

Fertilization of Soils.

BY J. B. EDMONDSON.

The man who farms is engaged in a business so complex and many-sided that it is no uncommon occurrence for him to escape to the city to take up a more simplified profession, or to see young men hesitate long before choosing the farm for their life's work. The universal cry of such individuals is that there is too little money in farming, when the trouble lies in the fact that they are not able to measure up to what is required of the man who is making a success on the farm today. One has but to glance about him and note the many examples that the country affords of men who have turned farming into a highly successful business, financially and otherwise, to be convinced of the truth of this statement. Reduced to its simplest terms, good farming consists of raising the biggest crops possible every year the business is followed, and, incidentally, the longer it is followed the more satisfactory should be the returns. That is, farming is a growing business if rightly engaged in. While the manufacturer's plant will be subject to several thousand dollars deterioration during the twelve months, the plant of the intelligent farmer will be in even better condition for manufacturing crops at the end of that time, notwithstanding the fact that it has already turned over a good crop account to the owner. The longer the intelligent farmer remains on the farm the more productive it should become, but the sooner the careless or ignorant farmer gets to town and into the shops the better off it is all around, provided his place is taken by one of more thorough understanding of the business in which he is engaged.

Of first importance in farm economics and in farm practice is the soil. So intimately is the soil related to every operation, and so complicated is its management, that a working knowledge of the principles that underlie its power to produce crops is one of the very essential qualifications of the farmer. So true is this that a man's success or failure can be determined by the manner in which he treats his soils almost as accurately as by an examination of his bank account. Fundamentally, it is not a question of whether the

farmer is raising pure bred stock, whether he is feeding balanced rations, or whether he is providing sanitary quarters for his cows; all these things are important, yet they will fail to keep him off the breakers unless he is on right terms with the soil that grows his crops. Essential as live stock is on the well regulated farm, even that must be regarded as subsidiary to the tilling of the soil and the raising of crops. With the soil cheerfully responding at harvest time with bountiful crops, all these other things will be added unto the farm by a sort of an evolutionary process; but with the soil sick and out of harmony with mankind and all useful plants, the whole situation is changed to one of more or less hopelessness. Strangely enough the great farming class seems to be the least concerned of any in regard to the condition of the soil. While business men, lawyers and ministers are agitating the subject of soil conservation through the medium of the press and from the platform, farmers continue to sow and plant their acres *with little or no evidence of improvement*. In fact, it is safe to say that the movement for better agriculture will have to be carried along and fostered by forces that are entirely foreign to the actual farming interests. The farmer has plenty to eat and wear and does not feel the pinch of high prices nor experience the prospects of finding his larder empty, and, consequently, he is unable to realize the necessity of increasing the output of his farm. The cry is gaining in volume every year from one end of the country to the other that the productive value of the soil is growing less and less under the present system of management, and very slowly the tide is turning in the direction of more careful and scientific methods.

In discussing the fertilization of soils, the writer realizes that the task is no simple one. In talking to farmers in regard to this matter one is impressed with the fact that, as a rule, the principles underlying practical soil fertility are but little understood. Thousands of farmers who have tilled the soil all their lives, feed to the soil fertilizer by the sack, much as they feed oats to the horses, and believe the problem is solved. While there are many points in regard to the action of fertilizers, the assimilation of plant food from the soil, and the relation of soil bacteria to plant life that are not clearly understood by the scientists, yet a man must have a fairly definite understanding of what his soil is actually in need of before he can set about to supply it. The more of a soil expert the farmer is the more liable he is to prosper; but it does not follow that the average farmer with the average education is doomed to failure. There are so many phases of soil management made mani-

fest to the eye that every farmer has ample opportunity to act intelligently in regard to it, whether he be able to write his name or not. A man need not be a college graduate to be able to tell that his soil is acid and needs lime; that his soil needs draining out in order to give the air and soil bacteria a chance to enter; that the humus is entirely burned out of the soil on his heavy, clay upland, or that a one-year rotation is a quick and sure way to destruction. The close observer can determine all these points from the outward indications of the soil itself. But before he can do even this he must know what to look for; that is, he must understand the ills of the soil sufficiently well to be able to recognize them whenever the symptoms are found. His own observations, coupled with his experience, will go far in guiding him in his operations.

When a soil refuses to produce crops in profitable quantities it is an indication that it is lacking in some essential that others, which raise large crops, possess. Just what this is is not easily determined in every case, but it is a safe assumption that were its needs supplied it would respond as satisfactorily as the other. Generally speaking, farmers do not believe this. That is, they consider the poor farm on the hillside as nothing but a hill farm with its stunted growth of corn and wheat, and that its chances of ever doing anything more are extremely remote; consequently such farms are usually farmed in accordance with this view. True, there is a wide variation between the rich, black loam of one section and the raw, gully-washed hillsides of another, with one producing seventy-five bushels of corn per acre and the other barely fifteen; but it has been clearly demonstrated many times over by practical farmers that whenever the latter extreme type of soil is supplied with those things which it was either deprived of by nature or robbed of by man, and which the former soil contained in abundance, the variation in the yields dwindles down until the hillside is growing as luxuriant crops as the other. The point is that, except in rare instances, there is no such thing as naturally sterile soil or permanently exhausted soil; but there is such a thing as keeping soils in such a low state of productiveness as to render their cultivation unprofitable. One man is considered a wizard because he succeeds in doubling the yield of his neighbors on the same type of soil; in short, it is not a question of soil in most cases nearly so much as one of whether the farmer understands the particular kind of treatment that his particular soil needs.

But another consideration enters here which accounts largely for why poor farms remain poor, and why they usually grow poorer

and poorer each year. Generally speaking, the poorest soil is compelled to support the most shiftless farmers. This means that soil which above all else needs a careful and intelligent farmer to manage it is doomed to sink lower and lower in the productive scale through the exploitation of ignorant soil robbers. On the other hand, soil that by happy circumstance was adapted for the growing of crops before man entered on the stage, from the first attracted the better class of farmers, and in the sifting and shifting process that followed the best farmers through their own fitness gained possession of the most productive lands. As a consequence of this the poorer farmers were gradually crowded out and were compelled to take up the cheaper and less productive lands. In studying rural conditions in the different sections of the State, it is a matter of observation that the poorer the land in a section the more shiftless and unconcerned are the farmers on it in regard to its needs. So many of our so-called "worn-out" soils are forced to carry a double burden—their own condition of semi-starvation and the persistent scourging inflicted by a grasping taskmaster. Under such conditions it is useless to expect the soil in the poorer sections of the State to be rapidly regenerated. The situation is all the harder to cope with since the many educational forces of the present day are unable to reach a large per cent. of those who are most in need of such help. The agricultural press, farmers' institutes, agricultural experiment station work and educational trains are not patronized by a large number of farmers simply because their interest is as slack in those things as in the welfare of their own soils.

The term "soil fertility," which has in the last few years come into such common usage, is a general one to denote that quality in the soil that determines its productive power when measured in crop yields. It is quite obvious from such a broad definition that many and varied conditions are involved. The supply and seasonal distribution of rainfall, the drainage facilities, the origin of the soil, the humus and mineral plant food supply, and even the cultivation, all figure largely in the production of the crop, and must be considered as phases of the soil fertility problem. While the rainfall is clearly beyond the control of the farmer, the drainage, the cultivation and, in a very large measure, the supply of plant food should be considered as under his controlling hand. True it is many farmers consider themselves responsible only for the cultivation and trust to nature for both the supply of plant food and the provisions for drainage; but such farming is extremely hazardous, for nature was not trained to grow crops by the well

regulated systems worked out by man. Nature's plan of sowing and reaping differs in that she is able to select her crop from a long list to suit the condition of the soil in which it grows, and she makes no attempt to alter the soil to suit the crop. For instance, red sorrel finds itself in almost undisputed possession of acid soils where other vegetation is unable to thrive; certain swamp grasses and smartweeds fill up the wet areas; and the various legumes assume control of the lime enriched soil. In fact, so wisely does nature distribute and establish her various crops that the farmer often finds it an extremely difficult task to subdue them, unless he strikes at the heart of the situation and alters the favoring condition of the soil. When man plants he has but a limited number of crops from which to choose, and he sows the seed on the ground that is white or black, rich or poor, heavy or light, without ever considering the adaptability of the crop itself in the matter. While it is not practicable to choose a special crop for every type of soil, it is practicable and necessary to approach as nearly as possible the ideal soil for the crop raised, whatever the original nature of the particular soil may be. Farmers fail to raise clover often because they expect it to thrive on soil that is better suited for red sorrel, and wheat is sown on ground that is the natural habitat of swamp grass or smart weeds. If the farmer is to claim the ground for the exclusive use of his cultivated crops he has a difficult problem before him all the time, for he must assist them in the struggle for supremacy by changing the soil conditions in their favor in every way that is within his power. This, in short, is what is involved in the great soil fertility question.

The yield of corn or wheat is the practical means of judging the quality of a soil, under normal conditions. A low yield indicates that something is wrong, and the real test of a farmer's efficiency lies in his ability to detect the causes and then to set about to remedy them. After years of failure the farmers on the muck soils of northern Indiana found that the secret of their troubles lay in the fact that their soils were practically devoid of available potash. The cause of their failure once determined, the remedy was easily applied, and enormous crops are now being raised in those sections. Although the above is a special and clear-cut instance, yet it illustrates the point that unless the farmer can put his finger on the specific needs of his soil he will necessarily remain in the dark as to what action to take toward improving it. Close observation of the soil in various conditions of moisture, and of the crops that grow on it, will reveal much, if rightly interpreted.

However, the lack of faith in the earning power of the soil is often now more responsible for the farmer's seeming indifference than is the lack of knowledge. For instance, the farmer of small means who gets meager returns for his labor is inclined to lack the moral courage to spend any considerable amount of hard-earned money on his land for drainage or fertilization, even though he may know that until these steps are taken he cannot hope for any improvement. The man with unlimited faith in the power of his land to return with interest every dollar that is rightly spent on it finds himself growing into prosperity.

From the average farmer's viewpoint the matter of using fertilizers is considered as the all-important one in keeping the soil in a prime condition for the production of crops. Commercial fertilizers have been thrown on the market in such quantities of late years, and such varied results have been obtained from their use, that the moment the subject of soils is introduced the farmer hastens to ask about commercial fertilizers. "What kind of fertilizer does my soil need?" is the universal question that is raised. The writer has visited many farms and discussed the soils with their owners, and almost invariably a deep concern was shown in the quality of fertilizer that should be used, to the exclusion of all other phases of the subject. For instance, the subject of drainage was rarely mentioned, even though the farm may have lain like a water-soaked log, every foot of which was crying out to be relieved of its load of water. Buying fertilizers of any kind for such a farm is extremely hazardous in any event, yet there are thousands of farmers who drill the commercial fertilizer into their soils year after year in the belief that they are doing all that can be done to insure a paying crop, when the thing that is needed is tile. Until land is drained, either naturally or artificially, there is little use to consider its fertilizer needs or any other phase, because, in the very nature of the case, the removing of the surplus water and admitting the air is the first furrow, and it must be turned first if the others are to follow successfully. If a goodly per cent. of our farmers were less concerned about having a chemical analysis made of their soils and were more interested in installing a complete drainage system in their fields fewer crop failures would be recorded.

The tendency among farmers in planning their drainage systems is to shy around the elevations and run the drains only through the low areas, in the belief that the upland, especially if sloping, is amply drained and that a string of tile extending down

a slope is so much money uselessly buried. This theory is a mistaken one, for it is often responsible for missing the wettest spots in the field with the drains, since they may be found on the higher points. Over large areas of upland in Indiana, where the Miami clay loam and Knox silt loam are found, the surface soil is fine and compact and is almost universally underlaid by a heavy, impervious subsoil, and natural drainage is decidedly poor, even on the slopes where the water has an excellent chance to drain away. Many instances have been found where tile drainage proved a great boon to such land, even in places where its installation would seem foolish to the casual observer. While the writer would not undervalue the practice of supplying plant food to the soil, he would, before taking that matter up, emphasize the importance and necessity of draining the land as the requisite for all later operations. If the surplus water were removed from the ground many fields that are believed to be exhausted of their available plant food would respond in a surprising manner. A free, open soil can go a long way toward manufacturing its own food for the plants within certain limits; but when it is cold, heavy and sodden it is practically helpless.

A farmer goes to the field and plants a gallon of seed corn. After cultivating it carefully for five months he gathers seventy-five bushels from the gallon of seed; or, in other words, he takes off six hundred times as much grain as he put on. Another farmer plants the same amount of seed corn, cultivates it as carefully, and gets in return only forty bushels, while a third may get only fifteen bushels. This is a matter of common experience; but why did not the third man fare as well as the first, and why will one acre raise only fifteen bushels of corn while another, across the fence, will produce five times as much? Why, indeed! If the farmer would seat himself on a stump in his own cornfield and ponder this question seriously himself he would undoubtedly be able to rub some of the scales from his eyes and see more light in his soil problems. The quality of the food ready for the use of the plant in the different soils can alone explain the difference in these yields. When the chemist analyzes the soil he finds certain elements; and when he makes an analysis of the corn that grew on the soil he finds several of those same elements in it. Ten of these elements of the soil, it has been found, are absolutely essential to plant growth. By leaving one of these out experimenters have been able to starve the plant to death after it has begun to grow, even though all the other nine are present. So, in farming practice, if one element is

seriously deficient or entirely exhausted the plant is just as helpless as if all its food were limited in the same degree. The comparison between the plant food in the soil and the weak chain is an apt one in this respect; the faulty link determines the strength of the chain, and the most nearly exhausted element of plant food determines the agricultural strength of a soil. By comparing the analyses of the soil and corn three elements are found in each, in considerable quantities in the corn plant, but in very small amounts—sometimes mere traces—in the soil. These elements—phosphorus, potassium and nitrogen—are the only three of the ten necessary elements that the farmer need concern himself about, because these are the only ones that show any likelihood of becoming exhausted. Their scarcity, then, and the ease with which they can be removed from the soil give them a place of greater importance than the others, and not the fact they are any more necessary to the plant itself than oxygen or iron.

In writing and speaking of chemical fertilizers and the chemistry of soils it is customary to refer to the element potassium as potash, the name given to the compound in which two parts of the element are combined with one of oxygen. In like manner phosphorus is spoken of in terms of phosphoric acid, or the compound containing two parts of phosphorus and five parts of oxygen. Just why these terms are used instead of the true ones is not clear, for it has led to considerable confusion and is misleading in many ways to the farmers. There has recently been an effort made on the part of some of the prominent soil chemists of the country to eliminate these old terms and to speak of the elements in their true sense, but little progress seems to have been made as yet. In this discussion the terms potash and phosphoric acid will be employed according to the common usage in referring to potassium and phosphorus respectively.

Practically all soils that are unable to produce profitable crops are limited by the lack of one or more of these three elements in available form. It is always the province of the wise farmer to induce the soil to manufacture its own plant food into a form that the crop can readily use, but experience has proven that it is a wise procedure to supplement this with ready-for-use plant food, either in the form of commercial fertilizers or manures. It is notably true that many soils are in greater need of an application of lime than of any of the three elements mentioned, but lime cannot be rightly considered in the sense of a fertilizer, since its action serves more as a tonic or conditioner for the soil than for furnishing

actual food for the plant. For instance, the soil, through its physical condition, may show a very great need for lime, yet, at the same time, it may contain sufficient to supply what lime the crops may actually need for years. Thus the liming of soils, which is becoming a very general practice in some sections of the State, is a distinctly different operation from that of applying chemical fertilizers. In fact, liming and its effect in opening the soil is more nearly comparable to artificial drainage, although the best results of the lime are never realized unless its application is preceded by adequate drainage. Wet upland soils that have been farmed for a long period are nearly always sour, and these two qualities are more responsible for low yields and total failures than even the lack of nitrogen, potash or phosphoric acid.

The means at first hand for the farmer to meet the demands of his soil is through the use of barnyard manure. Indeed, so important is the farm manure as a source of plant food to replace that which is removed in the crops that the whole system of live stock farming is centered around the production of this by-product; in fact, the manure is almost considered in the light of being the chief product by many successful farmers, with the gains produced on the animals relegated to a place of secondary consideration. While this is true in some cases, unfortunately it does not hold true in all. Thousands of our farmers, on farms that need the manure the worst, see in its accumulation about the barns little more than the disagreeable task of removing it to the fields. Under average conditions a farmer's success is in direct proportion to the value that he places on the manure that is produced on the farm. Where this crop is conserved as carefully as the corn, hay or any other crop produced on the farm, low yields are the exception and not the rule.

Even the most unskilled farmer is able to note the quick response that crops make when manure is used on the field. While the increase in crops by this means is easily demonstrated, it is not so clearly understood how the manure brings the change about in the soil, or how far it can be depended on to replace the supply of available plant food that leaves the field in the form of grain or hay. To a certain extent farm manure performs the same office as chemical fertilizers, in that it carries a considerable quantity of available plant food, but it goes farther than that—it furnishes a source for a large amount of vegetable matter, which the soil is often in greater need of than the other. It can be said, then, that manure applied to the soil gives the combined results of both commercial fertilizer and green manuring crops. While each of these func-

tions is distinct, yet they are so intimately associated with each other in promoting the growth of the plant that it is impossible to distinguish sharply between the two and say that a certain part of the beneficial results derived from the manure was due to one or the other. While usually the emphasis is laid on the fertilizing ingredients of the manure, common experience teaches that such quantities as are found are entirely inadequate to account for the ready response made by the crops for several years after its application. So the situation as regards the use of manure, and its action on the soil, is a decidedly complex one, and it cannot be pinned down by figures and calculations as is done in the case of commercial fertilizers. However, a technical understanding of these things is not at all essential or necessary to convince the farmer that his farm manure is of great value to his soils. Practical results are what interest and convince the farmers, and whatever they may think of the wisdom of using commercial fertilizers, all are agreed that in some way manure has a wonderful life-giving power to the soil.

Considering the average farm manure from a strictly mineral and chemical standpoint, it is worth something near two dollars per ton when it reaches the field, figured on the basis of the cost of the mineral elements in commercial fertilizers. As every farmer knows, this amount is entirely too small to account for the results that are obtained when compared with those obtained from mineral fertilizers. Even twice the plant food value of the manure invested in mineral fertilizers would be less valuable to the soils than the one ton of manure. The conclusion is, then, that the actual supplying of plant food is by no means the chief and only function of manure when applied on the heavy upland soils, which usually receive the bulk of the farm's supply. How the manure can so favorably affect the soil, over and above any consideration of its plant food, is a matter that has received much attention from scientists, and is now being cleared up. Suppose a farmer, becoming discouraged, goes to the chemist with a sample of soil from his worn-out field. The chemist makes an analysis and finds to the astonishment of the farmer that the supposedly exhausted soil actually contains enough plant food per acre to raise record-breaking crops for a number of years. At the same time, however, he knows from experience that the best the soil can do, even under favorable conditions, is thirty or forty bushels of corn. It is evident, then, that the corn plant, like shipwrecked sailors who die of thirst with an ocean of water about them, is actually stunted in its growth for want of food even in the midst of plenty. In practically all our so-called "worn-out"

soils the above condition prevails. It is not that the soil is actually exhausted of its mineral elements, as is generally believed by farmers, but the trouble lies in the fact that the plant food, while present more or less abundantly, is encouraged by the unfavorable conditions of the soil to enter into such compounds as will preserve them in a stable condition; consequently the plant is deprived of its source of available food, and so far as the plant roots themselves are concerned the plant food may just as well be entirely removed from the field. A worn-out soil, then, is not an exhausted one in the true sense, but merely a dead soil—dead because even the chemical changes that are continually going on in a productive soil are brought to a standstill, since the more active compounds—those containing the important elements of plant food—are converted into forms that are very slowly changed. There is little doubt but that manure, when allowed to decay in the soil, so influences the latter that as much or more plant food is rendered available than is actually supplied by the application. This factor entering as it does in the consideration of the beneficial effects of manure makes the matter of furnishing a balanced fertilizer for the crop an exceedingly complex and uncertain one. Manure is usually considered as being especially rich in nitrogen and the effect that its application has on the growth of the crop would warrant such a belief. Yet when the requirements of the plant itself are considered we find that were there no other source of plant food except what is applied in the manure the nitrogen would be the first element exhausted. Roberts calculated that for every 100 pounds of nitrogen contained in mixed manure there are 49.6 pounds of phosphoric acid and 77.8 pounds of potash; yet the corn plant in using this 100 pounds of nitrogen requires only 32 pounds of phosphoric acid and 100 pounds of potash. This means that for every 100 pounds of nitrogen furnished the corn crop by the manure there is an excess of 17.6 pounds of phosphoric acid and a deficit of 22.2 pounds of potash, when the composition of the manure and plant are compared. Conclusions based on these facts alone would lead the farmer to apply phosphoric acid sparingly and to make heavy applications of potash and nitrogen. Indeed, the figures show that manure should be a means of building up the supply of phosphoric acid in the soil, but in actual practice we know that this is not true, but rather the reverse; for manure is decidedly weak in phosphoric acid, and, as stated above, all the indications in the growth of the plant point to a gorging of nitrogen. How to account for this seeming paradox is not easy,

but it at least proves that the composition of the plant is not a safe guide in determining its fertilizer requirements in all cases. In the case of manure, experience teaches that its limiting element is its low supply of phosphoric acid, and many up-to-date farmers have been highly successful in increasing its value by adding acid phosphate or floats to it in the stable while it is being made. Not only is the ration for the plant balanced in this way, but at the same time the nitrogen in the manure is fixed and is prevented from escaping in the form of ammonia; likewise it has become the custom to use a fertilizer high in phosphoric acid for corn and wheat, and, in fact, many farmers use pure bone meal alone with excellent results. The only satisfactory means of explaining this situation is through the action of the manure itself. While the analysis shows that it is strong in phosphoric acid as compared with the other plant food elements, experience proves that it is notably weak in this respect. The conclusion is that the manure releases large quantities of both nitrogen and potash in the soil that had been held in an unavailable form, and this additional supply given over to the use of the plant makes the amounts too great for the phosphoric acid to balance, hence the deficiency.

Obviously the man with worn-out soil has two recourses that, theoretically, should meet the situation. He can make the ground itself the basis from which to work an improvement by persuading it to unlock its treasure house, or he may start the endless campaign of furnishing the available plant food for the crop each year before it is planted through the use of fertilizers. No more disastrous mistake could be made than depending on the fertilizer sack for every crop, yet thousands of farmers are doing it, to the exclusion of other means of fertilization, such as barnyard manure, green manuring crops or the growing of leguminous crops. While it is not denied that most soils respond readily to an application of commercial fertilizer, and will continue to do so for some time, it will eventually become sluggish through such an exclusive system of feeding; it will not only refuse to produce its former yields, but the soil will gradually become heavier, more cloddy and in poorer physical condition each succeeding year. Indeed, this has been the common experience of many farmers, and, as evidence of the final outcome, the cry is being raised in every section of the country that "commercial fertilizer ruins the soil."

There is little doubt but that mineral fertilizers, used alone, will actually work an injury to the soil after a number of years of heavy cropping, but in an indirect way. Where the farmer looks

after the supply of humus as zealously as he does the plant food, and keeps the soil darkened with vegetable matter, commercial fertilizers can be used for an indefinite number of years, and with intelligent management the soil should become more and more productive. It must be kept in mind that mineral fertilizers are unable to furnish the soil with anything but the nitrogen, phosphoric acid and potash that they contain, even though the soil may need, and very often does, a liberal supply of vegetable matter. Where this need is disregarded the putting on of the raw minerals only hastens the final exhaustion of the humus, since the crops are stimulated to more rapid growth and the soil is exhausted of its humus supply all the quicker. While salt is considered as essential to the growth of the human body, one would be extremely foolish to give an exclusive salt diet, simply because there are several other needs of the body that are in no way satisfied by the salt. Shall we say that salt ruins the body just because it will do so when eaten exclusively? Many farmers fail to recognize the limitations of commercial fertilizers, but consider them a panacea for all the ills to which the soil is subject.

But to return to a further consideration of the effect of barnyard manure on the soil. As every farmer's experience well teaches, the real value of the manure to the soil is out of all proportion to its content of plant food, due to the fact that it is able to influence the soil in such a way as to render available considerable quantities of the inert minerals that are locked up in the difficultly soluble compounds. The organic matter in the manure is responsible for this good work, an advantage that is entirely lost sight of by the man who depends on commercial fertilizers. Humus is the heart of the soil and common observation teaches that the deadest soil is the one most nearly exhausted of this important element of fertility. Very many of our so-called "thin" soils are suffering more for want of organic matter than from the lack of plant food. A rank-growing nonleguminous crop plowed under gives remarkable life and productive power to a humus-exhausted soil, yet there is absolutely nothing added to the soil in such a process but organic matter. The beneficial results of such green manuring crops are so pronounced that many farmers are firmly convinced that the soil is actually enriched in plant food. When the vegetable material is plowed under it is eventually converted into humus, a process which is of immense importance in giving life to the soil.

It would doubtless be putting the matter more nearly in the true light to consider barnyard manure as a source of organic mat-

ter, which, incidentally, carries considerable quantities of plant food in addition. If it could be definitely determined it would doubtless be found that the organic matter is the most important and most valuable part of the manure. At any rate the good effects of a load of manure can be noted on a poor soil for years, while the same quantity of plant food that is contained in the manure, if applied in commercial fertilizers, would be swallowed up in less than two growing seasons. While crossing an exceedingly thin, worn-out pasture recently the writer was ruminating on the possibility of anyone ever being able to bring such a soil back to a state of productiveness. The outlook was indeed a discouraging one. About the middle of the field an irregular patch of grass was noticed which had made a growth far beyond that surrounding it. This was found to be the site where one lone load of manure had been scattered some years before. So readily and certain did the grass respond to this treatment that it was almost possible to trace the separate forkfuls of manure as it was thrown from the wagon. Without question the supply of plant food that the manure contained had long since been exhausted, yet the good effects of the organic matter was still plainly visible after several years. Here, then, was the key to the situation—manure, and more manure, is what is needed to bring life back to our failing upland soils, and this can be done all the more quickly if it is properly balanced with commercial fertilizers. While the importance of commercial fertilizers in maintaining the fertility of the soil is not to be underrated, yet, under the present system of utilizing them, they can be considered nothing less than a very extravagant commodity. Thousands of dollars are paid out every year in this State for mineral fertilizers by farmers who allow their manure to collect under the eaves of the barn and wash away to the creeks or pile it up in some vacant stable to heat and burn out. The writer believes that the soils of Indiana, as a general rule, are not in need of more commercial fertilizers nearly so much as more barnyard manure, the use of cover crops to protect the humus from burning out, and a frequent plowing under of some green manuring crop. The more these things are practiced the more can commercial fertilizers be used to advantage both to the soil and to the pocketbook of the owner, but commercial fertilizers without any provisions for maintaining the supply of humus lead to final destruction.

A discussion of farm manures would be conspicuously incomplete if the matter of handling and caring for the manure on the farm were left out of consideration. The idea is quite prevalent

among farmers that quality in manure is a thing of little or no importance, and that manure will give equally good results when once gotten on the field, regardless of the manner in which it is cared for. As a matter of fact, there is often much more variation in the composition of the manure when produced under different conditions than in the composition of commercial fertilizers whose analysis serves as a guide in buying. The proper methods of caring for manure has been so often exploited by writers and lecturers that it hardly seems necessary to enter into an extended discussion of it here. However, the principles that underlie its preservation or deterioration are so fundamental that they cannot be brought to the farmer's attention too often.

Happily, the best way to handle the manure on the stock farm is the simplest way; that is, to haul it directly to the field as soon as made. Farmers, chemists and soil experts are agreed on this point and recommend that the practice be followed whenever possible. When the manure is hustled to the field in this manner two very serious dangers are avoided—dangers that together are responsible for the loss of thousands of dollars of plant food to the farmers of the State—leaching and heating. While these two processes are directly opposed to each other, they nevertheless often occur in the same manure pile at different times. Where the manure is removed at frequent intervals from the stables the most convenient means of disposing of it is to throw it through the window to the outside, where it is allowed to accumulate, unprotected from the sun and rain. In the meantime the barn roof collects the water that falls over a considerable area and pours it down bodily on top of the manure. During the spring months especially is the damaging effect of leaching felt. At this time the accumulation of manure is usually greatest and the wetting process is repeated until the pile is saturated in a short time. Following this, then, as much water runs away from the base of the pile as falls on top, and it naturally follows that whatever of a soluble nature that the water comes in contact with in percolating through the manure is carried to the bottom and away to the ditches, in solution. It happens that most of the nitrogen contained in fresh manure is held in the nitrate form, and this is very easily soluble in water. The water when it falls on top of the manure is clear, but when it issues at the base it has taken on the reddish brown color that is familiar to every farmer. In a very short time manure under such conditions will lose practically all its available nitrogen, the most valuable element that figures in the purchase of fertilizers. This happens

just as surely, and in the same way, as if a sack of commercial fertilizer were left under the eaves of the barn to catch the rains. The farmer who would treat his commercial fertilizer in this manner would be considered a disgrace to his profession, yet there is really little difference between letting nitrogen and potash wash away from the sack and allowing it to escape from the manure pile.

In view of the above, it seems logical that the manure should be kept dry if allowed to accumulate before hauling to the field. However, when piled so loosely as to allow the air to penetrate it manure is subject to even greater injury than in the other case. Animal manure is literally teeming with millions of bacteria which are ever ready to begin the work of removing it from the earth by converting it back to its primary elements. They must have a supply of oxygen, however, before they can thrive. Where the manure is not packed so closely, or is so wet as to exclude the air, the bacteria soon give evidence of their presence through the heating of the manure. This is especially noticeable in horse manure, which has much less moisture than other kinds. When allowed to remain in this condition for some time "fire fanging" results. During this process the various constituents of the manure part company and each goes its own way—the nitrogen escapes into the air in the form of ammonia, the mineral elements are either lost or converted into unusable compounds, and, most important of all, perhaps, the vegetable matter is burned out by the excessive heating so that when the process is completed only a white, chaffy mass of light material is left that is hardly worth hauling to the field. Obviously, then, the exclusion of air is just as essential for the preservation of manure as the exclusion of excessive water. A certain amount of water is of direct benefit to the manure, since it prevents the air from entering, and this is, in fact, the most practical means of preventing it from heating where it is piled in heaps. The only precaution necessary is to prevent it from becoming saturated, in which case leaching results.

The essential difference between barnyard manure and artificial fertilizers is that the latter is able to supply only the constituents that are actually demanded by the plant, and when this is done the fertilizer has spent its force. On the other hand, the manure not only does this, but also carries back to the soil large amounts of organic matter which affects the physical makeup of the soil in a very marked degree. This function of manures may be considered as the power for doing good to the soil, held in reserve, which is entirely absent in commercial fertilizers. In fact, where the after

effects of commercial fertilizers have been noted they are believed to be actually harmful to the physical texture of the soil. This occurs only on heavy clay land that has been exhausted of its humus and on which a continuous use of such fertilizers has been made, since on other soils they have no visible effect.

In view of these facts, it may seem that the use of artificial fertilizers is unwise in any case, and that the whole practice is more or less fallacious after all, since manures, legumes and turned-under crops seem to be able to take care of the situation. Such a conclusion is not based on fact, however, although many farmers cling to the belief that their soil can be kept in its present state of productiveness without in any way using artificial fertilizers. There are two legitimate reasons for urging every farmer to make a judicious use of commercial fertilizers in keeping the soil up to its standard of productiveness. In the first place, there is, on the average, not nearly enough manure produced on the farm to replace the plant food constituents that are removed through the medium of the hay and grain that are carted away to the cities. While this deficit varies greatly on different farms, according to the amount of live stock that is fed and the manner in which the manure is cared for, yet on every farm some of the products are removed, such as wheat, straw or hay, and there is also a considerable additional loss of plant food through leaching, heating, etc. This means that each year finds the farm somewhat poorer in plant food unless its equivalent is brought in from outside sources. While it is true that, under careful management, a naturally productive soil can be maintained for a long time by growing clovers and returning the manure, that results from feeding the crops, to the fields, yet sooner or later the yields will begin to dwindle as a direct result of exhausting the native supply of available plant food. If it were possible for the farmer who sells his farm products to realize a cash value for the plant food elements that thus leave the farm the objections to such a system of farming would not be so serious. But this is not the case; the prices of his crops and other products are based solely on their feeding value, and no consideration whatever is given to the fertilizing ingredients that they contain. This simply means that a considerable part of the farm's permanent asset is thrown in for good measure whenever a crop is removed bodily from the land that grew it. Since it is an absolute necessity to replace this plant food, farmers have naturally turned to the artificial fertilizers as the simplest way out of the dilemma.

There is still another important consideration in regard to the use of commercial fertilizers that would tend to give them a permanent place on every farm, even where an abundance of manure is produced. As has been previously noted, the immediate effect of an application of manure is to gorge the plants with nitrogen, especially if the application be heavy on a soil naturally deficient in phosphoric acid. This condition is noted by the rank growth of the stalk and leaves, with a disproportionately small production of grain. The overabundance of nitrogen can probably be accounted for by assuming that considerable quantities are made available in the soil by the action of the manure, and to this is added the amount that the manure carries with it. It is quite obvious in such cases that there is a notable deficiency of phosphoric acid as compared with the nitrogen at hand, and if no attempt is made to balance this excess of nitrogen it will not only likely be wasted, but the soil will be able to produce nothing more than stalk and leaves. The careful farmer who has figured these things out, and then has sufficient faith in his figures to act accordingly, finds that artificial fertilizers are indispensable to successful farming, simply because they are needed to maintain the supply of phosphorus, which is being removed more rapidly than any other of the plant food constituents in grain and stock, and also to balance the excess of nitrogen that is liable to accumulate in the manure.

Farmers as a rule do not understand the makeup of fertilizers. What the various ingredients are, how they are put together, and how much of the bulk of fertilizer is of actual use to the plant are matters that are perplexing to those who have not a thorough knowledge of the subject. Fertilizers usually look much alike to the farmer; they smell alike, and, in fact, the chief difference is found only in the attached analysis, which may mean much or little, and the prices that are paid for them. There is little wonder then that cheap, low grade fertilizers were pawned off on the farmers in the past so persistently that it became necessary for the State authorities to take the matter in hands to compel the fertilizer manufacturers to make the contents of the bag conform to the analysis on the outside.

So far as weight is concerned, the farmer who buys the ready-mixed fertilizers obtains the plant food in a very dilute form. In the ordinary 2-8-2 brand of fertilizer only 12 per cent. of the total weight of the material is accounted for on the analysis tag. That is to say, the farmer must handle and pay freight on eighty-eight pounds of filler in order to get twelve pounds of plant food. Just

what this eighty-eight pounds of material is composed of and how, if at all, it influences the value of the fertilizer, are questions that are often raised by farmers, and are answered in various ways by the representatives of the fertilizer manufacturers. It would be well to discuss briefly the different materials that are most commonly used as filler. In the first place, it should be understood that this material is not put in the fertilizer for the purpose of cheating the farmers, but because it is absolutely necessary in ordinary practice to dilute the concentrated compounds that carry the plant food. Were one to attempt to apply the twelve pounds of nitrogen, phosphoric acid and potash over the same ground that he would the hundred pounds of mixed fertilizer containing the filler he would not only get it unevenly distributed, but the concentrated material would come in contact with the roots of the plants and kill them. It would also be difficult to get these materials evenly and thoroughly mixed. So there is no complaint to be made against filler as such, but whatever material is used for this purpose, its value to the fertilizer in furnishing plant food ingredients should receive little consideration by the purchaser, notwithstanding the claims of the fertilizer companies to the contrary. It is safe to say that any material that contains any appreciable amount of available plant food would not be used for this purpose.

A filler that is used extensively by fertilizer companies in the Southern States is made of tobacco stems and bits of leaves, the waste which results from stripping the leaves for the manufacture of cigars and smoking tobacco. When ground, this material contains both nitrogen and potash in available forms. The tobacco wastes are free from harmful compounds and, withal, make a very excellent filler. Besides this, they have a decided insecticidal value, farmers reporting that both wireworms and cutworms can be successfully combatted by using a fertilizer with the corn which has a tobacco filler. Muck and peat are used by certain companies as filler, and are given credit for enhancing the value of the fertilizer. The basis of this claim lies in the fact that analysis shows that peat or muck contains a high per cent. of nitrogen, often running as high as two or three per cent. This fact is used to mislead the farmers, because it has been pretty well established that the nitrogen of muck or peat is largely organic, and that very little of it is available for the plant. There has been a tendency among companies using this material in their fertilizers to include the organic nitrogen which it contains, in the analysis of their fertilizers, and this, of course, would lead farmers to buy nitrogen in the un-

available or practically useless form. However, aside from a consideration of its chemical analysis, muck or peat makes excellent filler, since they are highly efficient absorbents, and can be depended upon to maintain the fertilizer in the very best mechanical condition. They are made up largely of partly decayed vegetable matter, and this, added to the soil in the fertilizer, contributes somewhat in keeping up an adequate supply of vegetable matter, and improves the physical condition. Leather scraps, ground up, have been used to some extent as filler. This product contains a considerable amount of nitrogen, but it is almost entirely in an unavailable form, and is of little use to the plant on that account.

It is not a wise plan, then, to buy a fertilizer on the strength of the filler that is used, for the filler usually has little influence on the efficiency of the fertilizer, provided its mechanical properties are satisfactory. Unless a fertilizer has more to recommend it than an alleged superior filler, it had best be left alone. By purchasing the raw materials and mixing them at home, the expense of handling and shipping eighty-five or ninety pounds of this filler for every ten or fifteen pounds of plant food purchased, is saved, but the latter operation is more or less complicated and requires some careful calculation and work that every farmer is not equipped to carry out successfully.

Nitrogen is by far the most expensive element to purchase, and unless it is derived from such materials as can furnish it in an available form, its purchase is a gamble. There are two general sources from which nitrogen in fertilizers is obtained—from organic materials, such as blood, tankage, guanos, etc., and from inorganic sources, chief of which compounds are sulphate of ammonia and nitrate of soda. Of the two classes of compounds, the latter is much more satisfactory in furnishing nitrogen in definite quantities, and in available form. In all organic matter, the rapidity with which its nitrogen becomes available, depends on the rate that it decays. In some cases, such as ground leather, this is very slow and, consequently, its nitrogen is of little value. Such homogeneous compounds always vary more or less in their total amounts of nitrogen as well as in their availability, and this fact renders uncertain the actual amount of nitrogen that is ready for use. However, the nitrogen in nitrate of soda or sulphate of ammonia is a definite quantity, and always remains the same in amount and availability. That is, a pound of nitrate of soda contains just as much, and of the same quality, of nitrogen as another, and it can always be depended on, regardless of the source of the material; provided, of

course, it is free from impurities. In other words, these are standard nitrogen furnishers, and stand in direct contrast to the organic forms; this is a very important point in favor of the commercial forms as the source for the nitrogen in the fertilizers. The rapidity with which the nitrogen in any material becomes available depends on how rapidly it is converted into the nitrate form, as this is the form in which it is taken up by the roots of the plants. Another great advantage in favor of the nitrogen in nitrate of soda and sulphate of ammonia is that in the one case it is ready to be absorbed by the plant forthwith, and in the other the change is quickly made. As both are perfectly soluble, they are rapidly and evenly diffused through the soil if the ground contains a fair amount of moisture. Nitrate of soda is obtained almost entirely from the rainless regions of Chili and is known commercially as "Chili saltpetre." The pure salt contains 16.47 per cent. of nitrogen, the other 83.53 per cent. being the sodium and oxygen with which the nitrogen is combined. Sulphate of ammonia is a product obtained in the manufacture of boneblack and in making illuminating gas and coke. It is a highly concentrated salt, the pure form containing 21.2 per cent. of nitrogen. It is a quick acting salt and is especially useful for quick-growing crops. Both of these are distinct and definite products and can always be depended on to give practically the same amount and quality of nitrogen at all times.

The phosphoric acid in artificial fertilizers is likewise obtained both from organic and mineral sources. The bones of animals are comparatively rich in phosphate of lime and serve as a very important source of this plant food for agricultural purposes. "Raw bone" is the term applied to ground bone that has not been altered in its composition in the process of manufacture. This form has the advantage of being pure, but the phosphoric acid is not so quickly available as in the treated product. Oftentimes raw bone contains considerable fatty material, which retards the decay of the bone in the soil. Good average raw bone should contain slightly over 20 per cent. of phosphoric acid and 4 or 5 per cent. of nitrogen. The greater part of the bone that is used to furnish phosphoric acid is first steamed or cooked and is known as "steamed bone." By this process the fatty material and some of the nitrogenous matter is removed. The effect of steaming, then, is to increase the per cent. of phosphoric acid and to lower the per cent. of nitrogen. The average composition of steamed bone is about 28 per cent. of phosphoric acid and $1\frac{1}{2}$ per cent. of nitrogen. Ani-

mal charcoal is becoming an important source of phosphoric acid. This material is a waste product resulting from the manufacture of sugar. The charcoal or boneblack has for its first purpose the clarifying of sugar, after which it is ground and used to furnish the phosphoric acid in artificial fertilizers. It contains 30 to 35 per cent. of this plant food. It has the disadvantage of being slow to decay in the soil, which means that its plant food constituents are only slowly available.

The mineral phosphates are found in natural deposits, chiefly in the States of South Carolina, Tennessee and Florida. They are found either in veins or in lumps and are obtained both from the beds of rivers and from the earth. After the impurities are removed by washing the South Carolina phosphate rock contains from 25 to 30 per cent. of phosphoric acid, while that from Florida often runs as high as 40 per cent. After the rock is ground finely it is known as "floats," and is either used on the soil in this form or is subjected to further treatment. As a matter of fact, the greater part of the phosphoric acid found in commercial fertilizers has been further treated in such a way as to render it quickly available to the plant. There is a wide difference of opinion as to whether best results can be obtained from the raw material or "rock phosphate" or from the treated form or "acid phosphate." The striking difference between the two is readily seen to be in the quickness of their action. Where immediate results are not desired and the crop to be raised is a slow-growing one, rock phosphate is highly efficient, as it becomes available slowly and is used by the plant as it changes to a soluble form. Acid phosphate or superphosphate is made from the raw material by treating it with a definite proportion of sulphuric acid. By considering the action that takes place it is easy to understand why the acid phosphate is so radically different in solubility. Most of the phosphorus in bones and in the minerals exist in combination with lime or phosphate of lime. While these elements are capable of uniting in several proportions, the most common form consists of three parts of lime in combination with one part of phosphoric acid. This form is insoluble and when ground and placed on the soil in the form of raw bone it changes slowly to the available form. Obviously such a compound would not be satisfactory to furnish the phosphoric acid in a commercial fertilizer, since only plant food that is ready for immediate use is wanted. So the bone phosphate is digested or made available artificially before it is mixed with the fertilizers by grinding it fine and mixing it with sulphuric acid. The phosphate

is dissolved, and during the reaction two parts of the lime in combination with the phosphoric acid is set free and taken up by the sulphuric acid to form sulphate of lime or "land plaster." This leaves the phosphoric acid in combination with only one part of lime and two parts of water, which takes the place of the lime that is removed by the acid. This form of phosphoric acid is very soluble and is ready for the use of the plant as soon as it comes in contact with the roots, and is known as acid or superphosphate.

While potash is probably more generally distributed through the surface soil than either phosphoric acid or nitrogen, and while it is removed in less quantities than either of the others, nevertheless it is an important constituent of fertilizers and should not be considered in any other light. Before the discovery of the potash mines in Strassfurt, Germany, its chief source for agricultural purposes was from barnyard manures and wood ashes. Now, however, the world's supply is taken from these and other mines, and there is little danger of there ever being a famine in this constituent. Potash may exist in the form of a chloride, sulphate or carbonate, and seems to be equally acceptable to the plant, judging from the rate at which it is absorbed. Of the crude products of the mines, kainit is used more in this country than any other. This material is ground fine and contains about 23 per cent. of sulphate of potash, 30 per cent. of common salt, and smaller quantities of other salts. The disadvantage of using kainit is that the various impurities found with the potash salt make the expense of handling and shipping rather high per unit of plant food obtained. Muriate of potash is a manufactured product and is used extensively in fertilizers and in the raw state. The average muriate contains about 50 per cent. of actual potash, with considerable quantities of common salt.

The question that arises every spring and fall is whether it will pay to sow commercial fertilizers with the corn or wheat crop. Entire dependence on fertilizers to increase the yields sufficiently to make the investment in them safe has not, nor can be, firmly established, on account of seasonal influences. If the season chances to be a very dry one, it is extremely doubtful whether commercial fertilizers will be able to influence the yield to any considerable extent when applied in the spring with corn. The occasional dry seasons are hence responsible for the refusal of many farmers to use commercial fertilizers, since, apparently, they fail to get any results. Yet, even when the immediate crop does not receive the benefit from the application, it is doubtful if anything is lost, since the plant food is retained in the soil and is ready to be taken up by the wheat

crop. For this reason the owner of the land is always pretty safe in investing in fertilizers, regardless of the season, while with the renter, who, according to custom, pays half the fertilizer bill, runs the risk of losing it all, since a dry season would mean little benefit and the owner would reap the results the following season. However, many careful farmers do not make a practice of fertilizing their corn, and it is an established fact that, except in special cases, corn does not respond as satisfactorily to an application of fertilizer as wheat. This is due largely to the fact that the corn is a warm weather crop and is not planted until after the ground is warmed in the spring and is mature before cold weather. A warm soil is able to produce large quantities of available plant food from its own store, and the corn plant draws from this supply much more than is possible for the wheat plant, which needs food right at the time when the soil is unable to furnish it. However, the farmer who uses fertilizers consistently, year after year, finds that the practice is a profitable one, even on his corn ground. While these cannot be depended on entirely, they are an important and indispensable supplement to the other farm practices that seek to retain the health and strength of the soil.

It is not to be hoped that the average farmer of the land will ever be able to understand all the theories that are involved in the fertilization of his soils; it is not necessary that he should. Others can work these things out for him while he is busy with his crops—others who, perhaps, know much less than himself in regard to the actual business of growing corn and wheat. While the theorists theorize, then, let the farmer farm, and let him put into practice those theories that are proven to be worthy of consideration in a practical way. Professor Roberts sums up the situation in the following words: "Timeliness, adaptation, thoroughness, economy in the use of energy and good judgment in the management of details—that is, farm practice—play such important parts in modern agriculture that they may be considered to be equal, if not superior, to the facts revealed in chemistry, botany, and allied sciences. Knowledge, and the application of it, should not be divorced, but joined so firmly by intelligent thought and action that the twain become one."

