and rock phosphate.

Rock phosphate, in an unprocessed form also can be used for this purpose. Field experiments show that it serves especially well in crop rotations in a long time soil improvement program where clovers and alfalfa are grown and in meadows and pastures.

Activities of soil micro-organisms which live and work in conjunction with these legumes set free the organic acids formed in the decomposition of the residues of these crops. This apparently can change the rock phosphate to an available condition more readily than

TABLE 1--DIFFERENT PHOSPHATIC MATERIALS AND THEIR CONTENT OF PHOSPHORIC ACID.

| Phosphatic Materials | Total Phosphoric Acid - Per Cent | How Made |
|---|---|---|
| Superphosphate | 16-20 | Ground phosphate rock is treated with sulphuric acid. |
| Triple Superphosphate | 40-50 | Ground phosphate rock is treated with liquid phosphoric acid. |
| Calcium Metaphosphate | 63 | Phosphate rock is treated with hot gaseous phosphorus. |
| Calcined Phosphate | 34 | Finely ground phospate rock is heated with alkali salts. |
| Mixed Fertilizers containing phosphatic material including ammonium phosphate | 12-54 | Superphosphate or triple phosphate is mixed with nitrogen, ammonium and potash materials. |
| Basic Slag | 10-25 | A by-product from the manufacture of steel. |
| Bone Meals | 17-30 | Ground animal bones are boiled or steamed under pressure. |
| Rock Phosphate | 25-35 | Mined in Tennessee, Florida, Idaho, Montana, Wyoming with small amounts in other areas. |
| Colloidal Phosphate | 18-24 | Finely divided low grade rock phosphate mixed with clay is removed from the phosphate rock in washing. |

can organisms and organic acids developed where no legumes are grown. This change is brought about in the same manner as the slowly available natural phosphate reserves in the soil have been converted in the past to forms available to plants. Legumes, such as clover and alfalfa, can use the phosphorus in rock phosphate more readily than non-legumes hence as producers of organic matter they are also converters of rock phosphate to available phosphates. For this reason these crops should always be included in the cropping system or in pastures or meadows where rock phosphate is used.

**Shall Phosphates of Low or High Analyses be Used?**

Phosphates are purchased for the plant nutrient they contain. Phosphates with a high content require less labor on the part of the

farmer, dealer and manufacturer, to handle a given amount of phosphate than do low grade fertilizers. For example, a ton of 45 per cent phosphate will supply the same amount of phosphoric acid ($P_2O_5$) as 2¼ tons of 20 per cent phosphate. One ton of 30 per cent rock phosphate will supply as much plant nutrients as 1½ tons of 20 per cent phosphate. Because of the saving in freight, etc., the plant food in the high analyses material usually can be purchased at a lower cost per pound than plant food in the low analyses material.

Experiments conducted by the Department of Soils show that the response from the plant food in the highly concentrated phosphate fertilizer is equal, pound for pound, to that in those of lower concentrations. It is sometimes pointed out that the low grade phosphates contain more trace or minor plant foods than high grade phosphates that may be beneficial to crops. The fact is that the high grade phosphates usually have some of the same additional plant foods in smaller amounts. Should these additional plant foods be needed, neither the high nor low grade phosphates will likely contain enough. The trace or minor plant nutrients can be added more effectively to the high grade goods than provided wholly by using the low grade goods.

These conclusions are substantiated by results obtained in field tests with high and low grade processed phosphates on the University South Farms in a wheat-lespedeza rotation from 1939 to 1947. Some data are given in Table 2.

TABLE 2--WHEAT YIELDS FROM THE USE OF PHOSPHATES OF LOW AND HIGH ANALYSES.

| Kind and Amount of Phosphate Used | Average Yield of Wheat in Bushels Per Acre | |
|---|---|---|
| | No Lime | Limed - 3 tons per acre |
| No treatment | 20.6 | 21.3 |
| 150 lbs. 0-20-0 (low analyses) | 27.3 | 26.3 |
| 79 lbs. 38% double superphosphate (high analyses) | 26.3 | 28.0 |
| 66 lbs. 45% triple superphosphate (high analyses) | 26.0 | 26.5 |

## Amounts of Phosphates To Use

The amounts of the different phosphorus carriers suggested as initial applications on the soils of the different phosphate levels, and required to restore the phosphate reserves in the soil so as to eliminate the deficiencies of phosphorus are as follows:

TABLE 3--AMOUNTS OF PHOSPHATES TO USE FOR DIFFERENT LEVELS OF SOIL DEFICIENCY.

| Phosphate Levels (Shown by Soil Tests) | Phosphate Carriers Required (Pounds Per Acre) | | |
|---|---|---|---|
| | Superphosphate 20% $P_2O_5$ | Triple Superphosphate 40% $P_2O_5$ | Rock Phosphate 30% $P_2O_5$ |
| Very low to low | 600 - 900 | 300 - 450 | 1000 - 1500 |
| Medium | 300 - 450 | 150 - 300 | 500 - 600 |
| High | 150 - 200 | 75 - 150 | - - |

Heavy initial applications of phosphate may remove the phosphorus deficiency for 6 to 10 years. They will make certain for this period that phosphorus is not an element limiting plant growth. If, in addition, some small applications of mixed fertilizers are used as "starters" with plantings of corn, seedings of small grain and grass, a high phosphate level can be maintained and the beneficial effects of the initial applications made to last longer. In addition, the labor of making more frequent applications is reduced. The annual cost of application is therefore less than for the numerous smaller applications.

### Split Applications

When it is not possible to use the heavy initial applications—the so-called "split" applications of superphosphate or triple superphosphate may be made. For example, where the soil test indicates that 800 pounds of superphosphate or 450 pounds of 40 per cent phosphate are needed, half this application may be made initially. Then by repeating this application once per round in the rotation, the phosphate levels can be built up and lack of phosphorus removed as a limiting factor to crop yields and crop quality. When phosphate is used in this manner best results likely will be obtained by application on small grains ahead of clover in the rotation.

### Phosphate Should be Placed Well Into the Soil

Since phosphate does not move through the soil to any appreciable extent but remains relatively close to where it is originally placed, it is highly important that it be put well into the soil in the feeding zone of plant roots. This is especially necessary when the subsoil is deficient in phosphate. When placed in the lower soil layers where the moisture supply is more constant the phosphate will be more readily available, especially the rock phosphate, by the action of soil acids.

Fig. 3.—Phosphate may be applied by scattering it on each load of manure before it goes to the field. Phosphate so treated is a better balanced plant food. One-half bag of 0-20-0, one-fourth of 0-40-0, or one bag of rock phosphate per spreader load of manure is suggested.

The phosphate can be placed into the soil by drilling or spreading it on the surface and plowing it under any time that machinery can be driven on the field without damage. Later it can be plowed under or worked into the soil in the regular cultural operations.

On pastures and meadows it may be spread when most convenient and cut into the soil in the fall or early winter when the soil has sufficient moisture to work well. On many weed-infested pastures, phosphate as well as limestone will need to be applied. After these treatments are made they can be plowed under or cut into the soil. When a good seedbed is made for the new grass legume seeding, a small application of 150 to 200 pounds of a complete fertilizer should be drilled in as a starter with the new seeding.

### Using Phosphate With Manure

An easy way of using phosphate is to apply it with animal manures.

One may simply scatter about 40 pounds of 20 per cent superphosphate, or 20 pounds of 40 per cent phosphate, or 80 to 100 pounds of rock phosphate, over the top of each load of manure before it goes to the field, or scatter up to 2 pounds of 20 per cent, or ½ to 1 pound of 40 per cent, phosphate per mature cow per day in the dairy barns and sheds. A like amount of phosphate is suggested on

the droppings pits in the hen house for each 100 hens. Phosphate used in barns and sheds helps conserve the nitrogen in manure and also helps keep down bad odors. Where the manure is treated in this manner and 6 to 10 tons of it used per acre, no additional phosphate will likely be needed. Each ton of average manure treated with phosphate as suggested above is approximately equivalent in nitrogen, phosphate and potash to 100 pounds of a complete 10-10-10 fertilizer containing 10 pounds of nitrogen, 10 pounds of phosphate and 10 pounds of potash.

### Machinery for Applying Phosphate

For applying the processed phosphates the fertilizer distributor or the fertilizer grain drill can be used. Placing the phosphate slightly into the soil will prevent its washing away. With the ordinary distributor it can be spread evenly over the surface and plowed under or cut into the soil when the soil is in workable condition.

With rock phosphate either a fertilizer distributor or special spreader is needed. The material is spread on the surface and later plowed under or worked into the soil.

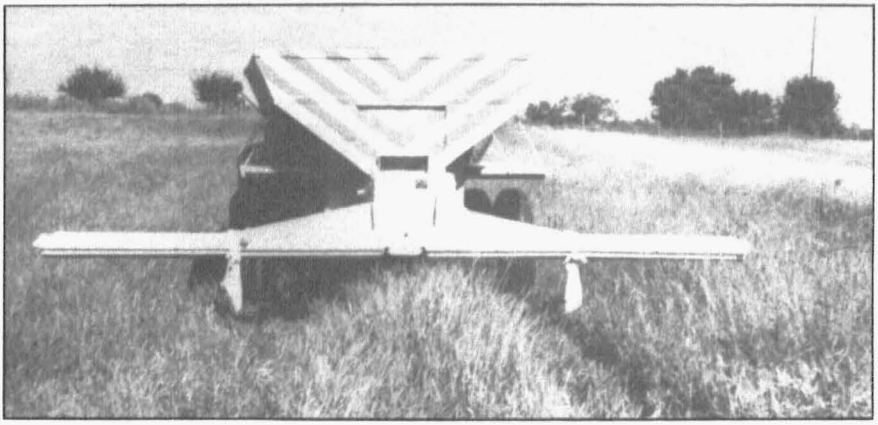


Fig. 4.—Phosphate can be applied with a truck spreader any time field conditions permit.

### Handling Phosphate with Machinery

Much labor can be saved by moving phosphate in carloads to the railroad station, unloading it into a truck equipped with a special attachment for spreading it directly on the crop or pasture land. If conditions are not suitable for hauling the phosphate directly to the fields it can be unloaded into a warehouse with machinery and then later into a truck spreader to be hauled to the fields. In addition to saving labor, the bagging cost is eliminated. These savings can be

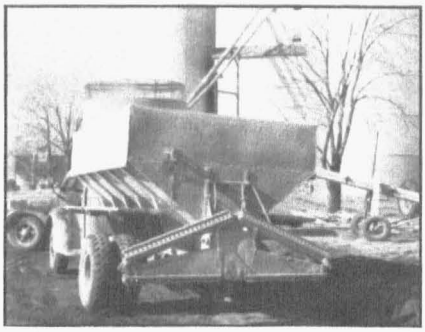


Fig. 5.—Auger type phosphate spreader and lime bed truck. Photos for Figs. 5, 6, and 7 courtesy of Ruhm Phosphate & Chemical Co.

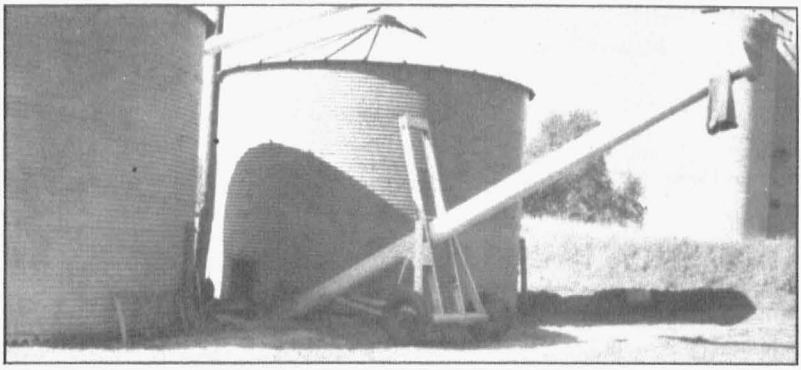


Fig. 6.—Truck loading screw conveyor. Note that there is a screw conveyor extending under both bins which moves phosphate to unloading hopper.

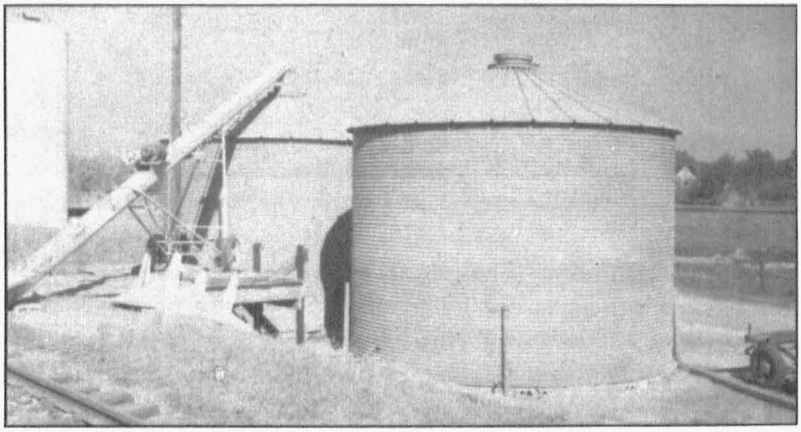


Fig. 7.—Typical small bulk handling plant. Bins are converted ever-normal granaries. Screw conveyors are used to (1) load phosphate into bins, (2) move phosphate from bins into unloading hopper and (3) load trucks.

applied to the spreading, making it possible to apply phosphate on the fields with much less labor than required when handled in bags.

This method of distribution requires considerable volume to justify the expenditures for the necessary machinery.

### Other Plant Nutrients Possibly Needed

In addition to phosphorus the other needed nutrients should be used to obtain full advantage of the phosphate. The need for other major plant nutrients also can be determined by soil tests. On calcium-deficient soils of significant degree of acidity, limestone should be applied to bring the soil to a reaction slightly below neutral. At this reaction the soil micro-organisms are most active. Excessive liming may reduce the availability of some of the trace minerals which, although used in very small amounts, are essential for optimum growth, proper performance and high quality crops. Potassium should be applied where needed. Adequate use of lime to supply calcium and magnesium along with the applications of phosphate, potash, and other needed plant nutrients will make it possible to more regularly grow clovers, alfalfa and other highly nutrious legumes in copping systems and in pastures and meadows. The regular growth of these legumes will provide a high turn-over of organic matter and nitrogen which are badly needed on most soils. When sufficient nitrogen is not applied by legumes, chemical nitrogen can be used to provide the needs for this element for grain and forage crops.

### Phosphorus and Other Nutrients Help Reduce Soil Erosion

Fig. 8.—Fall plowed treated soybean land where no other legumes were grown in the rotation. Note poor physical condition of soil.

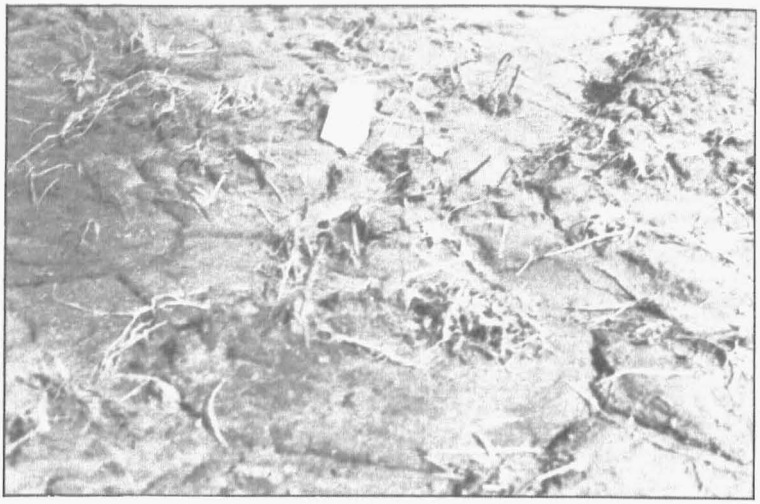


Fig. 9.—Fall plowed second year sweet clover land where lime and phosphate were applied enabling sweet clover to grow in the rotation with other crops. Note improved physical condition of soil.

The use of phosphorus along with the other necessary plant nutrients is one of the most effective soil conservation measures. Their use speeds the growth of vegetative cover on the land and provides for higher turnover of organic matter to the soil. Extra cover on the land breaks the force with which the rainfall hits the soil, prevents forming it into slush, and lessens the danger of losing the soil along with the running water.

A high turn-over of organic matter helps aerate the soil and permits the penetration of more rainfall thereby reducing water runoff and erosion. Building up the soil helps protect it against erosion while growing bigger crops of higher quality.

**Cost of Heavy Application Should Be Charged Over Several Years**

Applied plant food, such as phosphate and potash which do not readily leach out of the soil and which are not used by the immediate crop, builds up the soil reserve in these minerals. Their entire costs, therefore, should not be all charged to the immediate crop but allocated over several years. When the phosphate taken from the soil exceeds that returned, the actual value of the land is decreased. On the other hand, when phosphate is returned in larger quantities than those removed the actual value of the land is increased.

How this method of fertility valuation can be used is shown in the

following example: During 1944 to 1947 inclusive, 50 pounds of phosphate per acre was applied to a low phosphate soil ahead of corn. An average increased yield of 8.9 bushels per acre was obtained in 16 tests on eleven different soils. The average yield of corn from the soils which received no phosphate was 43 bushels per acre while the phosphated areas gave a yield of 51.9 bushels per acre. The 43-bushel crop removed approximately 17.9 pounds of phosphate per acre *from the untreated* areas while the higher yield from the treated area removed 19.2 pounds.

During this period the approximate market value of the phosphate removed by the crop from the untreated plots was $1.61 per acre while from the treated plots it was $1.74. On the untreated plots, the phosphate alone removed by the crop actually reduced the fertility value of the land $1.61 per acre. On the phosphate treated plots the cost of the treatment was $4.50 per acre. The money value of the phosphate removed was $1.74 leaving a net gain in soil fertility value of $2.76 per acre. Other plant foods should be considered in the same manner.

## Summary

1. Any kind of phosphate, whether the processed phosphate or the rock phosphate, should be applied in accord with amounts suggested by soil tests. Information concerning soil tests can be obtained through county agents.

2. Fertilizing the soil with heavy initial phosphate applications will remove lack of phosphorus as a limiting factor in plant growth for six to ten years. Phosphate used in this manner will make possible the production of high acre yields of quality grain or forage crops.

3. The application of processed phosphate split into the initial and subsequent additions may be applied more frequently to build back phosphate reserves.

4. There is no particular season for applying phosphate. It can be applied any time machinery can be driven over the field without damage to crops. For example, it can be applied in the late fall, or early winter on pastures, on corn fields to go to oats in the spring, on clover sod or other fields where it can be later cut into the soil or plowed under.

5. All phosphate should be placed well into the soil either by plowing under or by cutting it well into the soil in the case of permanent pasture not plowable. By putting the phosphate well into the soil, the soil acids help make it available to plants. This can be done in the regular cultural operations or, in the case of pasture, when the soil is in best condition for working.

6. When lime, potash, other minerals, or nitrogen is needed, it should be applied in order to get the best results from the phosphate. Likewise, good drainage and aeration are necessary for the highest efficiency from phosphate applications as for any other fertilizer.

7. When small grains or corn are grown in cropping systems, a light application of superphosphate (150 to 200 pounds per acre) or mixed fertilizer should be drilled in with the small grain or used as a "starter" on the corn. This method will help maintain a high level of phosphorus in the soil.

8. The cost of heavy applications of phosphate should not be charged to the immediate crop but should be allocated over several years and regarded as a gain in the fertility value of the soil. On the other hand, failure to replace the phosphate removed should be charged against the fertility value of the soil.

9. By fertilizing the soil with a sufficient amount of phosphate and other plant nutrients to remove them as limiting factors to plant growth, such soil treatments will help reduce fluctuations in yield and in quality of crops from season to season.

## THIS CIRCULAR AT A GLANCE