Fertilizers, What They Are and How to Use Them
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FERTILIZERS

What They Are and How to Use Them

C. E. MILLAR

The longer land is under cultivation the greater becomes the necessity of supplementing the supply of available plant food in the soil by addition of manure and commercial fertilizer if crops are to be produced economically. Right, no fertilizer. Left, 4-16-8 fertilizer.

AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

SECTION OF SOILS

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

C. E. MILLAR

Every resident of the State of Michigan is affected financially and socially by soil conditions, since the farmer's income and the cost of food stuffs and clothing materials are vitally influenced by the productiveness of the soil. In many sections of the State, the status of soil fertility is the outstanding economic problem for both the business man and farmer. 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. The farmers now are provided with better seed of adapted and superior varieties and improved tillage implements, have the services of county agricultural agents and other educational sources at their disposal, and are better informed regarding disease control and improved farming methods, so the reported decrease in yields may be ascribed, in part at least, to a decline in soil productivity.

In view of these facts, the writer presents 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, time, rate, and method of fertilizer application and their effects on soil and crops.

FOOD ELEMENTS REQUIRED BY PLANTS

The 10 plant food elements required in considerable quantities for growth are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulphur. If any one of these elements is not supplied in adequate quantity plant growth will be limited. Plants use several other elements in small quantities and cases have been recently reported from other states where plants were suffering from lack of manganese, boron, copper, or zinc. The plant has three sources, air, water, and soil, from which to obtain its food. Oxygen and hydrogen are procured from water by plants, while carbon and oxygen are taken from the air. Legumes, through the bacteria in the nodules which develop on their roots as a result of inoculation, procure some nitrogen from the soil air. All the other plant food elements

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

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. Unfortunately, soils may contain considerable total quantities of plant nutrients and yet supply very limited quantities in a form that is useable by plants. Even under very favorable conditions, the natural supply of insoluble food elements in soils passes slowly into an available state. It is highly desirable, therefore, that the humus content of the soil be maintained and the best farming practices be followed in order to facilitate the passage of the plant food into an available form. In the light of experimental results a brief discussion of the question as it pertains to Michigan is given.

Nitrogen—The soil's supply of this element is contained in the humus or organic matter. As the organic content of soils varies greatly, so must the nitrogen supply. Through the decay of the organic matter the nitrogen

Fig. 1.—Alfalfa removes large quantities of phosphoric acid, potash and lime from the soil. On heavy loams, silt loams, and clay loams a fertilizer high in phosphoric acid is essential for maximum yields. In many cases some potash is also advisable.

is converted into a soluble and useable form. Experiments have shown that at least a small quantity of nitrogen can advantageously be used for most crops on the majority of Michigan soils. In the case of badly run soils, especially of a sandy nature, larger quantities are desirable. Recent applications of manure and the plowing under of leguminous sods decrease the need for commercial nitrogen.

Potassium—Potassium is the active principle of potash and makes up about 83 per cent of pure potash and from 41 to 51 per cent of commercial muriate of potash. The total supply of this element in most mineral soils is large but the rate at which it becomes available is relatively slow, especially in sandy soils and those low in organic content. Alfalfa, clover, and similar legumes usually require liberal applications of potash when grown on sandy soils. Potatoes and sugar beets respond favorably to potash fertilization and the cereals and beans frequently are benefited by the presence of small percentages of this plant food in the fertilizer. Organic soils, muck and peat, contain much smaller quantities of total potash than mineral soils and additions of this elements are almost universally needed.

Phosphorus—Few soils in this state have been found to contain adequate supplies of phosphorus. The total supply is relatively small, and the quantity available falls short of crop requirements. Phosphorus is, therefore, more generally used on mineral soils than any other fertilizing element and virtually all crops respond to an application of phosphorus even on land which has been manured. In discussing fertilizers and soil fertility, it is

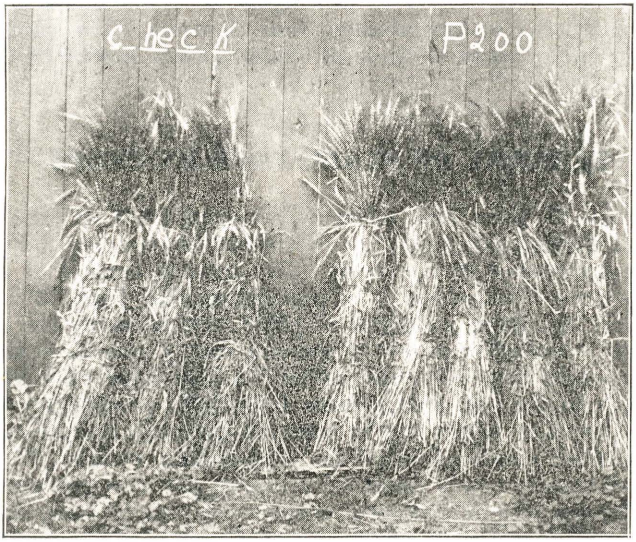

Fig. 2.—On many of the more productive soils of the State superphosphate gives very profitable returns.

customary to use the term phosphoric acid. Phosphorus is the active constituent of phosphoric acid and makes up 43.66 per cent of it. The term phosphate refers to the commercial superphosphate containing usually 16, 20, or around 45 per cent of phosphoric acid.

Iron, Magnesuim, and Sulphur—No soils deficient in available iron have been found in this portion of the United States. Experiments conducted by the Soils Section at Michigan State College have also shown that the response of mineral soils in Michigan 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.

The soils of central United States have been considered so well supplied with magnesium that additions of this plant food element were believed to be unnecessary. While this is undoubtedly true for most soils, experiments indicate that on certain types of soil alfalfa, sweet clover, and possibly other crops may be benefited 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, it must be remembered, is the active constituent of lime and the necessity of applying lime to the large majority of our soils to correct the acid condition before they will grow alfalfa, sweet clover, or clover successfully must not be overlooked. Many of the other crops commonly grown in Michigan yield better on soils which are not too strongly acid.

Manganese, Boron, Copper, and Zinc—Up to the present time, no mineral soils have been found in Michigan on which plant growth was limited by a deficiency of any of these four elements. The need of certain muck soils for one or more of these elements is yet a matter of experiment.

REMOVAL OF PLANT FOOD BY CROPS

The quantities of plant food elements removed from an acre of soil by good yields of the common crops are of interest in studying the problem of soil fertility maintenance on any farm. The nutrient content of many farm products is presented in Table 1. In considering this Table, it is important to bear in mind that these quantities of plant food elements are taken from the more readily *available* portion of the soil supply and while the amounts removed by a single crop may seem rather small in some cases compared to the *total* supply in the soil, they assume formidable proportions when compared to the quantities which can be removed by crops economically. Also, when the quantities contained in all the crops of the rotation are added, or the plant food removed as a result of cropping for one generation is considered, the reason why it becomes necessary to supply plant food in fertilizer and manure to maintain yields on a profitable level is apparent.

One should never lose sight of the fact that when any product is sold, whether it be beef, wool, milk, wheat, beans, sugar beets, potatoes, etc., the transaction represents a loss to the farm of the plant food elements contained in them.

In Figure 1 is presented the results of a study to determine whether the quantities of plant food elements removed from the soils of the State by staple crops is equalled by the nutrients returned in manure. In calculating the quantities of plant food removed by the crops, the average yields for the 10-year period 1921 to 1930 of the following crops were considered: corn, wheat, oats, rye, barley, beans, buckwheat, sugar beets, apples, peaches, pears, cabbage, onions, potatoes, mixed hay, and alfalfa.* This diagram shows plainly that if the plant food returned to the soil is to equal that re-removed in common crops other sources than manure must be resorted to.

*As inoculated alfalfa takes nitrogen from the air, the potash and phosphoric acid only are calculated as being removed from the soil.

Table 1.—Quantities of plant food elements contained in farm products.

Crop	Amount	Pounds				
		Nitrogen	Phosphoric Acid	Potash	Calcium	Magnesium
Sugar beets (Tops removed)	10 tons	36.6	13.4	56.2	....	....
Wheat	Grain 25 bu	30.0	12.8	6.0	0.64	1.98
	Straw 2,500 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 3,000 lbs	30.0	9.0	42.0	14.15	2.52
	Cobs 500 lbs	2.0	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 2,500 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 2,000 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 5,000 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 1,600 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 2,000 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 hay	2 tons	50.0	22.0	40.0	7.11	4.08
Clover hay	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 lbs	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
Sweet clover—about May 1st	1,995 lbs.—air dry tops	75.0	13.5	49.6	31.4	7.4

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.

WHAT TYPE OF FARMING MAINTAINS FERTILITY

The opinion is sometimes expressed that, in certain types of farming, virtually as much plant food is returned to the soil as is removed in the crops. In order to obtain some information on this point, calculations have been made of the plant food balance on a grain farm carrying practically no livestock, on the so-called general farm carrying a considerable number of livestock, and on a farm carrying a very large number of stock. The results of these studies are presented in Figures 5, 6, and 7.

As might be expected the Figures show a large deficit of all three plant food elements, nitrogen, phosphoric acid, and potash, on the farm carrying

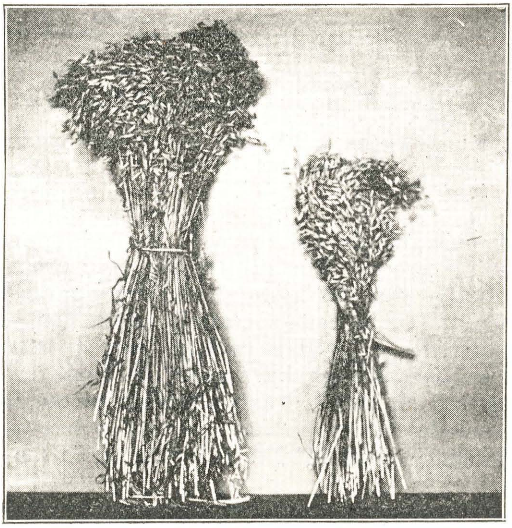

Fig. 4.—Plenty of available plant food means larger oat yields. Left, fertilized. Right, unfertilized.

virtually no livestock. It is evident that this system of farming will necessitate the purchase of considerable quantities of commercial fertilizer if soil depletion is not to result very quickly.

On the general farm carrying six cows, four young cattle, five horses, and fourteen hogs, the plant food balance is not improved as much as one might expect. This condition undoubtedly comes about through the fact that on such farms manure is usually handled very carelessly so that a maximum of waste results. Better methods of handling manure on these farms will decrease the quantities of commercial fertilizers required to maintain satisfactory yields.

The keeping of a large number of livestock make possible the return to the soil of much larger proportions of the plant food removed by crops than when these crops are sold from the farm. It is of vital interest, however, to observe that even with 55 head of stock on a 100 acre farm the manure

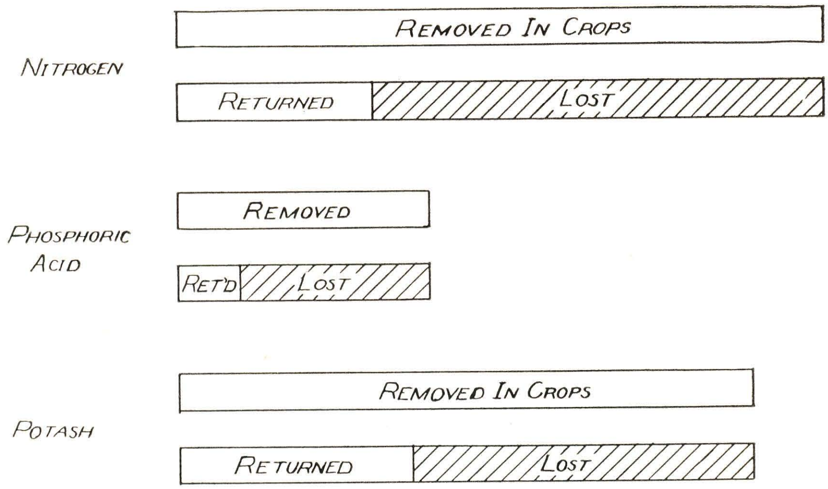

Fig. 5.—Plant food balance on a 100 acre grain farm carrying 2 cows, 5 horses and 14 hogs.

failed by a considerable margin to return to the soil as much plant food as was removed in the crops. The greater the care used in handling the manure the more nearly can the livestock farmer approach the goal of fertility maintenance. That he cannot entirely attain that objective without purchasing large quantities of feed is evident from an examination of the plant food content of livestock products given in Table 1.

A study of Figures 5, 6, and 7 draws attention to the fact that no type of farming which includes the marketing of crops or livestock products will return to the soil as much plant food as is contained in the crops produced.

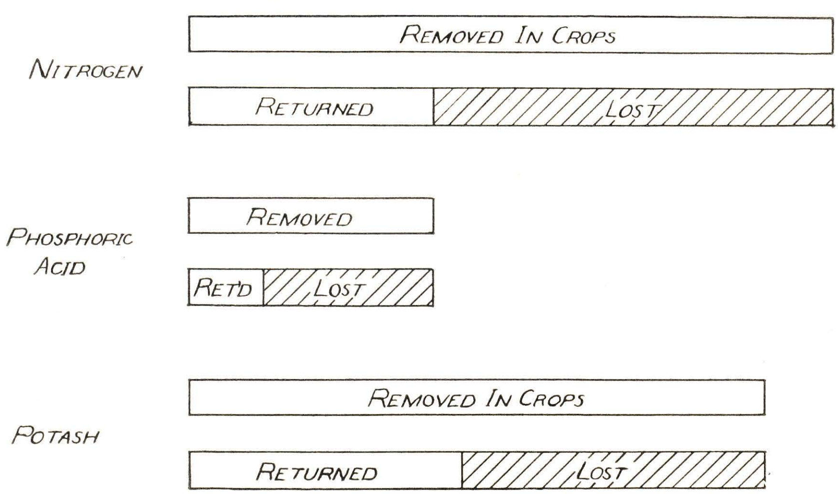

Fig. 6.—Plant food balance on a 100-acre general farm carrying 6 cows, 4 young cattle, 5 horses, and 14 hogs.

This relation is especially true with reference to phosphoric acid and potash. The facts regarding nitrogen are less definite because there is a certain 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 25 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 unquestionably vary considerably. 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.

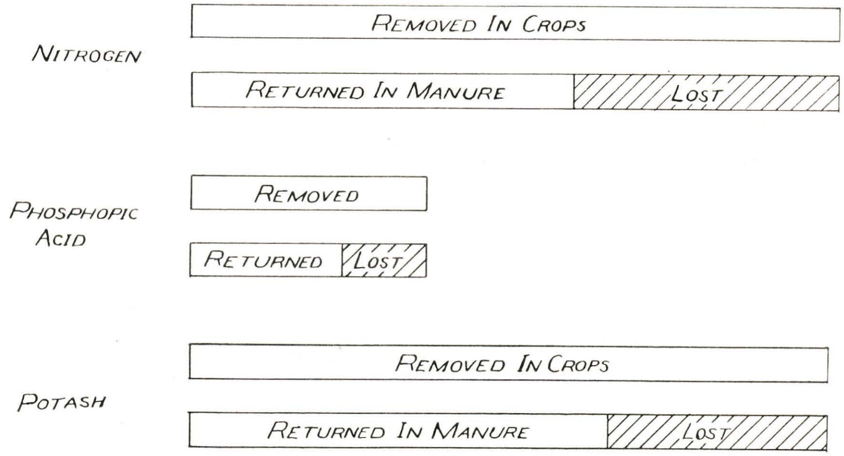

Fig. 7.—Plant food balance on a 100-acre dairy farm, carrying 20 cows, 10 young cattle, 5 horses and 20 hogs.

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 the plant turning yellow and by a slow and stunted growth, and an abundance of this nutrient results in a rapid growth with a much larger development of dark green leaves and stems. A supply of available nitrogen during the early life of the plant frequently stimulates growth and results in earlier maturity. On the contrary, when an excess of nitrogen is present throughout the growing period there is a tendency for the plant to fail to mature. An unnecessarily large supply of nitrogen also encourages the production of soft, succulent tissue which is susceptible to mechanical injury and the attack of disease. In the case of vegetables used for their leaves, nitrogen gives a crispness and improved quality. During the early spring, an application of available nitrogen on fall seeded grains growing on badly depleted and on sandy soils is very beneficial. Nitrogen has a place in the fertilization of most crops and is used in large quantities in the fertilization of lawns, golf courses, vegetables, and fruits.

Phosphoric Acid—When a soil is not well supplied with phosphoric acid, the plants do not grow as 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

Fig. 8.—Phosphoric acid plumps the kernels and improves the market grade. Right, fertilized with superphosphate. Left, unfertilized. On the heavier types of soil, well supplied with organic matter, phosphoric acid is the plant food element most needed.

a plant with a large root system can gather 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 fertilizers containing high percentages of soluble phosphoric acid have given profitable increase in yield. It is often the case with acid soils, however, that the returns from the use of phosphate are not so good as they are after the soil has been 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 stiff, thus preventing lodging to a certain extent.

When well supplied with potash, plants exhibit a green thrifty appearance. Where potash is lacking, the plants have a yellowish, unhealthy appearance and are somewhat more subject to disease. Clover, alfalfa, and sweet clover use large quantities of potash and are very sensitive to a lack of it. A peculiar spotting of the leaves of alfalfa is frequently noted when the crop is suffering from a lack of potash.

PLANT FOOD ELEMENTS CARRIED BY FERTILIZERS

The preceding discussions have pointed out three pertinent facts. First, farm products remove considerable quantities of plant food elements from the soil. Second, systems of farming commonly practiced fall far short of returning to the soil as much plant food as is removed in crops. Third,

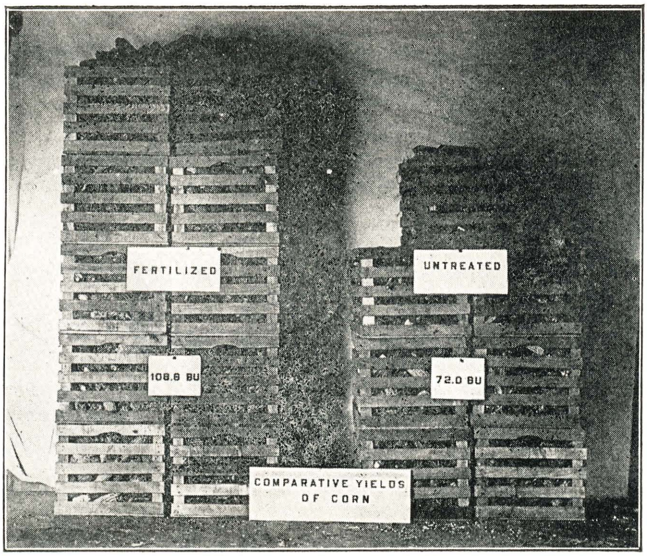

Fig. 9.—Corn responds markedly to fertilization.

the nutrients used by crops must be considered as coming from the limited *available* supply in the soil. It is very evident, therefore, that some means must be employed to supplement the quantities of plant food returned to the soil if yields are to be maintained at a profitable level because the available supply naturally in the soil is rapidly diminishing. Commercial fertilizers are the commodity prepared to meet this requirement. Furthermore, fertilizers are varied in composition to meet the different plant food relationships encountered in different soils resulting from different methods of management and from natural variations in soil composition. Thus, by careful selection of the fertilizer it is possible to enable the crop to make better use of the fertility in the soil.

As soils are more generally deficient in either nitrogen, phosphoric acid, potash, or some combination of these three nutrients, fertilizers are manufactured to supply any one, two, or all three of them. A mixture carrying all of these elements is called a complete fertilizer.

The various materials used to supply the plant food elements in making a fertilizer are called carriers. Thus superphosphate and bone meal are carriers of phosphoric acid. Sulphate of ammonia, nitrate of soda, and cyanamid are examples of nitrogen carriers. The following table gives the principal carriers of the plant food elements and the approximate percentage of the nutrient contained.

Table 2.—Important carriers of plant food and the percentage of nutrients they contain.

Carriers of nitrogen	Per cent nitrogen	Carriers of phosphoric acid	Per cent available phosphoric acid	Carriers of potash	Per cent potash
Nitrate of soda	15.5	Superphosphate	16.0	Muriate of potash	50.0 to 62.0
Sulphate of ammonia	20.7	Superphosphate	20.0	Sulphate of potash	50.0
Dried blood	11.2	....	....	Kainit	12.8
Tankage	4 to 12	Treble superphosphate.	43 to 46	....	....
Nitrate of lime	15.5				
Calcium cyanamid	21 to 24.6	Steamed bone meal	28.0*		

*Total phosphoric acid and **not available** as in the case of other carriers.

MANUFACTURE OF FERTILIZER

In the early years of the fertilizer industry, the majority of the materials used, especially to supply nitrogen, were waste products from other industries. The situation has rapidly changed, however, until now fertilizers are made very largely from materials prepared

Fig. 10.—An abundance of plant food is essential for maximum yields of legumes. Clover from equal acres of land, left, unfertilized; right, fertilized.

especially for the purpose. It is true that considerable quantities of tankage, bone, blood, cottonseed meal and other seed pomaces, fish meal, tobacco stems, wastes from sugar refineries, and similar materials are used as fertilizer. The major portion of the fertilizer nitrogen today, however, is derived from ammonium sulphate a byproduct of coke manufacture; nitrate of soda from Chile; and products prepared by fixing nitrogen from the air as calcium cyanamid, nitrate of soda, sulphate of ammonia, nitrate of lime, and Urea. Another product prepared from the sewage of cities is also being used in considerable quantities.

While bone meal is still sold as a fertilizer to some extent, the available phosphoric acid used in fertilizer manufacture is very largely derived from super-phosphate prepared by treating raw rock phosphate with sulphuric acid.

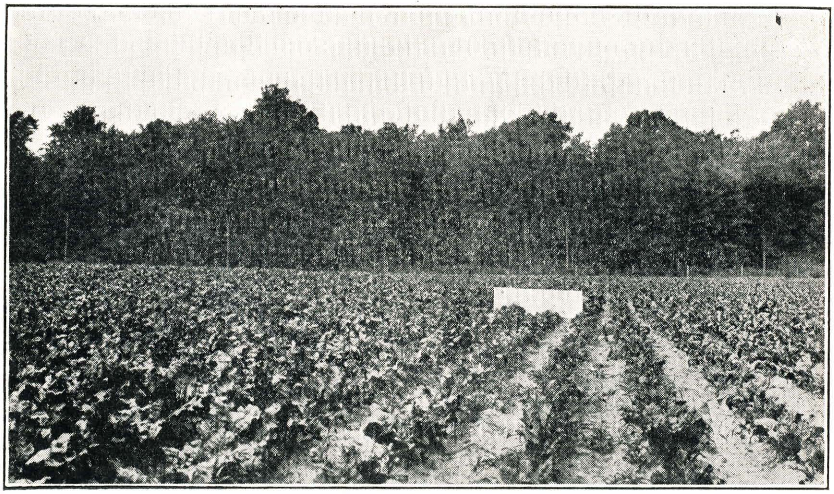

Fig. 11.—Sugar beets do not thrive unless there is ample plant food in the soil. On the majority of soils in the state suitable for beet growing a complete fertilizer is advisable. Right, 0-20-0. Left, 4-16-4 fertilizzer.

For years, Germany supplied nearly all the potash sold for fertilizer purposes. To the German supply, are now added appreciable quantities from the French mines and from Searles lake in California. Small quantities also come from tobacco wastes, sugar refineries, and other industries.

The manufacture of certain of the materials mentioned, the mining and purifying of others, and the final mixing to form fertilizers of definite composition which will retain their desirable physical condition for considerable periods of time constitutes the work of fertilizer manufacture. It is almost unnecessary to state that many of the larger fertilizer companies maintain research departments for the purpose of increasing the efficiency of manufacturing processes and of improving the product.

FERTILIZER ANALYSES

Since fertilizers are designed to supply one or more of the plant food elements, nitrogen, phosphoric acid, and potash, the law requires that the percentage of each of these nutrients be printed on the container or on a tag attached to the container. It has become customary on the larger containers at least to print the percentages with dashes separating the figures, as 2-12-6; 0-14-6; 4-16-8. This series of figures is popularly known as the analysis of the fertilizer.

In Michigan and the majority of the northern states the first figure in the analysis gives tht percentage of **total** nitrogen. Occasionally, the statement is made that the figure represents available nitrogen.

Fig. 12.—When little or no fertilizer has been used on the preceding crop, oats will be benefited by proper fertilization.

This statement is technically true since all fertilizer nitrogen, no matter in how crude a form, will ultimately become available even though it may take several years in the case of some materials. However, many fertilizers contain virtually all of their nitrogen in a quickly available and sometimes even water soluble condition. In general, the fertilizer put out by reliable companies, and especially the higher analysis fertilizers, can be depended upon to contain their nitrogen in such a condition that it will become available readily.

The second figure in the analysis represents the percentage of *available* phosphoric acid. In the case of bone meal, the total and not the available phosphoric acid content is given. In many of the southern and a few of the eastern States, the second figure gives the percentage of nitrogen and the first figure the percentage of available phosphoric acid.

The percentage of *water soluble* potash is presented by the last figure in the analysis.

When a company wishes to offer a fertilizer for sale in Michigan at a price of $10 or more per ton, a certified copy of the analysis together with the brand name or trademark and a two-pound sample in a sealed glass can must be filed with the State Commissioner of Agriculture. Upon payment of a fee, the company is licensed to place the designated fertilizer upon the market. This procedure is required for every brand or analysis of fertilizer offered for sale by any company.

The state chemist then has the responsibility of making sure that the companies furnish a product in accord with the guaranteed analysis. To render this service, inspectors are sent out who have authority to

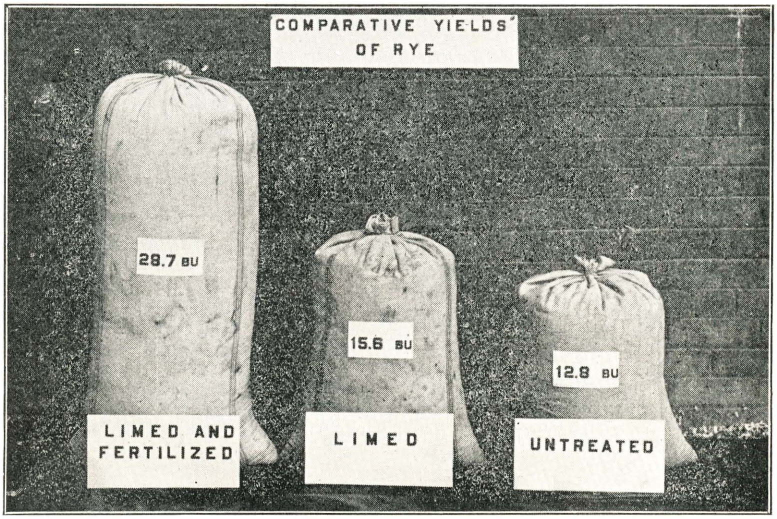

Fig. 13.—On quite acid soils rye is benefitted by liming after which the use of fertilizer rich in phosphoric acid is advisable.

sample the brands of fertilizer offered for sale at any point in the state. These samples are sent to Lansing where they are analyzed in the laboratory of the State Chemist and the results checked against the guaranteed analysis. By this means, the purchaser is protected from loss through the activities of unreliable companies.

Fertilizers sold for less than $10 a ton do not come under state inspection and, hence, are purchased at the buyer's risk. Fertilizers ordered from outside the State by mail are also not subject to State inspection.

THE PRICE OF 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.

Fig. 14.—Potatoes require an abundance of available plant food for large yields and high quality. A complete fertilizer is usually advisable in addition to manure. The result of using no fertilizer is shown in the foreground. In the background a 4-16-8 was applied.

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, since, as was just pointed out, the making of many different analyses is expensive. The Soils Section of the Michigan Station has selected a list of fertilizers 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, rate and method of application are contained in Circular Bulletin No. 53 of the Michigan Experiment Station. In the interest of economy, fertilizer users are advised to make their purchases from this list. Quite a number of analyses, differing slightly from those recommended, are on the market. It must be remembered that this increase in number of analyses adds to fertilizer prices. If you order early, your dealer can get what you want so do not accept goods that are similar in analysis and are "just as good."

Another source of expense to the user of fertilizer is the purchase of low analysis mixtures. It can be readily 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

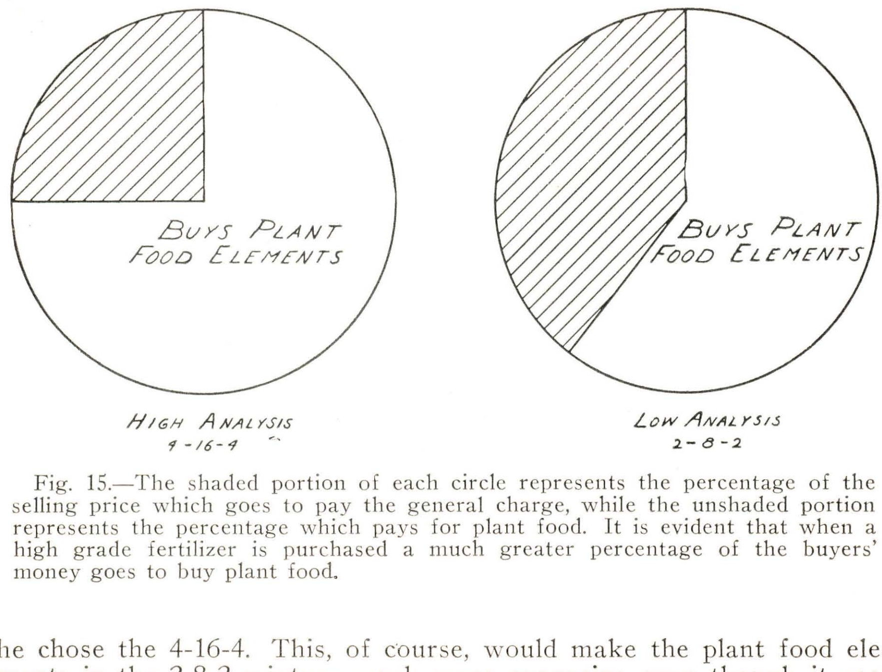

Fig. 15.—The shaded portion of each circle represents the percentage of the selling price which goes to pay the general charge, while the unshaded portion represents the percentage which pays for plant food. It is evident that when a high grade fertilizer is purchased a much greater percentage of the buyers' money goes to buy plant food.

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.

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.

CONCENTRATED FERTILIZERS

As just pointed out high analyses fertilizers can be purchased more economically than those containing lower percentages of plant food. The appearance on the market in considerable quantities, a few years ago, of super-phosphate containing approximately 45 per cent phosphoric acid seemed to be the signal for a very decided movement toward higher analysis goods. While fertilizers containing 10 to 12 per cent of plant food were common not many years back and a mixture with 14 per cent or more plant nutrients was considered of high grade, at present, a fertilizer must contain around 20 per cent or more of plant food to be considered in the high grade class and mixtures running from 30 to 60 per cent are not uncommon.

Fig. 16.—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 3-9-18 have proved very profitable.

These new fertilizers have brought with them new problems of utilization. The question of suitable distributing attachments to seeding machinery which will place the plant food in some definite location with reference to the seed and which will apply the small quantities that are commensurate with the richness of the fertilizer comes first. Then, there is the matter of how much of such concentrated material can be dropped near the seed without damage to germination or the young plant. While answers to these questions are being worked out, these and other problems place difficulties in the way of the general farm utilization of the extremely concentrated mixtures. This move toward higher analysis is highly desirable, however, and it is of interest to note that superphosphate of 45 per cent strength and mixtures of 30 per cent or more of plant food are being used satisfactorily by large numbers of farmers.

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 varies with the analysis to be mixed and the prevailing price of fertilizers, 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 for mixing. The procedure is as follows: Crush each material to be used by rolling with a heavy fence post or by

Fig. 17.—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.

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 2-12-6 using sulphate of ammonia, superphosphate, and muriate of potash, it will require according to the Table, 160 pounds of sulphate of ammonia, 1500 pounds of superphosphate, and 120 pounds of muriate of potash. These amounts total 1780 pounds. To make a

Table 3.—The amounts of materials to use in making 1,000 pounds of fertilizer having the percentage of plant food shown in the left hand column.

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

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

ton, therefore, it would be necessary to add 220 pounds of filler. If you plan to use 200 pounds per acre of this mixture and you 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 1780 is 178, so you could supply the same amount of plant food in 178 pounds of the clear mixture as you would in 200 pounds if filler were added.

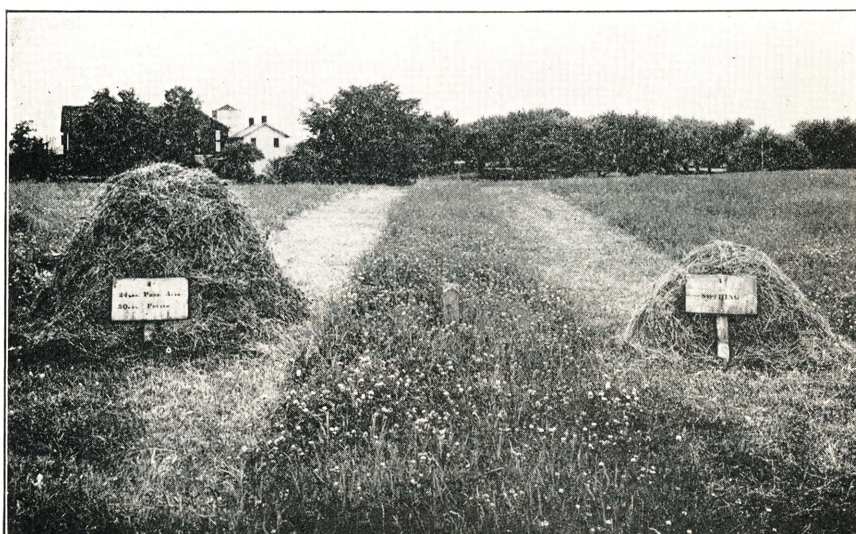

Fig. 18.—Proper fertilization not only makes a pasture capable of carrying more stock, but improves the quality of the forage by bringing in legumes. Left, fertilized; right, unfertilized. Courtesy of the Pennsylvania Experiment Station.

INFLUENCE OF FERTILIZERS ON SOIL ACIDITY

The opinion sometimes expressed that superphosphate makes soils acid is not based on experience. In fact, there is some experimental evidence that this fertilizer will delay the acidity of soils or help 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.

Some fertilizers have a slight tendency to increase or aggravate the acid condition of the soil. Muriate and sulphate of potash do this

Fig. 19.—Some of the most productive wheat soils give more profitable returns from fertilization than less fertile land. Above, unfertilized. Below, fertilized.

Fig. 20.—Fertilized wheat field.

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. Fertilizer containing sulphate of ammonia should not be discriminated against, however, since the increased quantity of lime needed to keep the soil in condition for growing legumes in a normal system of soil management is of little if any practical significance.

In general, it may be stated that the systematic use of medium to large quantities of superphosphate or of high grade mixed fertilizer at suitable times in the rotation may be used without fear of making the soil acid.

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 4.

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

Table 4.—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

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.

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 therefore to apply nitrogenous fertilizers relatively 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

Fig. 21.—When heavy applications of fertilizer are made, usually considerable phosphoric acid and potash remain for use by the following crop. Left, oats on land fertilized the previous year with 4-16-4 for sugar beets. Right, oats on land receiving no fertilizer the previous year for sugar beets.

potash so lost are comparatively 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 indicate that some of these soils fix in an insoluble form considerable quantities of phosphoric acid while others retain only small amounts. None of the organic soils retain any considerable quantities of soluble nitrogen, and potash leaches from them much more easily than from mineral soils.

MOVEMENT OF FERTILIZER IN THE SOIL

The appearance on the surface of many soils during dry weather of gray, ashy material indicates that soluble substance moves with soil water. During dry periods, chemical determinations show an accumulation of soluble salts at the surface of soils. Rains redistribute these salts through the soil. A crop or heavy growth of other vegetation greatly diminishes this accumulation at the surface because the plants use much of the soil water thus preventing its movement to the surface and evaporation, leaving the soluble salts.

Fig. 22.—Soils that are somewhat sandy need potash in addition to phosphoric acid for best results with legumes. Lelt, lime and superphosphate. Right, lime, superphosphate, and potash.

This movement of soluble material in the soil takes place almost entirely in a vertical direction. It is evident, therefore, that if plant food is to be utilized by crops, it must be placed so that the roots will quickly come in contact with it as it will not move toward the roots except in a vertical direction. Most soils have the power to "fix" or render relatively insoluble considerable quantities of certain plant foods, principally phosphoric acid, and to a lesser extent potash, hence these nutrients move very little even vertically and should be so placed that the roots of crops are sure to reach them.

METHOD OF APPLICATION

The returns from fertilizer are governed not alone by analysis and rate of application, but are influenced to a considerable extent by method of application. It is quite generally recognized that plant food applied near the seed stimulates the early growth of the plant and very frequently results in a greater increase in yield than when the fertilizer is worked uniformly through the soil. For the small grains, the fertilizer should always be dropped near the seed through the fertilizer attachment of the drill. In case the drill used has no attachment, the plant food may be broadcast and worked into the soil to the depth of several inches before planting. The results obtained by this method of application are usually not so satisfactory, however, as when the fertilizer is drilled with the seed.

Numerous experiments have indicated that, for corn, it is better to drop the fertilizer in bands on either side of the seed. It is not yet determined whether the bands should be above, level with, or below the seed. Undoubtedly, seasonal conditions will have much to do with this point. It is not advisable to drop the fertilizer directly with the seed as damage may result if large quantities are used or if there is a deficiency of rainfall shortly after planting. Distributing attachments to planters are rapidly being improved but as yet many of them may drop the fertilizer with or directly above the seed. It is not advisable, therefore, to use more than 125 pounds per acre when the corn is checked or 200 to 300 pounds when drilling in rows. This precaution is especially to be observed when high-analyses fertilizers are used.

Beans are very easily damaged by fertilizer and hence only small quantities should be applied with the seed. If planting is done with a grain drill, not more than 200 pounds of fertilizer per acre should be used if it is allowed to fall through all the holes. In case plant food is applied only through those drills which plant the beans, not more than 15 to 20 pounds per drill row per acre should be used. This is also a safe rule to follow when planting with a bean and beet drill. Some farmers follow the practice of sowing fertilizer through the drills on either side of the ones planting beans. There is no danger of damage by this method even when large quantities of fertilizer are applied, but there is the objection that the crop does not get the benefit of the plant food until the roots have extended over into the next drill row.

Experiments with sugar beets show that very satisfactory results are obtained by plowing under about three-fourths of the fertilizer, amounting usually to from 300 to 400 pounds, and by applying the remainder through the fertilizer attachment of the drill at seeding time.

Numerous experiments have shown that the potato crop profits more when the plant food is dropped near the seed piece than when it is distributed over the entire surface soil and worked in. Potato sprouts are very sensitive to damage from too much soluble material, especially in dry weather. It is advisable, therefore, that the fertilizer be so placed that no appreciable quantity of it can come in direct contact with the seed piece or young sprouts. Present indications are that placing the fertilizer in bands on both sides of and a short distance from the seed piece is a very satisfactory method of application. Further experiments are under way to determine whether this is the best location for the fertilizer and how deep the plant food should be placed.