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CROPS AND METHODS FOR SOIL IMPROVEMENT

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CROPS AND METHODS FOR SOIL IMPROVEMENT

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CROPS AND METHODS FOR SOIL IMPROVEMENT

CHAPTER I

INTRODUCTION

In Lieu of Preface.—This book is not a technical treatise and is designed only to point out the plain, every-day facts in the natural scheme of making and keeping soils productive. It is concerned with the crops, methods, and fertilizers that favor the soil. The viewpoint, all the time, is that of the practical man who wants cash compensation for the intelligent care he gives to his land. The farming that leads into debt, and not in the opposite direction, is poor farming, no matter how well the soil may prosper under such treatment. The maintenance and increase of soil fertility go hand in hand with permanent income for the owner when the science that relates to farming is rightly used. Experiment stations and practical farmers have developed a dependable science within recent years, and there is no jarring of observed facts when we get hold of the simple philosophy of it all.

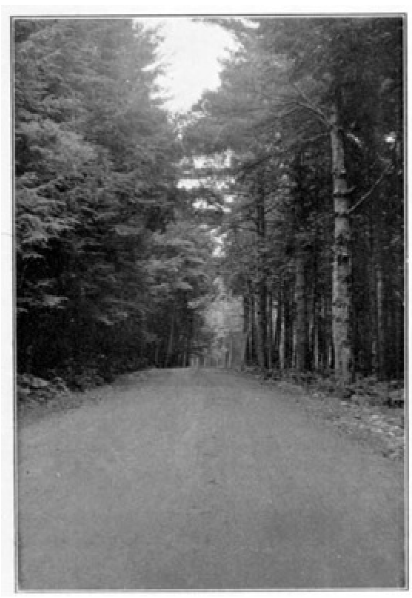
Natural Strength of Land.—Nearly all profitable farming in this country is based upon the fundamental fact that our lands are storehouses of fertility, and that this reserve of power is essential to a successful agriculture. Most soils, no matter how unproductive their condition to-day, have natural strength that we take into account, either consciously or unconsciously. Some good farm methods came into use thousands of years ago. Experience led to their acceptance. They were adequate only because there was natural strength in the land. Nature stored plant-food in more or less inert form and, as availability has been gained, plants have grown. Our dependence continues.

Plant Constituents.—There are a few technical terms whose use cannot be evaded in the few chapters on the use of lime and fertilizers. A plant will not come to maturity unless it can obtain for its use combinations of ten chemical elements. Agricultural land and the air provide all these elements. If they were in abundance in available forms, there would be no serious soil fertility problem. Some of their names may not interest us. Six or seven of these elements are in such abundance that we do not consider them. A farmer may say that when a dairy cow has luxuriant blue-grass in June, and an abundance of pure water, her wants are fully met. He omits mention of the air because it is never lacking in the field. In the same way the land-owner may forget the necessity of any kind of plant-food in the soil except nitrogen, phosphoric acid, potash, and lime. Probably the lime is very rarely deficient as a food for plants, and will be considered later only as a means of making soils friendly to plant life.

Nitrogen, phosphoric acid, and potash are the three substances that may not be in available form in sufficient amount for a growing crop. The lack may be in all three, or in any two, or in any one, of these plant constituents. The natural strength of the soil includes the small percentage of these materials that may be available, and the relatively large stores that nature has placed in the land in inert form as a provision against waste.

The thin covering of the earth that is known as the soil is disintegrated rock, combined with organic matter. The original rock "weathered," undergoing physical and chemical change. A long period of time was required for this work, and for the mixing and shifting from place to place that have occurred. Organic matter has been a factor in the making of soils, and is in high degree a controlling one in their production of food.

Organic Matter.—Nature is resourceful and is constantly alert to repair the wastes and mistakes of man. We may gain fundamental truth about soil fertility through observance of her methods in restoring land to a fertile condition. Our best success comes only when we work with her. When a soil has been robbed by man, and has been abandoned on account of inability to produce a profitable crop, the first thing nature does is to produce a growth of weeds, bushes, briers, or aught else of which the soil chances to have the seeds. It is nature's effort to restore some organic matter—some humus-making material—to the nearly helpless land. Vegetable matter, rotting on and in the soil, is the life-giving principle. It unlocks a bit of the great store of inert mineral plant-food during its growth and its decay. It is a solvent. The mulch it provides favors the holding of moisture in the soil, and it promotes friendly bacterial action. The productive power of most farming land is proportionate to the amount of organic matter in it. The casual observer, passing by farms, notes the presence or absence of humus-making material by the color and structure of the soil, and safely infers corresponding fertility or poverty. Organic matter is the life of the soil.



A GOOD CROP FOR A POOR SOIL.

A great percentage of the food consumed by Europe and the Americas continues to come out of nature's own stores in the soil, organic and inorganic, without any assistance by man except in respect to selection of seeds, planting, and tillage. The percentage grows less as the store of original supplies grows less and population increases. Our science has broadened as the need has grown greater. We have relatively few acres remaining in the United States that do not require intelligent treatment to insure an adequate supply of available plant-food. The total area that has fallen below the line of profitable productiveness is large. Other areas that never were highly productive must supplement the lands originally fertile in order that human needs may be met.

When soils have been robbed through the greed of man, nature is handicapped in her effort to restore fertility by the absence of the best seeds. Man's intelligent assistance is a necessity. Successful farming involves such assistance of nature that the percentage of vegetable matter in the soil shall be made high and kept high. There must be such selection of plants for this purpose that the organic matter will be rich in fertility, and at the same time their growth must fit into a scheme of crop production that can yield profit to the farmer. Soils produce plants primarily for their own needs. It is a provision of nature to maintain and increase their productive power. The land's share of its products is that part which is necessary to this purpose. Skill in farming provides for this demand of the soil while permitting the removal of a large amount of animal food within the crop-rotation. Lack of skill is responsible for the depleted condition of soils on a majority of our farms. The land's share of the vegetation it has produced has been taken from it in large measure, and no other organic matter has been given it in return. Its mineral store is left inert, and the moisture supply is left uncontrolled. Helplessness results.

Drainage.—Productive soils are in a condition to admit air freely. The presence of air in the soil is as necessary to the changes producing availability of plant-food as it is to the changes essential to life in the human body. A water-logged soil is a worthless one in respect to the production of most valuable plants. The well-being of soil and plants requires that the level of dead water be a considerable distance below the surface.

When a soil has recently grown trees, the rotting stump roots leave cavities in the subsoil that permit the removal of some surplus water, and the rotted wood and leaves that give distinctive character to new land are absorbents of such water. As land becomes older, losing natural means of drainage and the excellent physical condition due to vegetable matter in it, the need of drainage grows greater. The tramping of horses in the bottoms of furrows made by breaking-plows often makes matters worse. The prompt removal of excessive moisture by drains, and preferably by underdrains, is essential to profitable farming in the case of most wet lands. The only exception is the land on which may be grown the grasses that thrive fairly well under moist conditions.

Lime.—The stores of lime in the soil are not stable. The tendency of lime in most of the states between the Missouri River and the Atlantic seaboard is to get out of the soil. There is no evidence that lime is not in sufficient quantity in most soils to feed crops adequately, but within recent years we have learned that vast areas do not contain enough lime in available form to keep the soil from becoming acid. Some soils never were rich in lime, and these are the first to show evidence of acidity. In our limestone areas, however, acid soil conditions are developing year by year, limiting the growth of clover and affecting the yields of other crops.

The situation is a serious one just in so far as men refuse to recognize the facts as they exist, and permit the limiting of crop yields, and consequently of incomes, through the presence of harmful acids. The natural corrective is lime, which combines with the acid and leaves the soil friendly to all plant life and especially to the clovers and other legumes that are necessary to profitable farming. Nature is largely dependent upon man's assistance in the correction of soil acidity.

Crop-rotation.—A good crop-rotation favors high productiveness. One kind of crop paves the way nicely for some other one. The land can be occupied by living plants without any long intermissions. Organic matter can be supplied without the use of an undue portion of the time. The stores of plant-food throughout all the soil are more surely reached by a variety of plants, differing in their habits of root-growth. The injury from disease and insects is kept down to a minimum. There is better distribution of the labor required by the farm, and neglect of crops at critical times is escaped. The maintenance of fertility is dependent much upon the use of a legume that will furnish nitrogen from the air. A permanently successful agriculture in our country must be based upon the use of legumes, and crop-rotations would be demanded for this reason alone if none other existed.

Fertilizers.—When a crop is fed to livestock, and all the manure is returned to the land that produced the crop without loss by leaching or fermentation, there is a return to the land of four fifths of the fertility, and a good form of organic matter is supplied. A portion of the crops cannot be fed upon the farm, or otherwise the human race would have only animal products for food. The welfare of the people demands that a vast amount of the soil's crops be sold from the farms producing them. This brings about a dependence upon the natural stores of plant-food in the soil, which become available slowly, and upon commercial fertilizers.

There has been a disposition on the part of many farmers to regard fertilizers only as stimulants, due to the irrational use of certain materials, but a good commercial fertilizer is a carrier of some or all of the necessary elements that we find in stable manures. They may carry nitrogen, phosphoric acid, or potash,—any one or two or the three,—and the three are the constituents that usually are lacking in available forms in our soils. Examples of the best modern skill in farming may be found in the rational selection and use of commercial fertilizers.

Tillage.—Man's ability to assist nature in the work of production finds a notable illustration in the matter of tillage. Its purpose is to provide right physical condition of the soil for the particular class of plants that should be produced, while destroying the competition of other plants that are for the time only weeds. Most soils become too compact when left unstirred. The air cannot enter freely, plant-roots cannot extend in every direction for food, the water from rains cannot enter easily, there is escape of the moisture in the ground, and weathering of the soil proceeds too slowly. The methods used in plowing, harrowing, and later cultivations fix the productive power of a soil for the season in large measure.

Control of Soil Moisture.—The water in the soil is a consideration that has priority over plant-food in the case of agricultural land. The natural strength of the soil is sufficient to give some return to the farmer in crops if the moisture content is right throughout the season. The plant cannot feed unless water is present; the process of growth ceases in the absence of moisture. One purpose of plowing is to separate the particles of soil to a good depth so that water-holding capacity may be increased. When the soil is compact, it will absorb and hold only a very limited amount of moisture. We harrow deeply to complete the work of the plow, and the roller is used to destroy all cavities of undue size that would admit air too freely and thus rob the land of its water. Later cultivations may be given to continue the effect of the plow in preventing the soil from becoming too compact, but usually should be required only to make a loose mulch that will hold moisture in the ground, and to destroy the weeds that would compete with the planted crop for water, food, and sunshine.

CHAPTER II

THE NEED OF LIME

The Unproductive Farm.—When a soil expert visits an unproductive farm to determine its needs, he gives his chief attention to four possible factors in his problem: lack of drainage, of lime, of organic matter, and of available plant-food. His first concern regards drainage. If the water from rains is held in the surface by an impervious stratum beneath, it is idle to spend money in other amendments until the difficulty respecting drainage has been overcome. A water-logged soil is helpless. It cannot provide available plant-food, air, and warmth to plants. Under-drainage is urgently demanded when the level of dead water in the soil is near the surface. The area needing drainage is larger than most land-owners believe, and it increases as soils become older. On the other hand, the requirements of lime, organic matter, and available plant-food are so nearly universal, in the case of unproductive land in the eastern half of the United States, that they are here given prior consideration, and drainage is discussed in another place when methods of controlling soil moisture are described. The production of organic matter is so important to depleted soils, and is so dependent upon the absence of soil acidity, that the right use of lime on land claims our first interest.

Soil Acidity.—Lime performs various offices in the soil, but farmers should be concerned chiefly about only one, and that is the destruction of acids and poisons that make the soil unfriendly to most forms of plant life, including the clovers, alfalfa, and other legumes. Lime was put into all soils by nature. Large areas were originally very rich in lime, while other areas of the eastern half of the United States never were well supplied. Within the last ten years it has been definitely determined that a large part of this vast territory has an actual lime deficiency, as measured by its inability to remain alkaline or "sweet." Many of the noted limestone valleys show marked soil acidity. There has been exhaustion of the lime that was in a state available for union with the acids that constantly form in various ways. The area of soil thus deficient grows greater year by year, and it can be only a matter of time when nearly all of the eastern half of this country will have production limited by this deficiency unless applications of lime in some form are made. When owners of soil that remains rich in lime do not accept this statement, no harm results, as their land does not need lime. On the other hand are tens of thousands of land-owners who do not recognize the need of lime that now exists in their soils, and suffer a loss of income which they would attribute to other causes.

Irrational Use of Lime.—Some refusal to accept the facts respecting soil acidity and its means of correction is due to a prejudice that was created by an unwise use of lime in the past. Owners of stiff limestone soils learned in an early day that a heavy application of caustic lime would increase crop production. It caused such flocculation of the fine particles in their stiff soils that physical condition was improved, and it made the organic matter in the soil quickly available as plant-food. The immediate result was greater crop-producing power in the soil, and dependence upon lime as a fertilizer resulted. The vegetable matter was used up, some of the more available mineral plant-food was changed into soluble forms, and in the course of years partial soil exhaustion resulted. The heavy applications of lime, unattended by additions of organic matter in the form of clover sods and stable manure, produced a natural result, but one that was not anticipated by the farmers. The prejudice against the use of lime on land was based on the effects of this irrational practice.

There are land-owners who are not concerned with present-day knowledge regarding soil acidity because they cannot believe that it has any bearing upon the state of their soils. They know that clover sods were easily produced on their land within their remembrance, and that their soils are of limestone origin. As the clovers demand lime, these two facts appear to them final. The failures of the clovers in the last ten or twenty years they incline to attribute to adverse seasons, poor seed, or the prevalence of weed pests. They do not realize that much land passes out of the alkaline class into the acid one every year. The loss of lime is continuous. Exhaustion of the supply capable of combining with the harmful acids finally results, and with the accumulation of acid comes partial clover failure, a deficiency in rich organic matter, a limiting of all crop yields, and an inability to remain in a state of profitable production.

Lime deficiency and its resulting ills would not exist as generally as is now the case if the application of lime to land were not expensive and disagreeable. These are deterrent features of wide influence. There continues hope that the clover will grow successfully, as occasionally occurs in a favorable season, despite the presence of some acid. The limitation of yields of other staple crops is not attributed to the lack of lime, and the proper soil amendment is not given to the land.

Where Clover is not Wanted.—The ability to grow heavy red clover is a practical assurance that the soil's content of lime is sufficiently high. When clover fails on account of a lime deficiency, the work of applying lime may not be escaped by a shift in the farm scheme that permits the elimination of clover. The clover failure is an index of a condition that limits the yields of all staple crops. The lack of lime checks the activity of bacteria whose office it is to prepare plant-food for use. The stable manure or sods decompose less readily and give smaller results. Soil poisons accumulate. Mineral plant-food in the soils becomes available more slowly. Physical condition grows worse.

The limitations of the value of manure and commercial fertilizers applied to land that has a lime deficiency have illustration in an experiment reported by the Cornell station:

The soil was once a fertile loam that had become very poor. A part was given an application of lime, and similar land at its side was left unlimed. The land without lime and fertilizer of any kind made a yield of 1824 pounds of clover hay per acre. A complete fertilizer on the unlimed land made the yield 2235 pounds, and 15 tons of manure on the unlimed land made the yield 2091 pounds.

Where lime had been applied, the unfertilized land yielded 3852 pounds per acre, the fertilized, 4085 pounds, and the manured, 4976 pounds. The manure and fertilizer were nearly inactive in the acid soil. The lime enabled the plants to obtain benefit from the plant-food.

Determining Lime Requirement.—It is wasteful to apply lime on land that does not need it. As has been said, the man who can grow heavy clover sods has assurance that the lime content of his soil is satisfactory. This is a test that has as much practical value as the analysis of a skillful chemist. The owner of such land may dismiss the matter of liming from his attention so far as acidity is concerned, though it is a reasonable expectation that a deficiency will appear at some time in the future. Experience is the basis of such a forecast. Just as coal was stored for the benefit of human beings, so was lime placed in store as a supply for soils when their unstable content would be gone.

The only ones that need be concerned with the question of lime for soils are those who cannot secure good growths of the clovers and other legumes. Putting aside past experience, they should learn whether their soils are now acid. Practical farmers may judge by the character of the vegetation and not fail to be right nine times out of ten. Where land has drainage, and a fairly good amount of available fertility, as evidenced by growths of grass, a failure of red clover leads immediately to a strong suspicion that lime is lacking. If alsike clover grows more readily than the red clover, the probability of acidity grows stronger because the alsike can thrive under more acid soil conditions than can the red. Acid soils favor red-top grass rather than timothy. Sorrel is a weed that thrives in both alkaline and acid soils, and its presence would not be an index if it could stand competition with clover in an alkaline soil. The clover can crowd it out if the ground is not too badly infested with seed, and even then the sorrel must finally give way. Where sorrel and plantain cover the ground that has been seeded to clover and grass, the evidence is strong that the soil conditions are unfriendly to the better plants on account of a lime deficiency. The experienced farmer who notes the inclination of his soil to favor alsike clover, red-top, sorrel, and plantain should infer that lime is lacking. If doubt continues, he should make a test.

The Litmus-paper Test.—A test of fair reliability may be made with litmus paper. A package of blue litmus paper can be bought for a few cents at any drug store. This paper will turn pink when brought into contact with an acid, and will return to a blue if placed in lime-water. A drop of vinegar on a sheet of the paper will bring an immediate change to pink. If the pink sheet be placed in lime-water, the effect of the lime in correcting the acidity will be evidenced by the return in color to blue.

To test the soil, a sample of it may be put into a basin and moistened with rain-water. Several sheets of the blue litmus paper should be buried in the mud, care being used that the hands are clean and dry. When one sheet is removed within a few seconds and rinsed with rain-water, if any pink shows, there is free acid present. Another sheet should be taken out in five minutes. The rapidity with which the color changes, and the intensity of the color, are indicative of the degree of acidity, and aid the judgment in determining how much lime should be used. If a sheet of the paper retains its blue color in the soil for twenty minutes, there probably is no lime deficiency. The test should be made with samples of soil from various parts of the field, and they should be taken beneath the surface. One just criticism of this test is that while no acidity may be shown, the lime content may be too low for safety.

RED CLOVER ON LIMED AND UNLIMED LAND.

A Practical Test.—The importance of alkalinity in soils is so great, and the prevalence of acidity has such wide-spread influence to-day, limiting the value of the clovers on a majority of our farms, that a simple and more convincing test is suggested here. Every owner of land that is not satisfactorily productive may learn the state of his soil respecting lime requirement at small expense. When a field is being prepared for seeding to the grain crop with which clover will be sown, a plat containing four square rods should be measured off, and preferably this should be away from the border to insure even soil conditions. A bushel of lump-lime, weighing eighty pounds, should be slaked and evenly distributed over the surface of the plat of ground. It can be broadcasted by hand if a spreader is not available, and mixed with the surface soil while in a powdered state. The plat of ground should be left as firm as the remainder of the field, so that all conditions may be even for the test. The appearance of the clover the following year will determine whether lime was needed or not. There is no reason why any one should remain in doubt regarding the lime requirement of his fields. If income is limited by such a cause, the fact should be known as soon as possible.

Duration of Effect.—Soil acidity is not permanently corrected by a lime application. The original supply failed to prove lasting, and the relatively small amount given the land in an application will become exhausted. The duration depends upon the degree of acidity, the nature of the soil and its crops, and the size of the application. Experiments at the Pennsylvania experiment station have shown that an application only in sufficient amount to correct the existing acidity at the time of application will not maintain an alkaline condition in the soil, even for a few months. There must be some excess at hand to unite with acids as formed later in the crop-rotation, or limings must be given at short intervals of time to maintain alkaline conditions.

Experience causes us to assume that enough lime should be applied at one time to meet all requirements for a single crop-rotation of four, five, or six years, and, wherever lime is cheap, the unpleasant character of the labor inclines one to make the application in sufficient amount to last through two such rotations. It is a reasonable assumption, however, that more waste results from the heavier applications at long intervals than from light applications at short intervals. In any event need will return, and soil acidity will again limit income if applications do not continue to be made.

CHAPTER III

APPLYING LIME

Forms of Lime.—There is unnecessary confusion in the mind of the public regarding the forms of lime that should be used. If amounts greatly in excess of needs were being applied, the form would be a matter of concern. There would arise the question of soil injury that might result from the use of the lime in caustic form. Again, if pulverized limestone were used, a very heavy application would bring up the question of coarseness in order that waste by leaching might be escaped. Most farms needing lime do not have cheap supplies, and the consideration is to secure soil alkalinity at a cost that will not be excessive. Freight rates and the cost of hauling to the fields, added to first cost of the lime, limit applications on most farms to the necessities of a single crop-rotation which includes clover, or, at the most, to two crop-rotations. Under these circumstances it is best to let cost of correction of soil acidity determine the form of lime to be used.

The material that will render the soil friendly to clover for the least money is the right one to select. We need to be concerned only with the relative efficiencies of the various forms of lime, as measured in terms of money. That which will most cheaply restore heavy clover growths to the land is the form of lime to be desired. The contentions of salesmen may well be disregarded as they produce confusion and delay a work that is important to the farmer.

Definitions.—The use of the various forms of lime will become general, and the terms employed to designate them should be understood. They vary in their content of acid-correcting material, and their correct names should be used with accuracy.

Stone-lime, often called lump-lime or unslaked lime, or calcium oxide or CaO, is a form widely known, and may be taken as a standard. It is the ordinary lime of commerce, and is obtained by the burning of limestone. One hundred pounds of pure limestone will produce 56 pounds of stone-lime (CaO).

Pulverized lime, often called ground lime, is stone-lime after being pulverized to permit even distribution. When it is fully exposed to the air or moisture, it slakes and doubles in volume.

Hydrated lime, often called slaked lime, is a combination of stone-lime and water. The water causes an increase in weight of 32 per cent, 56 pounds of stone-lime becoming 74 pounds of the hydrate.

Pulverized limestone, often called carbonate of lime, is the unburned limestone made fine so that good distribution may be possible.

Air-slaked lime, often called carbonate of lime, is stone-lime or hydrated lime combined with carbonic acid from the air, and thereby increased in weight. Fifty-six pounds of stone-lime, or 74 pounds of hydrated lime, become 100 pounds of air-slaked lime.

Agricultural lime, or land-lime, may embrace anything that the manufacturer of lime chooses to market. It may be reasonably pure unslaked lime, or it may have less value than a finely pulverized pure limestone. There is a custom of grinding the core, or partially burned limestone of the kiln, together with impurities removed from builders' lime, and with this may be put some air-slaked lime. Some manufacturers market under this name a lime of excellent value. There is no standard, and one should not pay more than a finely pulverized pure limestone would cost unless he knows that the content of fresh burned lime is high.

The element with which we are concerned in any of these forms of lime is calcium. It is the base whose union with the acids destroys the latter. It should be obvious that the addition of water to stone-lime, which adds weight and causes 56 pounds of the stone-lime to become 74 pounds of hydrated lime, adds no calcium. Likewise the change to the air-slaked condition adds no calcium, but again adds weight.

The Kind to Apply.—If a soil contains free acid, the amount of calcium needed is definite. The form of lime that can supply the need in that particular field at least expenditure of money and trouble is the one to be selected. A ton of stone-lime, or pulverized lime, can correct as much acid as 2640 pounds of hydrated lime or 3570 pounds of pulverized limestone, if all the original material was pure.

In other words, if the value of a given weight of pulverized limestone is placed at 100, the value of the same weight of hydrated lime would be 132 and the value of stone-lime would be 180, when each was finely divided and distributed throughout the surface soil.

The Fineness of Limestone.—Experiments at the Pennsylvania experiment station have shown that limestone has practically immediate availability in an acid soil if all of it has ability to pass through a screen having 60 meshes to the linear inch. Much of the limestone meeting this test doubtless is fine enough to pass through an 100-mesh screen. The requirement that a 60-mesh screen be used in testing is a satisfactory one to the buyer that wants immediate results in the field. A coarser product must be used in larger amount per acre, as only the fine particles are available at once, and the object of the application is to correct all the acidity. Where a coarse product, containing some fine particles, can be used at such a low price per ton that the application may consist of a large number of tons per acre, the practice may be commended, but the essential thing is immediate results, and only finely divided limestone can give them. Any long railway or wagon haul makes a heavy application of coarsely pulverized limestone inexpedient.

Hydrated Lime.—Many salesmen are too enthusiastic in their claims for hydrated lime. It has advantages over pulverized limestone, stone-lime, and pulverized lime, and there are disadvantages. The buyer of pulverized limestone pays for the haul on 100 pounds of material to get the 56 pounds of lime carried, while 74 pounds of the hydrate furnish the same amount of actual lime, if all of it is a hydrate. While the hydrate contains less strength than the stone-lime, it is in good physical condition for distribution, and the stone-lime must be slaked. The buyer will bear in mind, moreover, that much of the stone-lime which is burned on farms comes from limestone that is not very pure, and all impurity is waste. Most manufacturers of the hydrate locate their costly plants where the limestone is relatively pure. Prudent business reasons dictate such a course. A careful manufacturer of hydrated lime takes out imperfectly burned and other faulty material with screens. These advantages have some weight, but the fact remains that a ton of pure stone-lime has considerably more acid-correcting power than a ton of the hydrate.

Stone-lime.—Stone or lump-lime is composed of the 56 per cent of a pure limestone that gives value to the limestone. Forty-four pounds of waste material were driven off in the burning. Where railway or wagon hauls are costly, the purchase of stone-lime is indicated. There is advantage in getting this lime in pulverized form, provided it can be distributed in the soil before moisture from the air induces slaking and consequent bursting of the packages. The necessity of rapid handling has limited the popularity of pulverized unslaked lime, but no other form is equal to it when it is wholly unslaked. Some manufacturers grind the partially burned limestone often found in kilns, and furnish goods little better than pulverized limestone.

The slaking of stone-lime should be done in a large pile, and the distribution may be made with lime-spreaders. When the application is fairly heavy, a manure-spreader does satisfactory work. A good lime-spreader is to be desired, but care must be used to remove any stones or similar impurities in the slaked lime when filling it. Such spreaders are on the market.

The practice of slaking lime in small piles in the field is wasteful. It is difficult to reduce all the lime to a fine powder and to make even distribution over the surface. Any excess of water from rains puddles some of the lime, destroying practically all its immediate effectiveness. Distribution with shovels is necessarily imperfect.

The labor of slaking stone-lime and the difficulty in distribution are two factors to be considered when selecting the form of lime to be used. They may counter-balance in some instances the higher percentage of actual lime when comparison is made with the hydrate. That is a question to be decided by the buyer. He must be willing to use methods that will secure even distribution. The prevailing practice, however, of marketing the hydrate at a much higher price per ton than the stone-lime should prevent sales to farmers. The price paid for ease of handling is too great when purchase of the hydrate is made under such circumstances. It is better to do the slaking at home, furnishing the added weight of 32 per cent in water on the farm.

Ashes.—Hard-wood ashes have ceased to have much importance as a source of lime for land, but their use is held in high esteem even by those who regard fertilizers as mere stimulants and doubt the efficiency of lime. Hard-wood ashes, unleached, clean and dry, are valuable for acid soils. Their content of potash, which is variable and averages about 4 per cent, formerly was given all the credit for the soil improvement and increased clover growth that resulted from their use. Tests with other carriers of potash have shown that the potash probably produced only a small part of the effect noted, and the benefit is attributable to the lime in the ashes which exists in an effective form. The content of lime is variable, and largely so on account of the percentage of moisture and dirt that may be found in most ashes, and when no analysis has been made, the estimate of value should not be based on more than 30 to 40 per cent of carbonate of lime. The price of ashes runs so high, as a result of prejudice in favor of this well-known kind of soil amendment, that it rarely is advisable to buy them. Pure lime is a cheaper means of correcting the soil acidity, and the sulphate or the muriate of potash is by far the cheaper source of potash.

Marl.—Marls vary widely in composition. When quite pure, they contain 90 or more per cent of carbonate of lime, and have a value per ton about equal to finely pulverized limestone, and near half the value per ton of stone-lime. There are marls that are carriers of potash and phosphoric acid, and are to be valued accordingly as fertilizers.

Magnesian Lime.—Some limestone is a nearly pure calcium compound, and yields a pure lime, while much limestone contains a high percentage of magnesia. The latter is preferred by manufacturers who furnish pulverized lime because it does not slake readily, and is less liable to burst the packages before required for use. A pound of magnesian lime will correct a little more acid than a pound of pure lime, and no preference may be shown the latter on that score. There are soils in which the proportion of magnesia to pure lime is too great for best results with some plants, as plant biologists assure us, but there is too little definite information respecting these soils to justify one in paying more for a high calcium lime than for a magnesian lime when it is to be used on acid land. The day may come when more will be known, but the rational selection to-day is the material that will do the required work in the soil for the least money.

Amount per Acre.—The amount of lime that should be applied to an acre of land depends upon the degree of its acidity, the nature of the soil, the cheapness of the lime, and the character of the crops to be grown. The actual requirement for the moment could be determined by a chemical test, but the application should carry to the soil an amount in excess of immediate requirement. When clover has ceased to grow within recent years, it is a fair inference that the deficiency, if it exists, has not become great. When sorrel and plantain have gained a strong foothold, indicating that good grasses are unable to replace clover, the degree of acidity probably is higher. The results of tests at experiment stations and on farms show that 1000 pounds of pulverized lime, or one ton of pulverized limestone, evenly distributed throughout the surface soil, can restore clover to the crop-rotation on much land. This is an application so light that a state of alkalinity cannot be long retained. It is better to apply the equivalent of a ton of stone-lime in the case of all heavy soils that have shown any acidity. Where lime is low in price, 3000 pounds of stone-lime, or its equivalent in any other form of lime, is advised, the belief being that such an application will maintain good soil conditions through two crop-rotations, or eight to ten years. This amount can be applied quite successfully with a manure-spreader, and meets the convenience of the man who burns his own lime and does not want to screen it for use in a lime-spreader. The man who must buy his lime, and pay a freight charge upon it, will find it better to use only a ton per acre. This advice applies to heavy soils. A light, sandy soil should be given only a small application, as otherwise physical condition may be injured. The lime, used in excess, has an undue binding effect upon the sand. An application of 1000 pounds of stone-lime per acre can be made with safety.

Time of Application.—The use of lime on land should be associated in the land-owner's thoughts with the growing of clover. It does help soil conditions so that more grain can be produced, but if it is permitted to displace the use of fertilizers, and does not lead to the growth of organic matter, harm will result in the end. Lime should be applied to secure clover, and therefore it should be mixed with the soil before the clover is sown. The application may be made when fitting the seed-bed for the grain with which clover usually is seeded, or may be given a year or two years previous to that time. The important point is to have the soil friendly to plant life when a sod is to be made.

Lime should be put on ground always after the plowing, and it should be well mixed with the surface soil. Even distribution is just as important in its case as in that of fertilizers. A good practice is to break a sod for corn, harrowing and rolling once, and then to put on the lime. A cut-away or disk harrow should be used to mix the lime with the soil before any moisture causes it to cake. When large crumbs form, immediate efficiency is lost.

If the application is light, and may barely be equal to immediate demand, it is better practice to put on the lime when preparing the seed-bed for the wheat or other small grain in which the clover will be sown. It should never be mixed with the fertilizer nor applied with the seed. The lime should go into the soil a few days, or more, prior to the seeding. The soil having been put into a condition favorable to plant life, the seeding and the use of commercial fertilizers should proceed as usual.

Lime should never be mixed with manure in the open air, but it is good practice to plow manure down, and then to use lime as indicated above, if needed. If manure and lime must be used after the land has been plowed, the lime should be disked well into the soil before the manure is applied, and it is advisable that the interval between the two applications be made as long as possible.

CHAPTER IV

ORGANIC MATTER

Office of Organic Matter.—The restoration of an impoverished soil to a productive state usually is a simple matter so far as method is concerned. It may be a difficult problem for the individual owner on account of expense or time involved, but he has only a few factors in his problem. Assuming that there is good drainage, and that the lime requirement has been met, the most important consideration is organic matter. A profitable agriculture is dependent upon a high percentage of humus in the soil. Average yields of crops are low in this country chiefly because the humus-content has been greatly reduced by bad farming methods.

TURNING DOWN ORGANIC MATTER WITH A GANG PLOW..

Nature uses organic matter in the following ways:

1. To give good physical condition to the soil. The practical farmer appreciates the importance of this quality in a soil. Clayey soils are composed of fine particles that adhere to each other. They are compact, excluding air and failing to absorb the water that should be held in them. The excess of water finally is lost by evaporation, and the sticky mass becomes dry and hard. The incorporation of organic matter with clay or silt changes the character of such land, breaking up the mass, and giving it the porous condition so essential to productiveness. Improved physical condition is likewise given to a sandy soil, the humus binding the particles together.

2. To make the soil retentive of moisture. Yields of crops are limited more by lack of a constant and adequate supply of moisture throughout the growing season than by any other one factor. Decayed organic matter has great capacity for holding moisture, and in some measure should supply the water needed during periods of light rainfall.

3. To serve, directly and indirectly, as a solvent of the inert plant-food in the soil that is known as the "natural strength" of the land. Its acids do this work directly, and by its presence it makes possible the work of the friendly bacteria that are man's chief allies in maintaining soil fertility.

4. To furnish plant-food directly to growing plants. Even when it has been produced from the soil supplies alone, there is great gain because the growing crop must have immediately available supplies. Many of the plants used in providing humus for the soil are better foragers for fertility than other plants that follow, sending their roots deeper into the subsoil or using more inert forms of fertility.

The Legumes.—Any plant that grows and rots in the soil adds to the productive power of the land if lime is present, but plants differ in value as makers of humus. There are only ten essential constituents of plant-food, and the soil contains only four that concern us because the others are always present in abundance. If lime has been applied to give to the soil a condition friendly to plant life, we are concerned with three constituents only, viz. nitrogen, phosphoric acid, and potash. The last two are minerals and cannot come from the air. They must be drawn from original stores in the soil or be obtained from outside sources in the form of fertilizers. The nitrogen is in the air in abundance, but plants cannot draw directly from this store in any appreciable amount. The soil supply is usually light because nitrogen is unstable in character and has escaped from all agricultural land in vast amounts during past ages.

Profitable farming is based upon the great fact that we have one class of plants which can use bacteria to work over the nitrogen of the air into a form available for their use, and the store of nitrogen thus gained can be added to the soil's supply for future crops. These plants, known as legumes, embrace the clovers, alfalfa, the vetches, peas, beans, and many others of less value. They provide not only the organic matter so much needed by all thin soils, but at the same time they are the means of adding to the soil large amounts of the one element of plant-food that is most costly, most unstable, and most deficient in poor soils. Their ability to secure nitrogen for their own growth in poor land also is a prime consideration in their selection for soil improvement, assuring a supply of organic matter where otherwise partial failure would occur.

Storing Nitrogen.—Man needs protection from his own greed, and nature's checks are his salvation. An illustration is afforded in the case of legumes grown for the maintenance of soil fertility. The clovers and some other legumes are seeded primarily for the benefit of the soil. The need of organic matter is recognized, and a cheap supply of nitrogen is wanted for other crops in the rotation. The purpose of the seeding is praiseworthy, but if all of the product were available for use off the land, observation teaches that the soil producing the crop probably would fare badly. The crops grown prior to the season devoted to legumes proclaim their need of better soil conditions, more organic matter, and more nitrogen, but the legumes, appropriating nitrogen for themselves, give to the land a more prosperous appearance, and the disposition to harvest everything that is in sight prevails.

There is the excusing intention to return to the soil the residue from feeding, which should be nearly as valuable as the original material, while the fact usually is that faulty handling of the manure results in heavy loss, and the distribution of the remainder is imperfect. There is no happier provision of nature for the guarding of the soil's interests than the unavailability for man's direct use of a considerable part of most plants, thus saving to the land a portion of its share of its products. The humus obtained from plant-roots, stubble, and fallen leaves forms a large percentage of all the humus obtained by land whose fertility is not well guarded by owners. This proportion is large in some legumes, amounting to 30 or 40 per cent in the case of red and mammoth clover.

The Right Bacteria.—The word "bacteria" has had a grudging admission to the vocabulary of practical farmers, and the reason is easily stated. The knowledge of bacteria and their work is recent and limited. They are many in kind, and scientists are only in the midst of their discoveries. The practical farmer does well to let bacteriologists monopolize interest in the whole subject except in so far as he can provide some conditions that have been demonstrated to be profitable. The work of bacteria must come more and more into consideration by the farmer because nature uses them to produce a vast amount of the change that is going on around us.

In consideration of the value of legumes we must take into account the bacteria which they have associated with them, and through which they obtain the atmospheric nitrogen. This would be a negligible matter, it may be, if all legumes made use of the same kind of bacteria. It is true that the bacteria must have favorable soil conditions, but they are the same favorable conditions that our plants require. A fact of importance to the farmer is that the bacteria which thrive on the roots of some legumes will not serve other legumes. This is a reason for many failures of alfalfa, crimson clover, the soybean, the cowpea, hairy vetch, and other legumes new to the region.

Soil Inoculation.—The belief that the right kind of bacteria may be absent from the soil when a new legume is seeded, and that they should be supplied directly to the soil, has failed in ready acceptance because examples of success without such inoculation are not uncommon. Even if the explanation of such success is not easy, the fact remains that legumes new to a region usually fail to find and develop a supply of bacteria adequate for a full yield, and some of these legumes, of which alfalfa is an example, make a nearly total failure when seeded for the first time without soil inoculation. Experiment stations and thousands of practical farmers have learned by field tests that the difference between success and failure under otherwise similar conditions often has been due to the introduction of the right bacteria into the soil before the seeding was made.

Explanations offered for any phenomenon may later become embarrassing in the light of new knowledge. We do not really need to know why an occasional soil is supplied with the bacteria of a legume new to it. We have learned that the bacteria of sweet clover serve alfalfa, and this accounts for the inoculation of some regions in the east. We believe that some bacteria are carried in the dust on the seed, and produce partial inoculation. Other causes are more obscure. The cowpea trails on the ground, and carries its bacteria more successfully than the soybean. Most legumes require a soil artificially inoculated when brought into a new region, failing otherwise in some degree to make full growth.

Method of Inoculation.—The bacteria can be transferred to a new field by spreading soil taken from a field that has been growing the legume successfully. The surface soil is removed to a depth of three inches, and the next layer of soil is taken, as it contains the highest percentage of bacteria. They develop in the nodules found on the feeding roots of the plants. The soil is pulverized and applied at the rate of 200 pounds per acre broadcast. If the inoculated soil is near at hand and inexpensive, 500 pounds should be used in order that the chance of quick inoculation may be increased. The soil should be spread when the sun's rays are not hot, and covered at once with a harrow, as drying injures vitality. The soil may be broadcasted by hand or applied with a fertilizer distributer. The work may be done at any time while preparing the seed-bed. The bacteria will quickly begin to develop on the roots of the young plants, and nodules may be seen in some instances before the plants are four weeks old.

Pure cultures may be used for inoculation. Some commercial concerns made failures and brought the use of pure cultures into disrepute a few years ago, but methods now are more nearly perfect, and it is possible to buy the cultures of all the legumes and to use them with success.

Prices continue too high to make the pure cultures attractive to those who can obtain inoculated soil with ease. If land has been producing vigorous plants, and if it contains no weeds or disease new to the land to be seeded, its soil offers the most desirable means of transferring the bacteria.

The claim is made by some producers of pure cultures that their bacteria are selected for virility, and should be used to displace those found in the farmer's fields. The chances are that, if soil conditions are good, the bacteria present in the soil are virile, and if the conditions are bad, the pure cultures will not thrive. All eastern land is supplied with red clover bacteria, just as some western land possesses alfalfa bacteria, and partial clover failure has causes wholly apart from the character of its bacteria.

We do not have definite knowledge concerning duration of inoculation nor the manner in which it is maintained when legumes are not growing, but we do know that when a legume has once made vigorous growth in a field, the soil will remain inoculated for a long term of years.

CHAPTER V

THE CLOVERS

Red Clover.—Wherever red clover thrives there is no more valuable plant than this legume for making and keeping soils productive under ordinary crop-rotations. The tyro in farming finds his neighbors conservative in thought and method, and may rightly see room for improvement. He naturally turns to new crops that are receiving much exploitation, but should bear in mind that the world nowhere has found a superior to red clover as a combined fertilizing and forage crop for use in short rotations. Farmers turn aside from it because it turns aside from them. There has been increasing clover failure in our older states for a long term of years. It has become the rule to seed to timothy with the clover in the short crop-rotations as well as in the longer ones, and chiefly for the reason that clover seeding has become no longer dependable. In many regions the proportion of timothy seed used per acre has been made large because the clover would not surely grow. In the winter-wheat belt, where the custom has been to make such seedings with wheat, timothy being sown in the fall and clover the next spring, this increase in the timothy has made matters worse for the clover, but it has helped to insure a sod and a hay crop. "Clover sickness," supposedly resulting from close clover rotations, and the prevalence of plantain and other weeds, have been assigned as a partial cause of clover failure. It is only within recent years that the true cause of much failure has been recognized.

Clover and Acid Soils.—There are limited areas in which some clover disease has flourished, and in some years insect attacks are serious. Barring these factors which have relatively small importance when the entire clover area is taken into account, the causes of clover failure are under the farmer's control. The need of drainage increases, and the deficiency in organic matter becomes more marked. The sale of hay and straw, and especially the loss of liquid manures in stables, have robbed many farms. These are adverse influences upon clover seedings, but the most important handicap to clover is soil acidity. There is sad waste when high-priced clover seed is put into land so sour that clover bacteria cannot thrive, and there is ten-fold more waste in letting land fail to obtain the organic matter and nitrogen clover should supply. When land-owners refuse to let their soils remain deficient in lime, clover will come into a prominence in our agriculture that it never previously has known.

Methods of Seeding.—It is a common practice to sow clover in the spring, either with spring grain or with wheat or rye previously seeded in the fall. This method has much to commend it. The cost of making the seed-bed is transferred to the grain crop, and there is little outlay other than the cost of seed. Wheat and rye offer better chances to the young clover plants than do the oat crop which shades the soil densely and ripens later in the summer. The amount of seed that should be used depends upon the soil, the length of time the sod will stand, and the purpose in growing the clover. When soil fertility is the one consideration, 12 to 15 pounds of bright, plump medium red clover seed per acre should be sown. A fuller discussion of the principles involved in making a sod and of seed mixtures is given in Chapters VII and VIII.

Fertility Value.—Attempts have been made to express the actual value of a good clover crop to the soil in terms of money. The number of pounds of matter in the roots and stubble has been determined, and analyses show the percentage of nitrogen, phosphoric acid, and potash contained. The two crops harvested in the second year of its growth likewise have their content of plant-food determined. If the total amounts of nitrogen, phosphoric acid, and potash have their values fixed by multiplying the number of pounds of each ingredient of plant-food by their respective market values, as is the practice in the case of commercial fertilizers, a total valuation may be placed upon the clover, roots and top, as a fertilizer. Such valuation is so misleading that it affords no true guidance to the farmer. In the first place, the phosphoric acid and potash were taken out of the soil, and while some part of these materials may have been without immediate value to another crop until used by the clover, no one knows how much value was given to them by the action of the clover. Again, no one knows what percentage of the nitrogen in the clover came from the air, and how much was drawn from the soil's stores. The proportion varies with the fertility of the land, the percentage of nitrogen taken from the air being greater in the case of badly depleted soils.

A big factor of error is found in the valuations of the ingredients found in the crop. All plant-food is worth to the farmer only what he can get out of it. He may be able to use 50 pounds of nitrogen per acre in the form of nitrate of soda, at 18 cents a pound, when growing a certain crop, but could not afford to buy, at market price of organic nitrogen, all the nitrogen found in the clover crop, and therefore it does not have that value to him.

On the other hand, these estimates do not embrace the great benefit to the physical condition of the soil that results from the incorporation of a large amount of vegetable matter.

Discussion has been given to this phase of the question in the interest of accuracy. Values are only relative. The practical farmer can determine the estimate he should put upon clover only by noting its effect upon yields in the crop-rotation upon his own farm. It is our best means of getting nitrogen from the air, it provides a large amount of organic matter, it feeds in subsoil as well as in top soil, bringing up fertility and filling all the soil with roots that affect physical condition favorably, and it provides a feed for livestock that gives a rich manure.

RED CLOVER ON THE FARM OF P. S. LEWIS AND SONS, POINT PLEASANT, W. VA.

Taking the Crops off the Land.—The feeding value of clover hay is so great that the livestock farmer cannot afford to leave a crop of clover on the ground as a fertilizer. The second crop of red clover produces the seed, and, if the yield is good, is very profitable at the prices for seed prevailing within recent years. The amount of plant-food taken off in the hay and seed crops would have relatively small importance if manure and haulm were returned without unnecessary waste. Van Slyke states that about one third of the entire plant-food value is contained in the roots, while 35 to 40 per cent of the nitrogen is found in the roots and stubble. Hall instances one experiment at Rothamstead in which the removal of 151 pounds of nitrogen in the clover hay in one year left the soil enough richer than land by its side to produce 50 per cent more grain the next year. He cites another experiment in which the removal of three tons of clover hay left the soil so well supplied with nitrogen that its crop of Swede turnips two years later was over one third better than that of land which had not grown clover, the application of phosphoric acid and potash being the same. When two tons of well-cured clover hay are harvested in June, removing about 80 pounds of nitrogen, 45 to 50 pounds are left for the soil. The amounts of potash are about the same, while phosphoric acid is much less in amount.

Physical Benefit of the Roots.—While the roots and stubble contain less than two fifths of the total plant-food in a clover crop, one may not safely infer that the removal of the crop for hay reduces the beneficial effect of the clover to the soil fully 60 per cent, or more. The roots break up the soil in a way not possible to a mass of tops plowed down. They improve the physical condition of the subsoil as well as the top soil. The amount of the benefit depends in part upon the nature of the land. Its value cannot be surely determined, but the facts are called to mind as an aid to judgment in deciding upon the method of handling the clover crop.

Used as a Green Manure.—Where dependence must be placed upon clover as a fertilizer, little or no manure being returned to the land, at least one of the two clover crops within the year should be left on the land. The maximum benefit from clover, when left on the land, can be obtained by clipping it before it is sufficiently heavy to smother the plants, leaving it as a mulch. When the cutter-bar of the mower is tilted upward, the danger of smothering is reduced. Truckers, remote from supplies of manure, have found it profitable to make two such clippings just prior to blossoming stage, securing a third heavy growth. The amount of humus thus obtained is large, and the benefit of the mulch is an important item.

Some growers clip the first crop for a mulch, and later secure a seed crop. The early clipping and the mulch cause increase in yield of seed.

A common practice is to take one crop off for hay, and to leave the second for plowing down the following spring. Early harvesting of the clover for hay favors the second crop.

When to turn Down.—When the maximum benefit is desired for the soil from a crop of clover, the first growth should not be plowed down. Its office should be that of a mulch. In its decay all the mineral plant-food and most of the nitrogen go into the soil. The second crop should come to maturity, or near it. As a rule, there is gain, and not loss, by letting the second crop lie on the ground until spring if a spring-planted crop is to follow. Some fall growth, and the protection from leaching, should equal any advantage arising from rotting the bulky growth in the soil. In some regions it is not good practice to plow down a heavy green crop on account of the excessive amount of acid produced. When this has been done, the only corrective is a liberal application of lime.

Mammoth Clover.—When clover is grown with timothy for hay, some farmers prefer to use mammoth clover in place of the medium red. It may be known as sapling clover, and is accounted a perennial, though it is little more so than the red. It is a strong grower and makes a coarse stalk but, when grown with timothy, it has the advantage over the red in that the period of ripening is more nearly that of the timothy. It inclines to lodge badly, and should be seeded thinly with timothy when wanted for hay. The roots run deep into the soil, and this variety of clover compares favorably with the medium red in point of fertilizing power, the total root-growth being heavier. While its yield of hay, when seeded alone, is greater than the first crop of the red, its inclination to lodge and its coarseness are offsets. It produces its seed in the first crop, and the after-growth is small, while red clover may make a heavy second crop. Its use should become more general on thin soils, its strong root-growth enabling it to thrive better than the red, and the lack of fertility preventing the stalks from becoming unduly coarse for hay. The amount of seed used per acre, when grown by itself, should be the same as that of red clover.

Alsike Clover.—A variety of clover that may have gained more popularity than its merit warrants is alsike clover. It is more nearly perennial than the mammoth. The roots do not go deep into the subsoil like those of the red or the mammoth, and therefore it is better adapted to wet land. It remains several years in the ground when grazed, and is usually found in seed mixtures for pastures. It is decumbent, and difficult to harvest for hay when seeded alone. It is credited with higher yields than the red by most authorities, but this is not in accord with observation in some regions, and it is markedly inferior to the red in the organic matter and the nitrogen supplied the soil in the roots.

The popularity of this clover is due to its ability to withstand some soil acidity and bad physical conditions. In regions where red clover is declining on account of lack of lime, one may see some alsike. The rule is to mix alsike with the red at the rate of one or two bushels of the former to six bushels of the latter. As the seed of the alsike is hardly half as large as that of the red, the proportion in the mixture is greater than some farmers realize. The practice is an excellent one where the red will not grow, and the alsike adds fertility, but when the soil has been made alkaline, the red clover should have nearly all the room. Alsike is a heavy producer of seed.

Crimson Clover.—Wherever crimson clover is sufficiently hardy to withstand the winter, as in Delaware and New Jersey, it is a valuable aid in maintaining and increasing soil fertility. It is a winter annual, like winter wheat, and should be seeded in the latter half of summer, according to latitude. It comes into bloom in late spring. The plant has a tap-root of good length, but in total weight of roots is much inferior to the red. This clover, however, compares favorably with red clover in the total amount of nitrogen added to the soil by the entire plant when grown under favorable conditions. It is peculiarly fitted for a cover crop in orchards and wherever spring crops are removed as early as August, or a seeding can be made in them, as is the case with corn. Even when winter kills the plants, a successful fall growth is highly profitable, adding more nitrogen before winter than red clover seeded at the same time. Where the plants do not winter-kill, they are plowed down for green manure when in bloom in May, or earlier in the spring to save soil moisture and permit early planting, although a good hay for livestock can be made, and the yield is about the same as that of the first crop of red clover.

In the northern states a large amount of money has been wasted in experimental seedings with crimson clover, and it is only in exceptional cases that it continues to be grown. There is reason to believe that many of these failures were due to lack of soil inoculation. The Pennsylvania experiment station is located in a mountain valley where winters are severe. Crimson clover is under test with other cover crops for an experimental orchard, and success with it has increased as the soil has become fully inoculated. This view is supported by the experience of various growers in the North, and while crimson clover can never make the success in a cold climate that it does in Delaware, there is a much wider field of usefulness for it than is now occupied. Experiments should be made with it under favorable conditions respecting moisture and soil tilth. Fifteen pounds of seed should be used, and the seed should be well covered, as is the case with all seeds sown in mid-summer.

CHAPTER VI

ALFALFA

Adaptation to Eastern Needs.—The introduction of alfalfa into the eastern half of the United States will prove a boon to its depleted soils, encouraging the feeding of livestock and adding to the value of manures. It will affect soils directly, as does red clover, when farmers appreciate the fact that its rightful place on their farms is in rotation with grain. Under western conditions, where no other crop can compete with it in value, as is the case in semi-arid belts, its ability to produce crops for a long term of years adds much to its value, but in eastern agriculture this characteristic is not needed. On most soils of the east it will not remain productive for more than four to six years, and that fact detracts little from its value. It should fit into crop-rotations, adding fertility for grain crops. When grown in a six-years rotation with corn and oats or other small grain, it furnishes a rich sod for the corn, and the manure made from the hay helps to solve the farmer's fertility problem.

Fertility and Feeding Value.—Vivian says that "the problem of the profitable maintenance of fertility is largely a question of an economic method of supplying plants with nitrogen." The greatest value of alfalfa to eastern farming lies in its ability to convert atmospheric nitrogen into organic nitrogen. It has no equal in this respect for relatively long crop-rotations, storing in its roots and successive growths of top far more nitrogen within three or four years than is possible to any other of our legumes. A good stand of alfalfa, producing nine crops of hay in the three years following the season of seeding, will produce from nine to twelve tons of hay. Good fields, under the best conditions, have produced far more, but the amounts named are within reach of most growers on land adapted to the plant. A ton of hay, on the average, contains as much nitrogen as five or six tons of fresh stable manure. Thus there comes to the farm a great amount of plant-food, to be given the land in the manure, and in addition the roots and stubble have stored in the ground enough nitrogen to feed a successive corn crop, and a small grain crop which may follow the corn. Moreover, the roots have filled the soil with organic matter, improving the physical condition of the soil and subsoil.

ALFALFA ON THE OHIO STATE UNIVERSITY FARM.

Another gain is found in the content of phosphoric acid and potash in the manure, much of which was drawn from soil supplies out of reach of the other farm crops. The profit from introduction of alfalfa into a region's agriculture is very great.

Alfalfa makes a nutritious and palatable feed for livestock. A ton contains as much digestible protein as 1600 pounds of wheat bran.

Climate and Soil.—The experimentation with alfalfa by farmers has been wide-spread, and the percentage of failure has been so large that many have believed this legume was unfitted to the climate and soil of the country east of the Missouri River. Successful experience has shown that it can be made to take a considerable place in eastern crop-schemes. The climate is not unfavorable, as is evidenced by large areas of good alfalfa sods on thousands of farms. The abundant rainfall brings various weeds and grasses into competition with it, and that will remain a serious drawback until growers learn to clean their surface soils by good tillage before seeding.

Any land that is sufficiently well drained to produce a good corn crop in a wet summer can grow alfalfa if the seed-bed is rightly made. The loose soils are more difficult to seed successfully than is the land having enough clay to give itself body, although most experimenters select their most porous soils. All farms having good tilth can bring alfalfa into their crop-rotations.

Free Use of Lime.—The conditions requisite to success in alfalfa-growing are not numerous, but none can be neglected. Alfalfa should be given a calcareous soil when possible, but an acid soil can be made favorable to alfalfa by the free use of lime. There must remain a liberal amount after the soil deficiency has been met, and when the use of lime is on a liberal scale, the pulverized limestone makes the safest carrier. However, 50 bushels of stone-lime per acre can be used safely on any land that is not distinctly sandy, and that amount is adequate in most instances.

Inoculation.—The necessity of inoculation has been discussed in Chapter IV. Eastern land would become inoculated for alfalfa if farmers would adopt the practice of mixing a little alfalfa with red clover whenever making seedings. Some alfalfa plants usually make growth, securing the bacteria in the dust of the seed, presumably. The addition of one pound of alfalfa seed per acre would assist materially in securing a good stand when the day came that an alfalfa seeding was desired.

Fertilization.—The ability of alfalfa to add fertility to the farm, and directly to the field producing it when all the crops are removed as hay, does not preclude the necessity of having the soil fertile when the seeding is made. The plants find competition with grass and other weeds keen under eastern skies where moisture favors plant-life. In their first season this is markedly true. There should be plenty of available plant-food for the young plants. Stable manure that is free from the seeds of pernicious weeds makes an excellent dressing. It is good practice to plow down a heavy coat of manure for corn and then to replow the land for alfalfa the next season. A top-dressing of manure is good, affording excellent physical condition of the surface for starting the plants. Eight tons per acre make a good dressing.

If land is not naturally fertile, mineral fertilizers should be applied. A mixture of 350 pounds of 14 per cent acid phosphate and 50 pounds of muriate of potash is excellent for an acre of manured land. In the absence of manure, 100 pounds of nitrate of soda and 50 pounds of muriate of potash should be added to the mixture. If the materials are wet, a drier must be used. The fertilizer should be drilled into the ground prior to the seeding.

A Clean Seed-bed.—Much failure with alfalfa is due to summer grasses and other weeds. The moisture in our eastern states favors plant-life, and most soils are thoroughly stocked with the seeds of a large number of weeds. The value of blue-grass and timothy would be comparatively small if they were not capable of monopolizing the ground when well started and given fertility. Alfalfa plants are less capable of crowding out other plants, and especially in their first season. Their habit of growth is unlike that of grass. Rational treatment of alfalfa demands that the surface soil be made fairly clean of weed seed, and this applies with peculiar force to annual grasses, like fox-tail. If attention were paid to this point, failures would be far less numerous.

Old grass land should not be seeded until a cultivated crop has followed the plowing. The land should be in good tilth, and capable of producing a good crop of any sort. Alfalfa is not a plant for poor land, although it does add organic matter and nitrogen.

Varieties.—There is only one variety of alfalfa in common use in this country, and the western-grown seed sold upon the market is known simply as alfalfa. Bound up in this one so-called variety are many strains differing in habit of growth, and their differentiation will occur, just as it has in the case of wheat, and is now proceeding slowly with timothy. The eastern grower at present should use the variety of the west that is furnishing nearly all the seed produced in this country. There is a variety known as Sand Lucerne that has shown value for the light, sandy soils of Michigan. The Turkestan variety was introduced for dry, cold regions, but does not produce much seed.

Clean Seed.—Care should be exercised to secure seed free from impurities. If one is not a competent judge, he should send a sample to his state experiment station for examination. The practice of adulteration is decreasing, but the seed may have been taken from land infested with pernicious weeds.

The impurity most to be feared is dodder. There are several varieties, the seeds varying in size and color. The same pest may be found in clover fields, but the injury is less because the clover stands only two years. The dodder seed germinates in the soil, and the plant attaches itself to the alfalfa, losing its connection with the soil and forming a mass of very fine vines that reach out to other alfalfa plants. In this way it spreads, feeding on the sap of the host plants and killing them.

When the infestation is in only a few spots in the field, the remedy is to cover with straw, soak with kerosene oil, and burn. All the infestation at the edges of these spots must be destroyed.

When the dodder is too widely distributed throughout the field to permit of this treatment, the only course is to plow the field at once, and to grow cultivated crops for two or three years. It is believed that no variety of dodder produces seed freely in the eastern states, and that the hay made from the first crop of alfalfa or red clover will not contain any seed of this pernicious plant.

The Seeding.—When alfalfa has become established on eastern farms, the difficulties in making new seedings will be smaller. The experience of growers will save from mistakes in selection of soils and preparation of the ground, and the thorough inoculation with the right bacteria that can come only with time will do much to insure success. The unwisdom of making seedings in ground filled with grass and other weed seeds will be appreciated. It is quite probable that much successful seeding will be made in wheat and oats, where the alfalfa is to stand only one or two years. These practices are not for the beginner. His land is not thoroughly supplied with bacteria, and every chance should be given the alfalfa.

If there are no annual grasses, such as appear so freely in some regions in mid-summer, spring seeding is excellent. A cover crop is then desirable, and nothing is better for this purpose than barley at the rate of 4 pecks of seed per acre. In all experimental work 25 pounds of bright, plump alfalfa seed per acre should be sown. The seeding should be made as soon as spring comes, the barley being drilled in, and the seed-spouts of the drill thrown forward so that the alfalfa will fall ahead of the hoes and be covered by them.

Seeding in August.—Much land is infested with annual grasses and other weeds, and in such case seedings should be made in August, as described in Chapter VIII.

Subsequent Treatment.—If the alfalfa plants find the bacteria at hand, they will begin to profit from them within the first month of their lives. A large percentage of the plants may fail to obtain this aid in land which has not previously grown alfalfa, and within a few months they indicate the failure by their light color, while the plants liberally supplied with nitrogen through bacteria become dark green. Where there are no bacteria, the plants turn yellow and die.

There are diseases that attack alfalfa, causing the leaves to turn yellow, and when they appear, the only known treatment of value is to clip the plants with a mower without delay. The next growth may not show any mark of the diseases.

Curing alfalfa at the Pennsylvania Experiment Station.

When alfalfa is seeded in the spring on rich land, a hay crop may be taken off the same season. If the plants do not make a strong growth, they should be clipped, and the tops should be left as a mulch. The clipping and all future harvestings are made when the stalks start buds from their sides near the ground. This ordinarily occurs about the time some flowers show, and is the warning that the old top should be cut off, no matter how small and unprofitable for harvesting it may be. The exception to this rule is found only in the fall. An August seeding may make such growth in a warm and late autumn that flowering will occur, and lateral buds start, but the growth should not be clipped unless there remains time to secure a new growth large enough to afford winter protection. This is likewise true of a late growth in an old alfalfa field.

Owners of soils that are not well adapted to the alfalfa plant will find top-dressing with manure helpful to alfalfa fields when made in the fall. The severity of winters in a moist climate is responsible for some failures. If the soil is not porous, heaving will occur. A dressing of manure, given late in the fall, and preferably during the first hard freeze, will prevent alternate thawings and freezings in some degree. The manure should have been made from feed containing no seeds of annual grasses or other weed pests.

Rolling in the spring does not serve to settle heaved alfalfa plants. The tap-roots are long, and when they have been lifted by action of frost, they cannot be driven back into place.

It is believed that the permanence of an alfalfa seeding may be increased by the use of mineral fertilizers in the early spring. In the case of one alfalfa field of fifteen years' standing in the east, the fertilizers were applied immediately after the first hay crop of the year was removed. Three hundred and fifty pounds of acid phosphate and 50 pounds of muriate of potash per acre is the mixture recommended. When old alfalfa plants do not stand thickly enough on the ground, grasses and other weeds come in readily. They can be kept under partial control by use of a spring-tooth harrow, the points being made narrow so that no ridging will occur. The harrow should be used immediately after the harvest, and will not injure the alfalfa.

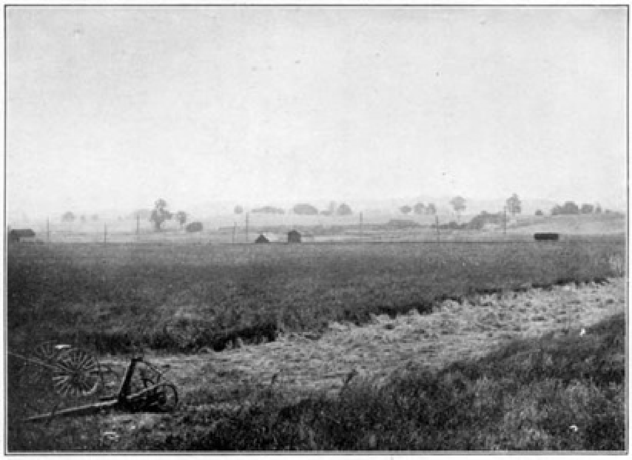
It does not pay to use alfalfa for pasturage in our eastern states because the practice shortens the life of the seeding.

Alfalfa makes a seed crop in profitable amount only in our semi-arid regions. No attempt to produce a seed crop in the east should be made.

CHAPTER VII

GRASS SODS

Value of Sods.—The character of the sods is a faithful index of the condition of the soil in any region adapted to grass. The value of heavy sods to a soil cannot be overestimated. They not only give to a farm a prosperous appearance, but our country's agriculture would be on a much safer basis if heavy coverings of grass were more universal. We do not hold the legumes in too high esteem, but the emphasis placed upon their ability to appropriate nitrogen from the air has caused some land-owners to fail in appreciation of the aid to soil fertility that may be rendered by the grasses. One often hears the statement that they can add nothing to the soil, and this is serious error. They add all that may be given in the clovers, excepting nitrogen only, and that is only one element of plant-food, important though it be. A great part of the value of clover lies in its ability to supply organic matter to the soil and to improve physical condition by its net-work of roots. Heavy grass sods furnish a vast amount of organic matter which not only supplies available plant-food to succeeding crops, but in its decay affects the availability of some part of the stores of potential fertility in the land.



A Heavy Grass Sod in New York.

Prejudice against Timothy.—Timothy, among the grasses, is especially in disrepute as a soil-builder, and yet its value is great. The belief that timothy is hard on land is based upon observation of bad treatment of this grass. There is a common custom of seeding land down to timothy when it ceases to have sufficient available plant-food for a profitable tilled crop, and usually this is the third year after a sod has been broken. The seeding is made with a grain crop that needs all the commercial fertilizer that may chance to be used. Clover may be seeded also, and on a majority of farms it fails to thrive when sown. If clover does grow, the succeeding crop of timothy may be heavy. If clover does not grow, the timothy is not so heavy. The seeding to grass is made partly because a tilled crop would not pay, and partly because a hay crop is needed. It comes in where other crops cannot come with profit, and it produces fairly well, or very well, the first year it occupies the ground by itself. With little or no aid from manure or commercial fertilizer, it adds much to the supply of organic matter in the soil, and it produces a hay crop that may be made into manure or converted into cash.

If the sod were broken the following spring, giving to the soil all the after-math and the mass of roots, its reputation with us would be far better than it is. This would be true even if it had received little fertilizer when seeded or during its existence as a sod, not taking into account any manure spread upon it during the winter previous to its breaking for corn. But the rule is not to break a grass sod when it is fairly heavy. The years of mowing are arranged in the crop-rotation to provide for as many harvests as promise immediate profit. On some land this is two years, and not infrequently it is three. Where farms are difficult of tillage, it is a common practice to let timothy stand until the sod is so thin that the yield of hay is hardly worth the cost of harvesting. Then the thin remnant of sod is broken for corn or other grain, and the poor physical condition of the soil and the low state of available fertility lead to the assertion that timothy is hard on the soil. This is a fair statement of the treatment of this plant on most farms.

Object of Sods.—The land's share of its products cannot be disregarded without loss. The legumes and grasses come into the crop-rotation primarily to raise the percentage of organic matter that the land may appropriate to itself within the rotation. Some of the crops usually are for sale from the farm. Most of the crops require tillage, and that is exhaustive of the store of humus. A portion of the time within the rotation belongs to a crop that increases the supply of vegetable matter, unless manure is brought from an outside source. Sods lend themselves well to this purpose because they afford some income, in pasturage or hay, while filling the soil with vegetation. The tendency is to forget the primary purpose of sods in the scheme, and to ignore the requirement of land respecting a due share of what it produces. Attention centers upon the product that may be removed. The portion of the farm reduced in productive power for the moment goes to grass, while the labor and fertilizers are concentrated upon the fields that are broken for grain and vegetables. The removal of all the crop at harvest, and probably the pasturing of after-math, are the only matters of interest that the fields, depleted by cultivation and seeded down to grass, have for the owner until the poor hay yield and the need of a sod for corn draw attention again to them.

Seeding with Small Grain.—The usual custom is to sow grasses with small grain, and there is much to commend it. The cost of preparing the seed-bed rests upon the grain crop, and the conditions are favorable to fall growth and winter protection, if the seeding is made in the fall. Wheat and rye are good crops with which to seed. In the case of fertile land there is the danger that the timothy will establish itself too well in a warm, moist autumn to permit clover to get a foothold the following spring, and clover should always be seeded for the sake of fertility. In northern latitudes clover cannot be seeded successfully as late in the season as wheat should be sown, as it fails to become well rooted for winter. The overcrowding of clover by timothy is met in part by reduction in amount of timothy seed sown with the wheat.

The oat crop is less satisfactory for seedings to grass and clover. The leaves near the ground are too thick, shading the young plants unduly, and the late harvest exposes the grass and clover when the season is hot, and usually dry. Some reduction in the amount of seed oats used per acre helps to save from injury.

Seeding in Rye.—When thin land is desired for pasture, and available fertility cannot well be applied, a sod may be formed more surely by seeding with rye, using the rye for pasture and a mulch, than, probably, in any other way. The ground should have good tillage and then be seeded to rye in September at the rate of six pecks of seed per acre. Timothy and red-top should be seeded with it, and in the spring red and alsike clover should be added. Whenever the ground is dry enough in the spring to permit the tramping of cattle without injury, the rye should be pastured, and preferably by a sufficient number of animals to hold the rye well in check. When the usual time for heading comes, all stock should be removed, and when heads do appear, the growth should be clipped with a mower and left as a mulch on the surface. A second clipping will be required later, with cutter-bar tilted well upward. When the usual summer drouth is past, livestock can again be turned into the field. This method is suggested only for thin fields that have failed to make catches of grass, and that for some reason cannot well be given the fertility that all thin soils need. The application of lime before seeding to the rye is an expense that usually must be met in the case of such fields, and fertilizers should be used.

Good Soil Conditions.—When the grasses and clovers desired for a sod are sown with small grain, there is competition between them and the grain crop for fertility, moisture, and light. The grain crop is the one that will produce the income the following summer, and naturally is given right of way. The amount of seed is used that experience teaches is best for a maximum yield of grain. Usually this gives a thicker stand of plants than is best for the tiny grass and clover plants that often are struggling for existence down under the taller grain. If the farmer could see his way clear to cut down the quantity of seed wheat or oats used on a fertile soil, the catch of grass would be better, but the small-grain crop is not very profitable at the best, and the owner does not like deliberately to limit it.

A greater amount of failure is due to an inadequate supply of fertility. The grass does not suffer so much from over-shading as it does from starvation, both during the growth of the grain and after harvest. The stronger grain plants appropriate the scanty stock of available fertility, and leave the grass and clover nearly helpless. This condition is especially noticeable in dry seasons when there is less opportunity to obtain food in solution. Plants which are expected in another season to fill the ground with vegetable matter are starved in the beginning and die. Plant-food is needed, and should be mixed with the soil when the seeding is made. The fertilizer needs are discussed in another chapter.

When manure is available, it should be spread on the plowed ground and mixed with the surface soil. If a soil is thin, or heavy, or light, the use of a ton of manure in this way can bring greater returns than under any other circumstances in general farming. It supplies some fertility, and it puts the surface soil into good physical condition for young plants. Land deficient in humus forms a crust after a rain, and a tiny plant suffers. A light dressing of manure, well mixed with the soil, tends to prevent this hardening of the surface and loss of water. There is no other form of fertility that can fully replace manure, for either compact or leachy land.

The probable need of lime has been discussed in other chapters. Clovers and the grasses want an alkaline soil, and there is waste of money and time in seeding acid land. The lime and the manure must not be mixed together in the air, but both can be used when fitting land for seeding, and both should be used if the need exists. One should be applied early and be well disked into the soil, and then the other application may be made and covered with the harrow. The soil is an absorbent, and the contact of manure and lime within the soil only leads to immediate availability, which is desirable in giving the grass a start.

CHAPTER VIII

GRASS SODS—(*Continued*)

Seeding in Late Summer.—The natural time of beginning life, in the case of timothy, blue-grass, red-top, red clover, and alfalfa is in the summer or autumn. The best conditions of growth are given where no stronger plants take the plant-food and moisture. Wherever there is any difficulty in getting heavy grass and clover sods after the lime deficiency has been met, and wherever a hay crop has more value than a small-grain crop, the method of seeding alone in August should be employed. In warmer latitudes the date may be a little later, but in the northern states it should be in the first half of August for best results. Seeding alone offers opportunity to make conditions right for the seeds which are to be used, and in view of the importance of heavy sods to our agriculture, this reason alone is sufficient. In some regions the ability to substitute a good hay crop for a cereal that brings small net income is an item of value, adding to the proportion of feeding-stuff produced in the rotation and to the resulting supply of manure. The practice of making seedings to grass and clover alone is growing, and it is based on sound reasoning.

Crops that may Precede.—Farms that are under common crop-rotations may adopt the practice of August seeding. The winter wheat comes off in time for preparation, and this is true of an early variety of oats, and of rye and barley. Early crops of vegetables get out of the way nicely. There is a vast total area of thin soil that may be brought up to a productive stage rapidly by the growth of a green-manuring crop to precede the grass and clover. Rye may be sown in the fall and plowed down in May, and cowpeas planted to be disked into the soil. Oats and Canada peas add organic matter with nitrogen when plowed down. The summer fallow, which deservedly has fallen into general disuse, may well be employed when a soil is in an inert state, provided grass and clover be permitted to appropriate the plant-food made soluble by the fallowing. The catch crops add organic matter while cleansing the land of weeds; the fallowing releases plant-food and is peculiarly efficient in killing out weeds.

Care must be exercised about preserving moisture in the ground, and therefore a green crop should not be plowed under immediately before seeding time. When a soil is thin, there may be no better preparatory crop than the cowpea, which will not make too rank a growth in the north to prevent its handling with a weighted disk harrow. By this means the soil below is left firm, and the rich vines are mixed with the surface soil, where most needed. It is always a mistake to bury fertility in the bottom of the furrow when a soil is thin and small seeds are to be sown. The infertile ground lying next the subsoil is not what is needed at the surface when preparing for a sod.

It is a good practice to use the early summer in making conditions better for an August seeding, if the land has fallen below a profitable state of productiveness. A growth may be plowed down in time for firming the seed-bed, or it may be cut into the surface soil with a harrow, or the time may be used in freeing inert plant-food and destroying weed seed. On better soils, and in warm latitudes, a crop for hay may be removed, especially in the case of the cowpea in the south, and the stubble prepared for seeding by use of the cutaway or disk harrow.

Preparation.—A seed-bed for small seeds planted in mid-summer must be able to retain moisture. Nothing robs a soil of water more surely than a breaking-plow. Its use is a necessity in farming, but this effect of plowing must be borne in mind when a seeding is planned for the driest period of the year. It goes without saying that sods should not be formed on land that is too solid for admission of air. A thorough plowing is needed by most soils prior to making a sod that will prevent further stirring of the ground for a long period of time. It is best when this plowing can be given in the preceding spring. This enables the ground to become firm enough to hold moisture. If there is time for a tilled crop, the cultivation is helpful. When the land must be broken in the summer, the plowing should be done several weeks before the seeding to grass must be made. The roller should follow the plow closely to destroy the spaces that lie open to the hot air, permitting the land to dry out. All deep harrowings should be given soon after the plowing, stirring and mixing the ground, and then leaving it to settle so that moisture can be held. It is bad practice to continue deep harrowing until the seeding time of any small grain or grass planted in a dry part of the year. Firmness is wanted in the soil.

The Weed Seed.—The seeds of tilled crops are planted in ground containing much weed seed, and no harm may result. The cultivation needed to keep the soil loose, or to prevent evaporation, destroys the weeds. Grass, clover, alfalfa, and like seeds are put into the ground to occupy it to the exclusion of other plants for several years, as a rule, and no tillage can be given. The rule is to sow such seeds after tilled crops have been grown, and some weed seed has been destroyed, but there is evidence on every hand that the weed seed remains in abundance. Summer preparation for grass gives opportunity to destroy a great part of the seeds in the surface of the ground, and it is only when they are near the surface that the seeds of most weeds will germinate. Deep harrowings, continued up to time of planting, not only rob land of water, but they bring to the surface new lots of seed that had been safely buried, and become a part of the actual seeding when the grass, clover, or alfalfa is sown. The obviously right method of preparing for planting is to use only a surface harrow for a few weeks previous to seeding time, stirring the ground after every rain to the depth of three inches, or near that, and destroying the plants soon after germination of the seed. The process which is right for holding moisture is right for cleansing the ground.

Summer Grasses.—One of the worst pests is the annual grasses, springing up in June, July, and August. They are responsible for many failures to obtain stands of alfalfa, clover, and the valuable grasses. The delay in seeding until August is due largely to this pest. When seedings are made in the spring, or in June, failure is invited where these grasses have a fast hold. The only effective way of combating them is to make the ground firm enough to encourage germination, and to stir the surface whenever a growth starts. The late seeding is the one means of escape, and if there is fertility and moisture, the newly seeded crop becomes well rooted by winter and takes the ground so completely that there is little room for weeds to start the next year.

Sowing the Seed.—Partial failure with August seeding is due to faulty methods. We are accustomed to broadcasting clover seed on top of the wheat fields and obtaining a stand of plants. A majority of the seeds do not become buried in the soil, or only very slightly, and yet germinate. Moisture is necessary, but in the spring, when this method is used, there is moisture at the surface of the ground under the wheat plants much of the time. The conditions respecting moisture are not unfavorable in most springs, and we come to think that a small seed should not be buried much if any. In the autumn, again, we sow timothy with the wheat, and while more prompt germination is secured by covering the timothy seed with the hoes of the drill, we often have seen a successful seeding made without any covering being given. The work is done at a time when fall rains may continue for days and, when the sun's heat does not continue long, the covering given by settling the seed into the loose earth is sufficient. Moisture does not leave rapidly because the air is not hot.

Deep Covering.—In August the air is hot, and the surface of the ground is dry nearly all the time. A shower may be followed by hot sunshine, and the water at the surface evaporates quickly, leaving the ground covered with a dry crust. There are two essential things to bear in mind: the seeding should be made only when there is enough moisture in the ground to insure quick germination, and preferably as soon as feasible after a rain, and the seed should be put down where moisture can be retained. It is poor practice to sow any kind of small seeds before a rain that seems imminent. If it forms a crust, or causes weed-seed germination along with that of the grass seeds, only harm results. When seeds are put into a dry soil, and a light shower comes, there may be germination without sufficient moisture to continue life in the plants.

The seeds should be well buried: the soil and air conditions are different from those of the spring. It is best to wait for moisture, and to save the seed if it does not come, but when enough water has fallen to make the firm soil moist, the danger of failure is very small if the seeds are buried one to two inches deep. A surface harrow will stir the surface, and then the seeds should be sifted down into the soil by another harrowing. A light plank float, mashing the little clods and pressing the soil slightly together, finishes the work. The plants will appear above ground within a few days, the only danger being in a beating shower that may puddle the surface before the plants are up.

Seed-mixtures.—When grass is wanted for hay as well as fertility, the clovers and timothy compose the greater part of a desirable mixture wherever the clovers and timothy thrive.

Probably this condition always will continue. The clovers are needed to supply nitrogen to the soil and to put protein into the hay for livestock. They give way, in large part, or entirely, the second year. Alsike is more nearly perennial than the red which practically lasts only through its second season, when its seed crop has been made, and its function performed. The sod is chiefly timothy in the second season. A little red-top is desirable, and the percentage should be heaviest for quite wet land or very dry land. When fertility is the first consideration, and the sod is left only two or three years, the following mixture is good, and is for one acre:

Red clover	10 pounds
Alsike	2 pounds
Timothy	8 pounds
Red-top	2 pounds

When a mixed hay is wanted the first year, the following mixture may be found better for the purpose:

Red clover	6 pounds
Alsike	2 pounds
Timothy	12 pounds
Red-top	2 pounds

Mammoth clover seed may be substituted for the red without change in number of pounds.

The amount of timothy and red-top in the second mixture suggested calls for a liberal supply of plant-food, and this is true of any heavy grass mixture. If fertility is not present, the seeding of grass should be lighter, but the clover should not be less in amount for a thin soil than for a good one. The question of fertilizers is discussed in Chapter XX.

CHAPTER IX

SODS FOR PASTURES

Permanent Pastures.—There is a large total area of land that can be brought into profitable production of food only by means of pasture grasses. A small part is too low and moist for tillage, but a larger part is too rough or too infertile. It can be made to yield profit in grasses that are harvested without expense by animals. The grasses afford feed and at the same time protect the soil from waste. The efficiency of much pasture land is kept low by poor stands of grass, the encroachment of weeds, bushes, and briers, close grazing, and the failure to supply fertility. When making a sod for mowing, the aim is to select varieties of plants that mature near the same time. Pastures need varieties maturing at different times, and this is a matter under control when temporary pastures are used. Permanent pasture land soon becomes occupied by the grasses best fitted to soil conditions or most able to crowd other plants.

GOOD PASTURE LAND IN CHESTER COUNTY, PA.

Seed-mixtures.—Several varieties of grasses should be used when making a sod for grazing. They occupy all the surface more quickly and surely than a single variety, and the pasturage is better. The character of the soil determines the character of the mixture in large measure. When land can be well fitted, a heavy seeding is best, but the cost is nearly prohibitive for thin, rough lands. A brief description of the leading pasture grasses east of the semi-arid region, and north of the gulf states, is given:

Blue-grass.—No other pasture grass equals Kentucky blue-grass wherever it thrives. It makes a close sod, preventing the growth of weeds and withstanding tramping, and contains a high percentage of protein. While it is best adapted to limestone soils, it is grown with success on clay land outside of limestone areas. It is slow in making a heavy sod, as a rule, and partly because the seeding is too light on account of low germination. The rule is to seed with timothy and other grasses which furnish the greater part of the pasturage for two or three years. When seeded alone, 20 to 30 pounds of seed per acre should be used. It may be seeded in the spring or fall, and preferably in August or September.

Timothy.—In a mixture of pasture grasses timothy has a place wherever it thrives. It is not naturally a pasture grass, standing grazing rather poorly, but it makes a large amount of feed quickly. The grass is one of the poorest in protein, and the pasturage gains much in quality when the timothy gives way to blue-grass, as it will in two or three years if the latter has favoring soil conditions. In most mixtures it is given a leading place. It may be sown in the spring, but preferably in the fall, and 15 pounds of seed will be found satisfactory, when seeded alone.

Red-top.—If red-top were as palatable to livestock as blue-grass, it would have one of the most prominent places among our pasture grasses. It is valuable anyway, thriving where land is too acid for blue-grass or timothy, or too thin. It is adapted to wet land, and yet is one of our surest grasses for dry and poor land. It makes a sod that lasts well, and yields better than most other grasses. Notwithstanding its lack in palatability, it should be in all pasture mixtures for soils not in the best tilth. When used alone, 15 pounds of seed per acre should be sown. The seeding may be made in spring or fall.

Orchard Grass.—In most mixtures recommended for pasture orchard grass has a place, but it should be a minor one. It makes early growth in the spring, which is a point in its favor. It stands shade and also drouth better than some other grasses, but is not at home in a poor or wet soil. It grows in bunches, and becomes unpalatable if not promptly grazed. It needs crowding with other grasses when grown for pasturage. When seeded alone for hay, 30 pounds of seed per acre may be used.

Other Seeds.—There are other grasses often recommended, but they have no wide acceptance. Meadow fescue is a palatable grass that would be used more often in pasture mixtures if the seed were not high in price. All land seeded for grazing should have some clover sown for sake of soil fertility. The alsike remains longer than the red or mammoth, and is better for undrained, thin, and acid soils.

Yields and Composition of Grasses.—The Ohio station has compared the yields of various grasses and their composition. The following table is arranged from its data, as given in Bulletin 225:

Name	Average Tons Hay per Acre	Pounds Protein per Hundred	Pounds Protein per Acre
Timothy	3.49	6.38	223
Blue-grass	2.18	10.12	221
Red-top	2.81	8.53	240
Orchard grass	2.19	7.81	171
Meadow fescue	2.10	8.97	188

Suggested Mixtures for Pastures.—For ordinary conditions, Williams suggests the following mixture for an acre of land:

Blue-grass	10 pounds
Timothy	6 pounds
Red-top	6 pounds
Orchard grass	4 pounds
Red clover	4 pounds
Alsike clover	2 pounds

For use on rather wet lands, and especially off the limestone, he suggests:

Red-top	12 pounds
Blue-grass	8 pounds
Timothy	4 pounds
Alsike clover	4 pounds

Hunt recommends the following as a basis, to be modified to suit varying conditions:

Timothy	15 pounds
Kentucky blue-grass	10 pounds
Meadow fescue	2 pounds
Red clover	4 pounds
Alsike clover	3 pounds
White clover	2 pounds

The Cornell station recommends the following for good land:

Timothy	8 to 12 pounds
Kentucky blue-grass	4 pounds
Meadow fescue	1 to 4 pounds
Orchard grass	1 to 4 pounds
Red clover	6 pounds
Alsike clover	3 pounds
White clover	1 to 2 pounds

For poor lands it recommends this mixture:

Timothy	8 to 12 pounds
Red-top	4 pounds
Canadian blue-grass	4 pounds
Red clover	6 pounds
Alsike clover	3 pounds
White clover	1 pound

Zinn, of West Virginia, recommends the following mixture for permanent pasture:

Timothy	4 pounds
Red-top	4 pounds
Orchard grass	4 pounds
Kentucky blue-grass	7 pounds
Red clover	2 pounds
Alsike clover	2 pounds
White clover	1 pound

Renewal of Permanent Pastures.—There is much pasture land that could not be broken with profit for reseeding. There is neither time, nor money, nor opportunity at the owner's hand for this purpose, and often the loss of soil resulting from washing would be a bar if the labor would cost nothing. The renewal of such grass lands can be made with profit if pernicious weeds are not in the way. Plant-food, lime, and grass seed are wanted. A disk or sharp spike-tooth harrow, used in early spring or after an August rain, will give some fresh earth for covering the seeds. A complete fertilizer always is needed. The clovers should go into the seed-mixture used.

SHEEP ON A NEW YORK FARM.

Destroying Bushes.—The absence of sheep is evident in the appearance of the greater area of permanent pasture in the mountainous regions of the eastern states. Bushes, briers, and other weeds must be destroyed if pasture land would be kept in a profitable state, and only the sheep or the goat is the fully efficient aid of man in caring for such land. The presence of dogs makes the tariff on wool, or lack of it, a minor matter. The cost to the country, in indirect effect upon pastures only, due to unrestrained dogs, is incalculable. The maintenance of good sods without sheep is a problem without solution in some regions.

Close Grazing.—Much harm results from turning livestock on pastures too early in the spring. The ground is kept soft by spring rains, and the hoofs cut the turf. The grass needs its first leaves to enable it to make rapid growth, and the first grass of spring is not nutritious.

Close grazing is harmful, exposing the soil to the sun and robbing it of moisture. When winter comes, there should be sufficient grass to serve as a mulch to the roots. It acts like a coat of manure, giving new life to the plants the next spring. Good sods are not easily or quickly made, and when they have been secured on land unfit for the plow, their value measures the value of the land itself.

CHAPTER X

THE COWPEA

A Southern Legume.—The soils of the cold north are protected from leaching during the winter by the action of frost. The plant-food is locked up safely for another year when nature ceases her work of production for the year. Farther south, in the center of the corn belt, there are leaching periods in fall and spring and oftentimes during the winter, but winter wheat thrives and, in ordinary crop-rotations, covers much of the land that might otherwise lose plant-food. As we pass from the northern to the southern states, the preservation of soil fertility grows more difficult and at the same time the restoration of humus becomes easier. The heat makes easy the change of organic matter to soluble forms, and the rains cause waste, but the climate favors plants that replace rapidly what is lost. In the work of supplying land with fertility, directly and indirectly, the southern cowpea has an important place. It is to the south what red clover is to the north, and it overlaps part of the red-clover belt, having a rightful place as far north as the Ohio Valley, and portions of Pennsylvania.

Characteristics.—The cowpea is closely related to the bean, and is very unlike the Canada pea, which is a true pea, thriving only in a cool climate. The cowpea has been grown in the southern states over one hundred years, and the acreage is large, but it never has come into the full use it deserves. Being a legume, it stores up nitrogen taken from the air, and unlike red clover it makes its full growth within a short period of time. It can grow on land too infertile for most kinds of valuable plants, and on better land. The vines can crowd out nearly all varieties of weeds. The roots go to a good depth and are thickly covered with the nodules of nitrogen-gathering bacteria.

Varieties.—There are many varieties of the cowpea, and confusion of names prevails, although some stations have done good service in identification of individuals carrying a number of names. The very quick-maturing varieties adapted to northern conditions do not make as much foliage as the rank-growing ones that require a relatively long season, but some of them are heavy producers of seed.

There are varieties requiring six months of southern heat to bring them to maturity, and some failures attending the introduction of the cowpea into more northern latitudes have been due to bad selection. A few varieties reach maturity within two months of hot weather.

The trailing habit is affected by the soil, the bunch varieties tending to trail when grown on fertile land. When the crop is wanted for seed, the peas that do not trail heavily will prove more satisfactory. The selection of variety is a matter of latitude and purpose, exactly as it is with corn.

Fertilizing Value.—A heavy growth of the cowpea is worth as much to the soil as a good crop of red clover. When the equivalent of two tons of hay is produced, the roots and vines contain nearly as much plant-food as the roots and first crop of medium red clover that makes two tons of hay. Some analyses show a higher percentage of protein in cowpea hay than in clover hay, and the experience of many stockmen indicates that such is the case. The roots and stubble have somewhat less fertilizing power than in the case of the clover, and all thin soils should have the entire plant, or the manure from the hay, saved without loss.

Comparison is made on the basis of equal adaptability of soil and climate to clover and the cowpea. Going southward, the cowpea has the advantage, and northward the clover gains. It is in the overlapping belt that both should be freely used. The cowpea has distinct advantage over the clover in its ability to supply nitrogen and organic matter within a few months, and in its adaptation to very poor soils where clover would not make much growth. As a catch crop it has great value.

Affecting Physical Condition.—The cowpea has marked influence upon the physical condition of heavy soils, even when the vines are not plowed down. This is due in some degree to the roots, and probably more to the mulching effect of the vines during their growth. Heavy soils are made much more mellow by the cowpea, and when the crop is removed for hay, the stubble-land is easily prepared for a seeding to grass or small grain. When the growth is plowed down, the soil may be made too loose for seeding to small grain, but is put into prime condition for a tilled crop.

Planting.—The land should be fitted as it is for corn. Light, sandy soils require little preparation, and too often the seeding is made in a woefully careless manner, the chief dependence being placed upon sufficiently deep covering to insure germination. The ground should be fitted as well as it is for a cash crop, being made fine and smooth. A grain drill makes the seeding in a satisfactory manner, and the seed may be drilled solid or in rows for cultivation. When the crop is grown as a fertilizer or for hay, solid drilling is good, and about five pecks of seed gives a good stand of plants if peas are sound. Much cowpea seed is low in germination power, and the buyer should exercise caution. When a seed crop is wanted, two to three pecks of seed per acre, placed in drills 28 to 32 inches apart, make an excellent seeding, as cultivation can be given. The amount of seed varies with the variety. In northern latitudes a warm soil is to be desired, and cultivation gives better results when a seeding to wheat will be made on the pea-stubble.

There is evidence that the cowpea can make a heavy growth in soils too deficient in lime for red clover, and it gained its first prominence in southern Ohio on land that was failing to grow clover. It is the plant of adversity as well as prosperity, adding rich organic matter to thin soils, but making its full returns under better conditions. Lime applications on acid soils give increase in yields. Its one absolute requirement is heat, and in a cold summer its northern limit is markedly depressed.

Inoculation.—The inoculation of the soil with cowpea bacteria is necessary to best results in most regions new to the plant. Self-inoculation is quicker in the cowpea than in alfalfa because the vines carry some soil on them, and thus the dust in the seed crop may be rich in bacteria. However, most new seedings of the cowpea do not show a large number of nodules on the plant roots, and inoculation pays. In some cases it makes the difference between failure and success. Two hundred pounds of soil from an old field should be well harrowed into each acre of land when preparing for a cowpea seeding in a new region. The soils of the southern states contain the bacteria just as the states in the clover belt are supplied with clover bacteria.

Fertilizers.—The light soils of Maryland, New Jersey, and the southern states are not naturally rich in phosphoric acid or potash. The cowpea can draw its nitrogen from the air, but on all thin land it pays to use 200 to 300 pounds of acid phosphate and 50 pounds of muriate of potash per acre for this crop which should have a luxuriant growth for the soil's benefit. Such use of fertilizers is more profitable than their use on the crop which follows.

Harvesting with Livestock.—When the cowpea is made into hay, there is always danger that the most of the plant-food contained in it never will get back to the soil on account of a careless handling of the manure. The practice of pasturing with cows and hogs is excellent. The feed is rich, and the manure is left on the ground. There is a saving of labor.

If the full fertilizing value is wanted for the soil, the crop should be plowed down. The trailing varieties form a tangled mass that cannot be handled by an ordinary breaking-plow, but a stalk-cutter, run in the direction the plow will follow, makes plowing possible. Pasturing with cattle and hogs sufficiently to reduce the growth so that a plow can be used is good practice.

The Cowpea for Hay.—The hay is one of our most palatable feeding-stuffs. Livestock may reject it the first time it is put into the manger, but a taste for it is quickly acquired, and soon it is eaten greedily. The high content of protein makes it exceptionally valuable for young animals and milk cows, and the manure contains a high percentage of nitrogen. The difficulty in making the hay is a drawback, but this is over-rated. While rain discolors the vines and makes them unattractive in appearance, the hay remains more palatable and nutritious than good timothy, if the leaves are not lost in curing. When the first pods turn yellow, the crop should be harvested. The vines can be left in the swath until the top leaves begin to burn and then be put into windrows with a sulky hay-rake. The windrows should be small, the rake merely serving to invert half the vines upon the other half, bringing new surface to the sun. After another day of curing, the windrows should be broken up into bunches no larger than can be pitched upon the wagon by a workman, thus saving the trouble of disentangling the vines. If rain comes, the bunches should be inverted the following day. In dry, hot weather the curing proceeds rapidly, while in cooler latitudes or cloudy weather the curing may require a week. The chief point is to prevent undue exposure of the leaves to the sun, and this is accomplished by the turning. The hay will mold in the mow if not thoroughly well cured, unless placed in a large body in a deep, close mow that excludes the air. Some farmers use the latter method successfully, but the experimenter with the cowpea usually will fail, and should prefer thorough field curing, at the risk of some damage from rain and sun. The leaves are the most nutritious part of the plant, excepting the seed.

As a Catch Crop.—A leading use of the cowpea is that of a catch crop, either between other crops or in a growing crop, such as corn. Early maturing varieties can be brought in between main crops of the rotation in warm latitudes. The growth prevents the leaching of plant-food, shades the ground, adds nitrogen to the soil, smothers weeds, and produces material that is valuable as feed for livestock or an addition of organic matter to the soil. When the time that can be devoted to the crop is short, an early variety should be selected because its vines are far more valuable to the soil than an equal volume of a rank-growing variety that is not near maturity.

The cowpea seeded at the last cultivation of corn in the Great Kanawha Valley, W. Va.

If this legume were used whenever opportunity afforded along the southern border of our northern states, and throughout the south, the faded color of soils, resulting from leaching rains, would be replaced by the darker colors that mark the presence of rich organic matter. It is one of nature's best allies in the maintenance of soil fertility.

CHAPTER XI

OTHER LEGUMES AND CEREAL CATCH CROPS

The Soybean.—The soybean is gaining a place among the valuable legumes of the United States, and the acreage is increasing as its merits become known to all. Its northern limits of profitable production are much farther north than those of the cowpea, and approach those of corn. In the south it is gaining friends. Some of the advantages of the soybean over the cowpea, as found by the Tennessee station, may be stated as follows:

1. Greater seed production in case of fertile soils.
2. Less sensitiveness to cold in spring and fall.
3. Greater feeding value of the seed.

On the other hand, a stand of cowpea plants is surer in the case of soils that crust, and germination runs higher. Its climbing habit makes it better suited for growing with corn for forage. A less amount of leaves is lost in curing.

Fertility Value.—There are so many varieties of the soybean and the cowpea, and adaptation to soil and climate varies so widely, that a fair comparison is difficult to make. In cool latitudes the soybean is recognized as distinctly more profitable, making larger yields of vines and of seed. Where adaptation is equal, the cowpea makes a slightly larger growth of vines for hay, but the soybean gives a much richer lot of seed for use as grain.

When soil fertility is the chief consideration, the adaptation of climate and soil should decide our choice between these two legumes. There is no serious difference where conditions for each are equally good. In cool latitudes the soybean should be chosen. In the Ohio Valley it is usually to be preferred. The greater part of the organic matter and the plant-food is stored in the vines and seed.

Feeding Value.—The soybean makes a rich hay, surpassing clover, but it is coarse, and its unattractive appearance has caused many farmers to condemn it without trial. Livestock eat it greedily, and it is one of our richest coarse feeds. The curing is more difficult than in the case of the cowpea because the leaves drop early, and the plants must be harvested before they approach maturity.

Probably the large yield of rich seed is the most important feature of the soybean crop. A ton of the seed contains as much protein as a ton of old-process oil meal, and three fourths as much as a ton of cottonseed meal. A good crop of the soybean will yield 18 to 20 bushels of seed, and as the nitrogen may be obtained chiefly from the air, the protein from this crop will come to be a leading substitute for purchased protein feeds.

Varieties.—There are many varieties of the soybean, and their characteristics are modified by climatic conditions. Each region will find the varieties best suited to its purposes by tests. When hay is wanted, the variety should have fine stems and a leafy habit of growth. It may not be a good producer of seed, or able to hold the seed unshattered. The harvesting should be done when some lower leaves turn brown and before the pods are half filled. This stage of maturity should be reached early enough in the fall to insure some hot days for making the hay, and to permit harvesting in time for seeding to wheat. The preparation for wheat is made with the harrow and roller or plank drag.

When the soybean is grown for seed, the variety should hold the peas without undue shattering, and an erect grower is more easily handled without loss of the crop. Varieties for regions will vary, as do varieties of corn, according to climate.

The Planting.—Early varieties of the soybean in the south can be planted as late as mid-summer, but farther north a profitable crop requires nearly all of the summer heat. The planting may be made soon after the usual time of planting corn, or whenever the ground has become warm. The preparation of the soil should be more thorough than that often given the cowpea. Solid drilling of five pecks of seed per acre is satisfactory when the crop is for fertilizing purposes only, and gives an excellent hay on land free of weeds. When the crop is wanted for hay, however, wheat usually will follow, and it is much better to plant in rows and to give two or three cultivations so that the ground may be easily prepared for the wheat.

A seed crop should be grown in rows. Three pecks of seed in rows 28 inches apart is the usual amount.

The soybean does not come up through a crusted surface as well as most other plants, and planting should not be made immediately before a rain. The plants are tender and easily injured by use of a weeder.

The fertilizer requirement is like that of the cowpea. An application of 200 pounds of acid phosphate per acre should be given, and the addition of 50 pounds of muriate of potash often pays.

Harvesting.—The soybean is not an easy crop to handle without loss. When grown for seed, the tendency of the pods to split and to drop the seed compels early cutting, and that makes curing more difficult. The mower is the only practical harvester on most farms, and the swath must be turned out of the way of the horses to save tramping. A side-delivery attachment can do the work. This is the best practice when cut for hay. When used for mixing with corn in a silo, the self-binder is satisfactory. The hay and seed crop must have thorough field-curing in windrow and bunches, and the harvest comes in a season when cold rains may prevail. This disadvantage of one of our most valuable crops is to be taken into account, but it will not prevent rapid increase in acreage as the merit of the soybean becomes known.

The Canada Pea.—Among field peas there are many varieties, but the one chiefly grown in the United States under the general name of the Canada pea is the Golden Vine. It makes a green forage or hay that is rich in protein. Usually it is grown with oats, giving a hay nearly as nutritious as that of clover. The crop is adapted to cold latitudes, and the planting should be made as early in the spring as possible. Fall-plowing of the land is to be advised on this account. A good method of seeding is to drill in six pecks of the pea seed to a depth of four inches, and then to drill in six pecks of oats.

The crop should be cut for hay when the oats are in the milk stage. At this time the peas are forming pods. The hay is not easily made, but is specially valuable for dairy cows.

There is no profitable place for the Canada pea in crop-rotations farther south than the true oat-crop belt, except as a green-forage crop. The soybean and red clover have greater usefulness in the center of the corn belt.

Vetch.—A variety of vetch known as winter, sand, or hairy vetch is coming into great usefulness as a catch crop. It is a winter annual, and being a legume, it has special value as a fertilizing crop. It is more hardy than crimson clover, and is grown as far north as winter wheat. The seeding is made in August in the north, and when grown for hay or seed, it needs rye or wheat to hold it up. Rye and vetch make a rich and early green forage crop, and the proportion in which they are seeded varies widely in practice. Six pecks of rye and 15 pounds of vetch make an excellent seeding per acre.

When grown for seed, one to two pecks of rye and 20 to 30 pounds of vetch may be used. The rye can be fairly well separated from the vetch by use of a fanning-mill or an endless belt of felt so inclined that the round vetch seed will roll down, while the rye sticks to the felt and is carried over.

Vetch is excellent as a fertilizing crop, adding a great amount of nitrogen to the soil when plowed down in May. If the seed were cheap, its use would become much more common. Thirty pounds should be used when seeding alone after summer crops or in corn. Farmers should produce the seed for their farms, and use it freely. When sown for seed, September first is a good date for the north. The seed matures in June.

As vetch matures with wheat, it may easily become a weed on farms devoted largely to small grain, but it is not to be feared where tilled crops and sods are the chief consideration. Inoculation is needed for best results, as in the case with other legumes new to a region.

Sweet Clover.—Much interest has been aroused within recent years in sweet clover, a legume that formerly was regarded as a more or less pernicious weed. Its friends regard it as a promising forage crop, but too little is definitely known to permit its advocacy here except as a soil-builder in the case of poor land that is not too deficient in lime to permit good growth. Experiments have shown that a taste for this bitter plant can be acquired by livestock, and it is nearly as nutritious as alfalfa when cut before it becomes coarse and woody. It is a strong grower, sending its roots well down into the subsoil, and its great ability to secure nitrogen from the air enables it to make a very heavy growth of top. The yield in forage usually exceeds that of the clovers.

Its most peculiar characteristic is its ability to thrive in a poor, compact soil that contains little humus. It may be seen in thrifty condition on roadsides and in waste places that seemingly would not support other plants. Laying aside all consideration of its possibilities as a forage crop, it will come into greater popularity as a soil-builder on thin land. It is found usually on land of limestone formation, and shares with other legumes a liking for lime, but it has been grown successfully in regions that are known to have a lime deficiency.

There are two biennial varieties and one annual. The biennial having white blossoms is the one most commonly seen, but the smaller variety with yellow blossoms is more leafy and palatable. The larger variety is the better fertilizer.

The seed does not germinate readily, and 20 to 30 pounds is used per acre. The soil should be compact, and the seeding can be made in the spring with a cover crop, or in August by itself. Inoculation is necessary if the right bacteria are not present. Soil from an alfalfa field will serve for inoculation.

An effort should be made to grow sweet clover on all infertile hillsides that are lying bare. It stops washing and paves the way for a sod of nutritious grasses.

Rye as a Cover Crop.—As has been stated elsewhere, the plant that stores nitrogen in its organic matter is most desirable, but the greater part of the soil's stock of humus did not come through legumes. Among the good cover crops is rye, both on account of its ability to grow under adverse conditions and because it produces a large amount of material for the soil. When seeded in the early fall, its roots fill the soil the following spring, and the tops furnish all the material that can be plowed down with safety. In northern latitudes it is the most dependable of all winter cover crops, making some growth in poorly prepared seed-beds and on thin land. The most value is obtained from early seedings, thus securing a good fall growth. Two bushels of seed are sufficient in good ground seeded ten weeks before winter begins, but two or three pecks should be added to this amount if the rye can be given only a few weeks of growth before frost locks up the soil. Rye can grow in warm spells of winter, and starts early in the spring. It uses up some available fertility that might otherwise be lost, and releases it when it rots in the ground.

When to plow Down.—If rye has made a good growth before spring, the roots run deeper than the plow goes, and holds the soil much like a grass sod. In such a case the plowing may be made early in the spring without regard to the rye, though organic matter increases rapidly day by day if the rye is permitted to grow. As a rule, it is safest to plow down before the plants are eighteen inches high. They dry land out rapidly, and any mass of matter in the bottom of the furrow interferes with the rise of water from the subsoil. When the land is wanted for oats or corn, a jointer should be used on the plow to insure burying all the crop.

Buckwheat.—An excellent crop for green-manuring is buckwheat. It has such unusual ability to grow in a poor soil that the farmer who makes free use of it as a grain crop never boasts of acreage planted, assuming that his land will not be highly regarded if known to be devoted chiefly to buckwheat. It does not withstand heat well, especially from period of blossoming to maturity, and therefore is restricted to cool latitudes. When grown for grain, it usually is not planted until July, and matures a crop in a shorter period than any other grain. It is sensitive to frost, but may be planted as soon as the ground is warm, and will give a good body of matter for plowing down within eight weeks. The root growth is not extensive, but the crop leaves naturally heavy soils more mellow, and it is an excellent cleansing crop for weed-infested fields. It makes a less heavy growth than rye, but can be used at a time of the year that rye would fail. There is time in a single season to grow two crops of buckwheat for green-manuring, turning the first crop down when the blossoms appear.

Oats.—When a fall growth is wanted for the soil, and it is preferred that the plants be dead in the spring, oats make a good catch crop.

Thin land which is wanted for seeding to wheat and grass in the fall, or for timothy and clover seeding in August, may use oats as a spring cover crop. A large amount of humus-making material may be gained by this means. The only danger lies in the effect upon soil moisture. The oat crop uses up the water freely in its growth, and when permitted to form heads before being plowed down, the mass of material in the bottom of the furrow does not rot quickly enough to induce the rise of water from the subsoil. The land should be plowed early enough to permit a solid seed-bed to be made.

CHAPTER XII

STABLE MANURE

Livestock Farming.—The fertility of the soil is most safely guarded in regions devoted to livestock farming. "Selling everything off the farm" is a practice associated in the public mind with soil poverty. It is a rule with few exceptions that the absence of livestock on the farm is an index of gradual reduction in the productive power of the land. Generally speaking, the farmers who feed the most of their crops on the farm are maintaining fertility, and those who do not feed their crops on the farm have been making drafts upon the soil's stores of available plant-food that are evidenced in a reduction of yields. These statements will have the assent of all careful observers. The inference has been that the maintenance of fertility requires the return to the land of all the manure that would result from feeding its crops on the farm. We know that by such feeding we can return to the fields at least four fifths of all the plant-food taken out by the crops, and we loosely reason that such a scheme is demanded by nature. The maintenance of fertility involves good arithmetic, and a plant must have certain weights of mineral elements at command before it can grow, but it is not true that the productive power of land is chiefly dependent upon the return to it in manure of all the fertility removed by its crops. If this were true, meat and other animal products would be the sole food supply of the world's markets.

Texas calves on an Ohio farm.

The Place for Cattle.—There are general trends in human practice that cannot be changed by man. A change in human diet that makes the percentage of meat lower will not come through propaganda, but there are forces at work that will restrict the consumption of meat by the individual. The increase in population makes heavier demand for food. Armsby has shown that the fattening steer returns to man for food only 3 per cent of the energy value of the corn consumed by it, and in pork-production this percentage scarcely rises to 16. This is the reason meat-making animals give way before increase in population in congested countries. Their office becomes, more and more, the conversion of products inedible to man to edible products. In our country their number will increase, doubtless, for a long period of time, finding their places more surely on eastern farms rather than on western ranches. They must find the cheaper land, and that is no longer confined to the west. They must be where coarse materials, inedible to man, are found, and that is on eastern as well as on western farms. Their office will not be the conversion of crops into manure, but the conversion of coarse materials into human food in the form of meat or milk. This is the trend, and while the consummation may happily be far in the future, its consideration helps us to an appreciation of the facts regarding nature's provision for maintaining the productiveness of the soil.

Sales off the Farm.—The day is now here when the major portion of human food must be provided in grain and vegetables and fruit, and the demand for hay and grain for animals off the farm is very large. Fiber products likewise must be supplied. The draft upon the soil is heavy, but it must be good farm practice to supply bread and vegetables and fruit to the 70 per cent of our population that is not on farms. The great majority of farmers do not feed all their crops to livestock, and the amount of food-stuffs, for human beings and animals, that is now going off the farms is none too great.

Many farmers who incline to believe that they are safely guarding fertility by feeding the most of their crops are not returning to the fields one third of the plant-food that their crops remove. There is no virtue in feeding when the manure is permitted to waste away. The losses in stable and barnyard, the wastes from bad distribution by animals, and the sales from the farm of some crops, animals, and milk, lead to the estimate that one half of the farms on which livestock is kept do not give to the fields in the form of manure over 30 per cent of the fertility taken out of them by crops. This estimate, for which no accurate data is possible, probably is too high. The sales of food for man and animal are a necessity, and the scheme of farming involving such sales is right, provided the farmer makes use of other supplies of fertility. The area devoted to such sales will grow greater because human needs are imperative. Livestock will become more and more a means of working over the material that man cannot eat—the grass, hay, stalks, by-products in manufacture, and coarse grains. The demand for meat and milk will lead to careful conversion of material into this form of food, and the animals on eastern farms will increase in number for a time, while sales of grain and vegetables grow greater. The draft upon soil fertility through sales must increase because every pound of material sold from the farm carries plant-food in it.

The Value of Manure.—It is not possible to put a commercial valuation upon farm manures that may be a sure guide to any farmer. The value depends upon what the individual can get out of it in crops and improved soil conditions. It is rather idle to say that the annual product of a horse in the form of manure is $30, or more or less, even when an analysis shows that the nitrogen, phosphoric acid, and potash contained in it are worth that sum when valued at the market prices of those plant constituents. If the total amount of fertility found in the voidings of all the animals of the farm were provided in a pile of commercial fertilizer containing the same amount of each plant constituent, its worth to the farmer would depend upon his ability to convert all that fertility into crops at a profit. There are farmers so situated in respect to soils, crops, and markets that they can make a good profit from an investment of $30 in the total liquid and solid voidings of a horse for a year. On the other hand, there are many who would fail. The values usually given are relative and suggestive. They are aids in forming judgment. Actual value on the farm depends much on the man.

The Content of Manure.—When the crops of a farm are fed, the manure contains nearly all the plant-food that went originally into the crops. In the case of idle work-horses on a maintenance ration, the manure contains practically all the plant-food. Cows giving milk remove some fertility, and a growing calf or colt may take out 30 per cent. There is some waste beyond control, but when manure is made on tight floors with good bedding, and is drawn to the field fast as made, on the average it carries back to the soil fully four fifths of the plant-food that existed in the feed. Disregarding all cash valuations for the moment, here is an index of value that should be sufficient in itself to encourage the feeding of crops on the farm and the careful saving of the manure. When one can market his crops to animals on the farm at their cash value, and at the same time retain for his fields four fifths of all the fertility, he is like a manufacturer who can use much of his raw material over and over again. The value is in the manure, and full appreciation is lacking only because a majority of farms do not provide for careful saving of its valuable constituents.

Relative Values.—The plant-food content of manure is determined chiefly by the feed. The animals add nothing: they subtract. The kind of animals consuming the feed does not affect materially the value of the manure made from it, if the animals are mature and not giving milk. The manures from the various kinds of animals differ in value per ton because the feeds differ in character and the manure varies in percentage of water. On an average, however, the total annual product of manure from farm animals, per 1000 pounds of live weight, does not vary widely in value. The rich protein feeds given the cow, and the heavy feeding, more than make amends for the fertility that goes into the milk, and her annual product, per 1000 pounds of live weight, may exceed in value that of the horse by 25 per cent. This is likewise true of the pig, figured on the 1000-pound basis, while in the case of the sheep the value, per 1000 pounds of live weight, is near that of the horse.

IN THE FERTILE MIAMI VALLEY, OHIO.

These variations are not wide enough to have great importance to the livestock farmer. The manure represents to him four fifths of all the fertility that was contained by the feed he gave the various animals. They added no plant-food, and they took away only a fraction that was not large. They converted the crops into a form of plant-food that either is available or can become so quickly enough, and in addition to the nitrogen, phosphoric acid, and potash that would have a high valuation in a commercial fertilizer, there is a body of organic matter that affects the physical condition of the soil favorably. The manure also promotes the multiplication of friendly soil bacteria. Its possibilities are so great that the inference of many farmers that no successful agriculture can be maintained without it is very natural.

Amount of Manure.—Vivian states that the amount of manure that may be made from feed can be determined by multiplying the total weight of dry matter in the feed by 3. This assumes that bedding will be used in sufficient amount to absorb the urine, and that will require material containing one fourth as much dry matter as there is in the feed. When the amount of hay and grain is known, and the dry matter in all succulent feed is estimated, the total product of manure in tons can be arrived at with fair accuracy.

Analysis of Manure.—As has been stated, the content of the manure must depend chiefly upon the character of the feed. We are accustomed to combine feeding stuffs in differing proportions for horses, cows, pigs, and sheep. Van Slyke names the following approximate percentages of plant-food constituents in fresh excrements of farm animals, the solid and liquid being mixed:

Animal	Per Cent Nitrogen	Per Cent Phosphoric Acid	Per Cent Potash
Horse	0.70	0.25	0.55
Cow	0.60	0.15	0.45
Pig	0.50	0.35	0.40
Sheep	0.95	0.35	1.00
Hen	1.00	0.80	0.40

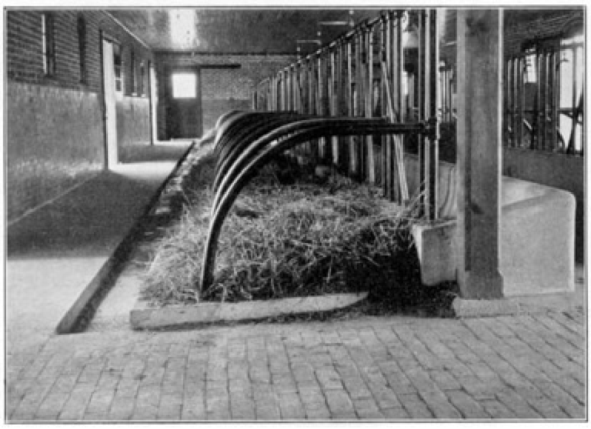
He estimates that one ton of average mixed stable manure, inclusive of absorbents, contains approximately 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash.

CHAPTER XIII

CARE OF STABLE MANURE

Common Source of Losses.—When we bear in mind that four fifths of all the fertility removed from the land in the grains and coarse stuffs fed on the farm may be recovered from the animals and returned to the soil, we can appreciate the consideration that the care of manure should have on every farm. The careless methods that prevail in most sections of the country are an inheritance from the day when soils were new and full of fertility. These methods continue partly through a lack of confidence in the statements that the liquid portion of animal excrements, in average mixed stable manure, has nearly as great value as the solid portion. If this fact were accepted, many of the losses would be stopped. Another reason for continuance of careless methods is failure to appreciate that the soluble portion of manure is the highly valuable part, and that leaching in the barnyard carries away value more rapidly than decrease in volume of manure indicates. The widely demonstrated facts do not have effective acceptance, and enormous loss continues.

Thorne found that manure placed in flat piles in the barnyard in January, and allowed to lie until April, lost one third of its value. Under the conditions prevailing on many farms the loss suffered by exposure of manure is far greater.



CONCRETE STABLE FLOORS.

Caring for Liquid Manure.—If all manure were in solids, one great difficulty in caring for it would not exist. The nitrogen is the most valuable element in manure, and two fifths of all of it in horse manure is found in the liquid. In the case of cow manure, over one half of the nitrogen is found in the liquid. More than this, a pound of nitrogen in the liquid has greater value than a pound in the solid because of its nearly immediate availability. There is only one good way of caring for the liquids, and that is by use of absorbents on tight floors or in tight gutters. American farmers find cisterns and similar devices nuisances. The first consideration is to make the floor water-tight, and clay will not do this. The virtues of puddled clay have had many advocates, but examination of clay floors after use will show that valuable constituents of the manure have been escaping. The soils of the country cannot afford the loss, and careful farm management requires acceptance of the truth that a tight floor is as necessary to the stable as to the granary. The difficulty in supplying a sufficient amount of absorbents on tight floors only emphasizes the loss where floors are not water-tight.

Use of Preservatives.—The use of land-plaster in stables helps to prevent loss of the nitrogen-content through fermentation. Its value does not lie chiefly in physical action as an absorbent, but the beneficial results come through chemical action. The volatile part of the manure is changed into a more stable form. In recent years this preservative has fallen somewhat into disuse, as acid phosphate contains like material and also supplies phosphoric acid to the manure. The phosphoric acid content of stable manure is too low for all soils, and the reënforcement by means of acid phosphate would be good practice even if there were no preservative effect. The use of fifty pounds of acid phosphate to each ton of manure will assist materially in preserving the nitrogen, and the gain in phosphoric acid will repay all the cost. It should be used daily on the moist manure, as made in the stable, and preferably just before bedding is added, so that the phosphate will not come into direct contact with the feet of the animals. Some stockmen prefer the use of acid phosphate and kainit mixed half-and-half. The latter is a carrier of potash, and is a preservative of nitrogen.

The use of ground rock-phosphate in stables is coming into use in some localities, chiefly through the recommendation that it be mixed with manure to secure availability of its own plant-food. It is not a preservative except in so far as it acts physically as an absorbent. It should not displace acid phosphate in stables, the preservation of nitrogen in the manure being the vital matter.

Spreading as Made.—When farm conditions make it feasible to draw and spread manure fast as made, the danger of heavy loss in storing is escaped. There is evidence that no appreciable escape of fertility occurs when manure is spread on land that is not covered with ice. The phosphoric acid and potash are minerals, and leach into the soil. The nitrogen does not change into a gas in any appreciable amount when spread over the surface, and it likewise leaches into the soil. There are soils in which the decay of the organic matter would have a more beneficial effect than the rotting upon the surface, it may be, but the mulching effect of the manure is valuable. There should be no doubt that the loss from manure is kept to a minimum when it goes directly to the soil. In some latitudes the snow and ice oftentimes prevent spreading, or make it inadvisable, and in many farm schemes it is desirable to hold manure for special fields and crops. Some means of storing manure must be provided in these instances.

The Covered Yard.—If the possible value of manure were realized, provision for its care would be made as promptly and surely as provision for the care of a harvested crop. There are only three conditions that must be provided in order that manure may be preserved without much loss. The manure must be protected from leaching rains, it must be kept moist, and air must be excluded. The exposure of stable manure to the processes of fermentation and leaching, produces a waste that is believed to amount to several hundreds of millions of dollars in the United States annually. The day will come when no farmer will be willing to share heavily in a loss from this source, but will either spread manure fast as made or provide a roof for the stored manure. An absolutely tight floor is not so great a necessity as it is in the stable, because the amount of moisture is under control, but many farmers prefer to make concrete floors for the manure-shed and thus to guard against any loss from leaching. The chief cost may be confined to the roof.

A better plan is to inclose three sides, making them so tight that all drafts will be prevented, and to use the shed as a place of exercise for cows or other livestock. We have learned within recent years that such an inclosure is more healthful and comfortable for cattle than stalls in an inclosed building, no matter how cold the weather may be. The fresh air without any drafts, and the liberty of movement, are needed. This shed should be connected with the stable, and on its floor the manure from the stables may be spread daily. It should be scattered evenly over the surface, and the mass can be kept firm by the tramping of the animals. It may be necessary to add some water at intervals to keep the mass sufficiently moist. The water excludes air and assists in holding harmful fermentation in check.

Harmless Fermentation.—There is a kind of fermentation in manure that goes on in the absence of air. It is due to bacteria that break up the organic matter, producing rotted manure. This is not attended by much loss, and proceeds beneath the surface of the moist and packed mass. Manure properly controlled under a roof goes into prime condition for spreading later in the season. The only danger is neglect, and especially when the livestock is removed to the pasture fields in the spring. If no water is added from time to time, hot fermentation replaces the harmless kind because air can penetrate through the bed of manure. Compactness and moisture can save the plant-food with small loss throughout the summer, and a body of good manure is available when needed for top-dressing land in the summer.

Rotted Manure.—Mixed stable manure contains in a ton as many pounds of potash as it does of nitrogen, and yet we speak of it as a highly nitrogenous fertilizer. When fresh manure has suffered no loss of the liquid part, much of its nitrogen is almost immediately available. The nitrogen in the urine is in soluble forms, and fermentation quickly occurs. When manure is used on grass, it cannot be too fresh, as the immediate action of the nitrogen is desirable. Vegetable growers often prefer a slower and more continuous action, and the rotting of manure under right conditions changes the liquid nitrogen into compounds that act more slowly.

The solid material in horse manure contains less water than that of the cow, and this absence of water permits quick fermentation when air is present. The use of large quantities of such manure per acre is not liked by vegetable-growers. Rotting under control in a covered barnyard has a beneficial effect for this reason when a hot manure is not wanted. The covered shed costs some money, and there is a loss estimated at 10 per cent under the best conditions, but when manure cannot be drawn fast as made, there is compensation in improved condition for certain soils and crops.

Composts.—The compost, involving the handling of manure and soil, has no rightful place on the average farm. The gardener or trucker using great quantities of manure per acre must let some of the fermentation occur before he incorporates it with the soil, or harm will result. He wants reduction in volume, and such change in character that it will add to the retentive character of the soil respecting moisture instead of drying the soil out. He can afford all the labor of piling the manure with layers of sods or other material, and the turning to secure mixing. It is his business to watch it so that loss will not occur.

The farmer uses manure in smaller quantities per acre. Probably all his fields need the full action of the organic matter in its rotting. The percentage of humus-making material is low. The place for fresh manure is on the land, when this is feasible. The covered shed is a device for holding manure with least possible loss when spreading cannot be done, or a supply must be carried over for land in the summer. The gain in condition is only incidental, and an advantage chiefly to vegetables. The composting of manure by gardeners is not a practice to be copied on most farms.

Poultry Manure.—The value of poultry manure often is overestimated. Its content of plant-food is one half greater than that of horse manure, ton for ton. The availability of the nitrogen is so great that returns from applications are immediate, and give the impression of greater strength than is possessed. Its availability makes it excellent for plants that need forcing. For such use it needs reënforcing only with acid phosphate, but as a general manure it should have the addition of potash. Acid phosphate should be used in the poultry-house to prevent loss of nitrogen, which escapes quickly on account of rapid fermentation, and to supply phosphoric acid. Thirty pounds of acid phosphate to each 100 pounds of the manure gives a mixture containing one pound of nitrogen, three pounds of phosphoric acid, and two fifths of a pound of potash. The addition of four pounds of muriate of potash makes the mixture a well-balanced and effective fertilizer when used at the rate of 500 to 1000 pounds per acre. Dry muck or loam should be mixed with it to serve as an absorbent and to give good physical condition.

CHAPTER XIV

THE USE OF STABLE MANURE

Controlling Factors.—The farm supply of stable manure is a carrier of plant-food, returning to the soil four fifths of all the fertility removed in the crops fed, but it is much more than this. Land which receives only plant-food, as may be the case when fertility is supplied in commercial fertilizers, loses good physical condition. Organic matter is needed for maintenance of physical condition, the retention of soil moisture, the freeing of inert minerals in the land, and the promotion of bacterial life in the soil. No small share of the value of a ton of manure is due to its organic matter. This is a factor in the problem when deciding what disposition of the manure will pay best. One field may be in condition to respond fully to the use of commercial fertilizers, while another is too deficient in humus for best results. Some crops are more insistent upon supplies of organic matter than others.

Again, the disposition of the manure depends upon the supply. If most crops are fed on the farm, the manure is a leading source of fertility for all fields and crops, and may be used once or twice in the crop-rotation on every field. If the manure is in small amount, due to a scheme of farming involving the growing of crops for market, the function of the manure may be only to encourage the starting of sods, in which legumes are a leading factor.

Direct Use for Corn.—The practice of spreading manure on grass land for corn is based upon much good experience. The custom is nearly universal in regions where corn is an important part of a four, five, or six years' rotation, and all of the corn and hay is fed on the farm. This disposition of the manure permits the handling at times when other work does not rush. The supply carried over from the spring is put on in late summer, and the manure made in the early part of the winter can be drawn to the field fast as made. Manure spread immediately before the sod is broken is less effective, as no leaching of soluble elements into the surface soil occurs before the coarse material is buried in the bottom of the furrow.

CORN IN THE OHIO VALLEY.

The use of fresh manures for corn is rational, because corn is a gross feeder and requires much nitrogen. All plants having heavy foliage can use nitrogen in large amounts. It is possible to apply manure in excessive amount for this cereal, the growth of stalk becoming out of proportion to the ear, but the instances are relatively few. Ordinarily corn suffers from lack of nitrogen. When the farm manure is in large amount, its direct use for corn is good practice.

Effect upon Moisture.—Coarse manures should not be plowed down late in the spring, as they increase the ill effects of drouth. Decayed vegetation, well mixed with the soil, increases the soil's water-holding capacity, but undecayed material in the bottom of the furrow is harmful. Fresh, strawy manure, made immediately before the time for breaking a sod, is preferably carried over in a covered shed until a later season of the year.

When manure has been spread upon a sod in the fall or early winter, it decays quickly after the plowing, and aids in resistance to drouth. When it is plowed down, the ground is kept more porous, and the presence of plant-food and moisture at or near the depth of plowing encourages deeper rooting of plants, and thus indirectly assists them to withstand dry weather. If the plowing is good in character, leaving the furrow-slice partly on edge, and permitting the harrow to mix part of the turf and the manure with the remainder of the soil, the best conditions respecting moisture are secured.

Manure on Grass.—When the crop-rotation embraces two or more years of grass, or one of clover followed by only one of grass, it is better practice to use the manure to thicken the sod. The object in view is the largest possible amount of crops, and the maximum amount of organic matter for the soil. Grass is a heavy feeder, like corn, and makes good use of nitrogen. Its roots fill the soil so that no loss attends the use of manure. When the supply is given the grass, after the harvest of the second crop of clover and during the winter, the timothy can make a rank growth. The part of the plant above ground has corresponding development below ground. Not only does a large increase in the hay crop result, but the heavy mass of grass roots, the aftermath, and the remains of the manure provide a great amount of fertility for the corn which follows. The increase in hay permits a corresponding increase in the manure supply the next year, if it is fed, and if it is sold on account of a market price greater than its value for feed and manure, it adds to income materially—and that is one reason for farming.

Manure on Potatoes.—There are excellent cash crops that may get more than their fair share of the farm supply of fertility, and against the interest of fields in the farm not adapted to cash crops. The justification is found in the farm ledger. In some regions potatoes are the best crop in point of net income per acre, where the acreage is kept restricted so that there may be plenty of organic matter to help in conserving moisture. It is not good practice to use fresh manure, and especially that from horse-stables, for potatoes. A heavy application makes an excessive growth of vine, and the yield of tubers suffers. A stronger deterrent is the effect that fresh manure has on the development of the spores that produce the disease known as potato-scab. Rotted manure is less dangerous, and few crops repay its use in higher degree than the potato. Some growers prefer to make heavy application of fresh manure to grass for corn, and follow with potatoes so that they can profit by the rotted organic matter that remains. In this way the physical condition is made excellent, moisture is well held in a dry season, and commercial fertilizers can supplement the plant-food left in the manure.

When to plow Down.—Excellent farmers differ regarding the relative efficiencies of manure plowed down and that mixed with the top soil. Both classes may be right for their individual instances. The plowing down of manure helps to deepen the soil, and that always is desirable. It causes plants to root deeply, and that is a distinct benefit in a drouthy season, and always desirable. When a soil is in such tilth that the breaking-plow always brings fertile soil to the surface, the plowing down of manure gives excellent results, though it should be permitted to leach at the surface for a few weeks before being turned under. When land is being prepared for a seeding to grass or clover, the supply of manure should not be plowed down wherever the breaking-plow brings soil to the surface that is deficient in humus. In the latter case the manure always should be used as a top-dressing, and should be evenly spread and well mixed with the surface soil. It is needed there far more than it can be needed farther down. The surface soil always should have a high content of organic matter.

Heavy Applications.—When the farm supply of manure is small, applications should be light. The manure should not be the dependence for plant-food on a part of a field, or a single field of the farm, under such circumstances. It is more profitable to give a light dressing to a larger area. The manure is needed to make a fertilizing crop grow, and a very few tons per acre can assist greatly, when rightly used. The manure is needed to furnish bacteria to the soil, and a small amount per acre is useful for this purpose. Always there is temptation to use all the manure on a field convenient to the barn, and to concentrate it on a sufficiently small area to make a good yield sure. The loss to the farm in this method is heavy. The thin spots and the thin fields have first right to the manure as a top-dressing, and six tons per acre will bring larger returns per ton than twelve tons per acre. At the Pennsylvania experiment station the land receiving ten tons of manure per acre in the common four years' rotation of corn, oats, wheat, and mixed clover and grass gives added returns of $1.63 a ton, while an application of eight tons pays $1.85 a ton, and a six-ton application brings the value per ton up to $2.41. These applications are made twice in the four years.

Reënforcement with Minerals.—A ton of mixed manure in the stable contains about ten pounds of nitrogen, five pounds of phosphoric acid, and ten pounds of potash. This makes the percentage of nitrogen and potash the same, while the percentage of phosphoric acid is only half as high. A commercial fertilizer of such percentages would be esteemed a badly balanced one. Certainly the phosphoric acid should be relatively high, as this constituent of plant-food runs low in the soil. If 50 pounds of 14 per cent acid phosphate were added to each ton of manure while it is being made in the stable, seven pounds of phosphoric acid would be added, making the percentage in the manure a little higher than that of the nitrogen and the potash. A better balance is given to the fertility. There cannot be any loss in this purchased plant-food, if the stable floor is tight. Fermentation cannot drive it off, and when applied to the soil it is tightly held. Practically no phosphoric acid is found in drainage waters. Eight tons of manure thus reënforced would contain the same amount of plant-food as a ton of fertilizer having 4 per cent nitrogen, 5 per cent phosphoric acid, and 4 per cent potash. The addition of the 50 pounds of acid phosphate per ton does not bring the phosphoric acid content up as high relatively as in most commercial fertilizers, but it helps. The total amount in the eight tons manure may be sufficient, and the greater part of the total has sufficiently immediate availability, while the manure must undergo decomposition, and some of the nitrogen and potash does not become available within the year.

Durability of Manure.—Tests of the durability of manure in the soil involve some uncertain factors, but we are interested only in the effects of applications. These effects may continue for a long term of years, and an example will illustrate. Land may be too infertile to make a good clover sod. If a good dressing of manure be given half the land, affording proper conditions for making a sod, the result will be a heavy growth of clover, while the seeding on the unmanured half will be nearly a failure. If no manure or fertilizer be used in the crop-rotation, the probability is the manured portion of the field will again make a fairly good sod. How much this success may be due to the remains of the manure, and how much is attributable to the effect of the clover and to better bacterial life introduced and favored by the manure, no one knows. Probably the greater part of the benefit comes only indirectly from the manure applied three or four years previously. Half of the field may thus be lifted out of a helpless state and remain out of it for a long term of years, while the other half grows only poorer. A probable illustration of this lasting indirect effect may be seen in one of the plats in the soil fertility experiments on the Pennsylvania experiment station farm.

Experiments at the Rothamstead station, England, show some lasting results from applications of manure. Director Hall cites the case of one plat of grass land which was highly manured each year from 1856 to 1863, and has since been left unmanured. In 1864 this plat gave double the yield of an adjoining plat which had been left unmanured during the eight years. In 1865 the plat, last manured in 1863, gave over double the yield of the unmanured. In the following ten years its yield was a half more than that of the unmanured. In the next ten years the yield was a quarter more. In the next ten years it fell to 6 per cent more than the plat that had received no manure in the beginning of the experiment. In the following ten years it rose to 15 per cent. Here is a lasting effect of manure for over forty years where grass was grown continuously.

CHAPTER XV

CROP-ROTATIONS

The Farm Scheme.—Notwithstanding some of the theorizing that does not commend itself to the practical man, farm management is taking on the form of a science. It involves the organization of a farm for best results, and in the scheme that should be worked out for any particular farm the most important feature is the crop-rotation. The selection of crops is controlled by so many local considerations, including the personal likes and dislikes of the farmer, that very rightly the kinds of rotation are innumerable. The order in which crops may be grown with most profit is less variable, and yet even here local conditions may quickly derange the scheme of a theorist. There is, however, such right relation of facts to each other that we are getting a working philosophy, and the individual farmer can bend practice to his own liking in considerable degree, and yet not compel plants to do their part at a disadvantage. He has much liberty in the order of their growing, without endangering profits materially. Theoretically, this is not true, and the factors of production on any farm are such that the largest return is obtainable in only one scheme of farming. Practically there is rather wide liberty.

Value of Rotation.—Experience has shown the benefit of variety in crops grown on land. Among the advantages of crop-rotation are the following:

1. It enables the farmer to maintain the supply of organic matter in his soil. The roots and stubble of a grain crop are insufficient for this purpose, and the introduction of a sod or cover crop is helpful.

2. It permits the use of legumes to secure cheap supplies of nitrogen.

3. Some plants feed near the surface of the ground, and the use of other plants which send roots deeper adds to the production.

4. Some crops leave the soil in bad physical condition, and the use of other crops in the rotation serves as a corrective.

5. The keeping of livestock is made more feasible and profitable, and this leads to increase in farm manures.

6. In a proper succession of crops the soil is covered with living plants nearly all the time, and thus is prevented from washing or leaching.

7. In addition to these influences upon soil fertility, crop-rotation assists in control of insect and fungous foes and of weeds; it permits such distribution of labor on the farm that the largest total production may be secured by its employment; and it saves the farmer from sole dependence upon a single crop.

PENN'S VALLEY, PENNSYLVANIA.

Selection of Crops.—The natural inclination of the farmer is a consideration that cannot be ignored. If a man does not like certain kinds of animals or crops, his farm or market must possess an unusual advantage to counter-balance. Illustration of this truth may be seen in every farming community.

As a rule, the crops should be those that are well adapted to the particular soils upon which they are grown. It is up-hill work to compete with producers whose soils have far better adaptation, unless the local markets equalize conditions.

The crops should follow each other in such succession that each crop naturally paves the way for the next one in the succession, or at least does not place its successor at a disadvantage.

When it is feasible, a rather large proportion of the entire produce of the rotation should be feeding-stuff for livestock, as soil fertility is most easily guarded by livestock farming. This is desirable when consistent with profit, but, as we have seen, it is not an absolute essential.

An Old Succession of Crops.—In the corn belt of the northern states some time-honored crop-rotations have been formed by corn, oats, wheat, clover, and timothy. The number of years devoted to the grain and to the sod has varied with the soil and the desire of its owner. A common succession is corn one year, oats one year, wheat one year, clover and timothy one year, timothy one year—a five years' rotation that has much substantial success behind it. Such a rotation is wholly reasonable and in accord with the nature of things. Every year furnishes some organic matter for the soil in roots and stubble, and all the produce of four years out of the five may be fed on the farm. There is one cash crop, or two if the price of the clear timothy hay justifies sale.

The manure may be hauled upon the sod when other work does not press, and it goes where the crop is one that prefers fresh manure, be that the grass or the corn. There is plenty of time after the corn to prepare for oats, and after the oats to prepare for wheat. The preparation for the wheat is sufficient for the clover and timothy. The seedings come only in the spring and the fall, when rainfall is more abundant and effective than in mid-summer. The danger of failure in case of this rotation is relatively small.

Corn Two Years.—Hunt says that the prosperity of the east, as a whole, would be greatly increased if the rotations of crops were so modified as to increase the corn acreage. He suggests the four rotations given in the table below, which is taken from Bulletin 116 of the Pennsylvania experiment station. The fertilizers recommended should maintain fertility.

CORN IN CROP-ROTATIONS

3 Yr.	4 Yr.	5 Yr.	7 Yr.	
			1	Corn: 6 to 10 loads of manure and 25 pounds of phosphoric acid.
1	1	1	2	Corn: 6 to 10 loads of manure and 25 pounds of phosphoric acid.
	2	2	3	Oats: no fertilizer.
2	3	3	4	Wheat: 50 pounds each of phosphoric acid and potash.
3	4	4	5	Clover and timothy: no fertilizer.
		5	6	Timothy: 25 pounds each of nitrogen, phosphoric acid, and potash.
			7	Timothy: 25 pounds each of nitrogen, phosphoric acid, and potash.

The Oat Crop.—In the northern part of the corn belt the oat crop is profitable. In the southern half of Ohio and regions of like temperature the oat crop rarely pays. The heat, when the oat is in the milk stage, usually is too great. The tendency there is to eliminate this crop. Where silage is wanted, the stubble-land can be seeded directly to wheat with good results. A common practice is to seed to wheat between the shocked corn, and the wheat does poorly unless the soil is quite fertile.

Two Crops of Wheat.—A common practice has been to grow two crops of wheat, seeding first in the corn stubble-land, and plowing the ground for the second wheat crop, making a smooth surface for mowing. This method ceased to pay well when wheat became low in price. It has the advantage of giving two cash crops to the rotation.

Where winter wheat does not thrive in the north, it is dropped out, and the seeding to clover and grass is with the oat crop. There is the compensation of a large oat yield where the climate is too cold for a good crop of wheat.

In the Shenandoah Valley.

The Clover and Timothy.—The timothy and clover sod is made inexpensively so far as labor is concerned. The first crop of hay is chiefly clover, and the soil is enriched by the roots and stubble, while the hay is converted into manure.

The second year the hay is nearly clear timothy. The sod should not be left until it becomes thin, but should be turned under while heavy, no matter if this must be after one season's harvest, or two. A sod stands three or four years for harvest on some farms, and without heavy fertilization there is decrease in fertility.

Two Legumes in the Rotation.—If all the crops of this five years' rotation, excepting wheat, were fed on the farm, and if all the manure were saved and rightly applied, there would be little or no difficulty in maintaining fertility, provided the soil were friendly to clover. The fact is that much such land has grown poorer, and it is known that another legume is needed in the rotation. The substitution of the soybean or cowpea for the oat crop gives excellent results. It makes a large supply of rich hay, and it fits the soil nicely for winter grain. The use of the breaking-plow is escaped. The surface of the land is in good tilth, especially if the legume was planted in rows so that cultivation could be given. A cutaway harrow, run shallow, and a roller make the seed-bed. Near the southern edge of the oat belt this substitution gives more value in the crop following corn, and at the same time conserves soil fertility.

Where land is thin, a four years' rotation of corn, soybeans or cowpeas, wheat, and clover is one of the best, because it contains two leguminous crops, and because one of them favors the wheat which follows and the clover seeded in the wheat.

Potatoes after Corn.—When potatoes are grown in the corn belt, a five years' rotation of corn, potatoes, oats, wheat, and clover, or corn, potatoes, wheat, clover, and timothy, is one of the best. When a late potato crop is grown, there is not time for seeding to wheat in cool latitudes, and the oat crop, or the soybean, fits in best. Farther south, where the oat crop is less profitable, there usually is time to go directly to wheat.

The advantage in this rotation is that the fresh manure can be used on the sod for the corn, and the potato thrives in the rotted remains of the sod and manure. Corn leaves the soil in good physical condition for the potato. Commercial fertilizer is used freely for the potato, which repays fertilization in higher degree than most other staple crops. The land can be prepared for seeding to wheat and grass with a minimum amount of labor. The rotation is excellent where there is enough fertility for the potato, which usually can be by far the most profitable crop in the entire rotation.

A Three Years' Rotation.—Farm conditions may require that certain fields in the farm go under a crop-rotation covering three years. In the winter wheat belt this may be clover, corn, and wheat, or clover, potatoes, and wheat. It is an excellent rotation when early planted potatoes or silage corn follows the sod, favoring the wheat in which the clover again is seeded. The ground is plowed only once in three years. The clover furnishes hay for the farm, and organic matter with nitrogen for the land. There are two cash crops in the rotation when potatoes are grown, and that makes a heavy draft upon fertility. Experience has demonstrated that commercial fertilizers or manure become necessary as a supplement to clover in a three years' rotation embracing potatoes. This rotation gives good control of most weeds and insect enemies.

Where wheat is unprofitable, the oat crop is used in its stead. If mixed hay is wanted, timothy is sown with the clover. This is poor practice from the standpoint of soil fertility because the draft upon humus is heavy in a close rotation embracing a tilled crop and small grain. The sod should be chiefly clover, or manure should be used in connection with commercial fertilizer.

Grain and Clover.—In the case of some soils it is possible to grow a wheat or corn crop each year, clover being grown as a catch crop. In the long run, this practice will fail because the clover will cease to make a thrifty growth when grown so nearly continuously. It succeeds best on fertile land.

Potatoes and Crimson Clover.—In some potato-producing sections in warm latitudes it is a not uncommon practice to grow potatoes year after year on the same land, seeding to crimson clover after the removal of the crop in August, and plowing the clover down early in the spring. Rye has been similarly used farther north. In each instance available plant-food must be freely supplied. The practice is a temporary expedient of value, but probably cannot be pursued indefinitely with profit. This is likewise true of similar close rotations.

CHAPTER XVI

THE NEED OF COMMERCIAL FERTILIZERS

Loss of Plant-food.—The soil is composed chiefly of material that never will enter into the structure of plants, but that serves us by affording a congenial place for plant-roots. It anchors the plants, holds moisture for them, and offers opportunity for all the processes necessary to the preparation of plant-food and to its use. In this material are the abundant supplies of such plant-food as silica, but, as has been previously stated, their very abundance leads us rightly to disregard them in our thinking. Our interest is only in the very small percentage of material that is composed of the four constituents which may be lacking in available form in the soil: nitrogen, phosphoric acid, potash, and lime. We believe that the only consideration that now need be given lime is as a soil-corrective and, when there is no acidity, we may assume that there is plenty of lime present. When yields of crops tend to decrease, the only plant-foods with which we are concerned are nitrogen, phosphoric acid, and potash.

The materials were stored in all agricultural land, and much of the supply is in inert forms. They help to make what we call the natural strength of the land. The rotting of organic matter, tillage, and many other agencies bring about some availability. The removal of crops, leaching, etc., reduce the supply. The right use of commercial fertilizers involves the addition of some plant-food when the available supply in a particular soil is inadequate.

Prejudice against Commercial Fertilizers.—The owner of land that was made very fertile by nature, and that has not been cropped long enough to reduce the supply of available fertility to the danger-point, rarely fails to entertain a prejudice against commercial fertilizers. It is the rule that he refuses to consider their use until the decrease in crop yields becomes so serious that necessity drives. If his land is not contributing its fair share of grain, vegetables, etc., to the markets, but has all its products converted into meat or milk, the supply of available plant-food may remain sufficient for so long a time that the matter cannot have any interest for him. If the land is producing some crops for market, there is reduction in its mineral store. It is the rule that the boundary of profitable use of commercial fertilizers pushes westward from the older and naturally poorer seaboard states about one generation after need shows in the crop yields. Lack of knowledge, the association of the use of commercial fertilizers with poor land, and some observation of the unwise use of fertilizers, combine to create a lively prejudice. They are viewed as stimulants only, and costly ones at that.

Are Fertilizers Stimulants?—Some words carry with them their own popular condemnation. We are accustomed to draw a sharp line between foods and stimulants, and to condemn the latter. To stimulate is to rouse to activity. Tillage does not add one pound of plant-food to the soil, and its office is to enable plants to draw material out of the soil. It makes activities possible that convert soil material into crops. Fertilizers add plant-food directly to the soil, and it is also to their credit that their judicious use favors increased availability in some of the compounds already in the soil. The greater part of the labor put on land is designed to make plant-food available, either by providing moisture, or ease of penetration of plant-roots, or activity of bacteria, or other means that will permit plants to remove what they need for growth. Fertilizers supply fertility directly and indirectly, but it is their direct service in meeting a deficiency in plant-food that affords all needed justification for their use by practical farmers.

Referring to the thirty years' soil fertility experiments of the Pennsylvania station, Hunt says that they "show that there is nothing injurious about commercial fertilizers. For thirty years certain plats in this experiment have received no stable manures. No organic matter has been added to the soil except that which was furnished by the roots and stubble of plants grown. These plats are not only as fertile as they were thirty years ago, but they have yielded, and continue to yield, as good crops as adjacent plats which have received yard manure every two years in place of commercial fertilizer."

Soil Analysis.—There is wide misconception regarding the value of chemical analysis of the soil as an aid in making choice of a fertilizer. Analysis has shown that some soil types are relatively richer in plant-constituents than are others, and it has shown abnormal deficiency in some types of limited area. It has given us more knowledge of soils, but as a guide to fertilization in particular instances it usually has no value. The samples used by an analyst are so small that the inaccuracy in his determination may easily be greater than the total amount of plant-food in a very heavy application of commercial fertilizer. A field that has been reduced to temporarily low productive power by heavy cropping or bad farming methods may show a greater content of plant-food than another field that is in a highly productive condition. This is a fact difficult of acceptance by some who want the aid of science, but such are the present limitations. The weight of a fertilizer application is so small in comparison with the weight of the surface part of an acre of land that the use of a ton of fertilizer may not be detected in the analyst's determinations, and moreover his determinations of actual availability in the soil's supplies are not serviceable in the selection of a fertilizer for any particular field and crop.

Physical Analysis.—Chemical analysis is costly and unsatisfactory as a guide to fertilization. Physical analysis by a competent man may have distinct value, and especially to one lacking experience with his soil. The mapping of soils by national and state authorities has given pretty accurate knowledge of hundreds of soil types, their location and characteristics, and when a soil expert obtains a sample of soil and the history of its past treatment, he can assign it to its type and give to its owner dependable advice regarding its crop-adaptation and probable fertilizer requirements.

The Use of Nitrogen.—There is no fully satisfactory way of determining the kind and amount of fertilizer that should be used at any particular time for any one crop. Perfection in this respect is no easier in attainment than in other matters. There are, however, means of arriving at conclusions that are a valuable guide.

In a general way, nitrogen is in scant supply in all worn soils. Wherever the cropping has been hard, and manure has not gone back to the land, the growth in stalk and leaves of the plant is deficient. The color is light. Inability of a soil to produce a strong growth of corn, a large amount of straw, or a heavy hay crop, is indicative of lack of nitrogen in nearly every instance.

The legumes, such as clover, and the stable manures are rich in nitrogen, and when the scheme of farming involves their use on all the land of the farm, no need of purchased nitrogen may arise in the production of staple crops. In the black corn soils the nitrogen content originally was high.

Lands that naturally are not very fertile rarely have enough available nitrogen. Where timothy is a leading crop, the demand for nitrogen is heavy. A cold spring or summer, checking nature's processes in the soil, may cause a temporary deficiency in available nitrogen in land that usually has a sufficient supply. Associating a rank growth of stalk and leaf with an abundance of nitrogen, the experienced man can form a pretty safe opinion regarding the probable profitableness of an investment in this element. It costs nearly four times as much per pound as either of the two other constituents of a fertilizer, and so far as is feasible it should be obtained through the legumes and stable manure.

Phosphoric-acid Requirements.—Soil analyses show that the content of phosphoric acid in most soils of this country is relatively small. The results of experiments with the various constituents of fertilizers are in accord with this fact. Fertilizer experiments at the various stations and on farms are nearly a unit in showing that if any need in plant-food exists, phosphoric acid is deficient. When crop-producing power decreases, and the farmer begins to seek a commercial fertilizer to repair the loss, he finds that bone-dust or acid phosphate is serviceable. The resulting increase in yield often leads to such sole dependence upon this fertilizer that clover and manure are disregarded, the percentage of humus is allowed to drop, and finally the fertilizer is brought into disrepute. The need of phosphoric acid is so common that it is the sole plant-food in much fertilizer, and the dominant element in practically all the remainder on the market.

PLAT EXPERIMENTS.

The Need of Potash.—Land which is deficient in organic matter ordinarily is lacking in available potash, and responds with profit to applications, provided the nitrogen and phosphoric-acid requirements have been met. Clay soils contain far more potash than sandy soils, and in a farming scheme for them that permits the use of manure and clover, it may not become necessary to buy much potash. The liberal use of straw in the stables, and the saving of all the liquid manure, are helps. Farms from which the hay and straw have been sold for a long period of time develop an urgent need of potash. Much muck land is very deficient in this constituent.

Fertilizer Tests.—Every farmer should conduct some fertilizer tests for himself. It is only the soil itself that can make an adequate reply to a question regarding its needs. The test should be made under conditions furnishing evenness in the soil, and it should be continued for years. There is pleasure to an intelligent farmer in such questioning of his soil, and only in this way can assurance be obtained that the investment in fertilizers is the wisest that can be planned for the farm.

There are only three plant constituents to be tested, but they must be used in combination as well as singly. A soil that is deficient in the three may not give any return from potash alone, and usually does not, although it may give a marked increase from use of phosphoric acid alone. The plats may be eight rods long and one rod wide, containing each one twentieth of an acre, and having strips two feet wide separating them. The following chart suggests quantities of fertilizers to be used on the one-twentieth acre plats, 10 in number:

	Nothing.
5	pounds nitrate of soda.
18	pounds 14 per cent acid phosphate.
4	pounds muriate of potash.
	Nothing.
5 18	pounds nitrate of soda. pounds 14 per cent acid phosphate.
5 4	pounds nitrate of soda. pounds muriate of potash.
18 4	pounds 14 per cent acid phosphate. pounds muriate of potash.
5 18 4	pounds nitrate of soda. pounds 14 per cent acid phosphate. pounds muriate of potash.
	Nothing.

Variation in Soil.—The difficulty in determining the character of fertilizer for a field, due to variation in the soil, is overestimated. Very often a land-owner says, "I have a dozen kinds of soil in every field." This is true in a way, it may be, but if all the field has had the same treatment in the past, the probability is that the fertilizer which is best for one part of the field will be quite good for the other parts. The likeness in characteristics that permits the land to be cropped as one field gives some assurance of likeness in plant-food needs, even where the proportion of clay and sand varies and the color is not the same.

There may be wide variation in the productive power of the fields of a farm, due to the treatments they have received. The land that grows heavy clover in a close rotation, or receives all the stable manure, may need neither nitrogen nor potash, while another field, hard-run by timothy and corn, may need a complete fertilizer. When a careful fertilizer test on land of only average productive power has been made, the owner has some definite knowledge of his soil that enables him to give more intelligent treatment to all his fields than was possible before the test had been made. He observes the appearance and yield of plants where the plant-food requirement was fully met, and makes allowance in other fields for gains or losses in the soil due to different treatment. It is out of the question to become discouraged before a beginning has been made. If yields are limited by absence of plant-food, fertilizers must be used. If money must be expended for fertilizers, it is only good business to know that the money is expended to the best advantage.

CHAPTER XVII

COMMERCIAL SOURCES OF PLANT-FOOD

Acquaintance with Terms.—The hesitation of many users of commercial fertilizer to master the few technical terms used in analyses of the goods, for which over one hundred million dollars annually are expended in this country, is to be deplored. The number of the materials available for any large use as sources of plant-food in a commercial fertilizer is small, and something of their characteristics should be known. Every farmer should have a working knowledge of these materials—their sources, the percentage of plant-food carried by them, and their probable availability. He should know in a general way their advantages and disadvantages in comparison with each other.

Nitrate of Soda.—One of the best carriers of nitrogen is nitrate of soda, which is imported from Chili, South America, where great beds exist. The most of the impurities are removed, and the nitrate of soda comes to us in bags holding 200 pounds, and looks much like discolored salt. It is easily soluble in water, and usually contains a little over 15 per cent of nitrogen, which is in a very available form. Its immediate availability brings it into use by gardeners and truckers, and it is an excellent source of nitrogen for grass fertilizers to be used in the early spring. It was formerly advised that nitrate of soda should not form part of a fertilizer for use before plant-roots had filled the ground, its high availability being supposed to lead to heavy loss by leaching. The Pennsylvania experiment station uses it as its sole source of nitrogen in fertilizers for staple crops on its 900 acres of farm land. It is effective in fertilizers for corn, wheat, potatoes, and grass, as well as for special crops.

The warnings regarding loss by leaching should not be disregarded, however. If the price of nitrogen in an organic form were as low as it has been in nitrate of soda, and if the soils of the Pennsylvania station farms were sandy, the use of nitrate of soda as the sole carrier of nitrogen would be inadvisable. The only fact of consequence is that the danger of loss has been over-stated, turning some farmers away from the use of a good and relatively cheap carrier of nitrogen.

Sulphate of Ammonia.—This is a by-product in the manufacture of coke and also of illuminating gas. Hunt estimates that the amount of nitrogen lost annually in Pennsylvania's coke industry would be sufficient, if recovered by proper type of ovens, to furnish every acre of land under cultivation in the state with four fifths of all the nitrogen needed to keep it in a maximum state of fertility.

Sulphate of ammonia contains about 20 per cent of nitrogen, which is in a quite available form. It has a tendency to exhaust the lime in the soil, producing an acid condition. Some plats in the fertilizer experiment at the Pennsylvania station have received their nitrogen in the form of sulphate of ammonia for 30 years, and are now in such acid condition that no crops thrive upon them. The corrective, of course, is lime, and if ammonium sulphate were somewhat lower in price, its use would be profitable, justifying cost of correction of acidity if it should occur. It is used by manufacturers of commercial fertilizers, and is well adapted to mixtures on account of its physical condition.

Dried Blood.—There is no more satisfactory source of organic nitrogen than dried blood of high grade. The best blood, red in color, contains nearly as much nitrogen as nitrate of soda, running from 13 to 15 per cent. The nitrogen is not as quickly available as that in the nitrate, but is more so than that in any other form of organic nitrogen. One would rarely go amiss in the purchase of dried blood as a carrier of nitrogen if the price were relatively as low as in the case of nitrate of soda, but he should not let any prejudice in favor of animal origin of fertilizers lead him to pay an excessive price per pound for the nitrogen contained in it. Such a prejudice has caused the nitrogen in a good red blood to sell for one half more per pound than in nitrate of soda, and it is not a good purchase on that basis.

The lower grades of dried blood on the market contain as low as 6 per cent of nitrogen, and the animal refuse put into it gives it a content of a few per cent of phosphoric acid. This black blood is very variable in composition, and should always be accompanied by a guaranteed analysis.

Tankage.—The waste from the slaughter of animals goes into a product called tankage. The refuse is cooked for removal of the fat, and then ground. It may run high in nitrogen on account of the amount of meat in the mixture, and it may be low in nitrogen and very high in phosphoric acid by reason of the large amount of bone in the mixture. Only a guarantee of analysis affords safety to the buyer. It is a relatively slow and good fertilizer, and is used usually in connection with forms of plant-food that are more quickly available.

Fish.—Near the Atlantic coast a large quantity of ground fish, after the extraction of oil, is used as a fertilizer, but the cost of the nitrogen and phosphoric acid in this carrier is relatively too high to justify its free use. Like dried blood, its organic character gains for it a popularity that does not have full justification in fact.

Animal Bone.—The original source of phosphoric acid as a fertilizer was animal bone, just as hard-wood, unleached ashes were the source of potash. The organic character of the animal bone made it appear more truly a manure than could any rock or other inorganic substance. There is no more satisfactory source of phosphoric acid than animal bone, and if it were in full supply for the needs of soils, there would be little occasion to discuss the merits of rock-phosphate and other similar materials. The supply is a small fraction of the need. If all animal bone were carefully saved and returned to the land that produced all of our animals, it would return to the soil only what those animals carried away in their bones, and that is indeed a small fraction of all the draft our crops make upon the soil's supply of this one substance. Some of the best animal bone goes into the manufacture of articles that never contribute anything to the soil, and there are other sources of loss. The supply of phosphoric acid from bone is too small, when compared with the land's need, to deserve more than a small fraction of the consideration it receives by users of commercial fertilizers.

The peculiar situation respecting animal bone has come about through a form of deceit. The demand for bone existed, and there was no legal restraint in the matter of branding phosphatic rock as "bone," "bone-phosphate," etc. In the past, nearly all forms of rock-phosphates have carried the word "bone" on the bag to quiet the apprehension of those who entertained a prejudice against anything other than animal bone. Nearly all the phosphoric acid has come from rock, and its use has been necessary and profitable, but the misrepresentation fostered the old-time prejudice. Within recent years some manufacturers have tired of the seeming deceit that served no purpose with many customers, and have placed acid phosphate and mixed goods upon the market without the intimation that the phosphoric acid was derived from animal bone.

The demand for bone makes prices high for the very limited amount upon the market, when availability is taken into account, and the advice that such goods be used would be valueless if it had any general acceptance. Prices would go higher, and the amount in the world would remain wholly inadequate.

Raw Bone.—Stable manure lasts several years in the soil because decay is slow. Raw bone has appealed to many because its action is likewise necessarily slow. The fat in it prevents fine grinding and protects the coarse particles from decay. It is known as bone-meal or coarse ground-bone. A good quality of raw bone may contain 4 per cent of nitrogen, while the phosphoric-acid content is 20 to 25 per cent. The bones of old animals is less rich in nitrogen. The age of the animals, and the sorting for manufactures of various kinds, cause variation in quality, and the purchase of raw bone should be made on guaranteed analysis just as surely as the purchase of bone that has been treated in any way for removal of various substances in it.

Steamed Bone.—When animal bone is boiled or steamed under pressure for removal of the fat and the cartilage, the content of nitrogen is reduced, and the percentage of phosphoric acid is increased by this removal of fat and nitrogenous substance. The nitrogen in steamed bone may run as low as 1 per cent, and the phosphoric acid may go up to 30 per cent. The composition of steamed bone is so widely variable that the name means little, and purchase should be made only on guaranteed analysis. Some grades run very low both in nitrogen and phosphoric acid, due probably to adulteration.

The boiling or steaming of bone makes fine grinding possible, and the fineness and absence of fat permit quick decay in the soil. Steamed bone is an excellent source of phosphoric acid. The availability is less immediate than that of acid phosphate, but much greater than that of raw bone.

Rock-phosphate.—While the greater part of our soils contain relatively scant stores of phosphoric acid, the deposits of this plant constituent in combination with lime are immense. The rock now chiefly used in this country is found in South Carolina, Tennessee, and Florida. It varies greatly in content of phosphoric acid. When pulverized for direct use on land, without treatment with sulphuric acid to make the plant-food available, a grade running 28 per cent phosphoric acid, or less, usually is selected, the higher grades being reserved for treatment with acid or for export. This untreated rock, pulverized exceedingly fine, often is known as floats.

The value of a pound of phosphoric acid in floats, as compared with that of a pound in the treated rock, known as acid phosphate, is a matter upon which scientists differ widely. Only a small percentage of the plant-food is immediately available, and the question of wise use hinges upon the degree of availability gained later, and the time required. The large amount of experimental work that has been done affords data that causes the following opinion to be stated here: Rock-phosphate, known as floats, is not a profitable source of plant-food for soils deficient in organic matter, when compared with acid phosphate. It is more nearly profitable in an acid soil than in one that has no lime deficiency. It gives more satisfactory results when mixed intimately with stable manure than when used upon land that remains deficient in organic matter. Applications should be in large amount per acre—500 to 1000 pounds—in order that the amount of readily available phosphoric acid may meet the immediate need of plants. Dependence should be placed upon the readily available acid phosphate in all instances until experiment on the farm shows that the rock-phosphate is a cheaper source of plant-food than the acid phosphate.

Acid Phosphate.—When animal bone is treated with sulphuric acid, the result is an acid phosphate, but treated animal bone is so rare on the market that it may be ignored. The acid phosphate on the market is rock-phosphate treated with sulphuric acid to render its plant-food available. The content of phosphoric acid varies because the original rock-phosphate varies, but the most common grade on the market is guaranteed to contain 14 per cent available phosphoric acid, and 1 to 2 per cent insoluble. Some acid phosphate is guaranteed to contain 16 per cent available phosphoric acid, and some runs down to 10 per cent available.

An acid phosphate contains quickly available plant-food. A prejudice exists against it on account of its source, and it has been a common practice to label the bags "bone-phosphate," or "dissolved bone," or such other designation as would imply an organic source, but the acid phosphate is made out of rock-phosphate, regardless of the name given. The prejudice against the rock as a source of plant-food is giving way. It is our chief and cheapest source of supply. The combination of sulphuric acid with rock-phosphate in the production of acid phosphate produces sulphate of lime, known as gypsum or land-plaster. The amount of gypsum in a ton of acid phosphate varies, but may be roughly estimated by the buyer as two thirds of the total weight of the acid phosphate.

The tendency of gypsum is, in the long run, to make a soil acid, and its use necessarily hastens rather than retards the day when a lime deficiency will occur. The influence in this direction is not great enough to be a very material factor in deciding upon a carrier of phosphoric acid. If a soil has little lime in it, a state of acidity soon will come anyway, and the increase in amount of required lime will be small. The cheapness of acid phosphate, as compared with animal bone, is the decisive factor.

The ill-effects usually attributed to acid phosphate are not due in any great degree directly to the sulphuric acid used in its making, but to the bad farming methods that so often attend its use. When the need of commercial fertilizers is first recognized, acid phosphate seems to meet the need. The soil's store of available phosphoric acid gives out first, and this fertilizer brings a new supply. If the available potash is in scant amount, the acid phosphate helps in this direction by freeing some potash. The phosphoric acid has peculiar ability in giving impetus to the growth of a young plant, and that enables it to send its roots out and obtain more nitrogen than it otherwise would do. The farmer thus may come to regard it as a means of securing a crop, and there is neglect of manure and clover. If a field is thin and fails to make a sod, there is no immediate compulsion to use manure or to grow a catch crop to get organic matter, but the field is cropped again with grain. Soon the supply of humus is exhausted, the soil lies lifeless, and the stores of available nitrogen and potash are in a worse depleted state than formerly.

The fault lies with the method. The phosphoric acid in the acid phosphate was needed. Profit from its use was legitimate, but the necessity of supplying organic matter became even greater than it would have been otherwise. Tens of thousands of our most successful farmers use heavy applications of acid phosphate, but they keep their soils in good physical condition by the use of manure or clover, and they apply potash and nitrogen when needed. The clover is assured by using lime wherever it is in too limited supply, and that is the case in most instances, regardless of the use of any kind of commercial fertilizer.

Basic Slag.—When iron ores contain much phosphorus, its extraction by use of lime gives a by-product in the making of steel that has agricultural value. The ores of the United States usually do not give a slag sufficiently rich in phosphorus to be valuable. Nearly all the basic slag used as a fertilizer is imported from Germany, and usually contains 17 to 18 per cent of phosphoric acid. The availability of the plant-food in this fertilizer has been the subject of much discussion. The chemist's test which is fair for acid phosphate is admittedly not fair when used for basic slag. Field tests, at experiment stations and on farms, are our best sources of knowledge. When the soil is slightly acid, each 1 per cent of phosphoric acid in the slag appears to be about as valuable as each 1 per cent of the available phosphoric acid in an acid phosphate. Some of the effectiveness may be due to the lime, although very little of it is in forms regarded as valuable for the correction of soil acidity. There is evidence that basic slag favors clover. It has not been found feasible to ship this material many hundreds of miles inland from the seaboard to compete with acid phosphate, but it is an excellent source of phosphoric acid for soils that are not rich in lime.

Muriate of Potash.—The mines of Stassfurt, Germany, contain an inexhaustible supply of potash in various compounds. Muriate of potash is prepared from the crude salts, and the commercial product on our markets has the appearance of a coarse and discolored salt. It is handled in large bags, and inclines to become moist by absorption of water from the air. It contains some common salt. The content of actual potash is about 50 per cent. The potash is readily available, but the loss from leaching out of the soil is very small. Muriate of potash is our cheapest source of potash, and should be used for all staple crops except tobacco, sugar beets, and, possibly, the potato. Tests even on heavy soils fail to show any injury to the quality of the potato, and on light soil the muriate may always be used.

Sulphate of Potash.—Some sulphate of potash is imported into this country. Its content of potash may vary 1 or 2 per cent below or above 50. Its physical condition favors mixing more than does the muriate. It usually costs several dollars a ton more than the muriate, and the fact that it is known to favor quality in tobacco, and is popularly supposed to do so in the potato, creates demand at the higher price. It is soluble in water, and quickly available. As a rule, it has no higher agricultural value than the muriate.

Kainit.—Unlike muriate and sulphate of potash, kainit is a crude product of the German mines, having received no treatment to remove impurities. It contains 12 to 13 per cent of potash, and is rated as a sulphate, but one third of it is common salt, and in effect upon quality it should be classed with muriate and not sulphate. Its low content of plant-food should confine its use to regions relatively near the seaboard. When shipped far inland, the price becomes too high to give a reasonably cheap pound of potash.

Wood-ashes.—Wood-ashes contain lime and potash, with a small percentage of phosphoric acid. The market price is above agricultural value, and any needed potash should be obtained from the German potash salts.

Other Fertilizers.—Manufacturers of commercial fertilizer make use of other materials, some of which, like manufactured nitrogen, are excellent, and others are low in quality and slow in action. The sources of plant-food that have been described form the great bulk of all fertilizers on the market, and from them may be selected all the materials a farmer needs to use on his land, either singly or home-mixed. In most instances the selection will embrace only four or five of these fertilizing materials.

Salt.—Salt is not a direct fertilizer, and its use is not to be advised unless it can be secured at a very low price per ton. Some soils have been made more productive by the application of 200 to 300 pounds per acre, and chiefly in case the salt was mixed well with the soil when the seed-bed was made. The practice of using salt as a top-dressing on wheat in the spring gives less effectiveness it is believed. Salt frees potash in the soil, and may have some practical effect upon soil moisture. As a soil amendment, salt has had more reputation than its performance justifies. If land is infertile, it is better, as a rule, to apply actual plant-food.

Coal-ashes.—There is no plant-food of value in coal-ashes. The physical condition of heavy soils is improved by an application, and their use may be quite profitable in this way if cost of application is small. When used as a mulch, ashes conserve moisture.

Muck.—The use of muck pays in stables, as it is a good absorbent and contains some nitrogen which gains in availability by mixture with manure. Its direct application to land as a fertilizer does not pay the labor bill under ordinary circumstances.

Sawdust.—As a fertilizer, sawdust does not have much value, but serves as an excellent absorbent in stables. Its presence in manure need not cause fear of injury to the soil. When fresh sawdust is applied in large quantity to a sandy soil, the effect upon physical condition is bad, increasing drouthiness.

CHAPTER XVIII

PURCHASING PLANT-FOOD

Necessity of Purchase.—The necessity of buying plant-food in the form of commercial fertilizers is a mooted question in any naturally fertile agricultural region just so long as crop yields do not drop to a serious extent. The natural strength of the land and the skill that enters into the farming are important factors in determining the profitableness of recourse to purchased plant-food. The free use of organic matter to maintain the supply of humus defers the time when commercial fertilizers should be used. Good tillage frees the potential plant-food of the soil, and delays the day of necessary purchase. The farm so situated that it can have all its products fed upon it is longer independent of outside help. The profitable use of feeding-stuffs from other farms is a safe way of escaping the direct purchase of fertilizers, although it is a transfer of fertility to the farm as surely as the employment of fertilizers, and is not a method that may have general adoption.

In the Lebanon Valley, Pennsylvania.

The organic sources of fertility, such as slaughter-house refuse, are containers of plant-food as surely as is stable manure. The inorganic sources, such as acid phosphate and muriate of potash, are containers of plant-food as surely as is animal bone or blood. There is no line that may be drawn to debar any substance that supplies plant-food profitably and contains no compound harmful to the soil.

The purchase of plant-food should begin whenever profit is offered by it, and in connection with its use there should be good tillage, organic matter, and healthful plant conditions in every respect. The use of a fertilizer pays best when the conditions are such that the plants can avail themselves of it in the fullest degree. Good farming and the heavy use of commercial fertilizers go consistently hand-in-hand.

Fertilizer Control.—The dreams of the patent-medicine vender never pictured more favoring conditions for his activity than were found by fertilizer manufacturers and agents before state laws provided for inspection and control. Men who wanted to do a legitimate business welcomed protection from the unscrupulous competition that dishonest men employed. The memory of some of the frauds perpetrated lingers, and causes a questioning to-day that is unnecessary. All fertilizer-control laws afford a good degree of legal protection to the buyer, although in most states they do not demand a clearness and fullness in statements of analyses that would be helpful to many, and they fail to require that sources of plant-food be given. Some fertilizers are sold for more than they are worth, and some are bought for soils and crops that need other kinds of plant-food, but this is due to lack of knowledge on the part of the buyer that he can acquire. The law does its part in the work of protection better than many buyers do their part. It has driven fraudulent brands off the market, compelled carefulness in factory-mixing, and given to the intelligent buyer a knowledge of the kinds and amounts of plant-food in the bag or ton. The sampling is done by disinterested men, and the analyses are made by competent chemists. There need be little distrust of the analysis as printed on the bag, unless a failure of the manufacturer to keep his goods up to the standard has been made public in the state's fertilizer bulletin.

Brand Names.—Notwithstanding all that has been done by the state to acquaint the buying public with the composition of fertilizers, many purchasers are guided in selection by the brand name, and that usually is fanciful in character, no matter whether it be "Farmers' Friend" or "Jones' Potato Fertilizer." In either case it may be far from friendly to soil or pocket-book, and widely at variance with the needs of the soil for which it is purchased. The pretense of making a fertilizer peculiarly adapted to the potato, or to wheat, or to corn would not attract a single buyer if the public would compare the analyses of these special crop fertilizers offered by manufacturers and note their dissimilarity of composition. Any kind of a mixture may be given any kind of a name. It is the composition that counts. The farmer is in the market for nitrogen and phosphoric acid and potash, singly or combined, for a certain soil, and all he wants is to know the number of pounds he is getting, its availability, and its price per pound. Any added detail not required by law is an impertinence.

Statement of Analysis.—It would be well if the law refused to the manufacturer the privilege of printing unnecessary detail in the statement of analysis that must be placed upon the fertilizer bag. It is added to confuse the buyer and mislead him regarding actual value. The following statement is an example of this practice:

ANALYSIS

	Per Cent		
Nitrogen	0.82	to	1.00
Equal to ammonia	1.00	to	2.00
Soluble phosphoric acid	6.00	to	7.00
Reverted	2.00	to	3.00

Available	8.00	to	10.00
Insoluble	1.00	to	2.00
Total	9.00	to	12.00
Potash (actual)	1.00	to	2.00
Equal to sulphate of potash	2.00	to	3.00

As the row of larger figures is not guaranteed percentages, it has no value.

The buyer is not concerned regarding the amount of ammonia to which the nitrogen is equal, and so the second line is a needless repetition.

The fifth line gives the sum of the third and fourth, the available being the total of the soluble and reverted. Therefore the third and fourth lines may be ignored.

The sixth line gives the percentage of unavailable phosphoric acid in the rock, and should be ignored by the purchaser who wants available plant-food.

The seventh gives the sum of the available and insoluble, and should be ignored.

The ninth is a restatement of the eighth line.

There then remains the following guaranty:

	Per Cent
Nitrogen	0.82
Available phosphoric acid	8.00
Potash	1.00

This is a low-grade fertilizer whose cheap character becomes apparent when the unnecessary statements and restatements are erased. A ton of it contains only 16 pounds of nitrogen, 160 pounds of phosphoric acid, and 20 pounds of potash.

Valuation of Fertilizers.—The manufacturer of a mixed fertilizer must make use of the unmixed materials he finds upon the market. The prices of the various plant constituents in the different unmixed materials can be determined by averaging quotations in leading markets for a given length of time. The fair retail price is obtained by adding about 20 per cent to the wholesale cash price. The retail cash price per pound of the plant constituents in leading markets is thus determined for their various forms and carriers. A pound of nitrogen in dried blood may have its valuation fixed at a figure 50 per cent higher than that of a pound of nitrogen in nitrate of soda simply because the dried blood sells at a price per ton that makes that difference. It is true commercial value that is sought, and that may be very different from agricultural value.

The mixed fertilizer of the manufacturer has its content of plant-food known by analysis. Its number of pounds of the various constituents in a ton is known, and the retail price per pound of these substances has been fixed. The commercial value per ton can then be determined, provided proper allowance is made for cost of mixing and bagging. The individual must pay in addition the freight, and usually a considerable sum for unnecessarily costly methods of distribution and collection.

A Bit of Arithmetic.—This paragraph is intended to serve the man who is willing to be reasonably near right if he cannot be wholly so: A ton is 2000 pounds, and one per cent is 20 pounds. In dealing with fertilizers it is the practice to call 20 pounds, or one per cent of a ton, a unit, and to base the price of the nitrogen, and phosphoric acid, and potash, on the unit. This is done for convenience. If five cents is a fair price for a pound of available phosphoric acid in one's locality, as it would be if a ton of 14 per cent acid phosphate cost $14, a unit of 20 pounds is worth $1. Each one per cent guaranteed is thus worth a dollar, and the phosphoric acid in the fertilizer is easily valued. If a pound of potash in a ton of muriate is worth five cents in one's locality, as it would be if a ton of muriate cost $50, the muriate being one half actual potash, a unit of 20 pounds of potash is worth $1. Each one per cent of guaranteed potash is thus worth one dollar, and the entire content of potash is easily valued. If a pound of nitrogen in nitrate of soda is worth seventeen and one half cents a pound in one's locality, as it would be if a ton of nitrate of soda cost $54, a unit, or one per cent, is worth $3.50, and the content of nitrogen is easily valued.

The prices named would seem high to good cash buyers near the seaboard, and they are too low for some other regions where freights are very high. They are only illustrative. The consumer can get his own basis for an estimate by obtaining the best possible cash quotations from city dealers. Some interested critic may point out that nitrate of soda should not be the sole source of nitrogen in a fertilizer on account of its immediate availability. Manufacturers use some sulphate of ammonia, and a pound of nitrogen in it has had practically the same market price as that in nitrate of soda. Tankage may be used in part, and in it the nitrogen costs very little more per pound.

It may be said that the potash in the fertilizer is in form of sulphate. Usually that profits the user nothing, and often the claim is baseless, but if it is a sulphate, the cost of the potash should have only 20 per cent added to the valuation of the potash, which usually will not add one dollar to the total cost of the ton of mixed fertilizer. Basing the valuations of the pounds of plant-food in the mixed fertilizer on the value per pound in unmixed materials delivered to one's own locality, there must be taken into account the added expense of mixing.

High-grade Fertilizers.—A high-grade fertilizer is not necessarily a high-priced one. What we want in a fertilizer is a high content of the plant-food needed, together with desirable availability. If only phosphoric acid is wanted, a 14 per cent, or 16 per cent, acid phosphate is high-grade because it contains as many pounds of available phosphoric acid in a ton as the public can buy in a large way. A 10 per cent acid phosphate is low-grade. The effort is to escape paying freight, and other cost of handling, on waste material as far as possible. Generally speaking, the higher the percentages of plant-food in a fertilizer, the cheaper per pound is the plant-food. A low-grade fertilizer rarely fails to be an expensive one because the expense of handling adds unduly to the price per pound of the small content of plant-food.

CHAPTER XIX

HOME-MIXING OF FERTILIZERS

The Practice of Home-mixing.—The business of compounding fertilizers has been involved in a great deal of unnecessary mystery. Many of our best station scientists have labored to show that the home-mixing of fertilizers is a simple and profitable piece of work, and the heaviest users of fertilizers in the east now buy unmixed materials, but a majority of farmers use the factory-mixed. Manufacturers are right in their contention that many people do not know what materials are best for their own fields, or what proportions are best, but the purchase of mixed materials does not solve their problem and it does not help them to a solution as quickly as home-mixing. The source of the plant-food in the factory-mixed goods is not known, while it is known in the home-mixed.

Effectiveness of Home-mixing.—Van Slyke says ("Fertilizers and Crops," p. 477): "Manufacturers of fertilizers and their agents have persistently sought to discourage the practice of home-mixing, but their statements cannot be accepted as the evidence of disinterested parties. It has been represented to farmers that peculiar and mysterious virtues are imparted to the plant-food constituents by proper mixing, and that really proper mixing can be accomplished only by means not at the command of farmers. Such statements are misrepresentations, based either upon the ignorance of the person who makes them or upon his determination to sell commercial mixed goods."

Criticisms of Home-mixing.—The manufacturer's advocate formerly laid much stress upon the danger attending the treatment of bones and rock with sulphuric acid. That is a business of itself, and the home-mixer has nothing to do with it. He buys on the market the acidulated bone or rock, just as a manufacturer makes his purchase.

It is claimed that the manufacturer renders a great public service by using supplies of plant-food that the home-mixer would not use, and thus conserves the world's total supply. Let us see the measure of truth in the statement. The manufacturer gets his supply of phosphoric acid from rock, bone, or tankage exactly as does the home-mixer. His potash he buys from the syndicate owning the German beds, and the farmer does the same. These sources must contribute all the phosphoric acid and potash used on land, if we except trifling supplies of ashes, marl, etc., and the only difference in the transaction is that in one case the manufacturer buys the materials and mixes them, and in the other case the farmer buys them direct and mixes them. The remaining constituent is the nitrogen. If the manufacturer uses nitrate of soda, sulphate of ammonia, bones, tankage, or manufactured nitrogen, he does what the home-mixer may do. Most nitrogen must come from these sources. If all came from these sources, the increased demand would not affect the price. The beds of nitrate of soda will last for hundreds of years, the present waste in ammonia from coal is immense, and the supply of manufactured nitrogen can be without limit. The saving in use of inert and low-grade forms of nitrogen is more profitable to the manufacturer than to the farmer who buys and pays freight on low-grade materials.

The rather remarkable argument is advanced that fertilizer manufacturers do not make a large per cent on their investment, despite the perfection of their equipment, and therefore the farmer cannot find it profitable to mix his materials at home. By the same reasoning, assuming for the moment that the profit in manufacturing does not pay a heavy dividend on all the stock issued, if a great hotel does not find its dining-room a source of profit, as many hotels do not, no private home should hope to prepare meals for its own members in competition with hotels.

As has been stated, every user of commercial fertilizer should learn what a pound of plant-food in unmixed material would cost him, selecting the common materials that are the only chief sources. If he can buy a pound of nitrogen in nitrate of soda or sulphate of ammonia, a pound of phosphoric acid in acid phosphate or steamed bone, and a pound of potash in muriate or sulphate of potash for less than they would cost in the factory-mixed goods offered him, allowing to himself a dollar or so a ton for the labor of mixing, it is only good business to buy the unmixed materials. The saving usually is from five to ten dollars a ton, excepting only interest on money, as he would pay cash for the unmixed material.

The cost of bags always is mentioned. That is not to be considered by the farmer, as he uses the bags in which the unmixed materials come to him.

The Filler.—There has been much misleading use of the word "filler," as applied to fertilizers. We have seen that a pure grade of dried blood contains about 13 per cent of nitrogen. The buyer of a ton of dried blood thus gets about 260 pounds of plant-food. The remaining 1740 pounds constitute what may be called nature's "filler." The blood is a good fertilizer. We do not buy nitrogen in a pure state. We buy a ton of material to get the needed 260 pounds of nitrogen. Thus it is with nitrate of soda, sulphate of ammonia, acid phosphate, muriate and sulphate of potash, and all other fertilizer materials. As freight must be paid upon the entire ton, it usually pays best to select materials that run high in percentage of plant-food. It is possible to get very low-grade fertilizers that have not had any foreign material added by the manufacturer. An acid phosphate may be poor in phosphoric acid because low-grade rock was used in its manufacture. Kainit is a low-grade potash because the impurities have not been taken out. Filler may be used, however, for two reasons, and one is legitimate. When limestone or similar material is used merely to add weight, reducing the value per ton, the practice is reprehensible. The extent of this practice is less than many suppose, preference being given to the use of low-grade materials in making very low-priced fertilizers.

A legitimate use of filler is to give good physical condition to a fertilizer. Some materials, such as nitrate of soda and muriate of potash, take up moisture and then become hard. The addition of peat or limestone or other absorbent is necessary to keep the mass in condition for drilling. The use of some steamed animal bone or high-grade tankage in the mixture helps to prevent caking. The home-mixer can use a drier without loss, as he does not pay freight upon it. Dry road dust will serve his purpose. His need of a drier may be greater than that of the manufacturer, as he probably will use only high-grade unmixed materials. If the use of the home-mixture is immediate, no drier to prevent caking is needed, but its presence facilitates drilling. Storage of unmixed materials in a dry place is an aid in maintaining good condition.

Ingredients in the Mixture.—The matters of interest to the farmer are the determination of the amounts of nitrogen, phosphoric acid, and potash that he should apply to a particular field, their availability, and their cost. Let us assume that he has found 300 pounds of a fertilizer containing 3 per cent nitrogen, 10 per cent phosphoric acid, and 6 per cent potash to be an excellent application for wheat on a thin soil that is to be seeded to clover and timothy. This fertilizer contains 3 pounds of nitrogen to each 100 pounds. He applies 300 pounds of the fertilizer per acre, or 9 pounds of nitrogen. The fertilizer contains 10 pounds of phosphoric acid to the 100 pounds. He thus applies 30 pounds of phosphoric acid per acre. The fertilizer contains 6 pounds of potash per 100 pounds, and he therefore applies 18 pounds per acre. What he has really learned, then, is that an acre of this land, when seeded to wheat, needs 9 pounds of nitrogen, 30 pounds of phosphoric acid, and 18 pounds of potash. It is in these terms he should do his thinking, and the matter of fertilization becomes simple.

In the general farming of the Pennsylvania experiment station, it is the practice to depend upon nitrate of soda as the source of a fertilizer for wheat. Manufacturers claim that sulphate of ammonia and tankage would be better. The farmer soon will learn what he prefers for his soil, provided he practices home-mixing.

Let us assume that he uses nitrate of soda, which never varies much from 15 per cent in its content of nitrogen. If 100 pounds of nitrate contain 15 pounds of nitrogen, the 9 pounds wanted for an acre will be found in 9/15 of 100 pounds or 60 pounds.

Thirty pounds of phosphoric acid are wanted for an acre. If the acid phosphate contains 14 per cent of phosphoric acid, or 14 pounds to the 100, the required amount will be 30/14 of 100, or 214 pounds.

Eighteen pounds of potash are wanted for an acre. The muriate of potash on our markets never varies much from 50 per cent in its content of potash. If 100 pounds of muriate contain 50 pounds of potash to the 100, the required amount wanted will be 18/50 of 100, or 36 pounds.

Adding the 60, 214, and 36 pounds, we have 310 pounds for the acre of land. If the field contains 20 acres, the order will call for 20 times the 60 pounds of nitrate of soda, 20 times the 214 pounds of acid phosphate, and 20 times the 36 pounds of potash.

If the farmer prefers to use sulphate of ammonia, which varies little from 20 per cent of nitrogen, or 20 pounds in the 100, he will get his 9 pounds of nitrogen for an acre by buying 9/20 of 100 pounds, or 45 pounds, and the substitution of the 45 pounds of sulphate of ammonia for the 60 pounds of nitrate of soda will reduce the total application of fertilizer per acre from 310 pounds to 295 pounds. The important fact is that in either case there is the required amount of nitrogen.

Let us assume that the field contains enough nitrogen, but other needs remain the same. In such case, the nitrogen is dropped out, and the application becomes 250 pounds per acre.

The home-mixer may substitute tankage of guaranteed analysis for part of the nitrogen and phosphoric acid. Let us assume that the tankage runs 9 per cent nitrogen and 20 per cent phosphoric acid. If half the required nitrogen per acre, or 4½ pounds, is wanted in tankage, 50 pounds of the tankage will supply it. At the same time the 50 pounds of tankage supplies 10 pounds of phosphoric acid, replacing one third of the 214 pounds of acid phosphate. We thus have for the acre 30 pounds of nitrate of soda, 50 pounds of tankage, 143 pounds of acid phosphate, and 36 pounds of potash, or 259 pounds. The content of plant-food remains the same, but one half of the nitrogen is only slowly available. The farmer who buys unmixed materials will incline to use only a few kinds, and at first he will confine himself chiefly to materials whose composition varies little. In this way he quickly sees in a ton of the material, not the whole bulk, but the definite number of pounds of nitrogen and other constituents of plant-food contained in it, and the calculations in home-mixing become simple.

Materials that should not be Combined.—The advocate of factory-mixed goods warns the farmer against the danger of making combinations of materials that will cause loss by chemical action. The danger is wholly imaginary if no form of lime, wood-ashes, or basic slag is used in the home-mixtures. As has been said, some materials will harden, if permitted to absorb moisture, and if the mixture must stand, a few hundred pounds of muck or dry road dust should be added to each ton as a drier, and a correspondingly larger amount per acre should be applied.

Making a Good Mixture.—The process of mixing is simple, and careful station tests have shown that it is fully as effective as factory-mixing. The unmixed materials should be kept in a dry place until the mixing is done. If there are any coarse lumps, a wooden tamper can crush them on the barn floor, and the material should be passed through a sand-screen. The material of largest bulk should be spread on the floor, and the other materials should be put on in layers. Three careful turnings with a shovel will secure good mixing. Scales should be used to secure accuracy in desired amounts of the materials.

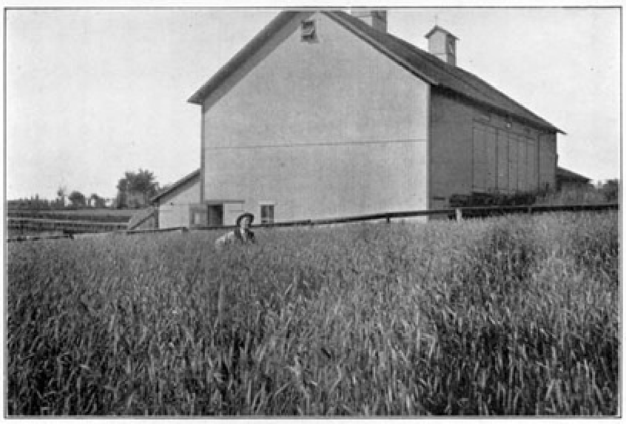
Buying Unmixed Materials.—Acid phosphate, animal bone, and tankage can be bought of any fertilizer agent, but when one pays cash, he does well to get quotations from various leading manufacturers. The names of dealers in nitrate of soda can be secured from the New York agency which keeps its address before the public in agricultural papers. This is likewise true in the case of the syndicate controlling all the potash. When the addresses of leading distributors of all needed materials have been secured, quotations should be obtained on a cash basis. The best terms are obtained by groups of men combining their orders.

CHAPTER XX

MIXTURES FOR CROPS

Composition of Plant not a Guide.—It has been pointed out that a chemical analysis of a soil is not a dependable guide in the selection of a fertilizer. Years ago the theory was advanced that the analysis of the crops desired should be a guide, but it has proved nearly worthless. This theory does not take into account the soil's supply of plant-food. Moreover, a certain crop may demand a large supply of an element at a time of the year when the soil's supply is inactive. The need of nitrogen for grass in the early spring, before nitrification in the soil is active, is an illustration. Let the causes be what they may, the fertilizer formulas that call for plant-food in a fertilizer in the same proportions that it is found in plants are disappointing in their results. The analysis of the plant is not a dependable index.

The Multiplication of Formulas.—Fertilizer manufacturers have made all possible combinations of fertilizer materials, using them in various quantities. Each manufacturer has given a mixture a brand of his own, and confusion reigns. There is no formula for a soil or crop that will remain absolutely the best, even for one particular field. It represents one's judgment of the present need, and is employed subject to change, just as is the prescription of a physician. It is usually only an approach toward the most profitable amount and kind of plant-food that may be supplied. The one important consideration is that no manufacturer can know the need nearly so well as the intelligent farmer who knows the history of his field and constantly tests its ability.



ON THE PRODUCTIVE FARM OF DR. W. I. CHAMBERLAIN, IN NORTHERN OHIO.

A Few Combinations are Safest.—It is the best judgment of scientists to-day that greater results would be obtained from the use of commercial fertilizers if the number of formulas could be reduced to ten, or even a less number. The satisfactory fertilizers fall into three classes:

> 1. The phosphatic fertilizer, carrying phosphoric acid to land that gets its nitrogen from clover or stable manure, and that continues to supply its own potash. Such a fertilizer should have a high content of phosphoric acid in order that the freight charge, per pound of plant-food, may be as low as possible. Acid phosphate, basic slag, and bone are chief in this group.
>
> 2. The combination of phosphoric acid and potash that is needed by soils obtaining all required nitrogen from clover or manure. In most instances the phosphoric acid should run higher than the potash, but the percentage of potash should never run lower than 4. A lower percentage of potash is not as profitable as a higher one, provided any potash is needed. The potash content should be greater than that of the phosphoric acid in case of some sandy soils and of some crops of heavy leaf growth, including various garden crops.
>
> 3. The so-called "complete" fertilizer that supplies some nitrogen with the two other plant-constituents. Such fertilizer should furnish, with few exceptions, 3 per cent of nitrogen, if no more.

Amount of Application.—In common practice fertilizers are not applied freely enough when they are used at all. The exception to this rule may be found in the case of small applications to cold and inert soils to force growth in the first few weeks of a plant's life. It is difficult to see how 80 or 100 pounds of fertilizer can affect an acre of land one way or the other, but experience teaches that such an amount can do so in respect to young plants. Phosphoric acid has peculiar power in forcing some development of roots in a small plant, and a small application in the drill or row may help the plants to gain ability to forage for themselves.

In early spring a small application of nitrate of soda has marked effect, tiding the plants over a period of need until the soil is ready to give up a part of its store.

If a soil is not fertile, and fertilizers are needed as an important source of plant-food throughout the season, the application should be liberal. If it is necessary to plant a field that is deficient in fertility, expending labor and money for tillage and seed, the only rational course is to furnish all needed plant-food for a good yield. There may be little net profit from the one crop, but there will be more than could be obtained without the liberal fertilization, and the soil will be better equipped for another crop. This applies, in a notable degree, to fertilization of a wheat crop with which timothy and clover will be seeded. The difference in cost of 350 pounds of a high-grade fertilizer and 150 pounds of a low-grade one, when applied to a poor soil under these circumstances, may be recovered in the grain crop, and at the same time a good sod will be made possible for the permanent improvement of the land. It is a safe business rule that land should be left uncultivated unless enough plant-food can be provided in some way for a good yield. The man who cannot incur a heavy fertilizer bill, when necessary, should restrict acreage for his own sake.

Similarity of Requirements.—Many of our staple crops are very similar in their fertilizer requirements, and this simplifies fertilization. Setting aside the impression gained from the dissimilarity in the so-called corn, potato, wheat, and grass fertilizers on the market, the farmer knows that the soil which is in a good state of fertility is best for any of them, and if the soil is hard-run, it should have its plant-food supply supplemented. The hard-run soil usually is lacking in available supplies of all three plant-food constituents. If a fertilizer containing 3 per cent of nitrogen, 10 per cent of phosphoric acid, and 6 per cent of potash serves the wheat well, it will serve the timothy that starts in the wheat. Likewise it will serve the corn, although a heavier application will be needed because corn is a heavy feeder. Experience has taught that it will serve the potato similarly, and that the potato will repay the cost of free use of fertilizer. If the soil is sandy and deficient in potash, the percentage of phosphoric acid may be cut to 8, and the percentage of potash raised to 10, and all these crops will profit thereby. If the nitrogen content in the soil is high, none of these crops may need nitrogen in the fertilizer. This is a general principle, and safe for guidance, though the best profit will demand some modification that readily occurs to the farmer as he studies his crops and their rotation. To illustrate: The corn is given the clover sod or the manure partly because it requires more plant-food than the wheat. It gets the best of the nitrogen, and may need only a rock-and-potash fertilizer, while the wheat that follows may need some available nitrogen to force growth in the fall. There is no fixed formula for any field or crop, and the point to be made here only is that the requirements of many standard crops do not have the dissimilarity usually supposed, except in respect to quantity. A marked exception is found in the oat crop, which does not bear the application of much nitrogen, and often fares well on the remains of the manure that fed the corn, if some phosphoric acid is added.

Maintaining Fertility.—A heavy clover sod gives assurance that a good crop of corn or potatoes can be grown. If the amount of plant-food in the sod is not excessive, a heavy crop of wheat can be produced. The condition of the soil favors many crops. The clover has placed it upon a productive basis for the time being.

The object that should be kept in view, when a scheme of soil fertilization is worked out, is the maintenance of such a state of fertility that the land can be depended upon for whatever crop comes round in the rotation. When a 3-10-6 fertilizer, or a 3-8-10 fertilizer, is used, the effect upon a thin soil is to restore it temporarily to this good-cropping power, the size of the application varying with the crop. A richer soil may want the phosphoric acid and potash without the nitrogen. A manured soil may need only the phosphoric acid. The purpose of the fertilizer in any case is maintenance or increase of fertility, and when this object has been secured, the crop may be whatever the rotation calls for. It is this rational scheme that gives success to the Pennsylvania station's methods on some of its test plats. A given amount of plant-food is put upon the land, which is under a four-years' rotation. One half of it is applied every second year. The corn gets one half because it can use it to advantage. The oat crop that follows finds enough fertility because the soil is good. Next in the rotation is the wheat, and the wheat and timothy and clover plants can use fertilizer with profit. There is no change in its character because it is the soil that is getting the assistance, and not primarily just one crop in a rotation. The land in this experiment that is well fertilized is more productive than it was thirty years ago, although no manure has been applied, and it is the general productive condition that assures good yields, and not chiefly any one application of fertilizer.

Fertilizer for Grass.—A fertile soil will make a good sod. A thinner soil should have a liberal dressing of complete fertilizer at seeding time, and the formula that has been suggested is excellent for this purpose. If a succession of timothy hay crops is desired, the problem of maintaining fertility is wholly changed. The nitrogen supplied by the clover is soon exhausted, and the timothy sod must be kept thick and heavy until broken, or the soil will not have its supply of organic matter maintained. Nitrogen must be supplied freely, and phosphoric acid and potash must likewise be given the soil. The draft upon the soil is heavy, and at the same time the effort should be to have a sod to be broken for corn that will produce a big crop without the use of any fertilizer. The grass is the natural crop to receive the plant-food because its roots fill the ground, and the corn should get its food from the rotting sod, when broken. Station tests have shown that a sod can be caused to increase in productiveness for several years by means of annual applications of the right combinations of plant-food in the early spring. A mixture of 150 pounds of nitrate of soda, 150 pounds of acid phosphate, and 50 pounds of muriate of potash is excellent. This gives nearly the same quantity each of nitrogen, phosphoric acid, and potash, and is near a 7-7-7 fertilizer. The only material change in relative amounts of plant-food constituents, when compared with a 3-10-6 and 3-8-10 fertilizer, is in the increase of nitrogen, due to the heavy drafts made by continuous mowings of timothy. This fertilizer should be used as soon as any green appears in the grass field in the spring after the year of clover harvest. The large amount of nitrogen makes this an unprofitable fertilizer for clover, and its use is not advised until the spring of the year in which timothy will be harvested.

All the Nitrogen from Clover.—The Pennsylvania station has shown in a test of thirty years that when good clover is grown in a four-years' rotation of corn, oats, wheat, and clover, the fertility of the naturally good clay loam soil may be maintained, and even slightly increased, without the use of any manure or purchased nitrogen. Phosphoric acid and potash have been applied, and the clover hay crop has been taken off the land. This result has been possible only by means of good clover sods. If there had been no applications of phosphoric acid and potash, the clover would have failed to maintain fertility, as is proved by other plats in this experiment. No one should continue to depend upon such a scheme of keeping land fertile whenever he finds that the clover is not thriving.

Method of applying Fertilizers.—If a fertilizer is used in small amount with the purpose of merely giving the plants a start, it should be near the seed. If the application is heavy, and the roots of the plants spread upon all sides, the fertilizer, as a rule, should be applied to all the ground, and should be mixed with the surface soil. This puts the plant-food where needed, and saves from danger of injury to the seed through contact. A seeming exception may be found in the case of the potato, but usually some close tillage confines its roots to the row for a time. Experience indicates that when a potato fertilizer does not exceed 500 pounds per acre, it may well be put into the row, but a heavier application should be divided, one half being broadcasted or drilled into the surface, and the other half of the application being made in the row.

An Excess of Nitrogen.—Too much nitrogen, due to heavy manuring or other cause, produces an excessive growth of stalk or straw, at the expense of grain production, in the case of corn, wheat, and other cereals. It produces a rank growth of potato vines and partial failure of the crop of tubers. It produces a tender growth of straw or vine that invites injury from fungous diseases. It is the rule that soils have a deficiency in nitrogen, but when there is an excess, the best cure comes through use of such crops as timothy, cabbage, and ensilage corn. Heavy applications of rock-and-potash fertilizers assist in recovery of right conditions, but are not wholly effective until exhaustive crops have removed some of the nitrogen.

CHAPTER XXI

TILLAGE

Desirable Physical Condition of the Soil.—Successful cropping of land is dependent upon favoring soil conditions. The plants to be grown must have ease in root extension, so that their food may be found. There must be moisture to hold the food in solution. There must be air. There must be destruction of plants that would be competitors of the ones desired. A soil rarely is in prime condition for the planting and growth of any crop without some change in its structure by means of tillage, and it does not remain in the best condition for any long period of time. If the number of plants required per acre for a crop is relatively small, tillage of the soil is continued after planting. If the necessary number makes tillage impossible, there is some loss in conditions most favorable to the plant. The particles of soil settle together, and there is loss of water at the surface. Most plants want a mellow soil, and tillage is in large part an effort to make and to keep the condition of the soil friendly to plant life in this respect. The wide variation in methods of tillage are due to the great differences in the texture and structure of soils, and to the habits of plants, and skill in selection of methods is a measure of the intelligence used in farming.

The Breaking-plow.—Land containing enough clay to give it an excellent soil inclines to become firm. During the growth of a crop, when plant roots fill the soil and prevent deep stirring, the particles pack closely together, limiting the power of the land to make fertility available. The presence of organic matter counteracts, in part, this packing tendency, but there are few soils that remain permanently mellow. The breaking-plow is used to loosen the soil, and to undo the firming that has been taking place while plant roots prevented deep tillage. At the same time the plow may be used to bury organic matter below the surface, affording a clean seed-bed. In some soils it has value in bringing inert soil to the surface, and in mixing the soil constituents.

Types of Plows.—The kind and condition of the soil, and the character of the crop, determine the type of plow to be used. A plow with a short and quite straight moldboard does not bury manure and turf in the bottom of the furrow so completely as is the case with a long, curved moldboard. The organic matter should be distributed throughout all the soil. On the other hand, it is essential to some plants that they have a fine seed-bed, and one whose surface is free from tufts of grass. The long moldboard is preferred in breaking a sod for corn. Its use in plowing for all crops is more general than it should be, the gain in pulverization of the furrow-slice, due to the curve, and the neatness in appearance of the plowed land, inducing its use.

The disk plow has been used chiefly in soils not requiring deep plowing. It pulverizes better than a moldboard plow, and buries trash more easily.

DEEP TILLAGE.

The device for using two disks to turn a single furrow-slice rests upon a sound principle. This plow may be set to run deeper than moldboard plows go, and it mixes well all the soil that it turns. The disks are so hung that the mixing of all the soil to a depth of twelve or fifteen inches is admirable. The deep-tilling plow does not bury the organic matter in the bottom of the furrow, and thereby permits the deepening of the soil without bringing an undue amount of subsoil to the surface.

Subsoiling.—The theory of subsoiling always has been captivating. Most soils are too shallow, inviting injury from drouth. Enthusiasm regarding subsoiling comes to large numbers of farmers at some time in their experience, and a great number of subsoil plows have been bought. The check to enthusiasm is the fact that few men ever have seen such a plow worn out. Some reasons are as follow:

> (*a*) The subsoil at time of spring-plowing rarely is dry enough for good results, and there is danger of puddling; (*b*) the subsoil often is too dry and hard in late summer, when rains permit easy breaking of the top soil for fall grain; (*c*) the work doubles the labor and time of plowing, and (*d*) the subsoil soon settles together because it contains little organic matter. Subsoiling is generally approved and little practiced. Land at plow-depth becomes packed by the tramping of horses upon it and the pressure of the plow, when the plowing is done at the same depth year after year, and in some soils subsoiling has been found distinctly valuable.

Time of Plowing.—In great measure the time of plowing is determined by the effect upon soil moisture, and is discussed in the next chapter.

Method of Plowing.—The depth of plowing should be fixed largely by the amount of organic matter in the soil. It is essential that a good percentage of this material should be mixed throughout the soil, and when it is in scant supply, the depth of plowing usually should not be great. Fertile soils should be plowed deep for their own good, and thin soils should be deepened gradually, as sods and manures afford a supply of humus-making material. Even when manure is used liberally in a single application on a poor soil, a large amount of inert subsoil should not be thrown upon the surface. The manure goes out of reach of the greatest need, which is in the surface soil where plant-life starts. A gradual process of deepening the soil is to be preferred, but such deepening should not be neglected. The subsoil is a store of inert fertility that should not remain dormant.

It may not do to say that the success of the best farmers is due to thoroughness in plowing, but it is true that the more successful ones are insistent that the plowing be absolutely thorough. Every inch of the soil should be stirred to a certain depth, and that requires a plow so set that it does not turn a furrow-slice much wider than the point can cut. Evenness in depth and width of furrow is seen in good plowing.

The Disk Harrow.—The purpose of the plow is to break up the soil so that it will be crumbly and mellow. The frequency with which land should be thoroughly stirred to full plow-depth depends upon the condition of the soil and the character of the crops. Oftentimes a disk or cutaway harrow may replace the plow. Its action is the same as that of the plow, loosening and turning the soil over. When land has had a good plowing within the year, and has not become compact, stirring to a depth of four inches may give a better seed-bed for some crops than could be made by use of a plow. This is true of land that has produced a cultivated crop and is being prepared for a fall-seeding. The gain in time of preparing ground for oats in the spring makes the use of the disk or cutaway harrow profitable on mellow corn-stubble land.

There is temptation to carry the substitution of the disk harrow for the breaking-plow too far. Its use alone would have the same effect as poor plowing, reducing the depth of the soil. The surface soil, down to plow-depth, is the chief feeding-ground for plants because it is kept in good tilth by organic matter and tillage. The depth of this soil affects the amount of available plant-food and water. The duration of time between deep plowings depends upon the soil and the crops. Experience shows that when land has been broken for corn or potatoes or beans or similar crop, the one plowing may be sufficient for a succeeding crop. If grass is not seeded with the succeeding crop, it is best to give another thorough plowing before seeding to grass in August if the soil is heavy, but in naturally loose soils a disk harrow makes a better seed-bed.

Two influences favor such undue dependence upon a disk harrow that a soil may become shallow: the cost of preparing the seed-bed is reduced, and the saving in moisture may give a better stand of plants when the harrow takes the place of the plow. The immediate productiveness of a crop is not an assurance that the method is right: consideration for the good of the land must be shown. Depth of soil is a requirement of a good agriculture, and deep plowing is a means to that end. The looseness of the soil and the character of the season may make substitution right in one instance and wrong in another. Deep soils, well filled with organic matter, will bear shallow preparation of a seed-bed more frequently than thin soils, and yet it is the latter that may profit most by having its best part kept near the surface at the time a new sod must be made. The disk harrow has some place as a substitute for a plow, but when its use results in making a soil more shallow, the harm is a most serious one.

Cultivation of Plants.—If a soil would remain mellow throughout the season, there usually would be no reason to disturb the roots of plants by any deep stirring, and all tillage would be only deep enough to make a mulch of earth for the retention of moisture and to destroy all weeds. Soils containing enough clay to make them retentive of moisture become too compact when rains beat upon the ground, as usually happens after the planting of spring crops. A deep and close cultivation of corn and potato plants after they appear in the row helps to restore the condition created by the plow and harrow, and often is the best practice. There is some sacrifice of roots, but the gain far exceeds the loss. It may be necessary to give a second such cultivation when a clay soil is deficient in organic matter, but the root-pruning is a handicap.

Controlling Root-growth.—The exception to the rule that plant-roots should not be pruned by deep cultivation is found in the case of a close soil in a wet season. The plants extend their roots only in the soil at the surface because the ground is soaked with water nearly all the time. They cannot form far enough below the surface to withstand a drouth that may follow the wet weather. Good tillage in such a case demands the pruning of the roots and the airing of the soil when the ground is dry enough to permit such stirring, and the plants then extend their roots in the lower soil where they rightly belong. Judgment is required to decide when such tillage is desirable, but judgment is needed all the time in farming. When a continued period of wet weather affects the position of the plant-roots, it rarely is advisable not to risk deeper tillage than is given in a normal season. Underdrainage helps to prevent such ill-effect of continued rains in the early part of a plant's life-time.

Elimination of Competition.—Weeds pump the water out of the soil, use up available plant-food, and compete for the sunlight. Tillage is given for several reasons, and one is the destruction of weeds. A weeder which stirs the soil only an inch or two deep is an excellent destroyer of weeds when they are starting, but after the weeds are well-rooted, the weeder acts only as a cultivator for the plants that should be destroyed. Modern cultivators have fine teeth that let the surface remain nearly level, and they do their best work when the weeds are small. The use of "sweeps" should be more general. The blades are so placed that they slip under the surface, letting the soil fall back so that a mulch is formed.

Length of Cultivation.—Most tilled crops grow rapidly until they shade and mulch the soil. Tillage should continue, if possible, until this occurs. The exception is in the case of orchard trees and other plants that should not have their period of growth extended late in the fall. Good tillage tends to increase the lateness of a crop by encouraging growth. The new wood of trees may not become hardy enough to withstand the frost of winter if tillage is continued. Early maturity is hastened by exhaustion of soil moisture and plant-food.

CHAPTER XXII

CONTROL OF SOIL MOISTURE

Value of Water in the Soil.—The amount of water in the soil each day of the growing season determines in large measure the possibility of securing a profitable crop from land. Observant farmers have noticed oftentimes that the differences in yields on the farms of a region are less in a wholly favorable season than in one of deficient rainfall. The skill of the farmer in conserving the moisture supply in a wet season is less well repaid because it is less needed. The poverty of a worn soil is less marked in a favorable season. The land is accounted poor because the supply of plant-food is inadequate for a drouthy year in which a considerable percentage of the time produces little growth, but most agricultural land has enough plant-food for a fairly good crop when water is present all the time to carry daily supplies into the roots. It is the amount of moisture in the soil that is the limiting factor in the case of most land that is not in a high state of productiveness.

The Soil a Reservoir.—The rains of the summer rarely are adequate to the needs of growing plants. Some water runs off the surface, some passes down through crevices beyond the effect of capillary attraction, and much quickly evaporates. The part that becomes available is only a supplement to the store of water made by the rains of the fall, winter, and early spring.

If the soil were viewed as a medium for the holding of water to meet the daily needs of plants, and were given rational treatment on this basis, a long step toward higher productiveness would have been taken. As has been stated, rotted organic matter gives a soil more capacity for holding water. It is an absorbent in itself, and it puts clays and sands into better physical condition for the storage of moisture. An unproductive soil may need organic matter for this one reason alone more than it may need actual plant-food.

Fall-plowing for a spring crop enables land to withstand summer's drouth if it gains in physical condition by full exposure to the winter's frost. It is in condition to take up more water from spring rains than would be the case if it lay compact, and it does not lose water by the airing in the spring that plowing gives.

Early spring-plowing leaves land less subject to drouth than does later plowing. As the air becomes heated, the open spaces left by the plowing serve to hasten the escape of moisture. If a cover crop is plowed down late in the spring, the material in the bottom of the furrow makes the land less resistant to drouth because the union of the top soil with the subsoil is less perfect, and capillary attraction is retarded. It is usually good practice to sacrifice some of the growth of a cover crop, even when organic matter is badly needed, and to plow fairly early in the spring in order that the moisture supply may be conserved.

The Land-roller.—The breaking-plow is a robber of soil water when used in warm weather. The air carries the water away rapidly. The air-spaces are large. The corrective of this condition is the land-roller. It presses the soil together, driving out the excess of air. Large crumbs are pressed down into the mass, and are kept from drying into hard clods. The roller never should be used on land when fresh-plowed in a moist condition, and it is not needed after fall-plowing, or early spring-plowing in most instances, but land broken when the season is advanced should be rolled before much water evaporates.

MAKING AN EARTH MULCH IN A NEW YORK ORCHARD.

The Plank-drag.—An excellent implement on a farm is the plank-drag. It is usually made of over-lapping heavy planks, and when floated over the surface, it both pulverizes and packs the soil. The effectiveness is controlled by the weight placed upon it, and oftentimes the drag is to be preferred to the roller.

The Mulch.—In conserving the supply of water in the soil the mulch plays an important work. The dry air is constantly taking up the water from the surface of land, and when the surface is drier than the soil below, the moisture moves upward if there is no break in the structure of the surface soil. The mulch is a covering of material that does not readily permit the escape of water.

The only available material for a mulch in most instances is the soil itself. Experience has taught that when the top layer of soil, to a depth of two or three inches, is made fine and loose, the water beneath it cannot escape readily. It is partly for this reason that the smoothing-harrow should follow the roller after land has been plowed. The plow is used to break up the soil into crumbs that will permit air to enter. The loosening is excessive when the planting must follow soon, permitting rapid escape of water. The roller or plank-drag is employed to compress the soil, and to crush crumbs of soil that are too large for good soil conditions. The harrow follows to make a mulch of fine, loose soil at the surface to assist in prevention of evaporation.

A sandy soil will retain its mulch in effective condition for a longer time than a fine clay, if no rain falls. When the air is laden with moisture, clay particles absorb enough water to pack together and form an avenue for the rise of water to the surface, where the dry air has access to it.

Mulches of Foreign Material.—The truth that moisture is a leading factor in soil productiveness is evidenced by the value of straw and similar material as a mulch. A covering of straw around trees in an orchard, or bush fruits, or such plants as the potato, may give better results than an application of fertilizer when no effort is made to prevent the escape of water. People so situated that little attention can well be given to the fruit and vegetable garden obtain good results by replacing tillage with a substantial mulch that keeps the soil mellow, prevents weed growth, and retains an abundant supply of water.

In grain-producing districts where all the straw is not needed as an absorbent in the stables its use as a mulch on thin grass lands, or wheat-fields seeded to grass, is more profitable than conversion into manure by rotting in a barnyard. The straw affords protection from the sun, and aids in the conservation of soil water, when scattered evenly in no larger amount than two tons per acre, and a less amount per acre has value. The sod is helped, and as the straw rots, its plant-food goes into the soil.

Plowing Straw Down.—The practice of plowing straw under as a manure is unsafe, when used in any large quantity per acre. It rots slowly, and while lying in the bottom of the furrow it cuts off the rise of water from the subsoil which is a reservoir of moisture for use during drouth.

The Summer-fallow.—Bare land loses in total plant-food, but may make a temporary gain in available fertility. The practice of leaving a field uncropped for an entire season has been abandoned in good farming regions. Where moisture is in scant supply, and a soil is thin, there continue instances of the summer-fallow. In a crop-rotation containing corn and wheat, the corn-stubble land is left unbroken until May or June, and then plowed. In August it is plowed again, and fitted for seeding to wheat. The practice favors the killing of weeds, and the soil at seeding time may contain more water than would have been the case if a crop had been produced, because its mellow condition enables the farmer to hold within it nearly all the moisture that a shower may furnish after the second plowing.

The Modern Fallow.—The modern method of making a grass seeding in August partakes of the nature of the old-fashioned summer-fallow. The desire is to eradicate weeds, secure availability in plant-food, and fit the soil to profit by even a light rainfall. Thin soils lend themselves well to this treatment, which is described in Chapter VIII, and there is no better method for fertile land. The benefit of the fallow is obtained without serious loss of time.

CHAPTER XXIII

DRAINAGE

Underdrainage.—There are great swamps, and small ones, whose water should be carried off by open ditches. Our present interest is in the wet fields of the farm,—the cold, wet soil of an entire field, the swale lying between areas of well-drained land, the side of a field kept wet by seepage from higher land,—and here the right solution of the troubling problem lies in underdrainage. An excess of water in the soil robs the land-owner of chance of profit. It excludes the air, sealing up the plant-food so that crops cannot be secured. It keeps the ground cold. It destroys the good physical condition of the soil that may have been secured by much tillage, causing the soil particles to pack together. It compels plant-roots to form at the surface of the ground. It delays seeding and cultivation. An excess of water is more disheartening than absolute soil poverty. The remedy is only in its removal. The level of dead water in the soil must be below the surface—three feet, two and one half feet, four feet,—some reasonable distance that will make possible a friable, aërated, warm, friendly feeding-ground for plant-roots. Only under drainage can do this.

Counting the Cost.—Thorough underdrainage is costly, but it is less so than the farming of fields whose productiveness is seriously limited by an excess of water. The work means an added investment. Estimates of cost can be made with fair accuracy, and estimates of resulting profit can be made without any assurance of accuracy. The farmer with some wet land does well to gain experimental knowledge, and base future work upon such experience. He knows that he cannot afford to cultivate wet land, and the problem before him is to leave it to produce what grass it can produce, sell it, or find profit in drainage. He has the experience of others that investment in drainage is more satisfactory than most other investments, if land has any natural fertility. He has assurance that debt incurred for drainage is the safest kind of debt an owner of wet land can incur. He has a right to expect profit from the undertaking, and he can begin the work in a small way, if an outlet is at hand, and learn what return may be expected from further investment. Almost without fail will he become an earnest advocate of underdrainage.

DRAIN TILE.

Where Returns are Largest.—The total area of land needing drainage is immense. Swamps form only a small part of this area. Yields of much old farm land are limited by the excess of water during portions of the year. As land becomes older, the area needing drainage increases.

The owner of wet land does well to gain his first experience in a field where a swale or other wet strip not only fails to produce a full crop, but limits the yield of the remainder of the field by delaying planting and cultivation. This double profit often is sufficient to repay cost in a single year.

Material for the Drains.—Doubtless there are places and times when stone, or boards, or brush should be used in construction of underdrains, but they are relatively few in number. Such underdrains lack permanency, as a rule, though some stone drains are effective for a long time. If drain tile can be obtained at a reasonable price, it should be used even in fields that have an abundance of stone. Its use requires less labor than that of stone, and when properly laid on a good bottom, it continues effective. There is no known limit to the durability of a drain made of good tile.

The Outlet.—The value of any drainage system is dependent upon the outlet. Its location is the first thing to be determined. If the land is nearly flat, a telescope level should be used to determine elevations of all low points in the land to be drained. The outlet should permit a proper fall throughout the length of the system, and it should not require attention after the work is completed. If it is in the bank of a stream or ditch, it should be above the normal level of the water in the stream. In times of heavy rainfall water may back up into the main with no injury other than temporary failure to perform its work, but continuous submersion will lead to deposits of silt that may close the tile.

Locating Main and Branches.—There are various systems of drainage. Wherever a branch or lateral joins the main, the means of drainage is duplicated within the area that the main can drain, and the system should call for the least possible waste of this sort. It usually is best that the main take the center line of the low land, laterals being used to bring the water to the main from both sides, but there is less duplication of work when the main can be at one side of the wet land. Branches of the main may be needed to reach remote parts of the area.

The Laterals.—Small lines of tile are used to bring the water to the main when the wet land extends beyond the influence of the main. The distance between these laterals depends upon their depth and the nature of the land. A tight clay soil will not let water pass laterally more than a rod or 20 feet, compelling the placing of the drains not over 40 feet apart, while an open soil may permit a distance of 60 or more feet between laterals.

Size of Tile.—The size of the main depends upon the area that eventually may be drained, the amount of overflow from higher land, the nature of the soil, and the grade of the drain. It is a common mistake to make the main too small because the drainage immediately contemplated is less than that which will be desired when its value is known. In the determination of the size the judgment of an expert is needed, and if this cannot be had, the error should be on the side of safety. If the main will not be required to carry overflow from other land, and has a fall of 3 inches to 100 feet, one may assume that a 6-inch main will carry the surplus water from 12 to 20 acres of land, and an 8-inch main will carry the water of twice that area. Some drainage experts figure larger areas for such mains, but there is danger of loss of crop when the rainfall is very heavy.

The laterals need not be larger than 3 inches in diameter when laid on a good bottom.

Kind of Tile.—When clay tile is used, it should be well burned. Some manufacturers offer soft tile for sale, as the loss from warping and cracking is less in case of insufficient burning. The claim may be made that the efficiency of soft tile is greater than that of the hard tile whose porosity has been destroyed. This is an error, as the water enters the drain at the joints, and not through the walls of the tile. Underdrainage should be permanent in its character, and it is essential that every piece of tile be sound and well-burned.

Vitrified clay tile is good for drainage, but no better than common clay hard-burned.

Round or octagonal tile is the most desirable because it can be turned in laying to secure the best joints. Collars are not needed in ordinary drainage.

Cement tile is coming into general use in regions having no good clay. Its durability has not been tested, but there is no apparent reason that it should not be a good substitute for clay.

The Grade.—The outlet may fix the grade. If it does not, the main, branches, and laterals should have a fall of 3 inches, or more, to the 100 feet. This grade insures against deposits of silt and gives good capacity to the drains. If the outlet demands less fall in the system, the main may be laid on a grade of only a half inch to the 100 feet with satisfactory results. Such a small fall should be accepted only when a lower outlet cannot be secured, and great care should be used in grading the trench and laying the tile.

Establishing a Grade.—If the grades are light, they should be established by use of a telescope level. Most of the cheap levels are a delusion. A stake driven flush with the surface of the ground at the outlet becomes the starting point, and by its side should be driven a witness stake. Every 100 feet along the line of the proposed drain and laterals similar stakes should be driven. Their levels should then be taken, and when the fall from the head of the system to the outlet is known, the required cut at each 100-feet station is easily determined. It may be necessary to reduce or increase the grade at some point to get proper depth in a depression or to save cutting when passing through a ridge.

Cutting the Trenches.—There are ditching-machines that do efficient work. The best are costly. Most of the work on farms will continue to be done with ditching-spades. The ground should be moved when wet, so that labor can be saved.

A line should be used to secure a straight side to the trench. The grade should be obtained by means of a system of strings. If two light poles be pushed into the ground at each 100-feet station, one on either side of the proposed trench, and a string be drawn across at a point 5½ feet above the bottom of the proposed trench, these strings will be in line on a grade 5½ feet above the grade the drain will have. As the cut at the station is known, the height of the string above the top of the stake is easily determined. These strings will reveal any inaccuracy in the survey. The workman can test every part of the bottom of the trench by use of a rod 5½ feet high, the top end being exactly in line with the strings when the lower end is placed on the correct grade of the trench. This device is better than running water where grades are slight.

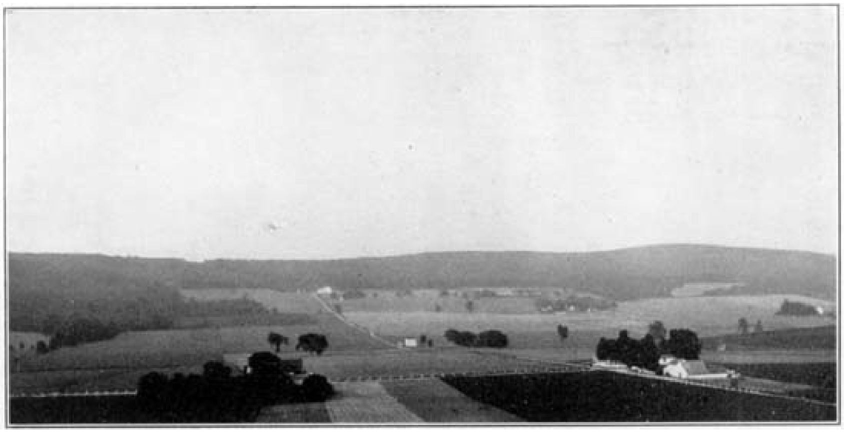
A drain scoop should be used in bottom of the trench to make a resting place for the tile that will prevent any displacement by the soil when the trench is filled.

Depth of Trenches.—Underdrains may be placed too deep in close soils for best results. In an early day it was advised that the drains be put down 4 feet deep. We now know that a tight clay soil may give best results from a drain only 28 inches deep, or even a little less. In a looser soil 3 feet is a better depth, and in porous swamp lands the drain may well go 4 feet deep, thus permitting increase in distance between drains.

Connections.—The laterals should enter the branches and mains near the top, so that the water will be drawn out rapidly. The tile should be laid with close joints at the top, so that the water may enter more freely from the sides than the top. No covering other than moist soil is needed unless there is very fine sand, when paper over the joints will serve a good purpose. After some moist soil from the sides of the trench has been tramped upon the tile, the trench may be filled by use of a breaking-plow or winged scraper.

Permanency Desired.—The expense of underdrainage demands care in every detail of the work. The grade of the trenches should be carefully tested. Every piece of tile should be examined. The outlet should be guarded against displacement or entrance by animals. A good plan is to lay the last few pieces of tile in a close-fitting wooden box, and to protect the end with iron rods placed 2 inches apart.

If the drain is on a true grade, so that no silt will collect, there need be no fear concerning its continued efficiency, provided water does not run in it all the time. If it carries the water from springs continuously, plant-roots may fill it, and tree roots are quite sure to do so when opportunity offers. This is notably true in case of elms and willows, but protection is afforded in such an instance by closing the joints with cement.



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