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THE FERTILITY OF THE SOIL

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The problem of maintaining soil fertility is one of the most important of those confronting the farmers of Missouri. The future prosperity of the state is closely associated with the future productivity of the soils. Unfortunately, the present methods of soil management are on the whole not maintaining soil fertility. They are, in general, better suited to a region of new and virgin lands

Figure I. COWPEAS ON THE BOWLING GREEN EXPERIMENT FIELD

This crop is well adapted to Missouri conditions and is very valuable for adding organic matter and nitrogen to the soil, when pastured or turned under.

than to one where farming is an old industry. In other words, the agriculture of the country is new as compared with that of European countries and the agricultural methods have not yet reached a condition suited to older settled regions. Nevertheless, the methods are changing as soils and crop adaptations are better understood. The increasing value of farm lands is making it necessary to get more out of the soil than ever before. With an increased productivity there must necessarily be associated a higher state of fertility, if larger yields are to be maintained.

SOIL COMPOSITION

Soil is composed of finely pulverized rock material or mineral grains, through which is mixed varying amounts of organic matter, sometimes spoken of as vegetable matter or "humus". These mineral grains are variable in composition, depending upon the rock or rocks from which the soil was formed. It is from these mineral grains, as they slowly dissolve under the influence of various agencies of weather and bacterial action, that the bulk of the mineral foods are derived which are used by plants in their growth.

The plant foods necessary to the growth of crops are usually spoken of as the elements of plant food. Those coming from the soil proper are seven in number and are as follows: nitrogen, phosphorus, potassium, calcium, magnesium, iron and sulfur. In discussing these elements of plant food it is very common to refer to the compounds in which they occur. For instance, nitrogen may be combined in the form of ammonia or ammoniates, phosphorus in the form of phosphoric acid or phosphates, potassium in the form of potash and calcium in the form of lime.[1]

Of these seven elements, the nitrogen is found in the organic matter of the soil, the other six, mainly in the mineral grains, only a very small per cent being found in the organic matter. So far as the needs of plants are concerned, nitrogen, phosphorus and potassium are the ones most commonly deficient in soils. It is to these three, therefore, that attention is usually confined in discussing problems of soil fertility.

Calcium (lime) is often applied to soils as a corrective of soil acidity, but rarely as a direct plant food. Magnesium compounds are sometimes applied in connection with lime for the same purpose

(1) The term ammonia as used in soil and fertilizer discussions refers to a compound of nitrogen and hydrogen (NH_3); the term phosphoric acid refers to a compound of phosphorus and oxygen (P_2O_5); the term potash refers to a compound of potassium and oxygen (K_2O).

and more rarely as a plant food, while sulfur, according to recent investigations may sometimes be applied to soils as a plant food with benefit.

HOW PLANTS FEED

Plants take up these mineral plant foods only in solution in soil moisture. In other words, the mineral grains in which are locked up the bulk of the mineral plant foods of the soil, must be gradually dissolved by various agencies in order that this mineral food may be absorbed by plant roots. It can, therefore, be said that there exists in the soil, first, what might be termed reserve or unavailable plant food, locked up in the mineral grains and undecomposed organic matter, and, second, available plant food or that which is in a sufficiently soluble form to be taken up by plant roots. This available plant food is present in only small quantities at any time, the reserve or unavailable plant food forming much the larger part of the total supply. The agencies which cause this reserve food supply to be gradually made available to plants are largely under the farmer's control and it is his problem to keep within the soil at those times when plants are growing, sufficient plant food in readily available form for the production of maximum crops.

Of the agencies instrumental in making available the insoluble plant foods in a soil the most important is the action of decaying organic matter. When organic matter decays certain organic acids, mainly carbonic acid, are set free, which aid in dissolving the less soluble compounds. Other agencies have a place in this action, but it is to the presence of considerable quantities of decaying organic matter in a soil that the most important dissolving action is due. Considerable quantities of plant food, particularly nitrogen, are also contained in the organic matter itself. This plant food is made available by the decay and decomposition of the organic matter. The decay of organic matter is largely responsible for the great productiveness of virgin soils containing much of this material.

THE ORGANIC MATTER OF SOILS

The fact that the supply of available plant food in a soil is largely determined by the quantity of organic matter present gives to this constituent of soils a very great importance. Moreover, there are various other ways in which organic matter acts beneficially, such as in preserving a friable condition of the soil, in conserving moisture and in preventing washing. It is to the presence of organic matter that the dark color in soils is usually due and a dark color generally indicates a fertile soil.

Unfortunately, the supply of organic matter may be rapidly reduced in a soil by exhaustive systems of cropping. The continued culture of any crop which necessitates a considerable stirring of the soil, such as corn, or in a lesser degree small grain, will rapidly reduce the supply. When a soil is stirred frequently the conditions are most favorable for a rapid decay of the organic matter. Naturally in this decay considerable quantities of plant food are set free and this is one of the immediate benefits from cultivating corn, but when this practice is continued year after year on the same land the supply of organic matter ultimately becomes so low as to reduce the productiveness below a profitable basis. The constant removal of crops from the land removes large quantities of immediately available plant food and this has much to do with the decreasing productiveness of such soils, but the most important reason for this condition is the reduced supply of organic matter which lessens the available plant food, allows the soil to become hard and compact and increases the amount of surface washing. One of the most disastrous effects of a decreased supply of organic matter is this tendency to wash. Missouri farmers must learn the methods of maintaining organic matter and of reducing washing if their soils are to remain permanently fertile.

LOSS OF PLANT FOODS FROM THE SOIL

As has already been mentioned, the loss of immediately available mineral plant foods where crops are sold from the land, is one of the important causes of a decreased productiveness. The table which follows shows the amounts of nitrogen, phosphorus and potassium contained in the most important crops grown in Missouri and it indicates the amounts of these mineral elements that are lost to the soil when various crops are removed from the land. The columns on the right show the value of the various quantities of plant food figured at the cost of these elements in the form of commercial fertilizers. This does not mean that the land is decreased in value by the amounts given, but rather that if it were necessary to purchase the plant foods in soluble form it would be necessary to invest these amounts to supply the elements the crops remove.

It will be seen by the table that to produce a 75-bushel corn crop there will be removed from the soil, 111 lbs. of nitrogen, 18¼ lbs. of phosphorus and 53 lbs. of potassium and it should be remembered that these amounts are necessary in approximately these

FERTILITY REMOVED BY FARM CROPS

Crop.	Pounds removed.			Value.			
	Nitrogen.	Phosphorus	Potassium.	Nitrogen.	Phosphorus	Potassium.	Total Value
Corn, grain 75 bu.	75.	13.75	14.	$11.25	$1.64	$0.84	$13.73
Corn, stover 2.25 T.	36.	4.5	39.	5.40	0.54	2.34	8.28
Corn. Total crop.	111.	18.25	53.	16.65	2.18	3.18	22.01
Oats, grain 60 bu.	36.	6.	7.	5.40	0.72	0.42	6.54
Oats, straw 1.6 T.	19.	2.5	32.	2.85	0.30	1.92	5.07
Oats. Total crop.	55.	8.5	39.	8.25	1.02	2.34	11.61
Wheat, grain 30 bu.	35.	4.5	8.	5.35	.54	0.48	6.37
Wheat, straw 1.5 T.	14.	3.	25.	2.20	.36	1.50	4.06
Wheat. Total crop.	49.	7.5	33.	7.55	.90	1.98	10.43
Timothy, 1.5 T.	36.	4.5	35.	5.40	0.54	2.10	8.04
Clover, 2 T.	80.	10.	60.	12.00	1.20	3.60	16.80
Cowpea Hay, 2 T.	93.	9.	63.	13.95	1.08	3.78	18.81
Alfalfa, 6 T.	300.	27.	144.	45.00	3.24	8.64	56.88
Fat Cattle, 1,000 lbs.	25.	7.	1.	3.75	0.84	0.06	4.65
Fat Hogs, 1,000 lbs.	18.	3.	1.	2.70	.36	0.06	3.12

proportions. If the soil is in such a condition that only half of the phosphorus, for instance, will be available for a crop in any given season only half a crop will be secured and if there is sufficient phosphorus available for two-thirds of a crop, two-thirds of a crop is all that can be harvested. The same rule would hold for the other elements. This emphasizes the necessity for a balanced food supply.

It will be noticed further that the legume crops such as clover, cowpeas and alfalfa remove very large quantities of nitrogen, but these crops have the power of fixing the free nitrogen gas from the air through the action of the bacteria within the nodules on their roots, so that the larger part of this nitrogen indicated comes from the air rather than from the soil. As a matter of fact, the nitrogen supply of the soil may be increased rather than decreased, by growing these legume crops, especially where they are all or, in part, fed back on the land.

THE COMPOSITION OF MISSOURI SOILS

Analyses which the Missouri Agricultural Experiment Station has made of the various soils of Missouri indicate their most striking deficiencies. The table which follows shows the amounts of nitrogen, phosphorus and potassium contained in the top seven inches (the plow soil) of an acre of typical Missouri soil as compared with a very fertile soil as standard. This standard has been secured by averaging the analyses of a large number of the most fertile soils of the United States and Europe.

ELEMENTS CONTAINED IN THE TOP SEVEN INCHES OF VARIOUS TYPICAL MISSOURI SOILS.

Soil.	Total nitrogen. Lbs.	Acid—soluble phosphorus. Lbs.	Acid—soluble potassium. Lbs.
The standard of a very fertile soil...	6000	2000	5300
Northeast Missouri Level Prairie (Vandalia).....................	3640	1918	6175
Northeast Missouri Level Prairie (High Hill).....................	2700	1608	4714
Northeast Missouri Rolling Prairie (Hurdland).....................	3760	1978	6089
Northeast Missouri Rolling Prairie (Fulton).....................	3640	1754	7188
North Missouri Timber Soil (Laclede)	3000	1221	5362
Ozark Upland (Climax Springs).....	1180	800	2889
Ozark Upland (Otterville)..........	1820	1350	4117
Ozark Upland (Stonehill)...........	1620	740	2623
Ozark Border (New Haven)........	1460	740	5495
Ozark Border (Wittenberg).........	1500	1660	5429
West Missouri Rolling Prairie (Garden City).....................	3560	1445	5262
Southeast Missouri Lowland Silt (Hayti).....................	5320	4584	17785
Southeast Missouri Lowland Sandy Soil (Campbell)................	1700	1711	3566

As will be seen from this table, Missouri soils as a class are lacking particularly in nitrogen and phosphorus. A low nitrogen supply means also a low supply of organic matter since the nitrogen of soils is contained within the organic matter. The potassium supply is comparatively high. Potassium is almost invariably associated with clay and the other fine particles of soils. The clayish nature of a large share of Missouri soils indicates rather a large potassium supply. In fact a number of soil types, particularly a considerable part of the prairies of North Missouri and the so-called "loess" soil of the central and western part of the state, in the counties bordering the Missouri River, contain this element somewhat in excess of the standard. Many of the soils of South Missouri, particularly those of a stony or of a sandy character, contain this element in less amounts, although even here it is in much greater abundance than the nitrogen and phosphorus.

The lime content of many Missouri soils is sufficient, although there are large areas, particularly the level wet prairies both of Southwest and Northeast Missouri, where lime carbonate is somewhat deficient. Since the fertility of a soil depends more upon the supply of lime in the form of carbonate, than upon the total supply of lime, these wet prairies as well as a considerable area of the old farmed land in Missouri will be benefited by liming.

The cause of the low content of organic matter and nitrogen in most Missouri soils has already been indicated as due to an excess of grain farming. This is not necessarily true in the eroded stony lands of certain sections of the Ozark Region since in this case the dry nature of the soil itself, coupled with the erosion, prevents the accumulation of organic matter in any quantity. Where soils are dry the organic matter oxidizes rapidly and only small amounts will accumulate.

The rather low phosphorus supply in most Missouri soils is due primarily to a natural deficiency of this element in the rocks from which the soils were formed and from its loss in the process of soil formation. It is of course true that the exhaustive grain farming that has been followed is responsible for the removal of considerable quantities of this element but this loss is by no means the most important cause of the deficiency that exists.

SOIL ANALYSIS

It would be expected, at first thought, that if one knew the quantities of the various elements of plant food existing within the soil, together with the quantities of these elements required for the production of a given crop, it would be a simple matter to determine not only the kind but the amount of commercial fertilizer to apply to produce a desired yield. Such a course of reasoning does not take into account the fact that the larger part of the plant food shown to be present by the analysis exists in an insoluble form and that only a very small per cent is soluble or available at any given time. It does not consider either that the amount available is variable, and that it depends not only upon the total amount of these elements present, but also upon the quantity of organic matter present, the season, the way the soil is handled and upon a number of other factors only partially within the farmer's control. It is true that there are methods of analysis which will show approximately the amounts of these elements that are soluble, at any given time, but since this amount is so variable and the method of analysis so laborious it is practically out of the question to make use of them.

It will, therefore, be seen that the matter of soil analysis has certain limitations and that individual analyses will mean but little to the average farmer. This is particularly true since the method by which the sample for analysis is taken may be very inaccurate unless one has had experience in taking soil samples for this purpose.

For these various reasons, as well as for the reason that this analytical work is very expensive, the Experiment Station is compelled to refuse to make soil analyses for individuals without cost. Moreover, the regular work of the State Soil Survey which is being carried on as rapidly as means will permit, includes the systematic sampling and analyzing of all the soils of the state. Analyses have already been made which include many of the more important soil areas and these results will be published in bulletin form.

It must not be understood from the foregoing, that soil analysis is of little value. On the other hand it is of great value. While it does not show for example, with great definiteness the exact fertilizer treatment demanded during any given season to produce a given yield of wheat, yet, it does show the elements in which a soil is lacking, as well as those which are abundant, and it indicates the system of farm practice which one should adopt to make a soil permanently productive. It shows, for instance, that if phosphorus is very deficient, a system of farming must be adopted which will continually maintain or even build up the phosphorus supply if the soil is to be kept fertile. This, after all, is really more important so far as the permanent effect upon the soil is concerned than it is to know the exact amount of fertilizer to apply in any given season. It is true that the total amounts of plant food present, as shown by the analysis, do bear a fairly close relationship to the average amounts of these elements that will be made available from year to year. For instance, if the analysis shows a striking deficiency of phosphorus it will usually happen that the amount of available phosphorus will be deficient also, although if the supply of organic matter is large the action of this decaying material upon even the comparatively small amount of phosphorus may make a sufficient amount available for an abundant crop. As a matter of fact, any so-called "worn-out" land of Missouri today is nonproductive, not because it is deficient in total plant food, but because with the low supply of organic matter present there is not sufficient available plant food set free to give remunerative yields. When this land is again built up in organic matter the yields will be almost, if not quite, as great as they were originally. This does not mean that one can continually remove crops from the land, and, merely by keeping up the supply of organic matter keep these lands permanently fertile, since the effect of this drain of plant food would sooner or later be felt, but it means rather that the total supply of plant food, even of phosphorus in most of our soils is large enough to give abundant returns for a considerable time if it can be made available. The present difficulty is, that with the supply of organic matter low, and with some of the elements, particularly nitrogen and phosphorus, also low, the supply that is made available from year to year is insufficient for maximum crops except under very favorable circumstances.

HOW FERTILITY MAY BE MAINTAINED

The maintaining of the productiveness of a soil means that there shall be preserved within the soil sufficient quantities of soluble plant food of the various kinds to produce maximum crops. To do this it is not only necessary to maintain a large supply of organic matter but the soil must be kept in a good physical condition and if it is to remain permanently fertile the total supplies of the various elements must be maintained. We should therefore distinguish between what might be termed a temporary system of agriculture in which the available plant food gradually decreases, and a permanent system of agriculture or that in which the available plant food shall be indefinitely maintained.

HOW ORGANIC MATTER IS MAINTAINED OR BUILT UP IN THE SOIL

Since organic matter may be so rapidly removed from a soil by exhaustive cropping it is highly important that a means be provided for replacing it. The first essential to the maintaining of this supply is the adoption of a crop rotation which shall include legume crops. Even a small grain alternated with corn will maintain the organic matter much longer than where corn is grown continuously, and where a legume crop such as clover is introduced, the supply will be much better maintained. The following tables showing the results of rotation experiments at the Missouri and Illinois Experiment Stations illustrate this point:

EXPERIMENTS IN CROP ROTATION ILLINOIS AGRI. EXPERIMENT STATION.[1]

Rotation	Acre yield of corn.*
Corn—28 years	22 bushels
Corn, oats—28 years	36 bushels
Corn, oats, clover—28 years	59 bushels

(1.) Reported in Cir. No. 96, Ill. Agr. Expt. Sta.

*All results except the first are for the year 1904.

EXPERIMENTS IN CROP ROTATION—MISSOURI AGRI. EXPERIMENT STATION.

Rotation	Acre Yield of corn, 1905.
Pasture—18 years; corn, oats, clover—10 years	74 bushels
Corn—17 years	11.8 bushels
Corn, wheat, clover—17 years	50.7 bushels
Corn, oats, wheat, clover, timothy, timothy—17 years	54.2 bushels
Corn, wheat, clover (manured)—17 years	77.6 bushels

In the results from the Illinois station it will be seen that where corn has been grown for twenty-eight years continuously the yield is now averaging 22 bu. per acre, while where corn has been alternated with oats the yield is 36 bu. per acre. The reason for the larger yield under corn and oats is due, first, to the fact that a crop of oats is not so exhaustive of organic matter as corn since it is not cultivated and since a greater or less quantity of weeds usually grows up in the stubble and falls down to add organic matter and, second, the rotation helps to keep in control certain injurious insects and probably to keep the soil in a more sanitary condition.

Where the rotation is one of corn, oats and clover, the yield is still higher, averaging now on those years when the land is in corn, 59 bu. per acre. This increase is due partially to the fact that corn is cultivated but one year in three, thus reserving the supply of organic matter; and to the fact that clover is inserted, which builds up the soil in organic matter and nitrogen.

In the experiments from the Missouri Station it will be seen that while the rotations were different from those in Illinois, the same general principles hold. The natural fertility of the land on which these experiments were conducted is appreciably less than the Illinois land thus giving uniformly smaller yields. Where corn has been grown for 17 years continuously without manure, the yield has been reduced to 11.8 bu. per acre. Where the land has been simply rotated to corn, wheat and clover, the yield was 50.7 bu. per acre, where the rotation has been corn, oats, wheat, clover, timothy, the yield was 54.2 bu. per acre, and where manure has been added in a corn, wheat, clover rotation the yield was 77.6 bu. per acre.

No more striking results of the effect of crop rotation could be found and there is little doubt that the most important cause for this increased yield is in the fact that the supply of organic matter, and, therefore, the supply of available plant food, has been more nearly maintained in the rotated or manured plots. A striking difference in the color of the soil of the two plots at the Missouri station where corn has been grown continuously both with and without manure is noticeable. The unmanured plot is much lighter in color, thus showing very clearly its lack of organic matter as compared with the one beside it. It must not be understood from this that a crop rotation alone will maintain fertility for it will not. This is only the first essential. Legume growing and manuring form an exceedingly important part of the plan.

THE IMPORTANCE OF LEGUMES IN MAINTAINING ORGANIC MATTER

It is not only beneficial to rotate crops in maintaining the supply of organic matter in a soil but the rotation must contain legume crops such as clovers and cowpeas if this supply is to be entirely maintained. These crops have the power of making use of the free

Figure II. THE MOST IMPORTANT SOIL BUILDING CROP IN MISSOURI

Clover should form a basic part of every crop rotation wherever it is adapted. Where it fails, an effort should be made to find the causes of failure and to remove them if practicable.

nitrogen gas of the air in their growth, thus obviating the necessity of using any great quantity of the supply in the soil. They are usually known as crops which build up organic matter because in order to build up this material in the soil, nitrogen is necessary, and these plants have the ability to secure it from the air, thus not depending entirely upon the soil nitrogen for making the organic matter of which they are composed. If these crops are removed from the land, however, the actual organic matter added to the soil is small, although since the land is not stirred when these crops are on the ground they tend to maintain it. To build up organic matter rapidly in a soil, it is necessary that these crops be pastured or fed and the manure returned, or better still, that occasional crops be turned under. This indicates another feature in the maintaining of organic matter and that is the return to the land of the manure produced, not only from legumes but from grain crops as well. Manure is mostly organic matter and while it returns only about one-third that contained in the crops fed, due to the digestive action of the animals upon this feed, it means a saving of this to the land.

It can readily be seen therefore, that to absolutely maintain the supply of organic matter and especially if it is to be built up, it is necessary to make wide use of legume crops to be pastured, or even occasionally turned under, unless feed or manure is to be brought in from sources outside one's farm. For the grain farmer who makes little manure and who sells the bulk of his crops from the land, resort must be had to the turning under of legume crops if the supply of organic matter is to be maintained. It is perfectly possible to use green manure crops in this way in grain farming with good profits, but organic matter is usually most easily maintained by the average man through the feeding back of a large part of the roughage and grains grown.

THE NITROGEN SUPPLY

Since a low nitrogen supply usually accompanies a low supply of organic matter the maintaining of this supply usually means the maintaining of the nitrogen, and as already indicated, this is most readily done through the use of legumes. The fixation of free nitrogen gas from the air by the bacteria within the nodules on the roots of legumes provides the most ready means of supplying this element to the soil. Farmers are all familiar with the so-called fertilizing effect of clover and this is due to the readily available nitrogen left within the roots of the clover to be used by crops following. It must not be understood, however, that the growing of legumes and removing them from the land will permanently maintain the nitrogen supply, for it will not. Approximately, two-thirds of the nitrogen contained in a clover plant is in the tops and when the hay crop is removed this is lost to the soil.

In ordinary soils only about two-thirds of the nitrogen supply of a clover plant comes from the air, the other third coming from the soil, so that when the tops are removed as hay, one is removing just about the proportion of nitrogen that came from the air, leaving in the root and stubble just about the amount that was taken from the soil. In taking off a clover crop, therefore, one is not actually building up the soil to any extent in nitrogen as a rule but is about maintaining it. The great stimulation that comes to a crop following clover is usually due to the fact that the clover roots and stubble leave within the soil in a readily available form practically the same amount of nitrogen that was present when the clover began growth.

Figure III. COWPEAS SOWN IN THE CORN ROW AT TIME OF PLANTING

A desirable means of soil improvement. The cowpeas may either be allowed to fall down for the purpose of adding organic matter and nitrogen, or they may be pastured.

Naturally the immediate effect of this is striking and it appears as if the soil were being greatly built up. The effect of growing clover and removing it may give excellent results for a great many years but the time will finally come when this will cease to have its effect if the crop is entirely removed from the soil. This has been true in the East and it will be true in Missouri if the same practice is followed. The only means of maintaining the nitrogen supply absolutely, is by growing legumes and feeding them back, pasturing them off or occasionally turning a crop under. Through such means a man can be absolutely independent of the fertilizer dealer so far as nitrogen is concerned and this is far more economical for the general farmer than the plan of buying nitrogen in commercial form. A man can put nitrogen into his soil through legumes at a cost of from three to six cents a pound while if he bought the nitrogen commercially it would cost fifteen to twenty cents a pound. The truck grower is the only farmer who can afford to use any considerable amounts of commercial nitrogen.

The feeding of crops back on the land is a very important means of maintaining the nitrogen supply as well as the supply of other elements. The nitrogen supply of manure is one of its most important constituents. The following table shows in brief form the amount of nitrogen, phosphorus and potassium recovered in the manure from some of the more important crops.

FERTILIZING MATERIALS RETURNED IN FARM MANURE

	Nitrogen lbs.	Phosphorus lbs.	Potassium lbs.
A 75 bushel crop of corn contains—			
In grain	75	13.7	14
In stalk	36	4.5	39
Total	111	18.2	53
Manure from grain returns	52.5	10.2	11.9
Manure from stalk returns	25.2	3.3	33.1
Total returned	77.7	13.5	45.0
A 60 bushel crop of oats contains—			
In grain	36	6	7
In straw	19	2.5	32
Total	55	8.5	39
Manure from grain returns	25.2	4.5	5.9
Manure from straw returns	13.3	1.8	27.2
Total returned	38.5	6.3	33.1
A 2 ton crop of clover contains	80	10	60
Manure from 2 tons clover returns	56	7.5	51

It will be seen by this table that about 70 per cent of the nitrogen, 75 per cent of the phosphorus and 85 per cent of the potassium of crops fed is returned in the manure. In round numbers this is often given as 80 per cent or four-fifths. As a matter of fact, it is rarely possible in practice to recover these amounts as there is always more or less loss in handling. Under an ideal system of manure saving these percentages could be recovered, but practically the general figure of 70 per cent saved, is nearer the truth and under the careless system too commonly followed, it is very much less than this. It must be understood that these figures are general, since the amounts of the various elements returned depend upon the age of the animals fed, upon the character and amount of the ration, upon the kind of animal, and especially upon the method by which the manure is handled.

THE USE OF MANURE

The Missouri farmer should appreciate more fully the value of manure and of proper methods of handling it. He should figure it as worth at least two dollars[1] per ton in crop returns and he should get that amount, or in some cases much more than that out of it by proper handling. Just how it shall be handled will depend upon conditions. The best method where cattle are fed in barns, sheds or lots, is to haul the manure to the fields day by day or week by week as it is made. There is the least loss in handling it in this way, although this plan is not always feasible. The next best plan is to feed under an open shed where the manure may accumulate and where it will be kept tramped down compactly by the animals. Under such a plan it will be kept sufficiently compact and moist to prevent rapid fermentation, and next to hauling to the fields as made, this is the plan which gives the least loss of fertilizing constituents. One of the cheapest plans is to feed directly back on the fields but too often in this case the feeding is done on some hillside where washing and leaching carries away the larger part of the fertilizing constituents contained or the cattle are fed in some sheltered wood lot where the manure is lost to the fields.

In this connection it should be said that a manure spreader will pay on the average farm of 100 acres or over, and where dairy stock is kept it will pay on farms of smaller size. Most men think that the value of a manure spreader lies in the saving of labor, and while this is an important reason for its use, it is not the only one. A reason that is as important, or even more important, is the fact that manure put on evenly and rather lightly over a large area will give larger returns per ton of manure applied than the same manure

(1) It should not be understood from this statement that a man can afford to pay $2 per ton for manure since the value of manure depends upon many factors, particularly the manner in which it has been kept. If one were buying average manure it is not usually safe to pay more than $1 per ton spread on the field if a good net return is to be expected.

put on heavily and irregularly over a smaller area. There is one other reason why a man should own a spreader and this is that when he has his money invested in such an implement he will almost invariably take better care of the manure than he otherwise would.

THE PHOSPHOROUS SUPPLY

Unfortunately, no simple means is available of supplying phosphorus to soils as is true in the case of nitrogen. Soils contain certain definite quantities of this element and when it is removed from the soil by crops there is no means of replenishing this supply except by feeding the crops and returning the manure, or by buying the phosphorus in commercial form. Moreover it is this element, which together with nitrogen, is lowest in amount in Missouri soils. Unfortunately, too, the grain of our common crops contains the largest proportion of phosphorus in the plant, so that when grain is sold from the farm the soil is being depleted of an element in which it is usually somewhat deficient. As has already been pointed out, the loss of total plant food from the soil is not the most immediate cause of unproductiveness but the continued removal of phosphorus from soils already deficient in this element will sooner or later have its effect in producing a decreased yield. It is therefore highly important that Missouri farmers learn the methods of maintaining not only the available supply but the total supply of this element in the soil.

The feeding back of crops is one of the easiest methods of preventing the loss of excessive quantities of phosphorus from the land, but reference to the table, page 14 on fertilizing constituents recovered in manure will show that of the three elements, phosphorus shows the least percentage return. This is due to the fact that a considerable per cent of the phosphorus especially in all but mature animals is fixed within the bones of the carcass. Such phosphorus comes on the market later as bonemeal to be purchased by landowners and returned to the soil. In spite of one's best efforts to save the phosphorus by feeding the crops on the place, there is still an appreciable loss and one which will ultimately be felt unless phosphorus is brought on the land from without, either in the form of fertilizer or of purchased feed. Naturally the loss in this case is much slower than where the crops are sold and if the organic matter is maintained, many years will elapse before the effect of the slowly waning phosphorus supply will be felt. With the low actual content of phosphorus in most Missouri soils, coupled with the low supply of organic matter for keeping this available, the need for phosphorus is becoming strongly felt over a great portion of Missouri today. It remains therefore for the farmer to supply either phosphorus through commercial fertilizers, or to build up the supply of organic matter of his soil. The wise farmer will build up the supply of organic matter and in addition he will seek to prevent the loss of phosphorus from the land in so far as possible. He will also accompany his efforts in this line by the return of phosphorus from outside sources, either in feed or commercial phosphates.

THE POTASSIUM SUPPLY

The potassium supply like that of phosphorus is found in the mineral grains of the soil, particularly in the clay and finer particles. Of the three most deficient elements it occurs in largest quantity and under ordinary systems of farm management it is the element most easily maintained. The stalks and stems of crops contain the larger part of the potassium stored within the plant and since it is this part that is usually returned to the soil as manure, the ordinary systems of grain or mixed farming remove less of it than of either nitrogen or phosphorus. Where the supply of organic matter is reduced, however, or where soils are naturally wet, it may frequently be deficient in available form. This is also true of the stony soils and the sandy soils of South Missouri where the total supply is more or less deficient.

Potassium in connection with phosphorus has the property of improving the quality of grain when it is present in large amounts in available form. Consequently its application on soils needing it serves to improve the quality of corn, wheat and oats very materially as well as to increase the yield. The best agricultural lands of the state will rarely give sufficient return from the application of potassium to pay unless they are considerably worn, but many of the poorer soils will respond profitably to its use.

THE LIME SUPPLY

A large supply of lime in a soil is necessary for the highest productiveness. A high lime content is almost always associated with fertility. The form in which it should occur is that of the carbonate of lime, which has the function of keeping the soil sweet and of favoring the growth of beneficial bacteria. Soils which are inclined to be wet, or those which have been subjected to excessive leaching, such as certain ridge lands, and those which have been farmed for a great number of years are usually deficient in lime carbonate and are therefore acid or sour. Consequently on such soils it is necessary to apply lime if the greatest productivity of the land is to be attained. It must not be understood that lime is a fertilizer in the usual sense of the word, since it is rarely applied to supply plant food, as in the case of fertilizers proper. It is used merely as a corrective of soil acidity. Fortunately, a considerable part of the soils of Missouri is still well supplied with lime carbonate, although there are large areas of rather wet prairie and of thin and worn soils where lime is needed.

The kind of lime to use on a soil is usually that which is cheapest per unit of sweetening power. In some cases it may be air-slaked lime where it can be secured in quantity at a reasonable cost; in other cases it may be the burned lime slaked to a powder with water such as is common in the eastern states, but in Missouri the cheapest form is ordinarily the ground limestone. This material is usually almost pure calcium carbonate, or calcium and magnesium carbonate, and it can be secured of several companies at a cost of approximately one dollar a ton in carlots at the crusher. It should be ground to the fineness of cornmeal or finer. The best grades are ground so that 90 per cent of the material will pass a 20-mesh sieve.[1]

In comparing the relative costs and the efficiency of different kinds of lime it should be remembered that pound for pound the burned lime is most efficient as a sweetening agent when this is finely ground, as is occasionally done, the water-slaked lime next and the ground limestone last. Fresh air-slaked lime is about equivalent to the water-slaked lime, and old air-slaked lime to the ground limestone. Briefly, 2,000 lbs. of ground limestone is equivalent to 1120 lbs. of burned lime and to 1480 lbs. of water-slaked lime.

Lime is best applied after the land is broken for a crop, preferably a fall sown crop, because the conditions for hauling and scattering are most favorable at that time. The land should be leveled by harrowing and the lime scattered after which it should be thoroughly worked into the soil. It should not be plowed under. It may at times be applied on permanent pastures and meadows with benefit, but on rotated lands it should be worked into the plowed soil.

It is best scattered with a special lime spreader, although a manure spreader may be used. Hand scattering except on small areas is not advisable.

(1) Lists of the companies supplying lime for agricultural purposes, those putting out limestone grinders, and those manufacturing lime spreaders may be obtained from the Department of Soils, of the University.

The rate of application depends upon the degree of soil acidity, but the usual application is from one to two tons of ground limetone per acre or its equivalent, once in 4 to 6 years. It is commonly applied heavily at one time rather than frequently in smaller amounts. The cost of such an application of ground limestone delivered and spread on the field should not be over $3 per ton if a fair net return is to be expected from its use.

THE USE OF COMMERCIAL FERTILIZERS

In the eastern and southern states, where commercial fertilizers are used in large quantities per acre, they form a very important means of assisting in the maintaining of soil fertility. The more extensive agriculture of Missouri does not lend itself so well to the profitable use of large acre quantities of these materials, particularly in the form of the mixed or complete fertilizers. The small amounts applied are therefore rarely sufficient to aid very materially in maintaining the supply of nitrogen, phosphorus, and potassium in the soil. They nevertheless form a very important means of increasing crop yields through the available plant food which they supply and their use in Missouri is rapidly increasing. They cannot be depended upon alone to maintain soil fertility, however, and their continued use should only be in connection with the best system of crop rotation, manuring, and legume growing that a man can practice. Where they alone are depended upon for maintaining soil productiveness, a decreased fertility will eventually result since they do not maintain the supply of organic matter in the soil. For this reason the opinion is more or less prevalent, that fertilizers injure the soil, or that when their use is once begun it must be continued. It is the man who must have immediate returns who can afford to use fertilizers alone for securing a crop. The landowner should use them in connection with all those other methods of soil management which aid in maintaining fertility.