Fertilizers, What They Are and How to Use Them
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FERTILIZERS

What They Are and How to Use Them

M. M. McCOOL AND C. E. MILLAR

The comparative growth of crops on new land and on land cultivated for many years indicates that the fertility of many Michigan soils has markedly decreased. Right, soil cropped 42 years. Left, soil newly brought under cultivation.

AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

SOILS SECTION

East Lansing, Michigan

FERTILIZER FACTS

There is no such thing as a special crop fertilizer such as a "Wheat Fertilizer" or "Corn Fertilizer" which is suitable under all conditions.

The fertilizer which will give the greatest returns on the money invested depends upon the nature of the soil and the farming system as well as upon the crop grown.

The best method of determining the fertilizer which should be used is by referring to the results of field experiments.

Fertilizers should be purchased on the basis of the analysis printed on the bag and never by the trade name.

The highest grade fertilizer which meets the individual requirements is the most economical to buy since a greater percentage of the purchase price goes to pay for plant food.

Soils which are properly managed will not be made acid or have their physical condition injured by the use of standard fertilizers.

FERTILIZERS

What They Are and How to Use Them

M. M. McCOOL AND C. E. MILLAR

Every resident of the State of Michigan is affected financially and socially by soil conditions, and in many sections of the State the status of soil fertility is the outstanding economic problem. This situation directly concerns the farmers, and indirectly, but none the less forcibly, the merchants, bankers, and other business men. The problem of increasing soil productivity then is one of general interest and concern.

The problem demands attention as is evidenced by the fact that in some localities considerable areas of land which were once the scene of prosperous agricultural communities are now largely untilled. In other sections land has been cleared, cropped a few years and then deserted. From practically every portion of the State come reports of decreased yields. Inasmuch as the farmers are provided with improved varieties of seed, superior tillage implements, have the services of county agricultural agents at their disposal, and are better informed regarding farming methods, it seems that the reported decrease in yields must be due to a decline in soil productivity.

In view of these facts the writers have prepared and present in the following pages a brief study of the plant food* relationships in the state as a whole and on types of farms common to various communities. In addition, information is given concerning the sources of fertilizer materials, the proper use of fertilizers, and their effects on soils and crops.

FOOD ELEMENTS REQUIRED BY PLANTS

Plants require ten food elements for growth. These are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulphur. If any one of these food elements is lacking proper growth cannot take place. The plant has three sources from which to draw its food; air, water, and soil. Oxygen and hydrogen are procured from water by plants, while carbon and oxygen are taken from the air. In the case of legumes, some nitrogen is procured from the air. All the other plant food elements must be taken from the soil by crops. The supply of these nutrients in the soil in a form suitable for plant use becomes, therefore, a very important consideration.

*In this publication the expression plant food is used because of its general usage among farmers.

IS THE SUPPLY OF AVAILABLE NUTRIENTS ADEQUATE?

Inasmuch as the supply of available plant-food in the soil is of great importance a brief discussion of the question in the light of experimental results is presented below.

Nitrogen.—The supply of this element in Michigan soils varies greatly. Experiments have shown that additions of nitrogen at proper times on badly run soils, especially of a sandy nature, generally result in quite large increases in yield. Whether it is necessary to supply this nitrogen deficiency by the use of commercial fertilizers or whether the utilization of legumes is sufficient is an important question and will be discussed in the following pages.

Fig. 1.—An abundance of plant food is essential for maximum yields of legumes. Clover from equal areas of land: left, unfertilized; right, fertilized.

Potassium.—Potassium is the active principle of potash, and it is usually referred to as potash in discussing fertilizers and soil fertility. The supply of this element in most mineral soils is very large, but the availability seems to be quite low especially in the more sandy soils. Applications of potash have increased the yield of legumes and special crops such as sugar beets and potatoes, and also, occasionally the cereal crops. Organic soils such as mucks and peats contain much smaller amounts of potash than the mineral soils and additions of this element are usually profitable.

Iron, magnesium and sulphur. No soils deficient in available iron have been found in this portion of the United States. Experiments conducted by the Soils Section have also showed that the response of Michigan soils to applications of sulphur is very questionable. These results are corroborated by the findings of the experiment stations in neighboring states. The farmers are cautioned that the increased yields of legumes advertised as resulting from applications of sulphur fertilizers were obtained in general in the far western states.

It has generally been considered that the soils of central United States were so well supplied with magnesium that additions of this plant food element were unnecessary. Recent experiments, however, indicate that on certain types of soil alfalfa and sweet clover may be much benefitted by applications of limestone or fertilizers carrying magnesium.

Calcium and Lime. The supply of calcium as a plant food element seems adequate in the majority of our soils. Calcium, however, is the active constituent of lime and the great need of so many of our soils for lime to correct acidity should never be overlooked.

Phosphorus. Few soils in this state have been found to contain adequate supplies of available phosphorus. It is, therefore, more generally used than any other fertilizing element. In discussing fertilizers and soil fertility relationships it is customary to use the term phosphoric acid. Phosphorus is the active constituent of phosphoric acid.

From the foregoing remarks it is seen that lime, magnesium, nitrogen, phosphoric acid, and potash are the only plant food elements which occur in Michigan soils in such small quantities or in such unavailable conditions that crop growth is limited seriously by the deficiency. In this bulletin we will confine our attention to nitrogen, phosphoric acid and potash.

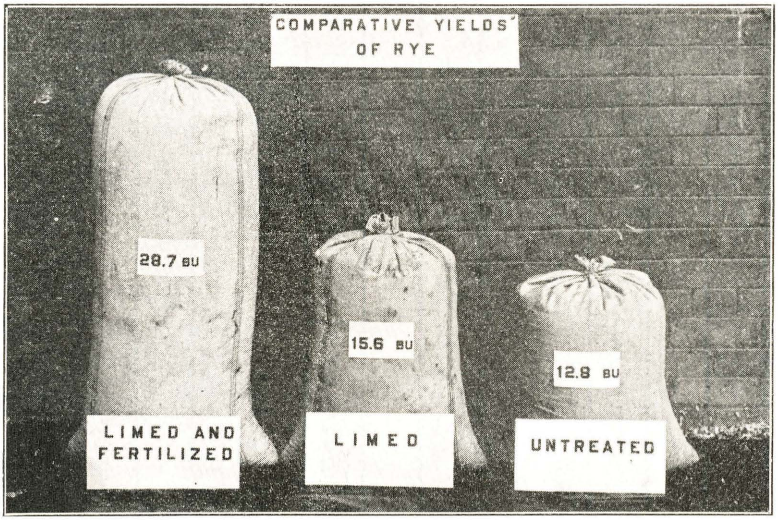

Fig 2.—On quite acid soils rye is benefitted by liming after which the use of fertilizer rich in phosphoric acid is profitable.

REMOVAL OF PLANT FOOD BY CROPS

The amounts of these plant food elements removed each year from the soils of the state by the staple crops are much greater than the amounts returned to the cultivated land in manure. This relationship is brought out in Fig. 3. In calculating the amounts of plant food removed, the average yields for 1920 and 1921 of the following crops

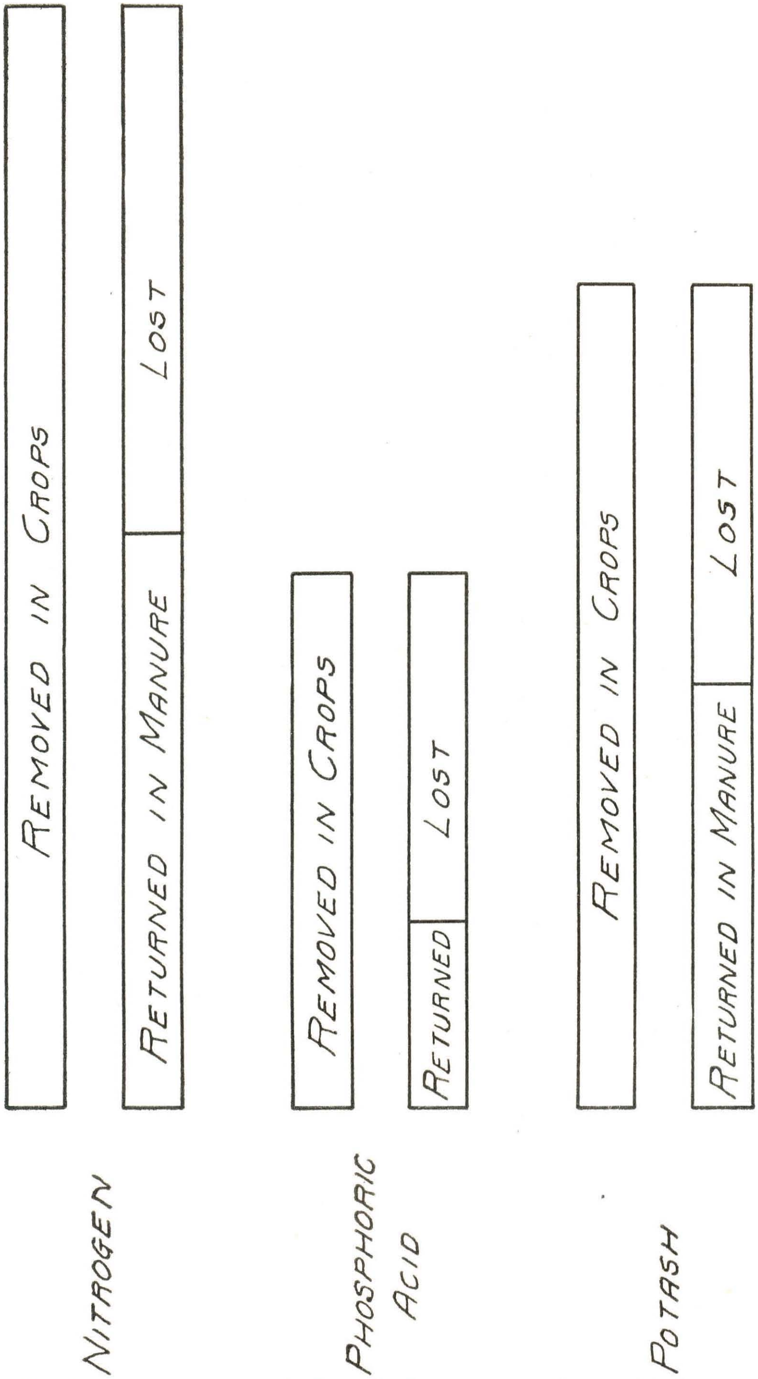

Fig 3.—Much larger amounts of plant food are removed annually in crops from Michigan soils than are returned to the cultivated land in manure.

Table 1.—Amounts of Plant Food Elements Contained in Farm Products.

Crop	Amount	Pounds				
		Nitrogen	Phosphoric Acid	Potash	Calcium	Magnesium
Sugar beets (Tops removed)	10 tons	30.0	14.0	70.0	....	....
Wheat	Grain 25 bu	30.0	12.8	6.0	0.64	1.98
	Straw 2500 lbs	12.5	3.8	15.0	5.20	1.50
	Total	42.5	16.6	21.0	5.84	3.48
Corn	Grain 50 bu	46.4	18.2	11.0	0.40	3.02
	Stover 3000 lbs	30.0	9.0	42.0	14.15	2.52
	Cobs 500 lbs	2.0	.4	2.2	0.05	0.05
	Total	78.4	27.6	55.2	14.60	5.59
Oats	Grain 50 bu	32.0	13.0	9.6	1.60	1.92
	Straw 2500 lbs	16.0	5.0	31.2	7.50	3.50
	Total	48.0	18.0	40.8	9.10	5.42
Rye	Grain 20 bu	19.1	9.8	6.7	0.45	1.34
	Straw 2000 lbs	10.0	6.0	17.0	4.40	1.40
	Total	29.1	15.8	23.7	4.85	2.74
Buckwheat	Grain 20 bu	15.0	6.0	3.0	....	....
	Straw 5000 lbs	62.5	7.5	57.5	34.50	6.00
	Total	77.5	13.5	60.5	....	....
Barley	Grain 35 bu	29.4	12.6	8.4	0.67	2.02
	Straw 1600 lbs	13.4	4.5	24.6	3.68	1.12
	Total	42.8	17.1	33.0	4.35	3.14
Beans	Seed 25 bu	60.0	18.0	19.5	3.00	2.61
	Straw 2000 lbs	28.0	6.0	38.0	....	....
	Total	88.0	24.0	57.5	....	....
Potatoes	150 bu	31.5	13.5	45.0	1.80	2.70
Beets, common, roots only	25,000 lbs	62.5	25.0	125.0	5.00	5.00
Beets, mangles, roots only	40,000 lbs	60.0	40.0	140.0	....	....
Turnips, common	20,000 lbs	50.0	20.0	90.0	10.00	2.00
Turnips, rutabagas	20,000 lbs	40.0	24.0	100.0	12.00	4.00
Carrots	10,000 lbs	23.0	13.0	53.0	6.00	2.00
Parsnips	12,000 lbs	26.4	24.0	78.0	9.60	4.80
Alfalfa hay	3 tons	147.0	30.0	126.0	83.50	21.30
Timothy	2 tons	50.0	22.0	40.0	7.11	4.08
Clover	2 tons	84.0	20.0	80.0	45.70	10.80
Soy beans hay	2 tons	92.0	28.0	44.0	49.20	15.50
Soy beans	10 bu	53.0	18.0	20.0	6.60	8.40
Cabbage heads	20,000 lbs	60.0	20.0	80.0	18.00	4.00
Cauliflower heads	15,000 lbs	42.0	15.0	50.0	6.00	3.00
Celery, tops	10,000 lbs	25.0	20.0	75.0	....	....
Sweet corn, ears	4,000 lbs	18.0	8.0	12.0	....	....
Cucumbers, fruit	100 bu	5.5	3.3	11.0	....	....
Onions, bulbs	300 bu	39.3	15.4	37.6	18.80	3.42
Muskmelons, fruit	10,000 bu	22.0	8.0	40.0	....	....
Peppermint	2,000 lbs	7.0	4.0	13.0	....	....
Apples	300 bu	6.0	3.0	15.0	1.18	1.68
Peaches	400 bu	22.0	11.0	45.5	....	....
Pears	300 bu	7.5	3.0	15.0	2.88	1.44
Plums	200 bu	15.3	5.5	21.3	....	....
Cherries	8,000 lbs	16.0	4.0	20.0	....	....
Blackberries	4,000 qts	11.0	3.0	12.0	....	....
Raspberries	4,000 qts	10.5	4.5	12.0	....	....
Grapes	6,000 lbs	9.0	6.0	18.0	0.42	1.20
Milk	1,000 lbs	6.0	1.7	1.7	1.21	0.12
Fat calf	100 lbs	2.46	1.5	0.21	1.18	0.05
Fat steer	1,000 lbs	23.3	15.5	1.8	12.80	0.37
Fat lamb	80 lbs	1.56	1.0	0.14	0.73	0.03
Fat pig	200 lbs	3.5	1.3	0.28	0.91	0.04
Wool, unwashed	1,000 lbs	54.0	0.7	56.2	1.30	0.24

were considered; corn, wheat, oats, rye, barley, beans, buckwheat, mixed hay, potatoes, apples, peaches, pears, peas, cabbage, and onions.

It is also of interest to note the amounts of the plant food elements removed from an acre by good yields of the common crops. In considering the preceding table, it is important to bear in mind that these quantities of plant nutrients are taken from the more readily **available** portion of the soil supply and while the amounts removed by one crop are quite small compared to the **total** amounts present, they assume formidable proportions when compared to the quantities which can be removed by crops economically. It should further be pointed out that

Fig. 4.—Some of the most productive wheat soils give more profitable returns from fertilization than less fertile land. Above, unfertilized. Below, fertilized.

Fig. 5.—Fertilized wheat field.

the composition of crops is varied by the composition of the soil on which they are grown. Thus crops grown on lime rich soils contain more lime than those grown on acid soils. Climatic conditions also influence the amounts of nutrients removed by crops.

One should never lose sight of the fact that when any of the above products are sold the transaction represents a loss to the farm of the plant food elements contained.

WHAT TYPE OF FARMING MAINTAINS FERTILITY?

From Fig. 3 it is seen that in the state as a whole very much larger amounts of plant food elements are removed in crops than are returned in manure. The question at once arises, therefore, as to what types of farming keep the most plant food on the farm and what types are most costly from a fertility standpoint.

To throw some light on this question the plant food balance has been carefullly calculated for the most common types of farms found in Michigan. These results cannot be absolutely accurate but the writers believe they represent conditions very much as they are at the present time. The results are shown graphically in Figures 6, 7, 8, 9 and 10.

The results of the study of the various types of farming, shown in these diagrams, indicate a deficit of plant food each year. This is true

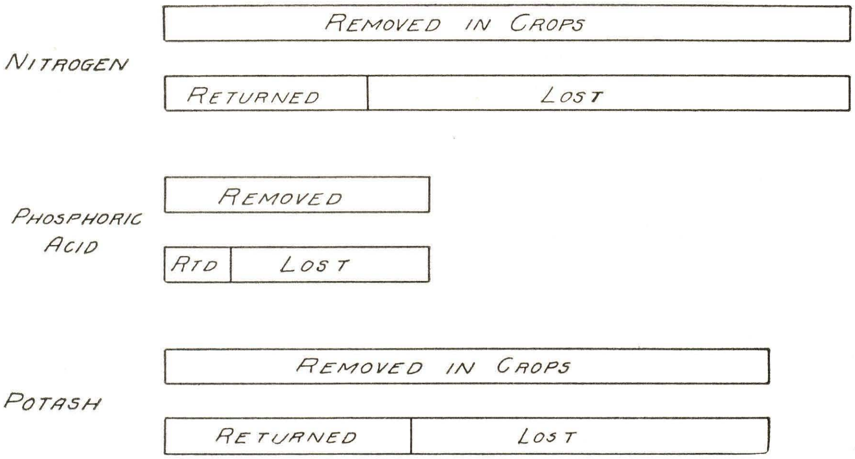

Fig. 6.—Plant food balance on a 100 acre grain farm carrying 2 cows, 5 horses and 14 hogs.

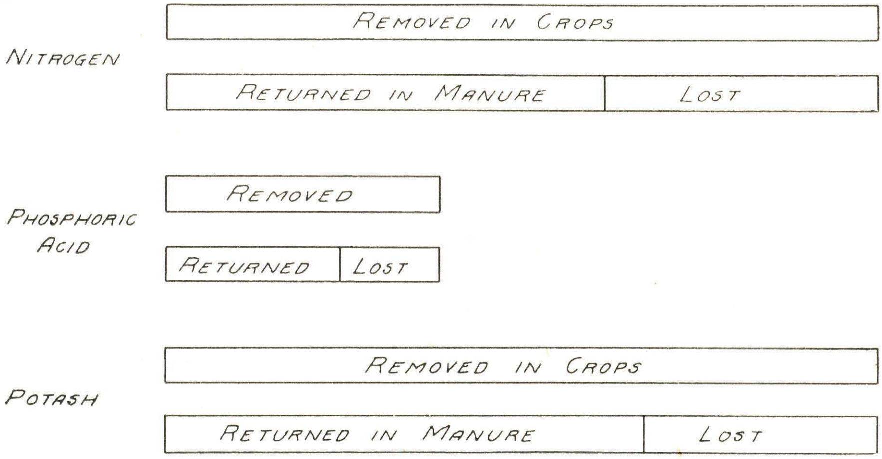

Fig. 7.—Plant food balance on a 100-acre dairy farm, carrying 20 cows, 10 young cattle, 5 horses and 20 hogs.

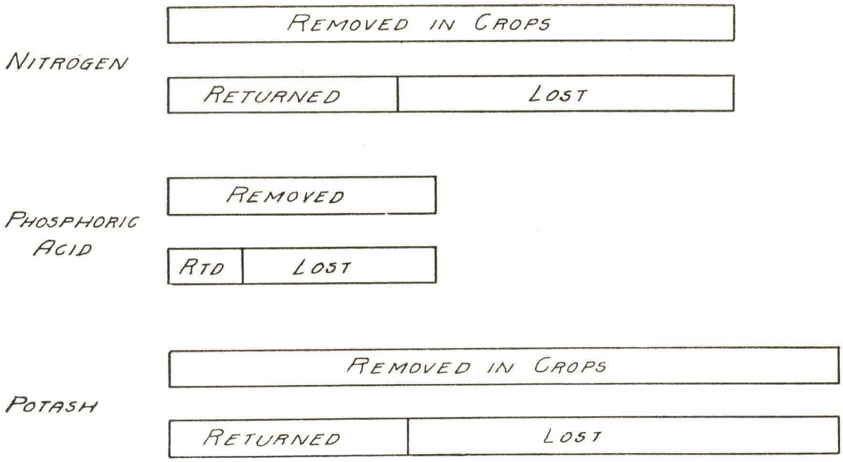

Fig. 8.—Plant food balance on a 100-acre general farm, carrying 6 cows, 4 young cattle, 5 horses and 14 hogs.

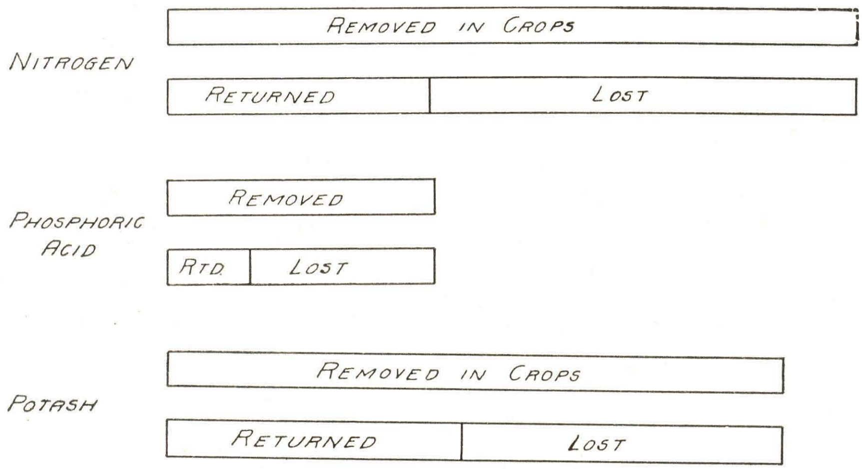

Fig. 9.—Plant food balance on a 100-acre general farm on a fertile, loam soil, growing 25 acres of clover, and carrying 6 cows, 4 young cattle, 5 horses and 14 hogs.

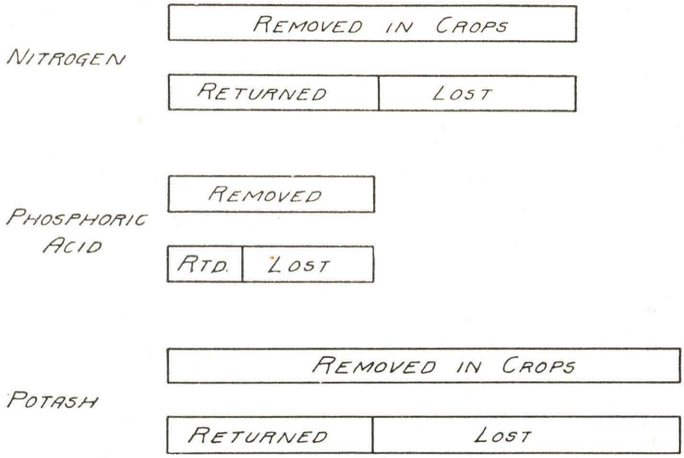

Fig. 10.—Plant food balance on a 100-acre general farm on sandy soil with a short rotation, including 25 acres of clover, and carrying 6 cows, 4 young cattle, 5 horses and 14 hogs.

on the heavily stocked dairy farms as well as on the grain farm, but to a much less extent. It is evident, therefore, that no type of farming which includes the marketing of grain, hay, livestock, or dairy products returns as much plant food to the soil in manure as is removed in crops unless an extremely large amount of feed is purchased. This is especially true of phosphoric acid and potash. The facts regarding nitrogen are less definite because there is a certin amount of direct fixation of atmospheric nitrogen by bacteria living in the soil, but not on the roots of legumes. Several investigators have found that when conditions are suitable an average of twenty-five pounds of nitrogen per acre per year are added to the soil by this means. The process is greatly modified by soil conditions, however, so that the amounts fixed in different soils are unquestionably quite variable. The Kansas Experiment Station found that soils which show more than a small degree of acidity fix very small amounts of nitrogen and in consequence it seems probable that many soils in Michigan are not enriched by this means to the extent they would be if properly limed. Since the quantity of nitrogen added to the soil by this process is not known, it is impossible to say how rapidly the nitrogen supply is being decreased by any given method of farming.

An important fact to bear in mind when studying the preceding diagrams and data is that the plant food removed from the soil by crops and not returned represents a loss from the supply of **available** plant nutrients in the soil. This is far more important than if the losses are considered on the basis of **total** plant food present.

The fact that the plant food losses shown in the above diagrams may be materially reduced if the manure is so handled as to decrease losses by leaching and decay is well worth the most careful consideration of every farmer.

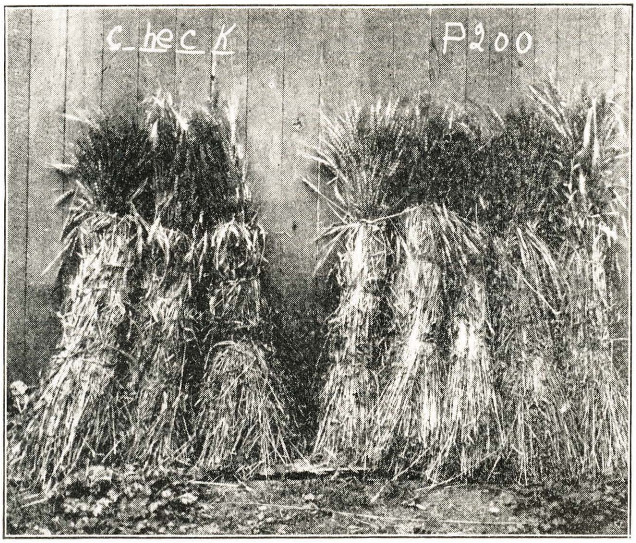

Fig. 11.—On many of the more productive soils of the State, acid phosphate gives very profitable returns.

EFFECTS OF PLANT FOOD ELEMENTS ON PLANT GROWTH

Each plant food element plays a specific part in plant growth. It is generally understood that one element cannot perform all the functions of another although a partial substitution can be made in some cases.

Nitrogen. A lack of nitrogen is evidenced by a turning yellow of the plant and the apparent cessation of growth. On the other hand, an abundance of this element results in a larger growth of dark green leaves and stems. When an excess of nitrogen is present there is a tendency for the plant to keep on growing instead of maturing, and the tissue is quite succulent and more susceptible to the attack of disease. In the case of vegetables used for their leaves, nitrogen gives a crispness and improved quality. On late fall seedings of rye and wheat, and also during the early spring, an application of available nitrogen hastens growth and often proves very beneficial especially on sandy or badly run soils.

Phosphoric Acid. When a soil is not well supplied with phosphoric acid, the plants do not grow so rapidly as they should and the yield and quality of the seed is inferior. Phosphoric acid, therefore, not only stimulates growth but gives a larger yield of seed of better quality and an earlier date of maturity. One of the most important properties of this element is to stimulate root growth. This is an extremely important consideration since a plant with a large root system can gather

Fig. 12.—Phosphoric acid plumps the kernels and improves the market grade. Right, fertilized with acid phosphate. Left, unfertilized. On the heavier types of soil, well supplied with organic matter, as a general rule, acid phosphate is the only commercial fertilizer that can be profitably used under present or similar conditions.

more food and water and thus better resist adverse conditions as well as make a more rapid growth. With very few exceptions, the application of soluble phosphate fertilizers have given profitable increase in yield. It is often the case with acid soils, however, that the returns from the use of phosphate are very much limited until the soil is limed.

Potash. This plant food element is closely connected with the formation of starch, sugar, and similar compounds in plants. It is for this reason that it is so often used in fertilizing potatoes, sugar beets, and other tuber and root crops. Potash also is credited with making the straw or stalk of plants more stiff thus preventing lodging to a certain extent.

When well supplied with potash, plants exhibit a dark green thrifty appearance. Where potash is lacking, the plants take on a yellowish unhealthy appearance and are quite subject to disease.

PLANT FOOD ELEMENTS CARRIED BY FERTILIZERS

Fertilizers are designed to offset plant food deficiencies in the soil. It is obvious from the above, therefore, that they must supply phosphoric acid, potash, and nitrogen in an available form. We all recognize that soils are quite different in their characteristics and needs, and consequently some soils may be deficient in only one plant food element while another soil may need two or three. It is necessary, therefore, to have fertilizers which supply the various food elements alone and in various combinations. A material which supplies a plant food element is called a carrier of that element. Thus acid phosphate is a carrier of phosphoric acid. The following table gives the principal carriers of the plant food elements and approximate percentage of the element contained.

Table 2.—Important Carriers of Plant Food and the Percentage of Nutrients They Contain.

Carriers of nitrogen	Per cent nitrogen	*Per cent ammonia	Carriers of phosphoric acid	Per cent available phosphoric acid	Carriers of potash	Per cent potash
Nitrate of soda	15.5	18.8	Acid phosphate	16.0	Muriate of potash	50.0
			Acid phosphate	18.0		to 62.0
Sulphate of ammonia	20.7	25.0	Acid phosphate	20.0	Sulphate of potash	50.0
Dried blood	11.2	13.5	Acid phosphate	24.0	Kainite	12.8
Tankage	4 to 12	5 to 14	Treble super phosphate	43 to 46		
Nitrate of lime	15.5	18.8				
Calcium cyanamid	21 to 24.6	26.0–30.0	Steamed bone meal	28.0		

*Ammonia is a substance containing 82.35 per cent of nitrogen. Since nitrogen is the element required by plants the state law requires that the percentage of **nitrogen** in a fertilizer be printed on the bag. In speaking of fertilizers, however, and in expressing their composition by means of a formula such as 3-12-4 it has been customary to give the nitrogen content in terms of ammonia. Beginning with January 1, 1929, however, the first figure of the formula will represent the percentage of nitrogen. To convert the percentage of ammonia in a fertilizer into terms of nitrogen multiply by .8235.

The preparation of certain of these materials and the mixing of them into combinations suitable for different soils and crops constitutes the work of the fertilizer factories.

A fertilizer prepared by a fertilizer factory in a suitable condition for application to the soil and containing either two or three of the plant foods, nitrogen, phosphoric acid, and potash is known as a "mixed fertilizer." If the mixed fertilizer contains all three of the plant foods mentioned it is called a "complete fertilizer."

As a matter of convenience the composition of a fertilizer is expressed by numbers thus, 2-16-2, which is spoken of as the fertilizer formula or analysis. These numbers represent the percentages of ammonia, (nitrogen after January 1, 1929) phosphoric acid and potash respectively. Since fertilizers are handled on the ton basis one per cent of a plant food element represents 20 pounds and is called a unit. Thus a 2-16-2 fertilizer contains 2 units of ammonia (nitrogen after January 1, 1929), 16 units of phosphoric acid, and 2 units of potash,—or one ton of the material contains 40 pounds of ammonia (nitrogen after January 1, 1929), 320 pounds of phosphoric acid, and 40 pounds of potash.

Fig. 13.—On the light sandy loams, wheat is often starving for nitrogen in the early spring. Left, spring top dressing of soluble nitrogen. Right, no spring application of nitrogen.

HIGH GRADE FERTILIZERS

The retail price of a fertilizer is the sum of four charges. First the price of the plant-food contained; second, the transportation charges; third, the profits and selling charges of the dealers, manufacturers, and salesmen; and fourth, the cost of maintaining and operating the fertilizer factory and mixing plant and other incidental items. The last three items may be grouped together and called general expense and constitute a more or less fixed charge against each ton.

A study of fertilizer costs reveals the fact that the general expense item amounts to quite a percentage of the total price. One of the causes for this large overhead on each ton of fertilizer is the making of such a large number of analyses. Every time a mixture of different composition is desired the mixing machinery must be allowed to run empty and readjustments and arrangements made which entail the loss of much time and means added expense.

Another source of expense to the user of fertilizer is the purchase of low analysis mixtures. It can readily be seen that the same amount of plant food will be contained in either one ton of 4-16-4 or two tons of 2-8-2, but the consumer would have to pay the general expense charge on two tons if he purchased the 2-8-2 and on only one ton if he chose the 4-16-4. This of course would make the plant food elements in the 2-8-2 mixture much more expensive even though it cost considerably less per ton. This point is illustrated in the accompanying diagram Fig. 14 which shows the proportion of the purchasers money which goes to pay for plant food in the case of a low grade mixture such as a 2-8-2 and a high grade as a 4-16-4.

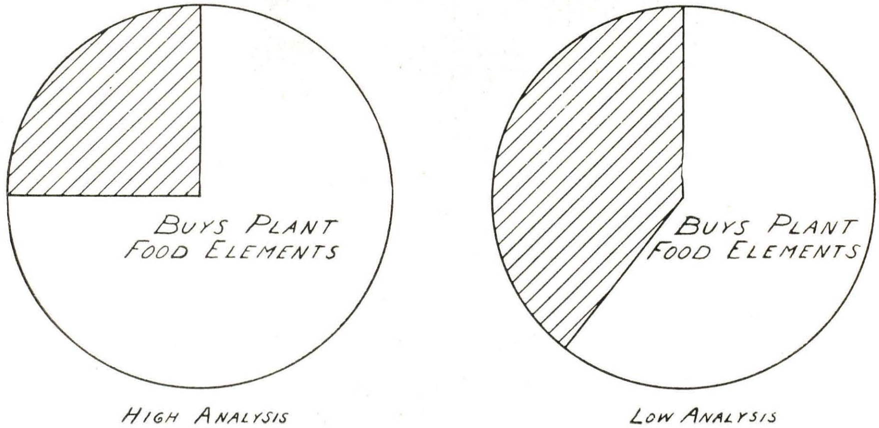

Fig. 14.—The shaded portion of each circle represents the percentage of the selling price which goes to pay the general charge, while the unshaded portion represents the percentage which pays for plant food. It is evident that when a high grade fertilizer is purchased a much greater percentage of the buyers' money goes to buy plant food.

It is thus evident that it is more economical for a farmer to buy the highest grade fertilizer that meets the needs of his soil.

In an effort to promote the more effective use of fertilizers and furnish plant food to the farmers at a lower cost, meetings of representatives of a number of experiment stations and of various fertilizer companies are held from time to time. At the first of these meetings it became very evident that the number of analyses put on the market could be greatly reduced and yet supply all the needs of farmers and other users of fertilizer. This was a move toward economy as the making of many different analyses is expensive. From the list of analyses decided upon as essential, the Soils Section of the Michigan Station has selected those which field experiments and the experiences of many farmers have showed to be needed under Michigan conditions. It is evident that the mixture or analysis which should be used will vary with the crop grown, the soil type, and the system of farming followed. Recommendations covering these points as well as the time of application are contained in Circular Bulletin No. 53 of the Michigan Experiment Station.

Fig. 15.—Soils that are quite sandy need potash in addition to phosphoric acid for the best results with legumes. Left, lime and acid phosphate. Right, lime, acid phosphate, and potash.

CONCENTRATED FERTILIZERS

With the introduction of treble-super-phosphate containing approximately 45 per cent phosphoric acid there has been a tendency, which will undoubtedly increase, toward the production of very highly concentrated fertilizer mixtures,—such as 5-30-5, 6-24-8, 6-36-6, 19-32-16, etc. Combinations of ammonia and phosphoric acid with such analysis as 20-20-0 and 13-48-0 are on the market. A mixture containing 18 per cent ammonia and 15 per cent potash has also recently appeared. Such high grade mixtures are more economical since the number of bags required, the freight, labor in handling, etc., is much reduced. Various questions arise, however, regarding the use of these concentrated materials such as the effect on germination when applied near the seed. These questions are being investigated but the results as yet are quite meagre. Those making use of these extremely high analysis goods should bear in mind that proportionately lighter applications will supply the usual amounts of plant food and tend to offset any detrimental effect to seed or plant.

USE OF FERTILIZERS

Experimental results and the experiences of many farmers have shown that the outstanding need of the majority of Michigan soils is for phosphoric acid. As a result it is quite common to apply from 200 to 300 pounds per acre of acid phosphate or of a mixture high in phosphoric acid every two years. The application is usually made on the wheat, rye, potato, beans or other cash crop in the rotation.

When grown on the light sandy loams and other soils quite low in humus, wheat and rye have been found to respond especially well to a spring top dressing of soluble nitrogen in addition to the application of fertilizer in the fall. This is due to the fact that nitrogen becomes available in the soil through the decay of organic matter by bacteria. These bacteria work very slowly in cold weather and when the supply of organic matter is meagre, not enough nitrogen is made available to supply the needs of the crop. The nitrogen may be supplied either in the form of sulphate of ammonia at the rate of 40 to 60 pounds per acre or of nitrate of soda at the rate of 60 to 100 pounds broadcasted just as early as growth starts.

Legumes such as alfalfa and the clovers are heavy feeders on potash and since the available supply of this nutrient is often meagre in the more sandy soils it has been found highly advisable to supply the deficiency by means of high potash fertilizers. If clover, alfalfa, or sweet clover is to be seeded in a small grain, a fertilizer high in potash and phosphoric acid should be applied at the time of drilling the grain. In case the legume is seeded alone the fertilizer should be applied and worked into the soil at the time of or shortly before seeding.

Fig. 16.—On worn soils, proper fertilization pushes the early growth of grains and gives increased yields. Wheat. Left, lime and fertilizer; right, no treatment.

INFLUENCE OF FERTILIZERS ON SOIL ACIDITY

The opinion sometimes expressed that acid phospate makes soils acid is not based on experience. In fact there is some experimental evidence that this fertilizer has a slight tendency to overcome the detrimental effects of acidity. Other fertilizers which are capable of neutralizing soil acidity to some extent are nitrate of soda, basic slag, calcium cyanamid, steamed bone meal, and rock phosphate.

On the other hand, some fertilizers have a slight tendency to increase or aggravate the acid condition of the soil. Muriate and sulphate of potash do this to a certain extent, but sulphate of ammonia is the most pronounced in its action. Experimental fields which have received applications of this fertilizer quite regularly for many years without being treated with lime have become too sour to grow clover. This tendency of sulphate of ammonia should be remembered, as its indiscriminate use on sour soils without addition of lime may not only result in no benefit to the crop but in some instances may actually be a detriment.

The farmer who applies from 200 to 300 pounds or more of acid phosphate or high grade mixed goods every two years need have no fear that the practice will make his land sour.

Fig. 17.—Plenty of available plant food means larger oat yields. Left, fertilized. Right unfertilized.

METHOD OF APPLICATION

The method of applying a fertilizer in order to obtain the greatest returns from the investment is governed by many conditions. When applied in the hill or row, detrimental results sometimes occur from delayed germination or damage to the young plant. This damage is governed not only by the amount of fertilizer applied, but by the kind of fertilizer and climatic conditions as well. On the whole, phosphatic fertilizers are less detrimental than are carriers of nitrogen and potash. When dry periods follow the application, the danger of damage is increased, some crops seeming to be much more sensitive than others. In general, it is advisable to limit the application per acre to 125 lbs. or less when there is a likelihood of considerable fertilizer coming in direct contact with the seed as in the case of corn or beans. In the case of small grains even though the fertilizer may be in contact with the seed the application is distributed over such a large area that 300 to 400 pounds per acre may be used with impunity.

When fertilizer is applied in the hill, little benefit is derived by the succeeding crop from the unused portion of the plant food. Hill fertilization leads to a spotted condition in the next crop while a broadcast application allows uniform feeding over the field. Some Experiment Station workers think this objection is so important that they never recommend hill application. Other workers feel that when fertilizer prices are high and labor and money are scarce it is more advisable to use smaller amounts in the hill than to broadcast larger quantities since the latter method requires going over the field a second time.

Fig. 18.—Potatoes need large quantities of available plant food for maximum yields. The potatoes on left were fertilized while the rows in the center received no fertilizer.

The position of the fertilizer with reference to the seed is important. Some planters drop the plant food above the seed where it is out of reach of the roots unless washed down by early rains. In dry seasons the plants may not receive any benefit from such an application during the early stages of growth and hence the final returns be diminished. In all applications whether broadcast or dropped near the seed it is advisable to have the fertilizer placed deep enough to be in contact with moist soil.

Results of experiments on methods of application of fertilizer to potatoes show that the sprouts are very easily damaged when the fertilizer comes too close to them, especially in dry seasons. Planters have therefore been developed which distribute the fertilizer at a good depth on both sides of the seed piece and several inches from it. Plant food so located is within easy reach of the roots of the young plants so that the crop is benefited from the early stages of growth without danger of damage. Under average conditions for the grower who is going to use a moderate amount of fertilizer this is the best method of application. If very large amounts of fertilizer are to be applied a portion should be broadcast and worked into the soil and the remainder applied with the planter as described.

LOSS OF PLANT FOOD ELEMENTS BY LEACHING

The question is often asked if the plant food applied in fertilizers will be carried away in solution by water percolating through the soil. This is true of nitrogen, as this element in a form which is available to plants is not retained by the soil to any great extent. It is necessary there-

Fig. 19.—Muck soils respond remarkably well to fertilization. They are almost universally deficient in potash and usually need phosphoric acid also. Heavy applications of such mixtures as 0-8-24, 2-8-16 and 0-12-12 have proved very profitable.

fore to apply nitrogenous fertilizers quite near to the time they will be utilized by the crops.

Phosphoric acid and potash on the other hand do not leach from the soil to any great extent. In fact practically no phosphoric acid passes through the soil with the drainage water and the amounts of potash so lost are quite small. This permits of the application of these plant foods at any convenient time with the knowledge that any portions unused by the plants will remain in the soil for succeeding crops.

The conditions are somewhat different on soils composed largely of organic matter such as mucks and peats. Data collected by this station indicates that some of these soils fix in an insoluble form considerable quantities of phosphoric acid and potash while others retain only small amounts.

HOME MIXING

Some farmers prefer to mix their own fertilizers as by this means they can procure any analysis they desire. There is also some saving in home mixing, which in the case of high analysis goods may amount to $9 or more per ton, if the farmer's labor is not taken into consideration.

The mixing process is very simple and requires no equipment beyond a pair of scales, a shovel, a screen, a tamp of any description, and a tight floor suitable to mix on. The procedure is as follows: Crush each material to be used by rolling with a heavy fence post or by means of some sort of a tamp and pass through the screen to be sure all lumps are removed. Then by referring to Table 3 find the amount of each ingredient needed to make the mixture desired. Weigh out these amounts and thoroughly mix them together by shoveling over and over on a tight floor. Sand or dry earth may be used for filler if any is needed although it is not necessary to use filler. When no filler is used, however, a proportionately less amount of fertilizer per acre is needed to supply the plant food desired. For example, if one wishes to make a ton of 2-12-2 using sulphate of ammonia, acid phosphate, and muriate

Table 3.—The amounts of materials to use in a 1,000-pound mixture in order to obtain the percentage shown in the left hand column.

Percentage required	Available nitrogen from		Available ammonia from		Available phosphoric acid from 20% acid phosphate	Available potash from sulphate or muriate of potash
	Nitrate of soda	Sulphate of ammonia	Nitrate of soda	Sulphate of ammonia		
2	134	97	110	80	100	40
3	200	146	165	120	150	60
4	267	194	220	160	200	80
8	534	388	440	320	400	160
9	601	437	495	360	450	180
10	668	485	550	400	500	200
12	801	582	660	480	600	240
16	1068	776	851	640	800	320

The remainder of the 1,000 pounds should be made up of dry earth or fine sand as a filler.

of potash, it will require according to the Table, 160 pounds of sulphate of ammonia, 1500 pounds of acid phosphate, and 80 pounds of muriate of potash. These amounts total 1740 pounds. To make a ton, therefore, it would be necessary to add 260 pounds of filler. If you plan to use 200 pounds per acre of this mixture and do not wish to use filler, use the same proportion of your mixture as 200 is of 1 ton. Thus 200 is 1-10 of 1 ton. 1-10 of 1740 is 174, so you could supply the same amount of plant food in 174 pounds of the clear mixture as you would in 200 pounds if filler were added.

It should be borne in mind that acid phosphate, sulphate of ammonia, muriate of potash, and similar carriers contain no added filler even though they do not consist of 100 per cent plant food. This is because the plant nutrients such as potash, phosphoric acid, and ammonia are of such a nature that they cannot be utilized alone and so must be combined with other substances. There are also certain amounts of materials produced during the process of manufacture and purification which could only be removed at considerable additional expense.

Fig. 20.—When properly fertilized sugar beets not only give a greater tonnage, but are also more disease resistant. Left, fertilized. Right, unfertilized. Note, poor stand due to ravages of disease.

FERTILIZERS DO NOT BURN OUT HUMUS

The opinion is sometimes voiced that fertilizers will burn out or decrease the supply of humus in the soil. There is no basis for this belief as is shown by the data from the Ohio Experiment Station in Table 2.

This experiment shows that while the fertilized land did not contain so much organic matter at the end of the test as did that receiving lib-

Table 2.—Effect of fertilizers on accumulation of organic matter.
All crops removed (15-year period)

Soil treatment	Total applied in 15 years Tons per acre	Total produce in 15 years. Lbs. per acre	Organic matter in soil at end of test. Lbs. per acre
No fertilizer	none	40,960	42,800
Complete fertilizer	5	117,910	60,800
Manure	190	139,670	73,600

eral applications of manure yet it contained approximately 50 per cent more than it would have if no fertilizer had been used.

It is also interesting to note that although the manured land produced approximately 16 per cent more crops than that receiving fertilizer yet the fertilized field yielded about 65 per cent more than the unfertilized even though no green crop or other humus forming material was turned under.

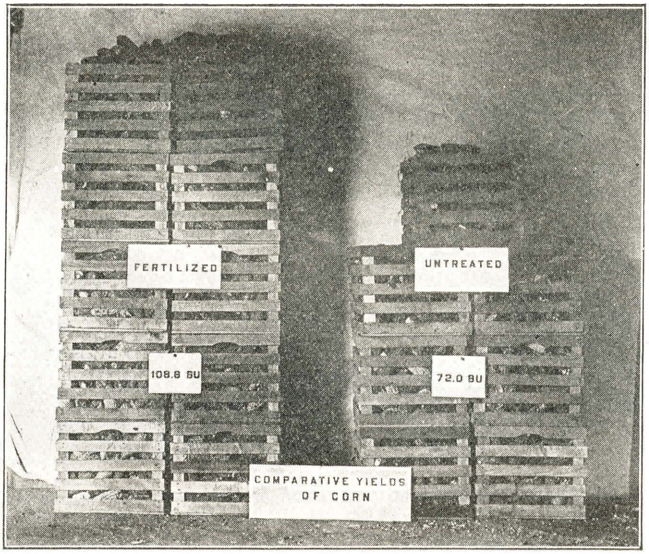

Fig. 21.—Corn needs to be fertilized on most Michigan soils.

FERTILIZATION OF PASTURES

Permanent pastures may be much improved by fertilization as has been shown by a number of Experiment Stations. The following results from West Virginia are representative of the improvement which may be expected. Sheep grazed on new pasture properly fertilized made an average gain of 43.0 pounds, while on a similar pasture which received no fertilizer the gain was only 29.5 pounds. During the following season the second pasture was also fertilized with the result that the average gain of the sheep was 61 pounds compared to 63 pounds on the pasture fertilized previously. The improvement in the pasture was largely due to the beneficial effect of the fertilizer on the growth of clover.

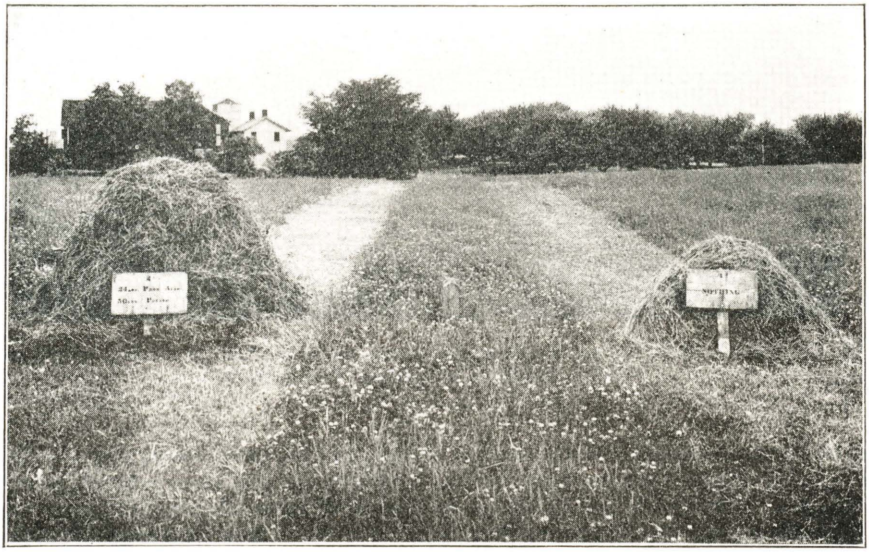

Fig. 22.—Proper fertilization not only makes a pasture capable of carrying more stock but improves the quality of the forage by bringing in legumes. Left, fertilized; right, unfertilized. Courtesy of the Pennsylvania Experiment Station.

NITROGEN FROM LEGUMES VS. COMMERCIAL NITROGEN

The question, "Is it not cheaper to supply nitrogen to the soil by growing legumes than to use commercial nitrogen" is quite common and is very pertinent. There is no doubt that nitrogen can be gathered by legumes at a lower cost than it can be purchased in fertilizers. In Regular Bulletin No. 290 of this Station the writers make the following statement. "The cost of production of a pound of nitrogen by means of leguminous crops in a rotation is difficult to determine. It should be conceded that much of the benefits derived from the use of lime is due to the effect on the legumes such as clovers and alfalfa. It seems fair to charge two-thirds the cost of the lime to these crops, and also to charge for the fertilizer that should be added to the soil for their benefit. If two tons of lime are applied per acre and endure six years and a four-year rotation is followed and two seedings of clover, vetch, or soy beans are obtained, and where one hundred pounds of acid phosphate are added to each seeding the cost of nitrogen runs from five to

Fig. 23.—When little or no fertilizer has been used on the preceding crop, oats will be benefited by proper fertilization.

eight cents a pound. If no lime is added to the land, naturally the cost is less or from two to four cents. Alfalfa is the cheapest source of nitrogen. On the same basis as in the first case above, nitrogen may be produced for less than one-half what it costs when obtained by means of other legumes. If the crop stands four years instead of six the cost is slightly higher."

When the cost of producing available nitrogen decreases, as it very probably will in the near future, the price of nitrogen in fertilizers will more nearly approach the cost of obtaining it through the growth of legumes. When these conditions come about much more nitrogen from this source undoubtedly will be used.