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KEEPING SOILS PRODUCTIVE

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Red Clover, the King of Soil Builders

NATURE OF SOILS

Soils are among the most complex of all the substances with which chemists have to deal. They consist of mineral matter derived from pulverized and weathered rock materials intermingled with organic matter from plant and animal refuse in all stages of decay. They also contain very large numbers of minute plant and animal forms still living. With such a mixture of materials it is not strange that many years of study have failed to solve all the problems of soil management; and no one should assume to know all the facts relating to soils. Nevertheless, much progress has been made and every agricultural worker should be as familiar as possible with this fundamental department of his industry.

From the foregoing statements it can be seen that soils must vary widely both in physical texture, or fineness of grain, and in chemical composition or the relative amounts of the different chemical substances contained. In texture soils may be coarse sands or fine clays or any combination of sands, silts and clays with values varying widely according to conditions. In chemical composition there are all gradations from rich black loams to poor white sands. Washing and leaching by rains is the most effective of all agents in removing many useful chemical elements found in virgin soils. This washing process is greatly increased when land is cultivated thus removing nature's protective covering of grass, weeds and leaves.

The variation in soil texture must always be considered along with the question of fertility since it has a very great effect on productiveness. Soils may be of such impervious clay texture that a large supply of plant food does not make them productive on account of the mechanical difficulties of cultivation or the interference with proper drainage. Good drainage and air circulation are necessary for productiveness. Often a compact impervious layer in the upper subsoil interferes with drainage and results in shallow-rooted crops that suffer from drought. In the spring, when roots are forming most rapidly they will not penetrate the water filled soil and hence spread out near the surface. Later the surface layer becomes very dry, and injury results to the shallow-rooted crop. The texture of the soil down to three or four feet is very important. A silt loam, loam or sandy loam surface is most desirable and the subsoil should be about the texture of a silt loam or pervious clay loam.

Plants, like animals, must have certain definite food materials. Two of these, iron and magnesium, are present in amounts sufficient for all plants in nearly all soils. Three others, carbon, hydrogen, and oxygen are taken from the air and water. They are therefore abundant. The other five may be so lacking in any given soil as to limit plant growth. These are nitrogen, phosphorus, potassium and less frequently calcium and sulphur. The nitrogen is found in the organic matter of soils while the others are found chiefly in the rock flour which forms the basis of soils. Fortunately these elements of plant food are normally in compounds that do not dissolve readily in water, else they would quickly be carried into the sea in regions of heavy rainfall.

Among the five elements sometimes deficient in soils nitrogen, phosphorus and potassium are of most importance agriculturally, because of their relative scarcity in forms which plants can use and because of their high cost in fertilizers. Calcium in the form of lime is often needed to supply sufficient amounts for the growth of lime loving crops such as alfalfa, the clovers and certain other crops. It is also needed at times to keep lands from becoming too sour for the growth of crops. Sulphur is needed on certain soils but such soils do not seem to be very common in the corn belt.

HOW PLANTS FEED

Animals have the ability to grind up solid food and take it into the stomach where it is exposed to liquids that have a high dissolving power. When dissolved the solution is absorbed thru the stomach and intestinal walls and goes into the blood stream. Plants, however, have no grinding apparatus and no stomach. Their food must be dissolved by the soil moisture before it can be absorbed thru the roots and carried up to the stems and leaves by plant sap. While the insoluble character of soil materials helps to prevent their loss by leaching, it also, in most soils, prevents the plant from absorbing plant food at a rapid rate. Available plant food is plant food that is dissolved or can easily be dissolved in the soil moisture. This necessity for the plant carrying its food materials in solution up thru root and stem accounts for the large quantities in which water is required by plants, for successful growth. Some soils have a large store of plant food but have little of it in available form; while others may contain less of the necessary elements but have them in a form more easily dissolved and hence more available.

Plant food is made available by slow processes some of which may be hastened by proper soil management. The chief agency is the decomposition of organic matter which breaks up plant food compounds into simpler and more soluble forms. In decay, also, acids and other groups of compounds get into the soil water and increase its dissolving power. Plants have the ability to excrete thru their roots carbon dioxide and similar substances; and these, mingling with the soil water, increase its dissolving power.

COLOR IN SOILS

Color has always been the practical man's guide to soil fertility and the scientific man finds it just as useful after working out the reasons back of it. In relative fertility black soils stand first, followed in order by the browns and dark grays, and these by the yellows and light grays, the lightest of which are nearly white.

As explained in the following pages black stands for organic matter which has a high valuation in fertility. The browns and reds are ranked above the corresponding shades of gray because the oxidized iron which gives the red and brown shades indicates that there is good under-drainage and good air circulation through the soil; otherwise the iron would not be so completely oxidized. Grays, particularly when light in shade, indicate poor air circulation from insufficient under-drainage or a very old soil that has been subject to much leaching until it has lost its content of lime and organic matter.

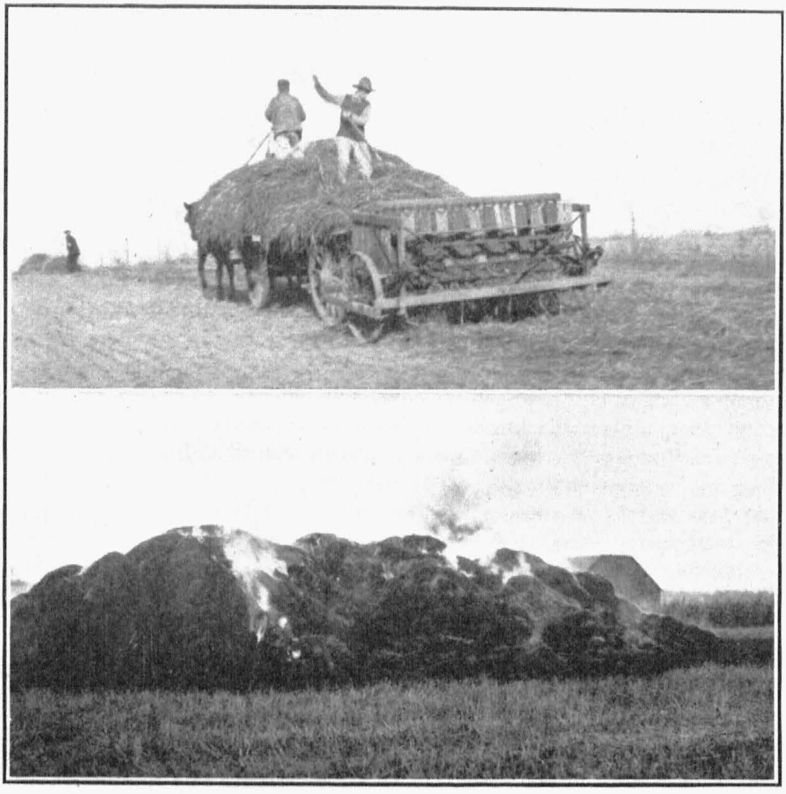
So long as a fair amount of lime is present it tends to hold the organic matter and retain the darkness of color. The light yellow to reddish brown loess soils of the "river hill" lands along the Missouri and Mississippi rivers might be considered as an exception to these rules but these soils are very young. Their iron is uniformly well oxidized but there has been little accumulation of organic matter even tho lime is usually abundant. This is due to the youth of the soils and to their topography which favors erosion. These soils also show their youth by the uniformity of their surface and subsoils. No differentiation has yet taken place.

In subsoils a white or light gray layer indicates poor drainage particularly if very distinct and very light in shade. Other color indications of the same undesirable condition are a bluish drab subsoil or a mottling of yellow and drab showing that there is poor air penetration which is usually due to the subsoil being water-logged at least during part of the season. This condition may exist even though the surface be perfectly drained. It is more commonly found in flat areas of poor surface drainage, however.

ORGANIC MATTER IN SOILS

The organic matter in soils has an importance vastly greater than the amount of it would seem to indicate. Besides making plant food available it improves the physical condition of soils by making them more friable. It increases the moisture-holding capacity, lessens washing and gives the dark color long recognized as the mark of a fertile soil.

Under nature's plan of soil maintenance all soils, where there is sufficient rainfall, are kept covered with a mat of dead grasses or leaves, and myriads of plants grow up only to die and leave their root systems decomposing in the soil. Man disturbs this balance by plowing and cultivating, leaving the soil bare of its protecting mat and increasing the rate of de-



Straw is a source of organic matter and plant food. Do you spread yours or burn it? Both pictures were taken in Missouri.

cay. This results from turning the soil over and over so that a greater amount of oxygen comes into contact with the organic matter and increases decomposition by oxidation. Washing is also increased by these processes and much valuable material is thus carried away. Large areas of soil have been laid waste and abandoned thru man's failure to maintain the balance of organic matter. Virgin soils are usually fertile, largely because of their supply of rapidly decomposing organic matter.

LOSS OF PLANT FOOD FROM SOILS

Under all systems of farming there is a constant drain of plant food from the soil and this loss must be returned if farming is to remain permanently productive. The two chief causes of loss are soil washing and removal in crops. The amount of loss by washing cannot be stated since it varies widely with the slope, amount and time of cultivation, texture of soil, amount of organic matter present, climatic conditions and cropping system. Numerous investigations have proved this loss to be enormous for most regions of abundant rainfall.

The amount of plant food removed by crops is easily determined since a given crop is always found to be of about the same composition and a very large number of chemical analyses have been made. The table which follows gives the amounts of plant foods removed by good crops of the kind commonly marketed in Missouri.

TABLE 1.—FERTILITY REMOVED IN FARM CROPS

Crop, Yield per Acre	Pounds of Plant Food Removed				
	Nitrogen	Phosphorus	Potassium	Calcium	[1]Sulphur
Corn, grain 75 bu.	75	13.8	14	0.8	[2]6.4
Corn, stover 2¼ tons	36	4.5	39	14.1	5.6
Corn, total crop	111	18.3	53	14.9	12.0
Oats, grain 60 bu.	36	6.0	7	1.3	4.0
Oats, straw 1.6 tons	19	2.5	32	9.0	6.5
Oats, total crop	55	8.5	39	10.3	10.5
Wheat, grain 30 bu.	35	4.5	8	0.7	2.5
Wheat, straw 1.5 tons	14	3.0	25	4.3	3.7
Wheat, total crop	49	7.5	33	5.0	6.2
Timothy, 1.5 tons	36	4.5	35	7.5	4.7
Clover, 2 tons	80	10.0	60	61.6	8.2
Cowpea hay, 2 tons	93	9.0	63	36.0	12.6
Alfalfa, 6 tons	300	27.0	144	222.0	18.1
Fat cattle, 1000 lbs.	25	7.0	1	12.8	[3]1.0
Fat hogs, 1000 lbs.	18	3.0	1	4.5	1.0
Milk, 10,000 lbs	57	7.0	12	12.1	2.5

(1) Sulphur analyses are reported not because sulphur has a proved value as a fertilizer on the average soil of Missouri, but because certain soils of other states have been found to need sulphur and it may later be found that some Missouri soils have become exhausted to the point of needing this element.

(2) Analyses of sulphur in farm crops computed from data by Hart and Peterson, Wisconsin Research Bul. No. 14.

(3) Sulphur in animal carcasses from unpublished data., Department of Agricultural Chemistry, University of Missouri.

THE COMPOSITION OF MISSOURI SOILS

In making a soil survey of the state, county by county, the Missouri Agricultural Experiment Station has collected and analyzed several hundred samples of soil from all parts of Missouri. The accompanying table shows the results of some of these analyses giving the amount of the three commonly deficient elements expressed as pounds of the elements in the surface soil of an acre, seven inches deep. The deeper soil layers have also been analyzed in each case but in general they agree with these surface analyses, excepting in the element nitrogen which is always highest in the surface soil.

By comparing the analyses of these types with those of a very fertile soil as a standard it will be seen that many of them are distinctly deficient in nitrogen and phosphorus. Age is a very important factor in soil fertility and to one familiar with the geological history of these soils it is not surprising that the bottom soils and some of the wind deposited soils of northwestern Missouri both of which are relatively young stand high in fertility. They have not been subject to leaching and washing for so many ages of time. Another factor that has a noticeable effect on fertility is the rock formation from which the soil was derived. It may also be noticed that there is a close correlation between the darkness of color

TABLE 2.—AVERAGE ANALYSES OF MISSOURI SOILS

Soil type	Color of surface soil	Amount of nitrogen, phosphorus, and potassium in surface soil 7 inches deep, one acre in extent (2,000,000 lbs.)			Part of state in which soil is found.
		Nitrogen	Phosphorus	Potassium	
		lbs.	*lbs.*	*lbs.*	
Standard fertile soil	Black	6000	2000	30000	
Memphis silt loam	Light brown	2050	1100	33500	Southeast
Knox silt loam	Brown	2500	1200	34300	River hills
Marshall silt loam	Black	3650	1450	33050	Northwest
Grundy silt loam	Black	3700	1300	30150	Northwest
Putnam silt loam	Dk. gray	2850	1050	29100	Northeast
Shelby loam	Dk. brown	2800	1050	22800	North Central
Lindley loam	Lt. brown	2150	1130	27600	North Central
Summit silt loam	Black	3300	1650	30300	North Central
Oswego silt loam	Dk. gray	2850	1450	27550	Southwest
Gerald silt loam	Brown-gray	2200	800	24150	Southwest
Cherokee silt loam	Gray	2150	700	22350	Southwest
Bates silt loam	Dk. brown	2900	1250	25450	Southwest
Eldon silt loam	Black	3650	900	24700	Southwest
Crawford silt loam	Red	2900	1350	31500	Southwest
Union silt loam	Yel. brown	1550	650	32750	South Central
Hagerstown silt loam	Red brown	1950	500	28800	Eastern
Clarksville silt loam	Lt. gray	1500	600	26250	Ozarks
Clarksville gravelly loam	Lt. gray	1650	350	20650	Ozarks
Lebanon silt loam	Gray	1950	550	23200	Ozarks
Chariton silt loam	Dk. brown	3150	1850	32300	Stream Ter.
Robertsville silt loam	Lt. gray	2300	1100	34650	Stream Ter.
Lintonia silt loam	Lt. brown	2300	1200	34700	River bottoms
Wabash silt loam	Black	3750	1600	30300	River bottoms
Wabash clay	Black	4600	2200	33000	River bottoms
Osage silt loam	Dk. brown	3200	1250	25950	River bottoms
Huntington silt loam	Lt. brown	2400	1050	25850	River bottoms
Sharkey clay	Black	4200	2650	29800	River bottoms
Waverly silt loam	Very lt. gy.	1914	1500	27500	River bottoms

and the amount of nitrogen. This is due to the fact that the nitrogen is contained in organic matter and it is organic matter which gives the dark color.

The phosphorus content is comparatively low in most Missouri soils which accounts for the fact that the use of available phosphates is becoming such a common and profitable farm practice.

Potassium is abundant in most soils but frequently in such insoluble compounds that production is limited. Small additions of potassium often give profitable increases, but a better plan is to handle the soil in such a way as to increase the rate at which the soil potassium becomes available.

SOIL ANALYSIS

It might be supposed 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 analysis exists in an insoluble form and that only a very small percent is soluble or available at any given time. It does not consider, either, that the amount available is variable; that it depends not only upon the total amount of these elements present, but also upon the quantity of organic matter, the season, the way the soil 's handled and a number of other factors only partially within the farmer's control.

It is true that there are methods of analysis which show approximately the amounts of these elements that are soluble at any given time; but this amount is variable and the method of analysis laborious and only approximately accurate. Little progress, therefore, has been made along this line. It is quite evident from soil investigations, also, that plant food may sometimes be available for one crop tho not for another and these fine differences in availability cannot be measured by present chemical methods.

It will be seen, therefore, that soil analysis has its limitations; and, because of its uncertainty and expense, it has no great value in the hands of the individual farmer. Even the taking of a sample for analysis must be very carefully done or it will not represent more than the small spot from which it was taken. Improperly taken samples only waste time and chemicals in the laboratory.

It is true that many soil samples are being taken from soil types found all over the state and these are carefully analyzed in the Experiment Station laboratories, but they are taken by men experienced in securing representative samples. Typical samples are taken systematically so as to be of value to the greatest number; and results are being published in bulletins covering the soil resources of the state and counties. When these records are complete they will constitute an inventory of the soil fertility of all parts of the state.

Significant differences are very evident between some soil types and these differences indicate the needs of each type. It is necessary, however, to follow these up and test them out thru field experiments in which the apparently deficient elements are supplied, before definite and dependable recommendations can be made. To solve this problem soil experiment fields are being established on all the extensive soil types as rapidly as funds are available. It is the actual yield from the field experiment which justifies the recommendation given out by the Experiment Station, and not the analysis of a small sample of soil taken from a particular spot on a field or farm. It is, of course, true that when the analyses show a given soil to be very low in one of the common elements of plant food it is usually found profitable to apply that element. Furthermore, some soils showing a good analysis for a given element may still give profitable returns from the addition of that element as fertilizer. This is due to the slow availability of the element in particular cases; and the final test should be made in the field.

HOW FERTILITY MAY BE MAINTAINED

To maintain the productiveness of a soil it is necessary to preserve within the soil sufficient quantities of available plant food at least to prevent the yield from falling off after a period of cropping. Hundreds of field experiments have demonstrated that the best of soils will gradually lose their virgin fertility unless more than ordinary care is given to the cropping system and the return of plant foods.

How do worn soils differ from virgin soils? The first noticeable difference is usually the loss of organic matter which permits the soil to run together and lose its open porous character. It begins to be compact and lifeless. This difference is very noticeable on the old Rotation Experiment Field at Columbia where systematic cropping has been maintained on the same plots for more than thirty years. Two of these plots have been in corn every year; one heavily manured annually and the other receiving no organic matter other than the corn roots and the stubs left from cutting the crop. After exposure to rains the manured plot now shows a roughened surface where the soil, held together by fibrous organic matter, resists erosion; but the untreated plot appears compact and run together. When the frost is going out in the spring a man walking across the untreated plot will sink almost to the shoe tops while the manured plot is firm enough to support his weight. A chemical analysis of the soil from these two plots shows that the chief difference between them is the lack of organic matter and nitrogen in the untreated plot. The manured plot is also noticeably darker in color.

Deficient not only in nitrogen and organic matter a worn soil may also lack lime, phosphorus, potassium and, in special cases, sulphur or calcium. It takes a long period of cropping to reduce the total supply of these elements to the point where a chemical analysis will detect it. The reduction in yield seems to be due to using up the available stock of these elements faster than it can be replaced. This is particularly true as the supply of organic matter becomes exhausted thus slowing down the process of growth and decay which helps make plant foods soluble or available. Only by maintaining a supply of organic matter and by returning an amount of plant food equivalent to that removed can any soil be maintained in a permanently productive state.

MAINTAINING ORGANIC MATTER

The organic matter in any soil is constantly changing as new material is introduced and old material reaches that stage of complete decomposition in which it ceases to have the desired properties of organic matter. It is this constant change which gives it its value, but which also makes it difficult to maintain. In the wild state nature covers all except the deserts and rougher mountains with a thick mat of vegetation but man soon disposes of this and proceeds to increase the rate of decomposition of the vegetable matter already in the soil. He does this by grazing, plowing and cultivating. The increased decomposition gives him plenty of available plant food until the store of organic matter begins to run down and by that time serious damage is done.

The rate of exhaustion of this valuable material may be checked by using a minimum of cultivated crops. Cultivated crops are necessary because of their money value and the opportunity they present for destroying weeds; but, used to excess, they are destructive of soils. They should therefore be used in a system or rotation along with legumes and sod crops.

TABLE 3.—EFFECT OF CROPPING SYSTEM ON CORN YIELDS AT MISSOURI AGRICULTURAL EXPERIMENT STATION

Rotation	30-yr. average acre-yield of corn.
Continuous corn	20.9 bu.
3-yr. Rotation, lorn, wheat, clover	34.1 bu.
4-yr. Rotation, corn, oats, wheat, clover	38.5 bu.
6-yr. Rotation, corn, oats, wheat, clover, timothy, timothy	41.4 bu.

It would be rare in practice to grow corn continuously on the same land for thirty years but it is often kept on the same field for excessively long periods, particularly on strong soils. The above table shows what a marked effect the cropping system has on soil maintenance. Rotation alone has maintained the yield at double that where a cultivated crop was grown continuously.

TABLE 4.—ILLINOIS EXPERIMENTS WITH CROP ROTATION[1]

Rotation	30-yr. average acre-yield of corn.
Continuous corn	34.0
2-yr. Rotation, corn, oats	40.8
3-yr. Rotation, corn, oats, clover	49.5

[1]Illinois Bulletin No. 219.

This table bears out the Missouri experiments, the higher level of yields being due to the fact that the Illinois experiments were conducted on a stronger soil, the brown silt loam of central Illinois. A study of the detailed records both at Missouri and Illinois shows that rotation alone does not keep the yield of crops up to that of the first few years on virgin soil. Even under rotation there is a gradual decline in yield except where the rotation is combined with proper soil treatment—application of manure or fertilizer.

The chart, on page 24, also from experiments at the Missouri Station, shows one of the underlying causes of reduced yields where poor cropping systems are followed and little or no manure is added. The length of the heavy black lines corresponds to the amount of nitrogen found after continuing the given treatment for twenty-five years. The amount of nitrogen is a very good measure of the organic matter present and hence the same chart can be taken to represent both nitrogen and organic matter. It is very noticeable that corn, the only cultivated crop, results in the most rapid loss of organic matter and nitrogen. Small grains come next, followed finally by sod crops. Rotations containing the three types of crops are intermediate. Naturally on the manured plots which have received heavy annual applications of manure the fertility is being maintained. Apparently, however, it is difficult to build up the organic matter and nitrogen to a very high level. This is due to the fact that the rate of decomposition increases as the amount of organic matter increases until the loss balances the gain. All manured plots in this group had received six to eight tons per acre annually for twenty-five years. In farm practice it is more economical to apply manure in lighter or less frequent applications since the amount available is usually quite limited.

These same plots were analyzed for phosphorus and potassium but it was found that the loss of these elements was in most cases too slight to be measured by present chemical methods. It was found, however, that applications of available phosphorus on these plots gave good crop increases.

This evidence of the value of crop rotation might be increased manyfold; and few doubt its value. Why then is it so common for farms to be operated without any systematic rotation? In many cases it is simply a failure of the land owner to think and plan ahead. Many farms are rented for short periods of one to three years with no continuity of plan so that a crop rotation is impossible. In still other cases a rotation is attempted but because of certain crop failures it is not continued. Lastly, market demands often cause farmers to change their cropping plan in order to reap a greater immediate profit even tho it may be at the expense of soil maintenance.

In adopting a plan of rotation as many fields should be established as there are years in the rotation; for this gives a fairly constant supply of each crop. When a crop fails a similar crop should be substituted, as for example, oats for wheat, soybeans or cowpeas for clover. There is no other way to maintain a systematic rotation.

FARM LEASES AND SOIL MAINTENANCE

The evils of the short time lease are many but probably the most serious of these evils is the ruinous effect upon the soil. The renter can not be expected to have any interest in the farm beyond the period covered by his lease. He is not to be blamed, therefore, if he wants to grow the crop of highest money value and eliminate the grass crop from which the immediate return is low. It is out of the question for him to plan a crop rotation if he expects to move on a year or two later. If renter after renter follow one another under these conditions, the strongest soil will soon begin to take on the run-down appearance of the typical tenant farm. Once the soil is exhausted it is much more expensive to build it up than to maintain it while its productive capacity is high, because the exhausted soil produces little growth from which to make manure and the profts are not sufficient to cover the cost of manure and fertilizer. The loss of fertility becomes a heavy debt with no sinking fund to retire it. Soil maintenance is therefore the responsibility of the land owner. He alone is in a position to control the cropping system. The lease should be so specific as to state the character of crop to be grown on each field, particularly those fields which are to receive legume or sod crops. He should bear part of the expense for grass seed and fertilizer and see that they are properly used. If unable or unwilling to do this then the land owner should secure a good tenant by renting on favorable terms and give him a lease for so long a period, never less than five years, that he may keep up the soil and share in the benefits to be derived.

These soybean crops grew in the northwest and southwest corners of Missouri, respectively. The soybean is a good legume crop for all parts of the state.

LEGUMES IN THE ROTATION

No rotation is satisfactory if it fails to include one or more legume crops since this group of plants, alone among our crops, has power to take nitrogen from the enormous supply in the atmosphere. Productiveness can not be maintained without maintaining nitrogen and the only inexhaustible supply is in the air. In recent years large amounts of money have been spent by all the leading countries in an effort to take free nitrogen from the air artificially and combine it in useful compounds. While these efforts are meeting with some success only an insignificant amount of nitrogen can as yet be supplied in this way. Nature's method is to use the bacteria growing on the roots of legumes. These little organisms have the power to assimilate the free and almost useless atmospheric nitrogen and to work it over into compounds which higher plants can use. While this process is rather slow it is, nevertheless, the cheapest and should be used just as far as it will go. Altho we can see these little bacteria only with the high power microscope, their presence is revealed by little knot-like nodules produced on the roots of their host plant and these may be seen by anyone who cares to dig up an inoculated plant and examine it. Care is necessary to prevent stripping these nodules off in pulling the plant.

The common legume crops are clover, alfalfa, soybeans, cowpeas, field peas, beans and vetch. They are crops having a high feeding value besides paying their way in combined nitrogen. Even legumes take some of their nitrogen from the soil, however, and if removed from the farm as hay they leave little or no accumulation of nitrogen. If it is desired to build up or even maintain the nitrogen of a soil some of the legumes grown must be turned under or the manure left from feeding them must be carefully returned to the soil. Too often it is considered sufficient if an occasional crop of legumes is grown. It is doubtful whether a thin soil on which growth is small can be built up or even maintained in nitrogen unless it is kept in legumes half of the time.

INOCULATION OF LEGUMES

Even legumes have no power to gather nitrogen unless aided by nodule bacteria and each kind of legume requires its own kind of bacteria. Careful studies have shown that certain similar legumes accomodate the same kind of organism. Following is a list of legumes grouped so that the same kind of organism may be used on all of the plants in a given group.[1]

GROUP I

Medium red clover
Mammoth red clover
Alsike clover
Crimson clover
Egyptian clover
White clover

GROUP 2

White sweet clover
Yellow sweet clover
Alfalfa
Burr clover

GROUP 3

Cowpea
Lima bean
Partridge pea
Peanut
Japan clover
Velvet bean

[1]Ill. Agr. Exp. Sta. Bul. No. 202.

GROUP 4

Garden pea
Canada field pea
Hairy vetch
Spring vetch
Broad bean
Sweet pea
Perennial pea

GROUP 5

Soybean

GROUP 6

Garden bean
Scarlet runner bean

GROUP 7

Lupine
Seredella

GROUP 8

Black or common locust

A legume which is to be grown on a particular soil for the first time, or one without nodules on the roots, should be inoculated. Cultures and directions for inoculating the seed can be secured from experiment station or commercial distributor. It is frequently possible, also, to inoculate by taking soil that is known to contain the proper kind of organism and either drill this soil into the new field or broadcast it on the surface and harrow it in so that the bacteria are not exposed to direct sunshine which may kill them. This soil may also be dusted over the moistened seed before sowing it.[1]

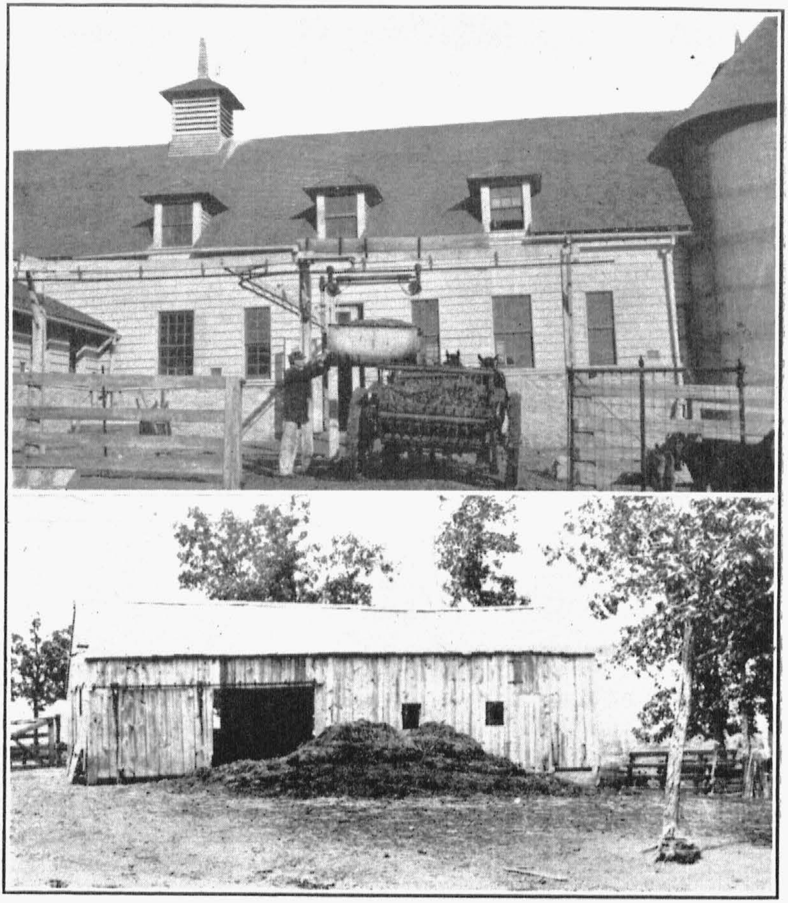
THE PLACE OF MANURE IN MAINTAINING SOIL FERTILITY

The feeding of crops back on the land is a very important means of conserving the supply of nitrogen and organic matter as well as that of the mineral plant foods. Nitrogen is the most expensive of the plant foods commonly purchased, and it is one of the chief constitutents of manure. About seventy-five percent of the plant food in animal feeds is voided as manure but great losses often occur in getting this back to the soil. Approxmately half the nitrogen and potassium of manure is in the liquid portion which is frequently allowed to drain away and waste. There is also an immediate beginning of the process of oxidation as soon as manure is voided and this causes a further loss of nitrogen. Hence, under common methods of handling, half the voided manure is lost which means that about one-third of the plant food in feeds actually gets back to the soil. Often the amount is less particularly where feeding is done in open, muddy lots or on hillside pasture.

How can these losses be avoided? Probably the cheapest method of reducing the losses from manure, where it can be used, is the pasturing of crops on the field. This keeps the loss down to the minimum. Often portable feed bins and racks can be used if changed from place to place over cultivated fields and not allowed to remain too long in one position. Where stock is fed in lots it has often proved profitable to pave the lots, thus conserving feed, producing better gains and saving manure. Better yet is the plan of feeding in covered sheds where the manure is kept tramped in a solid mass. In stables much bedding should be used to absorb the liquid manure and increase the amount of organic matter. Where sanitation is not a factor manure may be left tramped in the stalls using enough bedding to keep the stock clean. Of

[1]See Mo. Exp. Sta. Cir. No. 86, Soil Inoculation for Legumes.

course it must be hauled at fairly frequent intervals. Where it is necessary to remove manure from the stalls it should either be possible to haul to the fields and spread daily or provide a concrete pit which will prevent plant food from draining away. Manure should always be kept as compact as possible the idea being to prevent air from circulating thru it. If the pile is open and relatively



Manure saved or wasted. The two extremes.

dry so that air circulates freely thru it, oxidation is hastened and nitrogen as well as organic matter is lost. In any case the sooner it can be hauled to the field and spread, the smaller the loss is likely to be. Only on steep hillsides is there likely to be much loss after manure is spread.

The value of manure can be greatly affected by the manner of spreading For best results it should be spread evenly and lightly. Heavy applications or uneven spreading reduce the value received from each ton of manure. Even and light applications are practicable only where a manure spreader is used.

This implement should be on every farm of any size where livestock is kept and manure accumulated around barns or lots. While it is important as a labor saver it is much more important as a means of saving manure and getting the most out of every ton.

CROP RESIDUES AND GREEN MANURE CROPS

On many farms very little livestock is kept and little manure produced. This condition will probably always prevail since a considerable amount of grain and even some hay must always be sold. For such farms a substitute for manure must be used if the soil organic matter is to be maintained. The chief available substitute is crop residues consisting of straw, chaff from threshing clover seed, etc. All such materials should be left on the field or returned by spreading. It is scarcely less than a crime to burn these supplies of organic matter and plant food as was frequently done a few years ago; but, fortunately, is rarely done now. Selling them from the farm is only a little less foolish since the price is usually very small compared to their soil building value. The grain farmer can maintain his soil just as well as the livestock farmer if he will, but he usually doesn't. He has the advantage of not destroying his organic matter in animal digestion. It should be remembered that the organic matter in feeds is largely burned up in digestion so that only about one-third of it is voided as organic matter in manure. Formerly the grain farmer thought it impracticable to spread straw and clover chaff but the straw spreaders now on the market do this quite effectively.

A second source of organic matter for the grain farmer is the use of green manure crops. A green manure crop may be any crop grown to turn under for soil enrichment. A legume crop is preferable since it also furnishes nitrogen. Interest and taxes make it expensive to use the whole season for growing green manure, but the southern or more especially the southeastern part of the state can easily grow cowpeas after wheat and turn them under, thus getting a money crop and an application of green manure the same season. Other sections may use the second crop of clover to turn under or grow rye in fall and winter to plow under in the spring. Fertilizers may be depended upon to supply a certain amount of plant food but used in small amounts as practiced in Missouri they must be combined with the use of manure, green manure or crop residues if the soil is not to be run down.

THE PLACE OF PHOSPHORUS IN MAINTAINING FERTILITY

Phosphorus is essential to plant and animal growth and is used as a fertilizer in practically every country that is old enough to need fertilizer and progressive enough to know its needs. Bones were the first phosphate fertilizer and they have been in great demand since the discovery of their value. It is said that England ransacked the world for bones, even to Europe's battlefields. Fortunately other phosphates have been discovered which are abundant and reasonably cheap. The principal one of these is phosphate rock. By treating this with acid to make the phosphorus more soluble, acid phosphate, the most common phosphatic fertilizer, is produced. Other phosphatic fertilizers are basic slag from certain steel mills, dried fish scrap and guanos.

Besides aiding cell division and early growth in plants, phosphorus has the very noticeable effect of hastening maturity. Wheat well supplied with phosphates often ripens a week earlier than that which is starved for phosphates. Of still greater importance is the fact that phosphorus causes a more uniform filling of the grain of cereals.

The fact that phosphorus is largely found in the grain of crops results in a relatively rapid loss of available phosphorus from the farm, for the grain is usually removed and sold. Even where all crops are fed on the farm the loss is large because growing animals use it in bones and other tissues. Milk also carries considerable amounts of it.

As was shown in the table of soil analyses, Missouri soils are rather low in phosphorus. In this they are like most of the world's soils. It is highly important, therefore, that the methods of maintaining or building up this element be given consideration.

A substantial saving can be made by feeding as much of the farm produce as possible, but that in itself is not sufficient. No system has been devised which will prevent phosphorus loss. Practically all systems of farming will be improved by the purchase and use of some material containing phosphorus either as fertilizer or feed or both.

Raw rock phosphate which is just the natural phosphorus bearing rock ground to a very fine powder is the most abundant and cheapest form of phosphate. It is found in Florida, South Carolina, Tennessee and in several states of the Northwest. This raw material has not given as satisfactory returns on the Missouri experiment fields as has steamed bonemeal or acid phosphate. When used it should be bought under a guarantee that at least ninety percent will go thru a screen with 100 meshes to the inch. It usually contains 13 to 14 percent of the element phosphorus, but it is not in a readily available form. A good method of application is to spread from 40 to 100 pounds over each load of manure before taking it to the field.

The next phosphate in point of abundance is acid phosphate made by treating rock phosphate with sulphuric acid. It contains only half as much phosphorus as the raw rock and costs about twice as much, but it is in a more available form and gives quick returns. The acid it contains is not harmful and only good effects are found even where acid phosphate has been used for as many as seventy-five years.

Bonemeal is the oldest of phosphate fertilizers and has long been in great demand. In availability it stands between acid phosphate and rock phosphate and is particularly good on fall wheat, clover, and alfalfa. It usually carries one and a half to two times as much phosphorus as is contained in acid phosphate, altho it becomes available somewhat more slowly.

Both acid phosphate and bonemeal have given excellent results on nearly all Missouri soils especially where used on wheat.

POTASSIUM

The potassium supply, like that of phosphorus, is found originally in the mineral grains altho both elements are contained to some extent in vegetable matter and released by decay. Of the fertility elements commonly supplied in fertilizers potassium is most abundant in soils. Hence it is the unavailable form of soil potassium rather than an actual lack of the the element itself that requires the use of potash salts as fertilizers. Since the potassium of crops is largely in the stem and leaf this element need not be removed from the soil extensively except where the whole crop is fed. In this case care must be taken to prevent loss since at least half of it is found in the liquid manure.

Coarse soils such as those of a gravelly or sandy character are often lacking in available potassium; also those soils low in organic matter. Light applications of potash in mixed fertilizers are often used with profit on such Missouri soils. Some of the most striking results from the use of potash have occurred on peat soils; but few soils of this character are found in Missouri.

Potassium, altho contained chiefly in the stem and leaf of plants, has often been found to improve the quality of the grain where used in available form. The better soils of Missouri, where not worn too badly by poor management, will seldom respond profitably to potash fertilization; but many of the poorer soils will, especially when the applications are small.

THE LIME SUPPLY

One of the most urgent soil problems of Missouri is that of maintaining a supply of lime. Most soil formations of the state are so old and leaching has gone on so long that lime, which is easily dissolved, has been carried away. The easy solubility of lime is proved by the large amount of lime in well and spring water and by the large limestone caves in many sections of the state.

Soil that has lost its lime very soon begins to show an acid test and we say that it is sour. The only practical way to correct this sour condition, which is harmful to most crops, is by liming the soil. Even soils that were derived from limestone, are very often found to have lost all the lime and retained only the impurities contained in the original stone. This is true of many upland soils in the Ozarks while bottom soils of the same region are constantly receiving the lime which washes from the upland soils and hence are usually not sour. Other soils that are commonly sour are the prairies of northeast and southwest Missouri. Farming hastens the loss of lime thru its removal by crops; and the longer farms have been cultivated the more likely they are to become acid or sour.

The kind of lime to use is that which is cheapest per unit of neutralizing or sweetening power. The strongest lime is burned lime or quick lime which in the eastern states is often ground and used in this form. It is sometimes changed to the hydrated form by adding just enough water to bring it to a powder which of course weakens its strength per unit of weight. Air slaked lime is usually a mixture of the hydrated lime and carbonate of lime which is formed by quick lime taking up water and carbonic acid from the air. This air slaked form may be used where it can be bought cheaply enough but for nearly all Missouri conditions the cheapest and hence the best form of lime is ground limestone. This is carbonate of lime or a mixture of the carbonates of lime and magnesia; hence it is similar in composition to air slaked lime. Air slaked lime is usually finer, however. As to fineness, ground limestone should be as fine as ordinary cornmeal or finer; that which will pass an eight or ten mesh screen such as an ordinary fly screen is a standard grade. Coarser stone is slower in action and should be bought at lower cost. If it be put on more heavily it is not objectionable. There is usually much fine material even in the coarsest ground stone. If ground limestone is very fine and pure a ton of it will equal 1120 pounds of good burned lime or 1480 pounds of water slaked or hydrated lime, in sweetening power.

The best way to determine the amount of limestone needed is to write the Experiment Station and get instructions for taking a soil sample and then send the sample to the station for a test of its lime need. Samples should not be taken without these instructions.

Limestone may be applied at any time when men and teams are available but this is usually done to best advantage in late summer, fall or early winter. It will seldom if ever pay to put on less than a ton to the acre, and more should be used if the soil is very sour. Applications are usually not made more often than once in four to six years. The usual application varies from one to two and a half tons per acre.[1]

Where limestone is handled in quantity it is most easily scattered with a limestone spreader. There are several makes on the market, most of them satisfactory. The first requisite is that they be built strongly so as to handle this heavy material. Small plots or alfalfa patches may be limed by hand. The manure spreader may also be used by covering the apron with litter or soil and spreading a layer of proper depth in the spreader bed.

The cost of liming must be kept down since it usually does not quickly bring a large return. Exceptional results are sometimes secured with clover or alfalfa. On the other hand it must be looked upon as a soil improvement process bringing gradual and increasing returns. The highest productiveness can not be maintained without it on many Missouri soils.

COMMERCIAL FERTILIZERS

The Missouri fertilizer law defines a commercial fertilizer as any material, to be used as a fertilizer, the price of which is five dollars a ton or over, and no such material may be sold legally until it has been registered with the state Experiment Station and properly labeled and tagged. In more general terms a commercial fertilizer is a concentrated form of one or more of the necessary plant foods, usually in a fairly available form. Practically all commercial fertilizers contain one or more of the elements nitrogen, phosphorus and potassium; usually with phosphorus predominating. The percentage of these elements in available form is required to be clearly stamped on the bag or other package, and every user of fertilizer should buy only on the basis of the plant food contained. The price per ton means very little unless the amount of plant food contained is taken into consideration. Materials of very little value have sometimes been bought by Missouri farmers because the price was low or because no attention was given to the analysis stamped on the bag. Fortunately most users of fertilizers have now learned to know something about their composition and they are insisting on receiving the plant food paid for. The state inspection service has been developed until the fertilizer buyer is practically assured of receiving the amount of plant food guaranteed by the

[1]See Mo. Exp. Sta. Bul. 171 for full information on liming.

statement. Many samples taken by the state inspection service from all parts of the state each year show that fertilizer manufacturers nearly all live up to their guarantees.

Under the fertilizer law the nitrogen, phosphorus, and potassium must be shown as follows:

The guaranteed percentage of nitrogen is shown and some manufacturers also add a statement of the ammonia equivalent of the nitrogen. This is a second statement of the same thing, however, as ammonia is simply a compound containing nitrogen and hydrogen and therefore showing a little higher percentage than when expressed as nitrogen alone. To reduce the ammonia to its nitrogen equivalent multiply by 0.82.

The guaranteed phosphorus content is expressed as phosphoric acid which is a compound of phosphorus and oxygen. To find how much actual phosphorus is contained, multiply the amount of phosphoric acid by 0.43. From this it is seen that less than half of the phosphoric acid is actual phosphorus. It is an old practice among chemists to express the amount of a given element in terms of its oxygen compound. It is this custom and not the desire to mislead which causes the analysis to be expressed in terms of phosphoric acid. The percentage of available phosphoric acid must be given and in case of a material containing bone meal the percentage of total phosphoric acid from bone is given, also. Sometimes fertilizer literature expresses the insoluble phosphate of rock phosphate or other cheap forms as bone phosphate of lime but this does not mean that there is necessarily any bone in it. Bone phosphate of lime is only a trade name for a compound known to chemists as tricalcium phosphate.

The statement on the fertilizer bag must also show the percentage of available potassium; but here, again, it is expressed as the oxide of potassium which is known as potash. To find how much actual potassium is present multiply the amount of potash by 0.83.

Persons having to do with mixed fertilizers commonly use the abbreviated analysis consisting of three numbers instead of a name, as for example, 2-10-2 or 3-8-5. In the central states the first number is always the percentage of ammonia, the second, percentage of available phosphoric acid, and the third, percentage of available potash. Sometimes the fertilizer may have no nitrogen and the first number is omitted or more often potash is omitted but practically all mixed fertilizers used in Missouri contain a predominance of phosphoric acid.

The nitrogen in mixed fertilizers may come from one or more of many sources such as tankage, dried blood, hoof meal, etc. from packing houses, sodium nitrate from Chile in South America, leather scrap from tanneries, ammonium sulphate from coke ovens, and fish scrap from fisheries. These forms vary a great deal in availability, sodium nitrate being the most quickly available. When it is desired to have the effects of the nitrogen distributed thru the season a material of slower availability may be desired or perhaps a mixture of quickly and slowly available forms.

Among the mixed fertilizers commonly on the market in Missouri the phosphorus is nearly always in the form of acid phosphate altho limited amounts of bonemeal are also used for this purpose. Sometimes both forms are used together with a view to getting the early effects of the acid phosphate and the lasting qualities of bonemeal.

Potash to be considered available must be soluble in water and in normal times muriate or sulphate of potash from European mines is used. Potash from American scources has been on the market thru the war period.

HIGH GRADE FERTILIZERS BEST

Much has been said of high grade and low grade fertilizers during recent years with arguments for higher grade materials slowly gaining the ascendency. Mixed fertilizers in which the total percentage of ammonia, phosphoric acid and potash is less than twelve percent should be considered as low. If the total is fourteen percent or over the fertilizer may be classed as high grade. The question is frequently asked as to why we cannot have approximately 100 percent of plant foods or at least a much higher percentage than is commonly present, but it is impossible to do so in a practical way because we must use impure materials to begin with. For example, most fertilizers consist of a large amount of acid phosphate and acid phosphate contains only fourteen to eighteen percent of phosphoric acid when unmixed. With small amounts of nitrogen and potash carriers added, the percentage of phosphoric acid is reduced and only small percentages of the other plant foods added. It is this use of impure materials and not the use of filler which accounts for the small total percentage of plant foods in mixed fertilizers. In fact low grade fertilizers are mostly mixed from low grade materials and are not reduced in grade by adding much filler as is frequently supposed. High grade fertilizers are commonly cheapest per unit of plant food because the charges for handling and transportation are about the same per ton and therefore less per unit of plant food. It is not practicable to purify the materials commonly mixed for fertilizer use because the cost of purification is prohibitive.

THE USE OF FERTILIZERS

Commercial fertilizers as used in Missouri cannot be looked upon as soil building materials, neither are they harmful if used intelligently. Their purpose is chiefly to give immediate profit; altho, if used to produce more growth in order that more manure, green manures or crop residues may be turned under for organic matter, they may aid in soil building. Many believe fertilizers to be inherently harmful but it is only the abuse of them which results in harm. While using fertilizer the farmer can keep up the supply of nitrogen and organic matter by growing legume crops and turning under as much vegetable matter as possible. If he does this, no harm will result from fertilizers; but he who finds that the use of fertilizers gives a fair yield and thus continues growing grain crops on the same land and using rather small amounts of fertilizer will eventually find his soil sad and run together from the exhaustion of organic matter. The failure to get a yield of grain would stop this process more quickly if no fertilizers were used. Some fertilizers such as ammonium sulphate may cause soils to become sour if their use is continued but an application of lime will correct this condition, and very little of these acid forming fertilizers are used in this part of the country.

The surest and greatest profit from fertilizer on Missouri farms comes from the use of the proper kinds and amounts on wheat. No other common field crop pays so well for its use. For this purpose a highly phosphatic fertilizer is drilled in at rates varying from 100 to 250 pounds per acre, depending on the soil. For medium to good soils bonemeal or acid phosphate should be used and for soils that are worn or thin mixed fertilizers containing small amounts of both nitrogen and potash may pay better.

Fertilizers for wheat are best drilled in, while seeding, using a combination seed and fertilizer drill. This secures a uniform distribution beneath the soil surface, which is desirable.

Where clover or a grass crop is seeded in the wheat, phosphatic fertilizers usually aid materially in getting a stand. Where this is desired a somewhat heavier application should be made than with wheat alone.

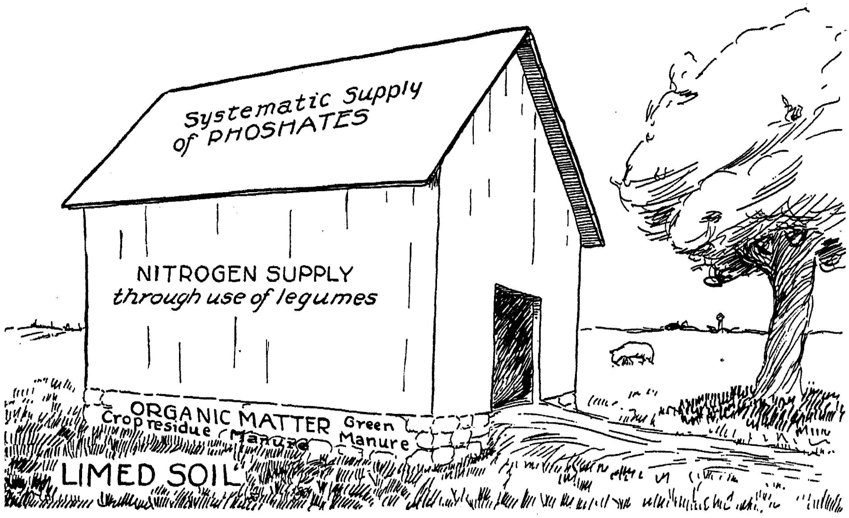
The yield of other small grains such as oats can usually be materially increased with fertilizers, used as with wheat; but the lower price per bushel and the frequent unfavorable seasons for oats in Missouri make their use less certain to return a profit.

Corn is also a bit less certain than wheat in its response to fertilization. In a good corn season fertilizers on medium to poor lands pay well; but when summer droughts occur the benefits from the use of fertilizer are frequently dwarfed.

There are two common methods of applying fertilizers for corn. One is to drill the fertilizer ahead of the corn planter using an ordinary combination seed and fertilizer drill and the other is to use a fertilizer attachment on the corn planter. This attachment will distribute the fertilizer along the corn row or drop it in the hill. Drilling the fertilizer ahead of the planter usually requires 150 to 200 pounds per acre while 50 to 100 pounds is enough if the planter attachment is used. Drilling ahead of the planter is usually better if the season is dry since it does not seem to concentrate the roots so much. In seasons of favorable moisture conditions the smaller applications in the corn row seem to give good returns. Such a plan of fertilizing is, however, not to be recommended generally.

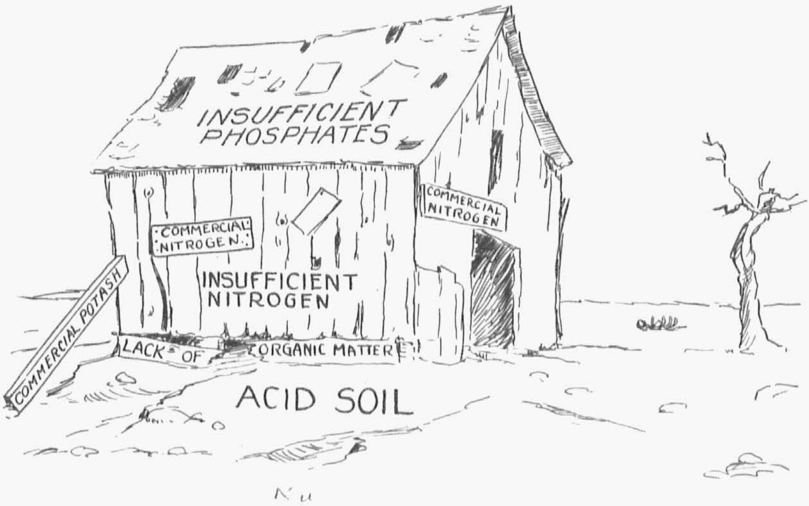
It is of interest to note that with the exception of nitrates fertilizers do not leach away if the immediate crop fails to use them. In most cases, at least, succeeding crops will benefit if the first season is unfavorable to the utilization of fertilizer. An exception should be made in case of steep land where the surface soil is subject to removal by washing.

For a number of years there has been a gradual increase in the amount of fertilizer used in Missouri. So long as they are used intelligently without neglect of the other factors in soil management this is to be approved, but should we get to depending solely upon the use of fertilizer and neglect crop rotation, the use of manure, etc., the soils of the state will eventually suffer. The history of older counties in which soils have been in cultivation for centuries where ours have been cultivated for years indicates that the use of fertilizers will be an increasing and permanent practice.

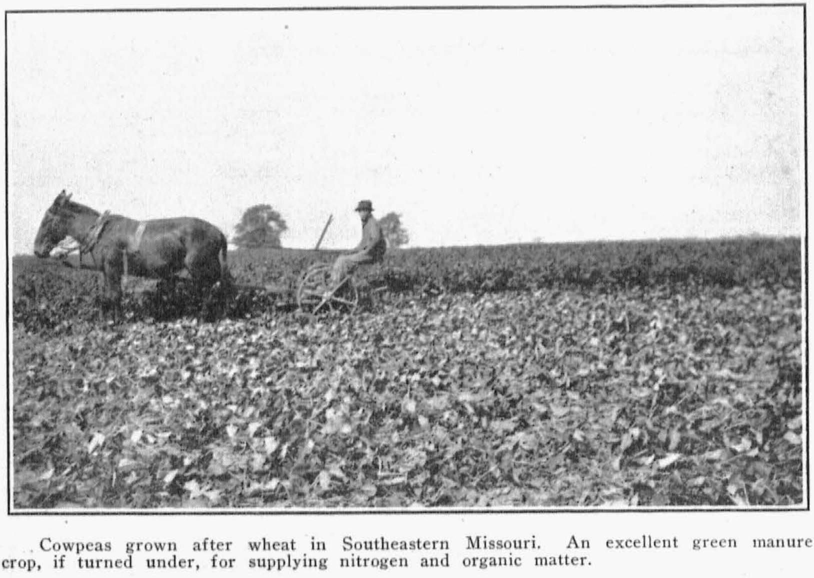


SOIL BUILDING AND MAINTENANCE

A good and complete soil management system is like a building in which the necessary elements are: a secure and permanent plot on which to build, a substantial foundation, true and well built walls protected and kept in repair and finally a roof constructed and kept with equal care. This idea is expressed graphically in the accompanying plate. In soil building and maintenance these elements are naturally or artificially limed soil for the building plot, the maintenance of organic matter thru manures, green manures and crop residues for a foundation, a system of nitrogen supply thru the use of legumes for walls and a systematic plan of phosphate renewal for the roof. Neglect of any one of these elements will eventually bring about the failure and ruin of the soil building and maintenance system. Each element must be carefully planned and kept in repair. If the soil lime is exhausted and the soil becomes sour the growth of legumes and other soil building crops will gradually be diminished, resulting in caving away of the building plot and undermining of the foundation of organic matter maintenance. This causes the walls to crumble thru failure of the nitrogen supply. A lack or failure of the plan to keep up organic matter is like allowing the foundation of the structure to crumble away. It results in wrecking the walls thru lack of nitrogen maintenance and since little potassium becomes available where organic matter is exhausted commercial potash must be bought even tho potassium is abundant in the soil. This is like a prop to the tottering building of soil maintenance. The walls representing nitrogen must be patched with the expensive plaster of commercial nitrogen. If the foundation of organic matter is maintained little trouble will be experienced in building and keeping up the walls of nitrogen and no potash prop will usually be needed. Phosphorus maintenance represented by the roof of the system will usually require the purchase of some phosphatic fertilizer in addition to prevention of waste. Failure to keep up the

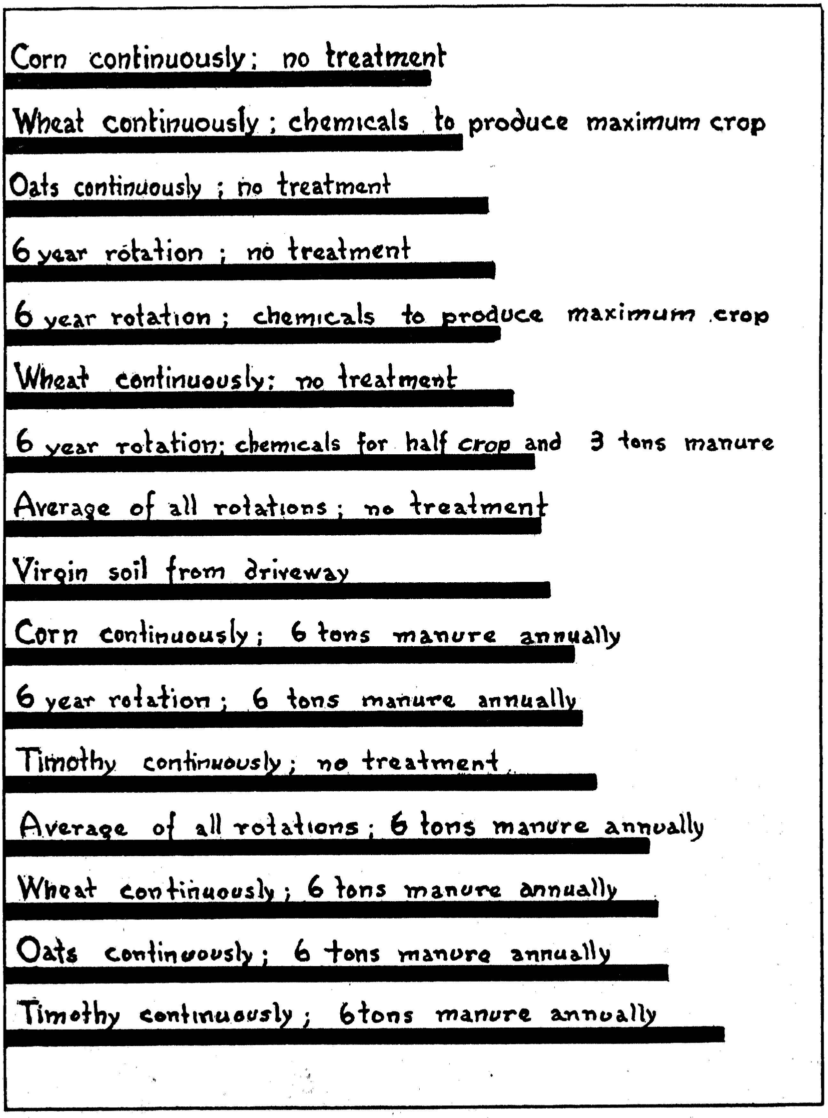


phosphate supply permits the leakage of diminishing crop growth which in turn rots away the walls and foundations of the structure because with diminished growth nitrogen and organic matter can not be maintained. If these four factors: lime, organic matter, nitrogen-yielding legumes and phosphates are taken care of, the Missouri farmer may be assured of the practical permanence of his system of soil maintenance.



Cowpeas grown after wheat in Southeastern Missouri. An excellent green manure crop, if turned under, for supplying nitrogen and organic matter.

NITROGEN IN SURFACE FOOT OF SOIL
(AFTER 25 YEARS OF CROPPING 1889 TO 1913)



The Missouri Experiment Station began field experiments with crop rotation, manure, and fertilizer in 1889. At the end of twenty-five years all plots were sampled and the soil analyzed. Marked differences were found in the amount of nitrogen in the soil as indicated in the above chart.