THE RURAL SCIENCE SERIES

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FERTILIZERS

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FERTILIZERS

THE SOURCE, CHARACTER AND COMPOSITION OF NATURAL, HOME-MADE AND MANUFACTURED FERTILIZERS; AND SUGGESTIONS AS TO THEIR USE FOR DIFFERENT CROPS AND CONDITIONS

BY

EDWARD B. VOORHEES, A. M.

Director of the New Jersey Agricultural Experiment Stations, and
Professor of Agriculture in Rutgers College

New York

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PREFACE

THERE is no question as to the desirability of the use of commercial fertilizers on most farms, though the methods now generally practiced are such as to indicate the very great need of a better understanding of what the functions of a fertilizer are, of the terms used to express their composition and value, of the kind that shall be used, and the time and method of application for the different crops under the varying conditions that exist.

In the preparation of this book, therefore, it has been the aim of the author to point out the underlying principles and to discuss, in the light of our present knowledge of the subject, some of the important problems connected with the use of fertilizer materials. The subject is a large one when considered in all its bearings, and much must necessarily be omitted in a book intended for the general reader as well as the student.

The author appreciates keenly his limitations, owing to the lack of definite knowledge on many vital points; yet it seems that at this time, when the investigations of the experiment stations are beginning to be regarded as important educational factors, and when these institutions are more than ever prepared to study the fundamental principles which underlie the various processes involved in plant nutrition, the practical man should have a clear understanding of what is now known, in order that he may be prepared to accept and use that better knowledge which will undoubtedly be provided for him in the near future.

E. B. V

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FERTILIZERS

CHAPTER I

NATURAL FERTILITY OF THE SOIL, AND SOURCES OF LOSS OF THE ELEMENTS OF FERTILITY

THERE is no one question of greater importance to the farming industry than that of soil fertility. In order that the industry may be successful, it is not enough to produce crops; it is necessary that their production shall result in a genuine profit. That is, it is not enough to produce crops which bring more than they cost in the way of labor and manures, without taking into consideration the effect of their growth upon the future productive capacity of the soil. The relation of the outgo and income of the fertility elements is an important factor in determining profits, and must be considered. The farmer who secures crops that bring more than they cost, and who, at the same time, maintains or even increases the productive capacity of his soil, is, other things being equal, the broadly successful farmer. Many farmers are able to accomplish this object because of the knowledge they have acquired through long years of experience, rather than because they possessed in the beginning of their work a definite knowledge of the fundamental principles involved in crop production, and upon the observance of which their success depended. One of the first needs, therefore, in the use of commercial fertilizers is a more or less definite knowledge of what constitutes fertility, and of the principles which underlie crop production.

SOIL FERTILITY

The full meaning of the term "soil fertility" is not easily expressed, since many conditions are involved, all of which exercise more or less influence. The potential fertility, which is measured by the total content of the food elements contained in a soil, is made practicable, or usable, in proportion as the conditions are favorable. The more important of these influencing conditions are here briefly discussed. In the first place, it is of the utmost importance that a soil should contain those elements found in the plant ; hence, it is almost self-evident that a fertile soil must contain a maximum quantity of those particular elements or constituents which are removed from the land in maximum amounts by the crops grown. The removal of crops rapidly exhausts the soil of these elements, and finally reduces the quantity contained in the soil to so low a point as to make profitable cropping impossible.

Chemical Elements Needed in Plant Growth

Careful studies and experiments have shown that plants actually take from the soil at least ten chemical elements which are required for their normal growth and development: viz., nitrogen, potassium, phosphorus, magnesium, sulfur, sodium, iron, chlorin, silicon and calcium. Yet the number liable to rapid exhaustion is limited in many cases to three, and at most to four, which are, nitrogen, phosphoric acid (phosphorus). potash (potassium), and lime (calcium), the latter only in exceptional cases. These are liable to be exhausted because they exist in larger amounts than the others in the plants that are grown, and in smaller amounts than the others in even the most fertile soils. It has also been proved that it is the one element of these which exists in the smallest amount which measures the crop-producing power, or fertility, in this respect, as one element cannot substitute or exert the full functions of another. That is, there may be a relative abundance in the soil of potash and of phosphoric acid, but practically no nitrogen, in which case good crops of cereals, for instance, could not be grown, because no other element can substitute the nitrogen required by the plant, and it can be obtained by it from no other source than the soil; and the soil, for all practical purposes, is quite as unproductive, lacking in productive fertility, as it would be if it contained much smaller amounts of the mineral elements mentioned, and thus be poorer in potential fertility.

Fertility as Influenced by Water, Climate and Season

In the second place, there are soils that are so rich in all of these elements that if productiveness depended upon them alone, maximum crops might be grown for centuries without exhausting them, while actually they are now incapable of producing a single profitable crop of cereals, grasses, fruits, or other products of the farm, because certain other conditions which are essential, in order to bring them into activity, are absent. For example, it may be that water, which is absolutely essential both for the solution of these food elements in the soil, as well as for their distribution in the plant after they have been acquired, cannot be obtained, or that the temperature of the soil and of the surrounding air is either too low or too high, thus preventing or interrupting the progress of those changes which must go on, both in the soil and in the plant, in order that normal growth and development may be accomplished. With a full supply of the fertility elements in the soil, the climatic and seasonal conditions exert an important influence upon its productive power.

It is evident, therefore, that the chemical elements of fertility in themselves are not sufficient to constitute what we understand by the term. Fertility is not measured by them alone; associated with them there must be other conditions. That is, while crops cannot be grown without these elements, it is the conditions which surround them that, in a large degree, determine the power of the crop to secure them.

The Influence of Physical Character of Soil

In the third place, the physical character of a soil is also a factor in determining actual fertility This has reference, first, to the original character of the rocks from which the soil particles were derived, whether hard and dense in their mineral character, thus resisting the penetration and the solvent effect of air and water and other agencies, or whether soft and friable, and freely permitting their entrance and action; and secondly, whether, in the formation of the soil, the particles were so fine and so free from vegetable matter as to settle in hard and compact masses, impervious to water, air and warmth; or whether they were coarse, and not capable of close compaction, thus giving rise to an open and friable soil, freely admitting the active natural agencies, such as we find to be the case in sandy soils. In addition to these properties of soils, which have a distinct place in determining fertility, there are many other minor ones which together constitute what is understood as "condition."

Location of Soil Qualifies the Term "Fertility"

Furthermore, fertility, even in this true sense, may be useless because of the location of the soil which possesses it. For example, there are many places on this continent where sugar-producing plants will grow and develop perfectly, since the soils are very rich in the fertility elements, and since the surrounding conditions are most favorable for their culture, yet, because of their location, it is unprofitable to grow them for the manufacture of sugar. In the first place, the soils are so situated as to make it impossible, or at least impracticable, to provide the means necessary for converting the sugar-producing crop into actual sugar, and, in the second place, even if it were possible to do so, the great distance from shipping stations to markets so increases the cost of transportation as to make it unprofitable to compete in the market with the crops grown upon lands possessing true fertility in a lower degree.

Practical Fertility is Usable Potential Fertility

Practical fertility is, therefore, dependent upon many conditions, and fortunately our own country possesses it in a marked degree; that is, the utility of the potential fertility, as represented by the total mineral content of our soil, is such as to make us one of the greatest agricultural nations in the world, both in the quantity and variety of products grown. Our soils possess the essential elements in lavish amounts, and our climatic and seasonal conditions are such as to permit of their ready conversion into a wide series of valuable products, and our location and facilities for handling and distributing our staple crops are such as to enable us to compete in any market of similar commodities.

Notwithstanding the truth of this general statement, it is also true that in certain sections of our country profitable crops cannot be grown without the addition of commercial fertilizers, because the soils are either naturally poor, or they have become partially exhausted of their plant-food elements. That is, the amounts that become available to the plant through the growing season are not sufficient to enable the plant to reach a maximum development, though other conditions are perfect.

Our future progress depends, therefore, upon how well we understand and apply the principles which are involved, both in the conservation and use of the fertility stored up in our soils, and in the use of purchased fertility; and in this connection it is important to consider the sources of loss of the essential fertility elements, or those which in the beginning measured our capabilities in crop production.

WHAT BECOMES OF OUR FERTILITY?

Since fertility is dependent upon so many conditions, or, in other words, since the essential elements of fertility are dependent upon their utility, and since, in this sense, fertility is largely determined by natural conditions, it is pertinent to inquire, first, whether under our present systems of management, or mismanagement, of the land, it is suffering any natural loss of fertility As already pointed out, the most important function of fertility is to furnish nitrogen, phosphoric acid and potash, and since the content of these in our soil, together with the knowledge we have as to their use, measures, in a sense, our prosperity as an agricultural people, the possibilities of losing them from the soil is a matter of national concern, and is of vital interest to individual farmers, who, in the aggregate, make up that part of the nation directly affected by the results of such loss.

It would, perhaps, be possible, by a careful chemical survey of our soils, to determine both the actual and potential fertility of our entire country, and this knowledge, together with an accurate measure of the intelligence exercised in its use, would enable a prediction as to our future development, if present methods were continued. That is, whether our land would become barren and worthless, as has been the case in many older countries which at one time were quite as productive, or whether it would constantly increase in productiveness, even with continuous and profitable cropping,—though, as already pointed out, the present barrenness or sterility of a country formerly fertile may not be due entirely either to the natural or to the artificial loss of these constituents.

SOURCES OF NATURAL LOSS OF NITROGEN

Of the essential constituent elements, nitrogen is, in one sense, of the greatest importance; first, because it is the one that is more liable to escape than the others, and secondly, because it is more expensive to supply artificially than are the minerals. It is the most elusive of all the elements: to-day it may be applied to the soil, to-morrow it may be carried in streams to the ocean. It is also unstable—which is not the least valuable of its characteristics if properly understood;—to-day it is an element of the atmosphere, to-morrow it is a constituent part of a growing plant, the next day the same element may exist as an animal product, and the day following it may be returned to the soil to feed the plant. It is more liable to escape than any of the others, because it is available as plant-food largely in proportion as it changes to a nitrate, and after it assumes that form it is seldom absorbed or fixed in the soil. Nitrogen in this form remains freely movable, and the probability of loss by leaching is increased in direct proportion to the lack of preventive measures used, or the presence of those conditions which favor leaching. The latter may be classified as follows: First, the amount and time of the rainfall; secondly, the absorptive and retentive power of the soil and subsoil, due to their mineral and physical character; and thirdly, the amount of vegetable matter (humus) acquired by the soil, which retards the passage of water. While the amount and time of rainfall cannot be controlled, its effect upon our soils in this direction can be largely governed if proper attention is given to correcting the other conditions, and these may be largely modified, if not entirely controlled. In the matter of the absorptive and retentive power of soils, it has been shown that if they are well supplied with vegetable matter and carefully cultivated, they retain and hold the plant-food constituents in a much greater degree than if devoid of humus and improperly managed, and also that the drainage water from soils upon which crops are growing seldom contains more than the merest trace of nitrates. The loss of nitrogen through the operation of the forces of nature may, therefore, be reduced by the careful management of the soil.

Importance of Careful Culture

The presence of suitable amounts of vegetable matter, and good cultivation, are conditions that are within the power of all farmers to provide, though it is sometimes impracticable to keep the land continuously covered with a crop; and sometimes it is thought that the loss incurred through leaching because of the absence of a growing crop is more than balanced by the gain in other directions. For example, though losses of nitrates may occur, the gain in availability of the mineral constituents, phosphoric acid and potash, with the accompanying improvement in texture, due to the exposure of the soil to atmospheric influence, more than balances these losses, particularly during the winter, with its wide changes of temperature.

Loss of Nitrogen by Drainage

It has been shown by carefully conducted experiments, both in this and other countries, that in a season of average rainfall the drainage waters carry away from one acre, from uncropped soils only fairly rich in plant food, as much as 37 pounds of nitrogen per year, while when continually cropped the drainage waters from the same soils contain practically no nitrogen. This difference in the loss of nitrogen under the two conditions may not seem a great matter at the first glance, but a careful study of the bearing of this loss in its relation to crop production shows that it is really a serious matter. In the first place, the amount of possible loss annually is practically equivalent in nitrogen to the amount contained in two tons of timothy hay. or in one ton of either wheat, rye, oats, corn or buckwheat, quantities nearly double the average yield per acre of these crops throughout our whole country; and in the second place, that the nitrogen which is carried away by the drainage water is in the very best form for feeding the plant, or it would not have been lost, and thus its loss leaves the soil not only poorer in this constituent element, but poorer in the sense that the remainder of it in the soil is in a less useful form.

Escape of Nitrogen into the Atmosphere

Another source of natural loss of nitrogen is its escape from the soil as gas into the atmosphere. This is due to the oxidation of the vegetable matter, or to "denitrification," which takes place very rapidly when soils rich in vegetable matter are improperly managed. The possibilities of loss in this direction are strongly shown by investigations carried out at the Minnesota Experiment Station on "the loss of nitrogen by continuous wheat raising."* The results of these studies show that the total natural loss of nitrogen annually was far greater than the loss due to the cropping. In other words, by the system of continuous cropping, which is universally observed in the great wheat

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*University of Minnesota Agricultural Experiment Station, Bulletin 53.

fields in the Northwest, there were but 24.5 pounds of nitrogen removed in the crop harvested, while the total loss per acre was 171 pounds, or an excess of 146 pounds, a large part of which loss was certainly due to the rapid using up of the vegetable matter by this improvident method of practice. Whereas, on the other hand, when wheat was grown in a rotation with clover, the gain in soil nitrogen far exceeded that lost or carried away by the crop. The continuous wheat- and corn-growing in the West, and of cotton and tobacco in the southern states, are responsible for untold losses in this expensive element of fertility, while in nearly every state of the Union, soils both rich and poor are suffering more or less from the effect of natural losses in this direction

THE NATURAL LOSS OF THE MINERAL ELEMENTS

In the case of the minerals, phosphoric acid and potash, which exist in fixed compounds in the soil, the actual losses are undoubtedly very much less than is the case with nitrogen, since only traces of these constituents are ever found in solution in the drainage waters under ordinary circumstances; yet, because of the large quantity of water that passes through many of our soils, the total amount of these rendered soluble and carried away by this means is very great. Our great rivers carry in solution into the ocean tons upon tons annually of these elements of fertility, and it is an absolute loss, as there is no natural means by which these may be returned to the soil, as is the case with nitrogen; and it is true, as in the case of the former, that the soil is not only absolutely poorer by virtue of the loss of its elements of fertility, but poorer in the sense that the immediate utility of those remaining is reduced. These silent and unseen forces constantly at work are reducing the content of these constituents in our soils to an alarming degree, and it is because they are unrecognized forces that the disastrous results of their activity are not fully appreciated, and, consequently. the best means for restoring them are not used.

Losses Due to Mechanical Means

A serious loss of all of the fertility elements is also due to mechanical means. Aside from the amounts that the rivers of water are carrying in solution into the seas, immense amounts are carried in them in suspension. The results of this kind of loss are painfully evident; in many of the southern states, and in sections where the forests have been removed and the land abandoned, the soils have been washed and gullied until not only the very best portions, but in some cases the largest portions, have been carried away.

It is not, however, in the abandoned parts of the country alone that these mechanical losses of constituents are of importance—they are more or less apparent on every farm, and are measured by the methods of management. Soils that are allowed to lie bare and fully exposed to the storms of wind and rain througnout the larger portion of the year suffer the greatest loss, while from those which, on the other hand, have crops growing during a large part of the year, and which hold the soil particles together and prevent their easy movement, the losses are reduced in both the directions mentioned. The beneficial results derived from the use of good methods are cumulative; the benefit is not only immediate, but continuous.

ARTIFICIAL LOSSES OF FERTILITY

In addition to these natural losses of fertility, there are the artificial losses of the constituents, or those due to the removal of crops. These, of course, necessarily accompany all farming operations, and, provided that in the removal and sale of the constituents in the form of crops, the farmer has received a fair price for them, they are entirely legitimate.

The sale of farm products is really in the last analysis a sale of actual constituents, together with a certain portion of the "condition" of our land, which is not readily measurable. That is, it is the constituents in the soil, together with the conditions surrounding it, that the farmer buys when he buys land. If an acre of land, containing within the reach of the roots of the plant, say 3,000 pounds of nitrogen, 5,000 pounds of phosphoric acid and 6,000 pounds of potash, sells for $100, the seller receives the $100, not for so much dirt, but really for the constituents contained in it. The purchaser believes that, with the conditions surrounding them, he can convert them into products which he can sell and from which realize a profit. If in selling these amounts of the constituents in the form of land, a lower price per acre is received, it is because the natural conditions which surround them, and which influence their utility, are less favorable, and a greater proportionate effort and expense are necessary to secure them in the form of salable products. The difference in the price of land is not always due to the content of the constituents, but often to the conditions surrounding them. In many cases, the soil may serve simply as a medium in which plants can grow, and the content of the fertility elements is of minor importance. Such would be the case in the growing of market-garden crops near large cities, the location near the consumer being of greater importance, in the case of perishable crops of this sort, than the chemical character of the soil. In the large majority of cases, however, the natural fertility fairly measures the market price. At the price per acre, and for the quantity of constituents here assumed, the buyer would pay at the rate of 1½ cents per pound for the nitrogen, and ½ cent per pound each for the phosphoric acid and potash, and it now constitutes his capital stock.

A Comparison of the Prices Received for the Fertility Elements in Different Crops

A comparison of the prices paid for the constituents in land, with the prices received for the same constituents when contained in the different crops (disregarding for the moment the value of the "condition" of soil), will make clearer this matter of rational sale of constituents, which represents a reduction of our capital stock of fertility. For example, if wheat is raised, which contains 1.89 per cent of nitrogen, .93 per cent of phosphoric acid and .64 per cent of potash—or in round numbers, 38 pounds of nitrogen, 19 of phosphoric acid and 13 of potash per ton—and is sold for 60 cents per bushel, or $20 per ton, the nitrogen sells in this form for 41 cents per pound, and the phosphoric acid and potash for 14 cents each per pound. That is, the 60 cents per bushel, or the 41 cents per pound, received for the nitrogen, and 14 cents for the potash and phosphoric acid, represent what has been received per pound for the capital stock of these elements, which at $100 per acre were purchased at the prices previously mentioned. The labor in raising the crop, the expense of harvesting and putting it upon the market, and the profit, must come out of the difference between what is paid and what is received. Naturally, as the ratio between the constituents contained in the products sold and the price received is increased, the rate of income per unit of exhaustion is increased, though in many cases the increased cost of the labor necessary is in proportion to the increased price received. This may be illustrated by a comparison on the fertility basis of the sale of wheat and milk. If milk, which contains on the average 12 pounds of nitrogen, 4½ pounds of phosphoric acid and 3½ pounds of potash per ton, is sold for $1.50 per hundred pounds, the nitrogen is sold for $2 per pound, and the phosphoric acid and potash for, approximately, 70 cents per pound. In the sale of milk at this price, the rate of income per unit of exhaustion is increased nearly five times over that of the wheat, though, because it is in one sense a manufactured product, the cost of labor per unit of plant-food contained is largely increased. Again, if cream is sold, the prices received for the constituents are still further increased, while if the milk is made into butter, and that alone is sold, the prices received measure the expenses and profit, and the capital stock of fertility is not materially reduced, though it is in another form and in another place.

Fertility Content of Cereals and Vegetables

The losses of the constituents in the sale of cereals and grasses, corn, oats, wheat and hay, are, too, relatively greater than in the sale of vegetables and fruits, as lettuce, celery, potatoes, tomatoes, sugar beets, apples, berries and kindred crops, though in the case of the latter, a higher degree of fertility is necessary in order to produce maximum crops, and the cost of production is again proportionately greater. These facts strongly emphasize the necessity of a careful study of the relation of farm practice to the artificial losses of fertility.

The artificial loss of fertility that may be incurred by the sale of crops is largely measured by the knowledge of the producer concerning the relation between the price received for the crop and the fertility contained in it, and thus removed when sold, and by his intelligence in adjusting his methods so as to reduce to a minimum the actual loss.

Irrational Farm Practice

There are methods of practice which are entirely irrational, and contribute to the real losses of fertility. Farming is unprofitable, not altogether because the land is exhausted, but because only those crops are grown which possess a high fertility value, and which have a low market price, and thus the prices received for the constituents in the crop are actually less than they cost in land and in labor; and these methods of practice are not confined to farmers whose lands of inexhaustible fertility have been given them by a generous government, but are followed by farmers who annually purchase commercial fertilizers to supply the losses of fertility thus sustained.

Where the conditions are such as to make it impracticable to grow and sell crops, as such, of a low fertility value, the producer should endeavor to sell the manufactured rather than raw materials,— that is, to so use his crude products as to lower the quantity of the constituents contained in those sold, which explains, in part, the greater success in the long run of a mixed husbandry, rather than single-crop farming.

The artificial losses of our national capital stock of fertility are, however, not absolute, if the products are consumed in our own country, as more or less of the constituents contained in the crude products sold find their way back to the farm, either in the by-products of the mills, in sewage, in the manure from cities, or in various vegetable or animal wastes; but when they are exported the loss is absolute, and the amounts so disposed of are in some degree a measure of the rate of loss of the capital stock of fertility in our lands, though to these must be added the losses due to the improper use of manure and other waste materials.

Losses in Manures

It is natural to infer that proper losses of fertility are confined to the removal of the constituents in the sale of farm products, and that those contained in the materials not sold and in the feeds used upon the farm, are again returned to the land. Theoretically this is correct, but the losses that do occur, particularly in the handling of manures, should not be overlooked. While it is impossible to even roughly estimate the waste or loss of fertility due to the improper making or handling of manures, some idea may be obtained when the enormous amounts produced and the sources of possible loss are considered.

If this enormous mass of waste material were properly used, it would go a great way toward increasing the present and immediate fertility of our soils, or in retarding the time of exhaustion, and it is quite pertinent to inquire if it is properly used. It has been demonstrated by experiments* that 50 per cent of the total constituents in farm manures is liable to be lost by ill-regulated fermentation and by leaching; and further, careful observations and experiments show that the conditions in the majority of barnyards are such as to encourage the maximum loss by these means. It is morally certain that a large percentage of the constituents contained in them are lost; they never reach the right place on the farm.

It is estimated that if but one-tenth of the present waste could be avoided,—and a very large part of it is practically avoidable, and at a very slight expense,—the total amount of constituents that may thus be saved for further use would be more than equivalent to the amounts now purchased in the form of commercial fertilizers. This estimate is certainly conservative, and clearly demonstrates the serious drain upon our resources of fertility elements, due to the lack of care in the handling of farm manures.

The conditions, as here pointed out, not only suggest the need of imported plant-food, but that there are opportunities for reducing this need by careful saving and use of the constituents that are subject to waste.

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*Bulletin 56, Cornell Univ. Agr. Ex. Sta., Ithaca, N. Y.

CHAPTER II

THE FUNCTION OF MANURES AND FERTILIZERS, AND THE NEED OF ARTIFICIAL FERTILIZERS

WHILE in a broad sense, a manure or fertilizer may be regarded as anything that will increase the yield of a crop if added to the land, the chief function of manures is to furnish nitrogen, phosphoric acid and potash.

THE ESSENTIAL ELEMENTS OF FERTILIZERS

These are called the "essential manurial elements," or "constituents," to distinguish them from the others that are needed by plants, because these three are contained in the crops removed in greater amounts than the others, and because they exist in the soil in much smaller amounts than the others. For example, cultivable soils seldom contain too little iron or sulfur, or magnesium. These elements usually exist in quantities more than sufficient to supply all the needs of the plant for them, and, because they are required in such exceedingly small amounts, the soils are seldom exhausted of them. In addition to this property of supplying essential manurial constituents, many substances useful as manures possess, however, a secondary function: they serve to indirectly increase the crop, but do not add directly to the potential fertility of soils.

NATURAL MANURES AND ARTIFICIAL FERTILIZERS

Farmyard manure, and many other natural products, possess this second function in a marked degree, and the indirect manurial value of these is due largely to the good effect that the substances associated with the nitrogen, phosphoric acid and potash in them exert in increasing the crop. This good effect is observed in two directions. First, the vegetable matter contained in the natural manure improves the physical character of soils—those that are clayey and compact, by making them more open and porous, separating the particles, so that the water and air can penetrate more freely, and thus act directly upon the dormant or insoluble constituents that are contained in it; and those that are light and sandy, by filling up the open spaces, thus making them more compact. In the second place, the addition of vegetable matter to soils, even though it contains no essential constituents, improves it by enabling it to more readily and completely absorb and retain not only the water, but also the soluble essential constituents that may be added. The chief distinction between what are known as manures and what are known as fertilizers, is the difference in respect to this secondary function. The manure possesses the two functions, the one to supply the essential constituents, and the other to assist plant growth by aiding in the improvement of those already contained in the soil, and this latter function it exerts in a marked degree; while the fertilizer, as a rule, possesses but one, namely, that of furnishing plant-food. The indirect effect of the materials associated with the constituents in artificial fertilizers is seldom very useful, and sometimes may be harmful.

DIRECT AND INDIRECT EFFECT OF MANURES

It is obvious, therefore, that any substance which contains nitrogen, phosphoric acid or potash may serve as a direct manure, and any substance which contains no plant-food, but which possesses the power of improving the physical character of soils, may also serve as a manure, though the one effect is quite distinct from the other. The first adds to the soil the essential constituents; the other helps to make the constituents already in the soil serve as food to the plant.

The use of the one will tend to increase both the potential and practical fertility in the soil, while by the use of the other, the active fertility is increased as the potential fertility is decreased. That is, when actual plant-food is added in the form of nitrogen, phosphoric acid or potash, and crops are removed, the exhaustion of the soil is in proportion to the amounts of these removed over and above the amounts which have been added. Whereas, in the other case, when no plant-food is added, the exhaustion is measured by the amount of the constituents removed. It is clear, therefore, that the addition of only indirect manures has a tendency to rapidly reduce the fertility of soils of low natural strength, or those that do not possess large stores of food constituents, whereas, on soils that are rich in the fertility elements, the indirect manuring may result in an increased yield for a long period, though ultimately the soil will become exhausted—if not completely, to such a degree as to render further cropping by this method unprofitable.

UNAVAILABLE AND AVAILABLE PLANT-FOOD

While, as already stated, any material containing either one or all of the three essential constituents, nitrogen, phosphoric acid or potash, may serve as a direct manure in the sense that it increases the potential fertility of any soil, the value of the addition of such materials will depend not so much on the amount, as upon the power that the plant may possess of acquiring it—and it is here that the difference between manures from natural sources and those from artificial sources is again quite manifest. That is, the fertility constituents in natural manures are in large part combined with others in the form of vegetable matter, and with the exception of potash, they are, when in this form, largely insoluble, and, therefore, cannot be used by the plants until after decay begins. Whereas, in artificial manures, the constituents may be not only soluble, but may be in a form in which the plants can take them up immediately. In the first case, the plant-food is said to be unavailable, and in the second, it is said to be available.

Nitrogen, one of the chief constituents of manures, for example, exists in three distinct forms: (1) the organic form, in animal or vegetable matter, which must first decay before it can serve as plant-food. (2) As the decay goes on ammonia is formed, and then (3) from the ammonia the nitrate is formed, which is the form in which plants take up the largest proportion of their nitrogen. Inasmuch as products exist which contain nitrogen in these three distinct forms, it is possible by their use to largely control the feeding of the plant in respect to this element, while in the case of natural manures, the feeding of the plant with nitrogen depends upon conditions which cause its change from the organic into the other forms. As these conditions are variable, the problem of the economical feeding of plants with nitrogen, other things being equal, becomes a more difficult matter with the natural than with the artificial manures.

Phosphoric acid also exists in different forms, the form measuring to a large degree its availability: the organic, in which the availability depends upon the rapidity of decay; and the soluble and immediately available form,—that is, the form that distributes everywhere, and which the plant can absorb immediately it comes in contact with the roots. Commercial products exist which contain the phosphoric acid in these distinct forms. The user is therefore enabled to supply this constituent in such form as may best suit his crop and soil conditions.

In the case of potash, distinct forms, as muriate, sulfate and carbonate, also exist, though in the case of potash, the form in which it is combined exerts less influence upon the availability of the element to the plant than is the case with nitrogen and phosphoric acid. All of these forms are soluble, and can be readily absorbed.

DANGER OF LOSS FROM THE USE OF SOLUBLE PLANT-FOOD

The fact that the artificial fertilizer-products contain the constituents in such forms and combinations as to enable them to feed the plant immediately, also presents some disadvantages from the standpoint of economical use. This is particularly true in the case of nitrogen, for nitrogen, when applied in the form of nitrate, in which form it is taken up by the plant, does not combine to make insoluble compounds, but remains freely soluble. A great waste, therefore, may ensue from leaching into the lower layers of the soil and beyond the roots of plants, or into the drains, and the plant-food be carried away, unless care is exercised both as to the amount and the method of application. With soluble phosphates, the danger of loss is much less than with nitrogen. If these are applied in too large quantities to meet the needs of the plants, or under improper conditions, their tendency is not to remain soluble, but to revert to their original and insoluble form. The main fact, however, is that in artificial fertilizers we may have the constituents in distinct and separate forms, which permits the feeding of the plant, rather than the feeding of the soil; and this is usually, and must necessarily be, the case when natural manure products serve as the entire source of the added fertility.

THE USEFULNESS OF A FERTILIZER CONSTITUENT DOES NOT DEPEND UPON ITS ORIGINAL SOURCE

It should be remembered, too, that artificial manures or fertilizers supply plant-food just as well as other and more common products. The fact that the food exists in substances other than those which are familiar to the farmer, is no evidence that it may not be quite as good, or even better, than when contained in his home-made products. It is not the outward appearance of a substance, but the kind and form of the elements contained in it, that measures its value as a fertilizer.

For example, the nitrogen that may be applied in the form of a commercial fertilizer exerts no different function in the plant than that which may be acquired from the original soil, or from materials that have recently been obtained from that soil, and again returned as yard manure. The same is true of phosphoric acid and potash. In their concentrated, artificial forms, they serve to feed the plants in exactly the same way, and exert the same function in them, as those contained in the soils themselves, or that may be contained in wood ashes, or materials more familiar, or of more common occurrence. The form in which they exist when applied does not necessarily imply that they are stimulants rather than food, though frequently, because of their form, the plants are able to absorb them more readily, and thus by their rapidly increased growth, encourage a belief that an undue stimulating effect accompanies their use. The famous experiments of Lawes & Gilbert, at Rothamsted, England, teach this one thing very emphatically; viz., the efficiency of chemical fertilizers as compared with yard manures.*

USE OF FERTILIZERS

While manures in the ordinary sense, and even materials which are now included under the head of artificial manures, such as ground bone and wood ashes, have been used for a very long time, the use of artificial products in a true sense is of comparatively recent origin. The first use of genuine artificial fertilizers dates from the publication of Baron von Liebig's book, "Organic Chemistry in Its Application to Agriculture and Physiology," in 1840; yet for a long time after this date the increase in their use was very gradual. The very excellent, and at that time surprising, results which were obtained from the application of Peruvian guano, one of the first products to receive attention, manifestly increased the interest in the subject, also. These good results were observed more particularly on the continent of Europe, where the lands had been under cultivation for a long time. The use in America, previous to 1860, was quite insignificant. Since the work of

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* Rothamsted Memoirs, Volumes i.-vi.

Liebig, a very great amount of study has been given to the subject, both in reference to the essential character of the various materials, and their influence upon the production of plants. Perhaps no other single subject relating to agricultural science has been studied more fully than the question of the use of artificial manures; and these studies have resulted, not only in the discovery of new materials, but in their better preparation for use as plant-food, which greatly increased their effective use: There is no question connected with agriculture which is of greater direct and practical importance, particularly in those countries which have been depleted of their active fertility by the means mentioned, or in which the conditions are as previously outlined, than definite knowledge of the true principles which govern in the profitable use of commercial ·fertilizers. Yet, notwithstanding all the good results thus obtained, and their great practical importance to agriculture, much still remains to be done, particularly in the establishment of fundamental principles.

While it is desirable that in a work of this kind, scientific discussions should be avoided as far as possible, and the subject made as plain as is practicable to those using fertilizers, it is necessary to their right use that those who apply them to their land should have a very clear conception of the underlying principles, so far as they are known, in order that they may intelligently increase their production, and thus reap a profit. Definite knowledge is an important factor in determing their profitable use.

THE NEED OF ARTIFICIAL FERTILIZERS

The considerations in the previous chapter explained in part, and in a broad, general way, the necessity for the use of commercial fertilizers. The conditions of farming in this country have greatly changed in the past thirty years, and these changes have, perhaps, a still more important bearing in showing the need of imported fertility than the conditions already discussed. The first direction in which important changes have taken place is in the increased cost of farm labor and in the relatively low prices now received for the staple crops, the cereal grains, cotton and tobacco.

The Cost of Production per Unit of Income is Increased

The cost of labor is increased because proportionately higher wages are now paid, and because the labor now obtainable is on the whole less efficient, being performed more largely by those untrained for their work, rather than by the owner and his sons ; and this increased cost of labor makes the cost of growing the staple crops much greater in proportion to their market value than was formerly the case, though there are, of course, exceptions.

For example, harvest wages throughout the eastern part of the country, at any rate, were in the sixties regulated somewhat by the price of wheat. When wheat was $3 per bushel in the eastern states, the daily wage was $3. Now the daily wage in the east ranges from $2 to $2.50 per day, while the price of wheat does not often exceeed $1 per bushel, and the price received is frequently much lower than this. The wages for other kinds of farm work are proportionately the same in reference to present prices of products. This condition, when considered in connection with the important fact that the total cost of crop per acre is practically the same, whether the yield is high or low, exerts a decided influence in determining profits, particularly on land of medium fertility. The cost of preparing the land for the seed, the cost of seed, and the seeding and harvesting, are the same for a crop of wheat, whether the yield is 10 or 30 bushels per acre; but this cost will not permit a profit from the 10-bushel yield, because the cost per bushel is too largely increased. The same considerations hold true for a number of other crops. Small yields of these relatively low-priced crops cannot be profitably produced with the present high price of labor; and it has been shown, furthermore, that land which is not in a high state of fertility will not produce large yields.

Many soils, especially those in the eastern and southern sections of our country, which were not originally very fertile, and which have been cropped for a long time, show abundant evidence of the need of fertility from sources outside of the farm, in order that maximum crops may be produced. The aim should be, therefore, to make the conditions of soil better, and, if possible, so perfect as to guarantee against any lack of food during the growing period, and thus make the conditions of climate and season, rather than the soil, the measure of the crop. That is, as far as practicable, the yield that it is possible to obtain in a given locality should be the aim of the farmers in that locality. In order to make the conditions of soil perfect in this respect, the fertility elements must be added, though indirect manuring, in the form of better cultivation and better use of the waste products of the farm, are also to be encouraged.

A Greater Demand for Special Crops

In the second place, the changed conditions of farming are shown in the constantly increasing demand for market-garden products and fruits. Not many years ago, the staple crops already described were practically the only ones raised and sold from the farm. The growing of vegetables and fruits was limited. They were regarded as luxuries, and the area given to them was, on most farms, only sufficient to meet the needs of the home. These were not regarded as crops in the same light as the others, and were seldom the source of direct income. At the present time, vegetables and fruits are regarded as necessities in every home, and their use is not confined to the season in which they can be provided in the immediate vicinity of the cities or towns where they are used; they are drawn from points far distant, and the demand is such as to require the use of wide areas in order to supply the needs. The growing of market-garden crops and fruits is now the basis of specific agricultural industries which have assumed large proportions.

Much progress has been made, too, in the development of methods of practice in these lines of farming, and the experience gathered has shown that even our most fertile soils in their natural conditions contain too little active food to insure maximum yields of crops of the best quality; in these lines of farming, too, earliness and edible quality of products, which are influenced by the food supply, are important factors in determining the profits to be derived. The areas now necessarily devoted to these crops are so great that soils of a high natural fertility, even if natural fertility alone could be depended upon, are too limited to meet the demand and enable a profit, especially in the vicinity of good markets; in other respects a good location, because permitting of cheap distribution, is an important factor.

Farm Manures are Inadequate

Farm manures might meet the needs for the staple crops, as they are well adapted in many respects for the purpose, but, under present systems of management, the amount is not sufficient to meet the annual losses from the sale of crops, much less to provide an increase, and the only other source is an artificial supply, or commercial fertilizers. For the special crops already described, the natural manures of both farm and city are not only not sufficient, but, because of their character and composition, are not well adapted to economically meet the entire demands of the plants. In the first place, they are bulky, and thus expensive to handle. In the second place, the fertility elements contained in them are not in good proportion; they are, as a rule, poor in the mineral elements and rich in nitrogen, and their use in sufficient amounts to meet the needs of the plant for the mineral elements results in a waste of the nitrogen. Third, the constituents contained in them are not in sufficiently active forms to provide for a rapid and continuous growth without an excessive application, which frequently results in a serious waste not only of the nitrogen, as already indicated, but, in the case of many crops, an abnormal growth of vine or stalks, which may seriously injure the marketable quality of the crops. For many crops, economical production requires that the natural manures should be supplemented by artificial supplies, by means of which the form and amount of the individual constituent can be regulated to meet the needs of the various plants.

The Growing Importance of Fruit-growing

In fruit-culture, an industry of growing importance, it has been found that soils in their natural condition, while they may be well adapted in other respects—that is, possess a suitable physical character for the growth of this class of crops—contain insufficient amounts of the mineral constituents which are required in order that continuous and large crops of perfect fruit may be secured. To supply this deficiency from yard manure would cause in many cases an over-supply of vegetable matter containing nitrogen, which for these crops is frequently followed by disastrous results, not only causing an abnormal growth of leaf and wood, but inducing it at such periods of the year as to materially interfere with the proper ripening of both the wood and the fruit. By the use of artificial fertilizers, these difficulties may be largely overcome.

WILL IT PAY TO USE FERTILIZERS?

It must be confessed that to give a definite and positive answer to this question, with our present state of knowledge, is a difficult matter, if not well-nigh impossible, because of the very large number of varying conditions that are involved.

Usually such a question cannot be answered in a rational way without first securing definite information concerning the conditions under which they are to be applied, as, for instance, the character of soil, whether a sand, clay or loam; situation in reference to moisture, whether too dry or too wet; the kind of subsoil, whether a loose, open sand or gravel, a medium clay, or a tight, impervious hard-pan; the character of the previous treatment and cropping, whether the land has been manured or fertilized, whether good cultivation has been practiced, whether leguminous crops have been grown to any extent, whether the produce raised has been sold, or fed on the land; whether the object of the growth has been for immature produce and for early market, and artificial growth demanded, or whether for maturity, when the natural tendency has simply been assisted and the development normal in all directions.

If these questions are answered truthfully and in detail, a scheme of fertilization may be adopted that will enable the farmer to secure the greatest returns for the plant-food applied.

That the returns from the use of fertilizers are frequently unprofitable, is not always the fault of the fertilizer, and this point may be illustrated by the following typical case: One farmer applies plant-food, his crop is doubled or trebled, and a reasonable profit is secured. Another farmer applies the same amount and kind of fertilizer under similar natural conditions of soil, and he receives no benefit. The same climatic conditions surrounded the crops of both, the sun that warmed the soil and furnished the energy necessary for the production of the largely increased crop, is the same sun that shone upon the small crop; the air that furnished a large proportion of the food for the one is the same air that surrounded the other; the rains that moistened and assisted in the solution and circulation of plant-food for the one were the same for the other. Why, then, the difference in results? In one case the natural agencies, sun, air and water, were assisted and enabled to do their maximum work, while in the other, they were prevented from exercising their full influence. Physical conditions of soil were imperfect, due to careless plowing, seeding, cultivation and cropping.

In other words, the profit from the use of plant-food is measured to a large degree by the perfection of soil conditions, which are entirely within the power of the farmer to control. The production possible from a definite amount of plant-food can be secured only when the conditions are such as to permit its proper solution, distribution and retention by the soil.

The fact that fertilizers may now be easily secured, and the ease of application, have encouraged a careless use, rather than a thoughtful expenditure, of an equivalent amount of money or energy in the proper preparation of the soil. Of course, it does not follow that no returns are secured from plant-food applied under unfavorable conditions, though full returns cannot be secured under such circumstances. Good plant-food is wasted, and the profit possible to be derived is largely reduced.

Again, because farming, in its strict sense, is the conversion of three essential elements into salable products, the time to apply plant-food must be governed largely by its cost and the kind of crop upon which it is applied.

CHAPTER III

NITROGENOUS FERTILIZERS

NITROGEN is the most expensive constituent of fertilizers, and, all things considered, it is one of the most useful. Nitrogen exists in nature as a component of the air, and though quite as necessary to vegetation as carbon or oxygen,—which also exist in the atmosphere, and which are readily acquired by all plants,—all plants do not have the power of acquiring nitrogen from this source. This power seems to be limited to a class of plants called Leguminosæ, to which belong the various clovers, peas, beans, vetches, and a number of others. The important farm crops belonging to the other botanical groups of plants obtain their nitrogen largely, if not altogether, from the soil.

Vegetable or animal matter containing nitrogen may serve as a source of nitrogen to plants, though it cannot feed them with this element to any extent until it decays or rots. In order to obtain a clear conception of the use of nitrogen as a fertilizer, we should understand the need of plants for it, what is meant by form of nitrogen, and the sources from which the various forms may be derived, as well as the relative agricultural or crop-producing value of the nitrogen in existing commercial forms.

WHAT IS MEANT BY FORM OF NITROGEN?

Strictly speaking, form of nitrogen has reference to its combination or association with other chemical elements, though sometimes the term form is used to indicate rate of solubility, which also measures to some degree availability, since it happens that soluble forms of nitrogen are really more available than the insoluble forms, though neither the soluble nor insoluble forms show the same rate of availability; that is, a pound of soluble nitrogen is not equally available from whatever source derived, and a pound of insoluble from one source may be much more available than a pound from another. The form in which nitrogen exists in vegetable and animal matter is called the "organic form," because it is associated with other constituents, as carbon, hydrogen and oxygen, which are necessary to make the substances that constitute animal or vegetable matter, as we see them. The term "organic," as applied to nitrogen, covers a whole series of substances, and does not indicate a uniformity, either in content or quality of the nitrogen, as is the case with distinct chemical compounds; hence, associated with the knowledge of form of nitrogen, when it exists in organic products, must be a knowledge of whether the material contains a very considerable amount of nitrogen, and whether it is likely to be readily changed, and thus become available as food for plants.

Any nitrogenous vegetable or animal matter may serve as a fertilizer, though organic nitrogen in commercial fertilizers is usually obtained from products relatively rich in this constituent, and it is only these that can be used to advantage in making what are known as "high-grade fertilizers." The leading animal substances of this class are now mentioned.

DRIED BLOOD

One of the chief products from which organic nitrogen is derived for commercial fertilizers is dried blood. It is one of the most important, because it is one of the most concentrated, one of the richest in nitrogen of the organic nitrogenous fertilizing materials, and it is one of the best, since its physical character is such as to permit of its very rapid decay in the soil during the growing season. This tendency to rapid decay is plainly apparent, when we remember that blood as it exists in the animal is in a fluid form, and naturally any material which is sufficiently finely divided to permit of its ready flow, and is not associated with any hard or fibrous material, possesses characteristics which enable a rapid breaking down when subjected to the proper temperature and moisture, conditions which promote decay.

Dried blood for fertilizing purposes is chiefly obtained from the large slaughtering establishments, and the markets recognize two distinct kinds; namely, that which is red and that which is black. The red dried blood results from the careful drying of the fresh blood with hot water, at which temperature it does not char, nor become injured in quality. When dried at a higher temperature, and by other methods, it is darker in color, and has a leathery character, is less useful in the arts, and is slower to decay. Red blood, which commands the highest price, is reasonably uniform in composition. It contains from 13 to 14 per cent of nitrogen, and but traces of phosphoric acid—it is always classified as "high-grade." The black dried blood is of a lower grade, and may range in content of nitrogen from 6 to 12 per cent; it also contains considerable phosphoric acid, frequently as high as 4 per cent. Usually the lower the content of nitrogen, the higher the content of phosphoric acid; the latter is contained in the impurities (other substances, largely bone) with which it is contaminated. The lower grade blood is very generally used in the manufacture of fertilizers, since it is really the only good use to which it may be put; the high-grade is useful for other commercial purposes.

DRIED MEAT OR MEAL, AZOTIN, AMMONITE, OR ANIMAL MATTER

Dried meat or meal, azotin, ammonite, or animal matter, are terms applied to practically the same product, though produced in a different way. This material is another source of high-grade organic nitrogen. It is rich in the constituent element, and also decays rapidly in the soil. When relatively pure, it contains as high as 13 or 14 per cent of nitrogen, and thus in this respect compares very favorably with blood. The largest supply comes from rendering establishments, where the different portions of dead animals are utilized. These are subjected to treatment, usually dried and extracted with steam, for the purpose of securing the fat, though formerly, and even now, a large portion of this product is obtained from the beef extract factories.

HOOF MEAL.

Hoof meal is a reasonably uniform product, rich in nitrogen. It averages as high as 12 per cent, and in reference to availability has heretofore been classed with leather and horn. In recent culture experiments, however, the results indicate that it is much more valuable as a source of nitrogen than horn meal, leather, wool or hair. Commercially, it ranks with the high-grade products.

DRIED AND GROUND FISH, OR FISH GUANO

This product is obtained from two sources: first, from the offal, largely bones and skins, of fish packing or canning houses; and second, from the fish pomace resulting from extraction of the oil from the menhaden. The latter product is richer in nitrogen and is more uniform in character than the wastes from the packing houses. Dried ground fish from this source contains from 7 to 8 per cent of nitrogen, and from 6 to 8 per cent of phosphoric acid. The former, owing to the varying proportions of bone, skin and flesh contained in it, varies widely in its content of nitrogen. Fish, besides affording a considerable supply of nitrogen, is also regarded as a good source of this element, ranking in availability well up to blood and tankage, and is largely used in the northern coast states, where the supply is reasonably abundant.

KING CRAB

King crab is found in considerable quantities along the Atlantic coast, and is not only used directly as a fertilizer, but is also dried and ground and introduced into commercial mixtures. It is a highly nitrogenous product, containing in the dry state an average of 10 per cent, with traces only of phosphoric acid. It also possesses a high rate of availability, though information on this point is derived from the practical experience of farmers, rather than from actual scientific test.

TANKAGE

Tankage is a highly nitrogenous product, and consists chiefly of the dried animal wastes from the large abattoirs and slaughtering establishments. It is variable in its composition, since it includes the otherwise unusable parts of the carcass, as bone, tendons, flesh, hair, etc. The portions of this from the different animals not only vary in their composition, but they are used in varying proportions, which naturally results in an extremely variable product. What is known as "concentrated tankage," which is obtained by evaporating the fluids which contain certain extractive animal matter, is the richest in nitrogen, and is more uniform in character than the others; and because of its fineness of division and physical character, the nitrogen contained in it is also more active than in the other forms. Two distinct kinds of tankage can, therefore, be obtained; first, concentrated tankage, which is the richer in nitrogen, ranging from 10 to 12 per cent, and which contains very little phosphoric acid; and second, crushed tankage, which is of several grades, ranging from 4 to 9 per cent nitrogen, and from 3 to 12 per cent of phosphoric acid. Products are sometimes sold as tankage, which contain much more than the maximum of phosphoric acid and less than the minimum of nitrogen here given, in which case they are to be classed with bone, rather than with tankage. Tankage varies so much, both in its content of phosphoric acid and nitrogen, that in the trade it is always sold on the basis of its composition. The percentage of nitrogen and phosphoric acid is distinctly stated, and because it contains very considerable amounts of phosphoric acid, its commercial value is not wholly based on its content of nitrogen, as is the case with dried blood, dried meat, and concentrated tankage.

GARBAGE TANKAGE

Garbage tankage is a name given to a product now obtained by the drying, and sometimes partial charring, of the garbage of cities. It usually contains variable percentages of all of the constituents, though chiefly valuable for the nitrogen, and as yet cannot be classed among the standard fertilizer supplies, because of its variability, and because the usefulness of the constituents have not yet been determined.

LOW-GRADE NITROGENOUS PRODUCTS

Other products which contain a high content of nitrogen are frequently used. These, because of their low rate of availability, constitute a separate and distinct class. For example, horn meal, or ground horn, is reasonably uniform in its composition or content of nitrogen. It contains as high as 10 or 12 per cent of nitrogen, but it is so slow to decay when used in its natural state, that it is not regarded as an economical source of this element, though it may be obtained at a very low price.

Leather meal.—Leather meal is another product which is rich in nitrogen, but which is so slow to decay that its use in the natural state is not recommended. One object in making leather is to render it resistant to the conditions which promote decay, and ground leather may remain for years in the soil in an unchanged condition.

Wool and hair waste.—Wool waste and hair waste are also products which exist in considerable quantities, and while variable in composition, are frequently rich in nitrogen, but they are classed with leather because of their slow activity. Their mechanical form, coarse and bulky, makes it impossible to use them to advantage in the manufacture of fertilizers without previous treatment. The use of these materials, untreated, can only be regarded as desirable when they may be obtained at a very low cost. When dissolved with acid, or treated in such a way as to render them more immediately available, they may be used to advantage, though the cost of such treatment is usually so great as to make it impossible to thus improve their form and still be able to compete commercially with the other nitrogenous products.

VEGETABLE NITROGENOUS PRODUCTS

Cotton-seed meal is one of the best of the vegetable nitrogenous fertilizing materials. It is reasonably concentrated, and decays rapidly. Tests which have been made show that it ranks with blood in the availability of its nitrogen. Properly prepared, that is, when free from hulls, this product contains nearly 7 per cent of nitrogen. It is used in very large quantities, particularly in the southern states, where it is in abundant supply. It is, however, a most excellent cattle feed, and its use directly as a fertilizer will be reduced in proportion as its usefulness for this purpose is more fully appreciated.

Linseed meal is a material somewhat similar in character to cotton-seed meal. It contains on the average 5.5 per cent of nitrogen. The demand for this product for feeding purposes at good prices makes it, however, an expensive source of nitrogen.

Castor pomace.—Castor pomace, the waste resulting from the extraction of oil from the castor bean, is also a valuable nitrogenous fertilizer. It contains, on the average, 6 per cent of this element, and decays rapidly in the soil. This product differs from the cotton-seed and linseed meal, in that it is not useful as a cattle food. Practically its only use is as a fertilizer.

NATURAL GUANOS

A series of nitrogenous products which constitute still another separate class, consists of the various natural guanos. These were formerly a very large and valuable source of nitrogen, though at the present time they are not commercially important, owing to the practical exhaustion of the best supplies. Of the guanos, the product obtained from Peru, or from islands on the coast of that country, is the richest in nitrogen. It is derived almost entirely from the excrement of sea birds, as well as from the remains of the birds themselves, and from various other animals. The composition of this guano is of a very complex character. The nitrogen exists largely as ammonia, combined with oxalates, urates, humates, sulfates, phosphates, carbonates, and to some extent in purely organic forms. In these forms the nitrogen is quickly available, and marvellous results are obtained from their use.

Other guano deposits of considerable value, though poorer than the Peruvian, are found farther north on the coast of South America, as well as upon certain islands on the southwest coast of Africa. Ichaboe guano, for example, is at present exported, though it is a fresh deposit, and is annually collected for shipment. It is very inferior to the Peruvian guano, containing a very considerable amount of insoluble matter. At the present time, too, we have "bat guano," found in caves in Mexico and in some of the southwestern states. This product is very inferior to the Peruvian guano in its content of nitrogen, though the form is good, a considerable portion existing as nitrate. Owing to the very excellent results that were obtained from the early use of guanos, many attempts have been made to improve the lower grades obtainable at the present time, by the addition of nitrogenous matter of a higher rate of availability. These rectified, or fortified guanos, while containing nitrogen in good forms, cannot entirely substitute the original guanos, owing to the impossibility of adding forms identical with those existing in the natural product. That is, the total content of nitrogen in a rectified guano may be the same as in the genuine product, though the special forms and their proportions cannot be simulated. The distinctive value of the natural guanos is due to the fact that the nitrogen existed in a number of differently soluble compounds, which became available at different times in the soil, and thus constantly fed the plant with this element. The fact that nitrogen guanos gave such good results, is an evidence of the advantage of introducing different forms into artificial mixtures,

It is argued that because of the very great value of guanos, which consist very largely of the excrement of fowls, that droppings of pigeons, particularly, and of domestic fowls should also possess a high value, and for this reason a rather fictitious value has been fixed upon these products. These products differ very materially from natural guanos, and it is due probably both to the character of the food eaten by the domestic fowl, and to the different methods by which the material is obtained. The birds producing the guanos feed largely upon fish, a highly nitrogenous food, resulting in an excrement richer in this element than that from the domestic bird, feeding largely upon vegetable matter; and, besides, the former were accumulated in a hot, dry climate, which quickly absorbs the moisture contained in the fresh droppings, thus leaving it in a much drier state than is the case with the domestic product.

It will be observed from the foregoing brief description of the chief sources of organic forms of nitrogen, that a very wide variation occurs both in the composition or content of nitrogen in these products, and in the availability of their nitrogen, or rapidity with which, under similar conditions, it is given up to plants. The fact that a substance contains nitrogen in considerable amounts and in an organic form, then, is not a sufficient guide as to its usefulness. Its mechanical condition, or physical form, must also be taken into consideration, and, other things being equal, the tougher and denser the substances, the longer the time required to decay, and hence the more slowly will the material feed the plant.

AMMONIA COMPOUNDS

As already stated, nitrogen does not feed the plants in organic forms; it must first decay. The first product of the decay of a nitrogenous organic substance is ammonia, a combination of two elements, hydrogen and nitrogen. As the organic animal or vegetable substance which contains carbon, hydrogen, oxygen and nitrogen in combination breaks up, the carbon combines with part of the oxygen to form carbonic acid; part of the hydrogen also combines with oxygen to form water, and the nitrogen combines with hydrogen to form ammonia. Yet even in this form, plants do not absorb it freely. Ammonia is in a better form than the organic material, because, in the first place, it is soluble in most of its combinations with other substances, and is thus readily distributed in the soil, and in the second place, it is very liable to change. That is, its future availability is no longer dependent upon any mechanical or physical form; every portion or pound of ammonia is as good as any other portion or pound. Ammonia, however, does not occur as a natural product, like the organic forms, blood, meat and fish. Commercial forms are the result of a manufacturing process, and they may exist as distinct chemical substances, as sulfate of ammonia, in which case the ammonia is combined with sulfuric acid; as chlorid of ammonia, in which case it is combined with hydrochloric acid; as nitrate of ammonia, in which case it is combined with nitric acid; and as carbonate of ammonia, in which case it is combined with carbonic acid.

Sulfate of ammonia is the only one of these compounds which can be now obtained at a sufficiently low cost to encourage its use as a fertilizer. Sulfate of ammonia is a chemical salt which, when pure, contains 21.2 per cent of nitrogen. In commercial forms, however, it usually contains about 20 per cent of nitrogen, and even this makes it the richest in nitrogen of any of the commercial nitrogenous products. That is, every ton contains 400 pounds of nitrogen, and is thus richer by 60 pounds per ton than nitrate of soda, the next highest grade nitrogenous product. Sulfate of ammonia is obtained from the dry distillation of animal bone in the manufacture of bone-black, from the distillation of coal in the manufacture of illuminating gas, and from coal in the manufacture of coke. The quantity now made is increasing annually, largely because of the improved methods used in the manufacture of coke, which permit the saving of the ammonia. The cost of nitrogen in this form is likely to be so much reduced in future as to encourage its very considerable use by fertilizer manufacturers. Its chief advantages are that it is very concentrated, therefore reducing the cost of handling; it is always in the same form, a distinct and definite product, thus rendering its purchase a safe proceeding; and it is very quick to act, thus making it a very useful form, especially for quick-growing crops. Its physical character is such as to permit its ready distribution in a mixture.

NITRATE NITROGEN

As previously stated, neither organic nor ammonia compounds containing nitrogen are capable of fully meeting the demands of plants for this element. The first, or organic nitrogen, must pass through two changes, first to ammonia, and then to nitrate, and the ammonia must change to a nitrate. The nitrate is directly absorbed by plants, and the larger portion obtained by them is taken up in this form. Hence, from the standpoint of availability, nitrate nitrogen must be regarded as the most useful form. Like ammonia, too, a pound of it is as good as any other pound, from whatever product it may have been derived. It is a relatively concentrated material; and as it is perfectly soluble, it readily distributes itself everywhere in the soil to which it may be applied.

Nitrate of soda.—Although nitrogen as nitrate is not generally distributed as a natural product, vast deposits of crude nitrate of soda are found in the rainless districts of South America. These crude salts contain from 4 to 10 per cent of nitrogen, which are dissolved and re-crystallized before they are put upon the market, in order to remove as far as possible the impurities which are associated with them. The chemically pure salt, nitrate of soda, contains 16.47 per cent of nitrogen, and the commercial article, called "Chili saltpeter," contains from 15.5 to 16 per cent. The impurities which remain in it consist mainly of sodium chlorid, or common salt, which, together with moisture, causes a lower percentage in the commercial product.

THE RELATIVE AVAILABILITY OF THE DIFFERENT FORMS OF NITROGEN

From this discussion of the kind and source of nitrogenous fertilizer supplies, it is shown that the form of the nitrogen is an important factor in determining the rate at which the plants may obtain it. In the case of nitrate, the form is such as to enable the plants to take it up immediately. It is, therefore, theoretically the best, because as soon as it comes in contact with the roots, it is absorbed by them; there is no appreciable time required to enable the element to get into a condition to be taken up. Furthermore, its extreme solubility makes it possible, when moisture conditions are good, to reach every portion of the soil in which the roots are located, so that it is not only more available by virtue of its being in the right form, but because it readily goes to the place where the plant roots are. The next substance in order of availability is ammonia, and the rapidity with which ammonia will change to a nitrate makes it under many circumstances quite as useful. It possesses, too, one great advantage possessed by the nitrate, that of being soluble in water, and thus readily distributing itself throughout the surface soil. The difference in usefulness of these two forms seems to depend more largely upon the character of the season than upon the exact form. In a very wet season the nitrate is less useful, because liable to be washed below the reach of the roots, or lost altogether, and in a dry season it is more useful than the ammonia, because as soon as it is in solution it is capable of being absorbed. It must be remembered, however, that these two forms possess the further advantage over organic forms, that they are definite chemical compounds, which always possess the same characteristics, and under similar conditions they always act in the same way If nitrogen is purchased as ammonia, the source of the nitrogen is not important; that is, whether derived in the manufacture of bone-black, or of illuminating gas, or coke, if it is ammonia, it is identical in its character. The same is true of nitrate—the original source of the nitrogen is immaterial.

The availability of organic forms, as already pointed out, depends upon the rapidity with which they will change to the nitrate form. Such products as dried blood, dried meat, dried fish and concentrated tankage change rapidly, and are, therefore, good forms, while products like raw leather and horn meal are very slow to change.

The practical point, and the one of prime importance to the farmer, is, then, to know how to estimate the relative value or usefulness of these different products, what is the rate of availability as compared with nitrate, and thus the relative advantage of purchasing the one or the other, at the ruling market prices. Relative values, however, cannot be assigned as yet, though careful studies of the problem have been made, chiefly by what are known as "vegetation tests," that is, tests which show the actual amounts of nitrogen that plants can obtain from nitrogenous products of different kinds, when they are grown under known and controlled conditions. The results so far obtained, while only serving as a guide, indicate that when nitrate is rated at 100 per cent, blood and cotton seed meal are about 70 per cent, dried and ground fish and hoof meal 65 per cent, bone and tankage 60 per cent, and leather, ground horn and wool waste range from as low as 2 per cent to as high as 30 per cent. These figures furnish a fair basis for comparing the different materials, when used for the same purpose or under the same conditions. If, for example, the increased yield of oats due to the application of nitrate of soda is 1,000 pounds, the yield from blood and cotton-seed meal would be 700 pounds, the yield from dried ground fish and hoof meal would be 650 pounds, from bone and tankage 600 pounds, and from leather, ground horn, and wool waste, from 20 to 300 pounds.

Conditions Which Modify Availability

These figures alone are, however, not a sufficient guide as to the kinds to buy under all conditions, since the usefulness of the different forms are again dependent upon such other conditions as the kind of crop, the season, and the object of the application. The kind of crop is an important factor, since certain crops grow and develop quickly, while others grow for a comparatively long period; the season, because the changes from organic forms to ammonia, or nitrate, only take place when the temperature reaches 37° F., l when in addition sufficient moisture is present. nce, a material which might give excellent results en applied to a crop that grows through a long iod in a climate where the season is very warm l moist, might be very unsatisfactory where the son is short, cold and dry. These are a few of conditions which modify the rate of the decay of same material.

The object of the application should also be taken o consideration. The rate of the feeding of the nt with nitrogen in organic forms is measured by rate of decay of the organic material containing while when nitrate is used, its feeding is direct. e result is really a sort of feeding of the soil in one case, and a direct feeding of the plants in the er. Where the purpose is to get the largest pro-tionate increase in crop from the least amount plied, either the nitrate, or the ammonia, or the re active of the organic forms, would be likely to e the best returns. Whereas, if the object to be ained is not so much a large increased crop as it increase in the future productive capacity of the l in respect to this element, the slower-acting ma-ials will often answer the purpose quite as well as use of the more active nitrate form, as in this m no insoluble combinations are formed, the rate is freely movable, and if the plants do not sorb it, and heavy rains come, the water contain-; the nitrate is carried through the soil into the ins and the nitrogen lost. The disadvantage of nitrate is, then, that there is a greater possibility of loss from its use than from the use of materials which are either insoluble, or which are readily absorbed. The ammonia, while perfectly soluble, is fixed by the other substances in the soil, and is not, therefore, readily leached out, though if heavy applications are made the possibility is increased, because of the rapid change of the ammonia into the nitrate form. In the case of organic materials, the losses from leaching are seldom worthy of consideration in good practice, since an appreciable time is required, even in the case of the best forms, to change all of the nitrogen into ammonia, and then to a nitrate; while in the case of the poorer forms, still more time is necessary to cause the change, and losses are not liable to occur. In the making up of fertilizers, all of these considerations should be carefully balanced, and it is the practice on the part of many manufacturers to use a part of each of the three forms, so that a continuous feeding of the plant may be insured. Therefore, while the fact remains that fertilizers containing only the one form may not be the poorest, the chances are that those which contain all forms are likely to give more satisfactory results.

CHAPTER IV

PHOSPHATES—THEIR SOURCES, COMPOSITION AND RELATIVE VALUE

MANY farmers apply the term "phosphate" to all manufactured fertilizers, without regard to the kind and character of the fertilizing constituents contained in them. The term "phosphate" should only be applied to materials which contain phosphoric acid, and it does not necessarily imply that the phosphoric acid is in an available form. The term "superphosphate" implies that the phosphoric acid contained in the material is available. The phosphates constitute a class of products from which superphosphates are made, and which are used in the manufacture of fertilizers that contain immediately useful or available phosphoric acid. The following discussion of phosphates is quoted from the author's "First Principles of Agriculture:"*

The phosphoric acid in artificial manures is derived from compounds called "phosphates." In phosphates the phosphoric acid is united with lime, iron and alumina, forming phosphates of lime, iron and alumina, as the case may be. The phosphates of

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*"First Principles of Agriculture." Silver, Burdett & Co., Boston, 1896. The quotation comprises the entire discussion preceding "Phosphates as Sources of Phosphoric Acid to Plants," except "Bone Tankage" and "Tennessee Phosphate."

lime are better calculated for the purpose, and are, therefore, used more largely than any other as a source of phosphoric acid, in the manufacture of artificial manures.

The phosphates available for this purpose are not, however, pure salts, but exist in combination either with organic substances, or with minerals, or both, the content of phosphoric acid and its combination with other substances determining the usefulness of the phosphate to the manure-maker.

The phosphoric acid in these materials is soluble with difficulty in the soil water; and hence in their original condition, or in the crude raw forms, they give up this element in proportion as they decompose or decay in the soil. Those in combination with organic substances, either animal or vegetable, are, as a rule, more quickly useful as a source of phosphoric acid than those composed entirely of mineral constituents.

PHOSPHATE OF LIME, OR BONE PHOSPHATE — ANIMAL BONE

The bones of animals are the chief source of phosphates that exist in combination with organic matter, and were for a long time the main source for manurial purposes.

Bone consists chiefly of three classes of substances; viz., moisture, organic matter, containing nitrogenous and fatty matter, and phosphate of lime, or bone phosphate — the proportion, particularly of e nitrogen and phosphoric acid, depending upon e kind of bone and the method of its treatment.

Bone from the same kind of animal differs in mposition according to the age of the animal and location in the body In a general way, the unger the animal the softer the bone, the poorer in osphate of lime and the richer in nitrogen; the ler the animal, the richer in phosphate of lime and e poorer in nitrogen. The large and hard thigh nes of an ox, for instance, differ in composition om the softer and more porous bones of other parts the body.

The phosphate of lime of the harder bones is nse and compact; that from the softer bone is ore open and porous. The chief cause of variation the composition of bones used as manure, however, is due to the treatment they receive. This is cognized by manufacturers and dealers, and different names of brands are used to indicate the method manufacture or treatment. As applied, however, ey do not always correspond to the methods of eatment.

Raw Bone

The term "raw bone" is properly applied to bone at has not suffered any loss of its original constituents in the processes of its manufacture, and is r this reason highly regarded by farmers, who lieve that it is purer than any other form. This is ue in a large measure, though the fact that it is raw bone is not altogether an advantage from the standpoint of usefulness. Raw bone too often contains considerable fatty matter, which makes it a difficult process to grind it fine, and which also has a tendency to retard the decay of the bone in the soil. A considerable amount of fat also reduces proportionately the percentage of the valuable constituents, phosphoric acid and nitrogen. Good raw bone, free from meat and excess of fat, should contain on the average 22 per cent of phosphoric acid and 4 per cent of nitrogen.

Fine Bone

The trade terms "bone meal," "bone dust," and "fine bone," are used to indicate mechanical condition, or fineness of division, and do not refer especially to composition. These names should not be taken as indicating the fineness without personal examination, since frequently the products do not, in this respect, correspond to the name.

Boiled and Steamed Bone

The larger portion of the bone used as manure has been boiled or steamed for the purpose of freeing it from fat and nitrogenous matter, both of which are products valuable for other purposes. The fat is, of course, of no value as a manure, and its absence is an advantage. The nitrogen, while useful as a manure, is extracted chiefly for the purpose of making glue and gelatine.

By boiling or steaming, the bone suffers a loss of its original constituents, the chief result of which is to change the proportions of the nitrogen and phosphoric acid contained in it. Steamed or boiled bone contains more phosphoric acid and less nitrogen than raw bone, and is also more variable in composition, the relative percentage of these constituents depending upon the degree of steaming or boiling to which the bone has been subjected.

Bone that has been used for the purpose of making glue, where the chief object is to extract the nitrogenous matter, contains from 28 to 30 per cent of phosphoric acid and from 1¼ to 1¾ per cent of nitrogen. The steaming of bone, particularly when conducted at high pressure, also exerts a favorable effect upon the physical and mechanical character of the bone. It destroys its original structure, makes it soft and crumbly, and often reduces it to a finer state of division than can be readily accomplished by grinding; and, since it is also free from fat, and is finer, it is more directly useful as a source of phosphoric acid to plants than purer raw bone.

In some cases, the fat is extracted from bone by means of such solvents as petroleum or benzine. These methods of extracting the fat have the advantage of increasing the relative proportion of the nitrogen, this element not being attacked by the solvents. The more complete extraction of the fat and moisture by these methods also aids in the final preparation of the bone by grinding. Bone prepared in this way frequently contains as high as 6 per cent of nitrogen and 20 per cent of phosphoric acid.

The nature and composition of animal bone is such as to make it a valuable source of phosphoric acid; and, while it is largely used with nitrogenous and potassic materials in the manufacture of artificial manures, its best use is, perhaps, in the fine ground form, particularly for soil improvement and for slow-growing crops.

Phosphoric acid applied in this form gradually gives up nitrogen and phosphoric acid to the plant; and its physical and chemical characteristics are such that it forms in the soil, during the growing season, no compounds more insoluble than the bone itself. Of all the phosphatic materials available as manure, bone is the only one that is now used to any extent without further treatment than simple grinding.

Bone Tankage

As already intimated in the discussion of nitrogenous materials, certain products valuable for nitrogen also contain considerable amounts of phosphoric acid. Among these, tankage is the most important, and six definite grades are now recognized in the trade — the richest containing as high as 18 to 19 per cent of phosphoric acid, or equivalent to 40 per cent bone phosphate; the second containing 16 per cent phosphoric acid, equivalent to 35 per cent of bone phosphate; the third containing 13½ per cent of phosphoric acid, or equivalent to 30 per cent of bone phosphate; the fourth, 11½ per cent of phosphoric acid, or equivalent to 25 per cent of bone phosphate; the fifth, 9 per cent phosphoric acid, or equivalent to 20 per cent bone phosphate, and the sixth containing about 7 per cent phosphoric acid, or equivalent to 15 per cent bone phosphate.

It will be observed that certain grades of tankage approach the composition of bone in their content of phosphoric acid; the nitrogen increases as the phosphoric acid decreases, as already pointed out in the discussion of nitrogenous materials. Since tankage is made from the residue remaining in the tanks used for boiling cattle heads, feet, clippings, and other refuse animal matter, it may be classed with boiled bone in reference to the quality of its phosphoric acid. Its agricultural value is further modified by the fineness to which it is ground; it is frequently substituted for bone in the manufacture of fertilizers, where phosphate derived from bone is regarded as an important constituent of the mixture or brand.

Other Organic Products

There are also other products which should not be disregarded in a discussion of phosphates, though because of their content of other constituents they are primarily valued for them, rather than for the phosphoric acid. A good example is the dried ground fish, which often contains as high as 8 per cent of phosphoric acid, or an equivalent of 17 to 18 per cent of bone phosphate of lime. The phosphoric acid in dried fish is frequently more available than in other organic forms, owing to the fact that in the drying of the scrap it is often necessary to add sulfuric acid to prevent putrefaction. On the average, more than one-half of the total phosphoric acid in this product is in an available form.

The phosphoric acid contained in other nitrogenous products, as cotton-seed meal and castor pomace, while not large, is of some importance, as it is relatively more available than in raw bone or in tankage.

Bone-black, or Animal Charcoal

This material becomes an important source of phosphoric acid for artificial manures, after it has served its chief and first purpose in clarifying sugar. In making bone-black, only the best bones are used; they are cleaned and dried, and placed in air-tight vessels, and heated until all volatile matter is driven off; the resultant product, which retains in part the original form of the bone, is then ground to a coarse powder; it then becomes a bone charcoal, consisting chiefly of carbon and phosphate of lime, though also containing small amounts of magnesia and carbonate of lime.

Bone-black, as received from the refineries, contains the impurities gathered there, consisting chiefly of vegetable matter and moisture. It is somewhat variable in composition, containing from 32 to 36 per cent of phosphoric acid and a small amount of nitrogen. It decays slowly in the soil, and is not now used to any extent directly as a manure.

Bone-Ash

Bone-ash is an excellent, though not large, source of phosphoric acid. It is exported in considerable quantities from South America, where the bones are burned and the bulk reduced, in order to facilitate transportation. It does not contain nitrogen, and is more variable in composition than bone-black, though usually somewhat richer in phosphate of lime. Good samples contain from 27 to 36 per cent of phosphoric acid.

Bones themselves; and the phosphates derived from bones, constitute a class differing from other phosphates used in making manures, in that they are derived directly from organic materials and, as a class, they possess characteristics, due to this fact, which render them more useful than those derived from purely mineral sources.

MINERAL PHOSPHATES

These constitute a class of products differing from those of immediate or recent animal origin mainly in the fact that they are not combined with organic matter, and are more dense and compact in their structure. They occur in several different forms, and are procured from distinct sources.

South Carolina Rock Phosphates

These are found both on the land and in the beds of rivers in the vicinity of Charleston, S. C., and are sometimes called "Charleston phosphates." The deposits vary in thickness from one to twenty feet, through which the phosphate is distributed in the form of lumps or nodules, ranging in weight from an ounce to over a ton. These nodules are irregular, non-crystalline masses, often full of holes, which contain clay or other non-phosphatic materials. That obtained from the river is called "river phosphate," or "river rock;" and that from the land, "land phosphate," or "land rock." The two varieties do not differ materially in composition, particularly in the content of phosphoric acid.

The rock contains from 26 to 28 per cent of phosphoric acid. Its uniformity, in connection with the fact that it contains but small percentages of compounds of iron and alumina, minerals which prevent its best use by the manufacturer, make it a highly satisfactory source of phosphoric acid.

The river rock is secured by dredging; that from the land is largely dug. In either case it is washed to remove the adhering matter, and then dried, when it is ready for grinding or shipment. South Carolina rock phosphate, when very finely ground, is called "floats." It is sometimes used upon the land in this form, and when used for certain crops, as turnips, for example, and on certain soils, notably those wet and heavy and rich in vegetable matter, very satisfactory returns are obtained.

These deposits were first worked in 1868, though the presence of phosphate at this point was known at a much earlier date.

Florida Phosphates

The presence of phosphate in commercial quantities in Florida was discovered in 1888, since which time very great progress has been made in developing the deposits. The deposits occur in a number of forms, — first, "soft phosphate," a whitish product, somewhat resembling clay, and largely contaminated with it; second, "pebble phosphate," consisting of hard pebbles, occurring both in river beds and upon the land, and mixed with other materials; and third, "rock," or "bowlder phosphate," which occurs in the form of stony masses or bowlders, both large and small. These three forms also differ widely in composition, both in reference to their content of phosphoric acid and in respect to the presence of other minerals.

The soft phosphate is the poorest in phosphoric acid. It is easily prepared, and is largely used directly upon the land. It is also the most variable in composition, ranging from 18 to 30 per cent. The pebble rock is also variable in composition, though, when washed free of sand and clay, it is richer in phosphoric acid than the soft variety. Good samples contain as high as 40 per cent and over of phosphoric acid. The bulk of the "Florida phosphate" is believed to exist in the pebble form.

The rock or bowlder phosphate, though apparently much less in amount, is more uniform in composition, and is much richer than either of the other forms. The clean, dry bowlder phosphate often contains as high as 40 per cent phosphoric acid, far exceeding in richness the South Carolina rock superphosphate.

Canadian Apatite

This material is a crystallized rock of true mineral origin, and occurs associated to a greater or less extent with other materials. It is, therefore, not uniform in character, the phosphoric acid varying according to the amount of the other substances present.

It is mined in the provinces of Quebec and Ontario, and separated into various grades at the mines. The mining is expensive, and the necessity for grading in addition makes the cost of production proportionately high. The highest grade of this phosphate is very pure, containing 40 per cent of phosphoric acid.

Tennessee Phosphate

The phosphate deposits in Tennessee were discovered in November, 1894, since which time they have been exploited and a rapid development made. This phosphate differs from the phosphate of South Carolina and Florida in that it does not exist as nodules, pebbles or bowlders, but in veins and pockets, and, therefore, does not need to be washed and dried previous to its treatment. While the phosphates from the various deposits are not uniform in their composition, it is possible to secure large quantities that equal or exceed 30 to 32 per cent of phosphoric acid, or 70 per cent or over of bone phosphate, and that are relatively free from deleterious substances, thus making them not only a rich but a valuable source of supply for the manufacturers of superphosphates.

Iron Phosphate, or Thomas Phosphate Powder

This is a waste product from the manufacture of steel from phosphatic iron ores, by what is known as the "basic process." It is sold under several names, as "Thomas phosphate meal," "phosphate slag," "basic slag," and "odorless phosphate." It is produced in large quantities in England, France and Germany, and in those countries is not only one of the cheapest sources of phosphoric acid, but is regarded as a very valuable product. It contains from 15 to 20 per cent of phosphoric acid in the form of phosphate of lime, in connection with large amounts of lime and oxide of iron. It is used almost altogether in the form of a fine powder, since it is not suitable for the purposes of the manufacturer.

Phosphatic Guanos

Previous to the discovery of the phosphates in South Carolina, these guanos were a very important source of phosphoric acid. They are now but little used in this country They are obtained from the rainless districts of the world, chiefly from the islands bordering the coast of South America and from the West Indies. They are derived from the excrements of birds, and frequently include considerable organic matter containing nitrogen.

The Peruvian guano of earlier times was particularly rich in the best forms of nitrogen. The purely phosphatic guanos are rich in phosphoric acid, and are excellent materials. Like the iron phosphate, they are not suitable for the manufacture of artificial manures.

PHOSPHATES AS SOURCES OF PHOSPHORIC ACID TO PLANTS

The phosphates mentioned constitute what are called "raw materials," and, with the exception of bone, are not largely used directly. or without further treatment to render the phosphoric acid more soluble, and thus more immediately available to plants. As already stated, the phosphoric acid in them becomes food in proportion to the rapidity of decay, which is influenced both by the character of the material and the fineness of its division. Fine materials, too, permit of a more even distribution, thus bringing more particles of phosphate in contact with the roots of plants.

As already stated, a phosphate is a substance in which the phosphoric acid is combined with lime, iron or alumina. The phosphates of lime are the only ones that are used to any extent in the manufacture of artificial fertilizers. The phosphoric acid contained in animal bone is in the form of phosphate of lime, hence the term "bone phosphate of lime" has been applied to all phosphates that contain their phosphoric acid as phosphate of lime. In fact, statements of analysis of iron and alumina phosphates are frequently expressed in terms of phosphate of lime. That is, the content of phosphoric acid is stated as equivalent to a certain percentage of bone phosphate, the term expressing the total amount of combined phosphoric acid; as, for example, a bone which contains 20 per cent of phosphoric acid, which is the average content in good bone, is equivalent to 43.60 per cent of phosphate of lime.

All phosphates are insoluble in water, but, as phosphates, they are not capable of feeding the plant directly; they must first decay. Hence, the usefulness of a phosphate depends upon the rate of decay, or time required to change to such a form as to become available to the plant. The rapidity with which a phosphate will feed the plant depends upon a number of conditions, chief among which are, first, the character of the substance itself; second, the fineness of its division; third, the character of the soil to which it is applied; and fourth, the kind of crop for which it is used.

The Influence of Source of Phosphate Upon Availability

The chief point to be observed in the first case, is whether the substance is animal or vegetable, or whether it is mineral. Phosphates of immediate animal or vegetable origin decay more rapidly than purely mineral phosphates, because of the greater tendency of the organic matter with which the phosphate is associated to respond to the action of the natural agencies which cause decay. A bone, for example, if kept in a suitable condition of moisture and warmth, will soon begin to rot, the rotting affecting not only the animal matter, but more or less the phosphatic matter with which it is so closely identified, the fermentation primarily attacking the organic substances, but exercising a greater or less solvent effect upon the phosphates.

In the case of the mineral substances, the rate of decay is usually much slower, because there is no organic fermentation. The material changes or is broken up only by virtue of the action of the natural solvents, air and water, and solvent substances in the soil. Furthermore, the phosphate of the animal bone is always a phosphate of lime, which, while not soluble, is in itself more readily attacked by the natural agencies than a mineral phosphate which has associated with the bone phosphate other minerals that are not readily attacked by those agencies. That is, the mineral phosphates, while they are made up chiefly of phosphate of lime, are associated with other minerals, as iron and alumina, that are more slowly attacked than the phosphate of lime itself, and to some extent, too, prevent the full effect of the solvents, rather than encourage their action, as is the case with bone.

Influence of Fineness of Division

In the second place, fineness of division has an important bearing upon availability, since the finer the substance is ground, the greater will be the surface area exposed to the natural agencies which cause decay. Thus the application of a coarsely ground phosphate may not show any results the first season, while the same substance ground to a powder may have a good effect the first season; that is, its fineness permits of the solubility of a considerable portion of its phosphoric acid.

The Character of Soil as a Factor Influencing Availability

In the third place, the kind of soil to which the phosphate is applied may influence the rate at which the plants may obtain it. A soil which is open and porous, and thus permits the free access of air and circulation of water, and one which contains a large portion of other matter capable of decay, vegetable or animal, presents more favorable conditions for the solubility of phosphates than one which is close and compact in texture and purely mineral in its character, thus preventing the free access of air and water, and in which no organic changes are taking place. In the one case the conditions are such as to favor the action of the natural agencies, and in the other they are such as to retard their action.

Influence of the Kind of Crop

In the fourth place, the value or usefulness of phosphates is measured to some extent by the characteristics of the plant or crop to which they are applied. Plants differ in their power of acquiring food. Certain plants are able, because of their peculiar root system, or period of growth, to appropriate food more readily from insoluble sources than others.

General Considerations

All these considerations must be observed in determining the usefulness of a phosphate. It is believed by experienced farmers, though not absolutely confirmed by experimental inquiry, that animal bone, for example, is far superior, as a source of phosphoric acid, for most crops, to the mineral phosphates, though both may be ground to the same degree of fineness; and also, that the finer the bone is ground, the more rapidly will it give up its phosphoric acid.

Laboratory tests show that the phosphoric acid in bone, while insoluble in water, may be partly dissolved at a certain temperature by a neutral solution of ammonium citrate. This medium is used to determine what is called "available" in other phosphatic products. The rate of solubility in this medium is measured by the method of preparation of the bone and its fineness, the phosphate in raw bone meal of the same fineness showing rather a lower rate of solubility than the phosphates in steamed bone. The phosphate in the finest steamed bone is much more soluble than that in the coarser grades. This measure of the rate of solubility of bone, while not, perhaps, showing the exact rate at which the plants may obtain it, is a fairly safe guide in its use for most crops, as compared with those mineral phosphates which are not perceptibly soluble in this medium. The range of solubility of different kinds and grades of bone is from 20 to 75 per cent, and the average of a large number show about 30 per cent soluble in citrate of ammonia, which would be called "available" if found in mixed fertilizers, and probably can be as safely depended upon as the available shown in other products.

In any case, animal bone, or finely ground mineral phosphates, cannot be depended upon to fully meet the needs of quick-growing crops for phosphoric acid, but may answer an excellent purpose where the object is to gradually improve the soil in its content of this constituent, as well as to supply such crops as are continuous, or that grow through long periods, as, for example, meadows, pastures, and orchard and vineyard crops.

As to the specific substance, the iron phosphate, or Thomas phosphate powder, experiments in Europe have shown that it possesses a higher rate of availability than other phosphates which are insoluble in water, but which show the same rate of solubility in ammonium citrate, though its solubility, or availability, is measured to some extent by the degree of fineness to which it is ground; and it is believed that its special form, the tetra-calcic, also exercises a considerable influence upon the rate of availability.

European vegetation and field experiments show pretty clearly that two parts of phosphoric acid from the Thomas phosphate powder are approximately equivalent to one part from soluble phosphoric acid, and that this phosphate is especially useful on wet, marshy soils and those poor in lime. Experiments conducted in this country practically confirm these conclusions.

The relative availability of the phosphates in the natural guanos has also been shown to be somewhat higher than in other insoluble phosphates. These latter substances for this reason possess a distinct value over others for certain classes of crops, as, for example, cranberries, where the soluble phosphates would be liable to be washed out, and where the organic phosphates would be liable to float on the surface of the water, and also where lands are cold and sour, and not readily fermentable.

The practical point, however, to the farmer, is the amount of increase that he may obtain from a certain definite expenditure, a matter which will be discussed later, in the discussion of the use of fertilizers for the various crops.

CHAPTER V

SUPERPHOSPHATES—POTASH

THE different phosphates mentioned in the previous chapter constitute the sources of supply for the manufacture of commercial fertilizers. That is, with the exception of animal bone, Thomas phosphate powder and natural guanos, they are used more extensively for this purpose than directly on the land in their raw state. They are the raw materials from which the manufactured phosphatic fertilizers are derived. The purpose of the manufacture is to convert them into a form in which the phosphoric acid is immediately available, and thus directly useful to the plant. The term "available" in this case is used in the same sense as in the discussion of the forms of nitrogen (Chap. iii.), and it means that when the phosphoric acid is in this form, the plants may acquire it immediately.

INSOLUBLE PHOSPHORIC ACID

Phosphate of lime is, chemically speaking, a salt capable of existing in various forms, the form measuring in large degree the rate of availability. The phosphate of lime, as it exists in the animal bone and mineral phosphates, for example, consists of three parts of lime and one of phosphoric acid. This is the insoluble form. It is not immediately available, and because of the three parts of lime to one of phosphoric acid, which it contains, it is also called tricalcic, tribasic, or bone phosphate, and is graphically expressed in the accompanying formula:

Lime	
Lime	Phosphoric Acid
Lime	

That is, in each molecule, however small, there are three parts of lime and one part of phosphoric acid.

SOLUBLE PHOSPHORIC ACID

In another form, the phosphate consists of one part of lime and one of phosphoric acid, two parts of the lime in the tricalcic form being replaced with water. This form is called monobasic, or monocalcic. It is a saturated phosphate. There could be no less than one part of lime to one of phosphoric acid, and such phosphates are called acid phosphates, or superphosphates. The combination of the lime and phosphoric acid may be shown as follows:

Lime	
Water	Phosphoric Acid
Water	

This form is completely soluble in water and immediately available, and when applied to the soil readily distributes itself everywhere, thus making it more useful than any other form.

REVERTED PHOSPHORIC ACID

Another form of phosphate consists of two parts of lime and one part of phosphoric acid, and is called dicalcic, dibasic, or reverted, One part of the lime in the insoluble is replaced by an equivalent of water, and is expressed as follows:

Lime Lime Water	Phosphoric Acid

The reverted form, which means a going back from the soluble toward the insoluble form, is also insoluble in water, but is readily soluble to the roots of plants.

It was formerly supposed that these three were the only forms in which phosphoric acid existed, but another form, in which four parts of lime are combined with one of phosphoric acid, and thus called tetrabasic, or tetracalcic, has been found quite recently to exist in the Thomas phosphate powder:

Lime Lime Lime Lime	Phosphoric Acid

This form is insoluble in water, though it has been found to be more available than the insoluble tribasic form.

HOW SUPERPHOSPHATES ARE MADE

Any material which contains a high content of the tricalcic or bone phosphate, 60 per cent or over, is suitable for the manufacture of superphosphates, provided it does not possess a too high content of deleterious substances. In the manufacture of superphosphates, the phosphate is first ground to a fine powder, then mixed with sulfuric acid. The acid dissolves the phosphate, and two parts of the lime which are combined with the phosphoric acid in the tricalcic form are first set free, and then combined with the sulfuric acid, making a superphosphate (monocalcic), and a sulfate of lime or gypsum. That is, in this process, two of the three parts of the lime combined with the phosphoric acid to form the insoluble phosphoric acid, are removed, thus leaving one part of the lime combined with the phosphoric acid, making the superphosphate. A pure superphosphate is, therefore, a mixture of soluble phosphate and of sulfate of lime or gypsum.

The Difference in the Superphosphates made from the Different Materials

In the early use of superphosphates, the chief raw material was animal bone. The superiority of the bone superphosphate, or dissolved bone, as it was called, over the raw bone, was manifest at once, and the familiarity with genuine bone superphosphates thus early acquired by farmers was, perhaps, quite as influential as any other in creating a prejudice in favor of their continued use in preference to superphosphates derived from mineral phosphates. The opinion that the bone superphosphate is "the best" is held even at the present day, notwithstanding the equally satisfactory results that have been obtained from the use of the superphosphates from other sources.

Soluble Phosphoric Acid Chemically Identical, from Whatever Source Derived

Chemically speaking, the soluble phosphoric acid produced by the action of sulfuric acid upon mineral phosphates is identical with the soluble phosphoric acid derived from animal bone, and if the soluble from each could be separated from the other substances with which they are associated, there would be no difference whatever in the results of their use. They are identical; just as much so as ammonia obtained in the manufacture of bone-black from bones is identical with the ammonia obtained in the manufacture of illuminating gas or coke. In many cases, doubtless, superior results have been obtained from the use of the animal bone superphosphate, though this has not been due to any inferiority of the available phosphoric acid in the mineral superphosphate, but rather to the fact that substances have been compared that are not strictly comparable. They are radically different. The one contains, in addition to its available phosphoric acid, the only fertilizing ingredient in the mineral superphosphate, considerable nitrogen, and, moreover, it contains its insoluble phosphoric acid in a form that is liable to decay more rapidly than the insoluble in the mineral phosphate.

Soluble phosphoric acid is a definite compound. The source from which it is derived does not influence this point, and the action of a definite quantity is also identical when conditions are similar.

PHOSPHATES AND SUPERPHOSPHATES ARE NOT IDENTICAL

The idea in the term "phosphate" should also be kept distinct from that conveyed by the term "superphosphate." The first means, and should be applied to, any material containing as its chief constituent phosphoric acid; the other means, and should be applied to, any material containing soluble phosphoric acid as its chief constituent. The phosphates which have already been described are each capable of being converted into a superphosphate, as animal bone superphosphate, South Carolina rock superphosphate, bone-black superphosphate, bone-ash superphosphate, Florida rock superphosphate, and Tennessee rock superphosphate. These superphosphates vary in their content of soluble phosphoric acid, due both to the variation in the content of the phosphoric acid in the phosphates used as raw materials, and to the excellence of the method of manufacture. In other words, the superphosphates, while practically identical in so far as the form of phosphoric acid is concerned, vary in their total content of soluble phosphoric acid. For example, superphosphates made from the animal phosphates, as bone-black, bone-ash, etc., are usually richer in soluble phosphoric acid than those made from animal bone, or from many of the mineral phosphates, because these phosphates are of such a character as to enable the manufacturer to convert all the phosphoric acid present into a soluble form, and at the same time to secure a fine, dry product, that may be readily handled — an important consideration in making superphosphates.

"Mineral phosphates, both because of their hardness and of the presence of other minerals, which are attacked by the acid, are less easily dissolved, and require more acid in proportion to the phosphate present than those from organic sources. They are also less absorbent, preventing the acid from permeating the mass of the material, and hence it is more difficult to secure good condition when sufficient acid is used to dissolve the phosphate. In making superphosphates from these materials, less acid is used than is required to completely dissolve the phosphates, and there is, therefore, always present in them more or less of the insoluble phosphoric acid.

"In the case of animal bone, too, less sulfuric acid is used than is required to completely dissolve the phosphoric acid. Otherwise, a gummy, sticky product would result, due largely to the organic matter in the bone. The insoluble phosphoric acid in bone, bone-black, and bone-ash superphosphates is, however, of greater value than the insoluble in the mineral phosphates, for reasons already given.

"In superphosphates, too, there is nearly always present a greater or less amount—depending upon the material—of the second form of phosphoric acid, the dicalcic, reverted or retrograde. This form usually exists in the greatest amounts in those made from mineral phosphates, which is believed to be due either to the soluble acting upon the insoluble portions, or to the presence of oxide of iron and alumina, which combine with a portion of the soluble phosphoric acid. The soluble goes back to the less soluble dicalcic form."*

Aikman states the matter very clearly in the following words:† "A change which is apt to take place in superphosphate after its manufacture is what is known as 'reversion of the soluble phosphate.' Thus it is found that on keeping superphosphate for a long time the percentage of soluble phosphate becomes less than it was at first. The rate at which this deterioration of the superphosphate goes on varies in different samples. In a well-made article, it is practically inappreciable, whereas in some superphosphates, made from unsuitable materials, it may form a considerable percentage. The causes of this reversion are two-fold. For one thing, the presence of undecomposed phosphate of lime may cause it. This source of reversion, however, is very much less important than the other, which is the presence of iron and alumina in the raw material. When a soluble phosphate reverts, what takes place is the conversion of the monocalcic phosphate into the dicalcic.

"Where reversion is due to the presence of iron and

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*"First Principles of Agriculture." Silver, Burdett & Co., Boston.

†"Manures and Manuring." An excellent English work, of recent issue.

alumina in the raw material, the nature of the reaction is not well understood, and is, consequently, not so easily demonstrated as in the former case. Where iron is present in the form of pyrites, or ferrous silicate, it does not seem to cause reversion. It is only when it is present in the form of oxide (and in most raw phosphatic materials it is generally in this form) that it causes reversion in the phosphate."

Aikman also discusses the value of reverted phosphates, showing the estimation in which they are held in England: "The value of reverted phosphate is a subject which has given rise to much dispute among chemists. That it has a higher value than the ordinary insoluble phosphate is now admitted, but in this country, in the manure trade, this is not as yet recognized. At first it was thought that it was impossible to estimate its quantity by chemical analysis. This difficulty, however, has been overcome, and it is generally admitted that the ammonium citrate process furnishes an accurate means of determining its amount. Both on the continent and in the United States reverted phosphate is recognized as possessing a monetary value in excess of that possessed by the ordinary insoluble phosphates. The result is, that raw mineral phosphates containing iron and alumina to any appreciable extent are not used in this country, although they do find a limited application in America and on the continent."

As stated by Aikman, the reverted phosphoric acid due to the presence of undecomposed phosphate, as well as the reverted due to the presence of iron and alumina, are recognized by the chemists in this country, and this recognition is strongly encouraged by commercial interests, because of the fact that our mineral phosphates contain, as a rule, iron and alumina, which by their action reduce the percentage of the soluble. The method of chemical analysis which has been adopted by the American Association of Official Agricultural Chemists recognizes this form, and it is, therefore, determined and included in the "total available" in statements of analysis. In one state, New Jersey, the law requires that the dicalcic form only shall be recognized, and it assumes that the agricultural value of this form is equal to that of the soluble.

DOUBLE SUPERPHOSPHATES

In addition to the superphosphates made directly from the various materials mentioned, a special substance, called a "double superphosphate," which may be made by dissolving low-grade phosphates with an excess of dilute sulfuric acid, or those too poor in phosphoric acid to make a high-grade superphosphate. The dissolved phosphoric acid thus obtained, together with the excess of sulfuric acid, are separated from the insoluble materials by filtering, which acids, after concentration, are then used for dissolving the better phosphates; and because the acids used for dissolving the phosphates contain phosphoric acid, the content of available phosphoric acid in these products is more than double that contained in the ordinary products. These are mostly manufactured in Europe, and are not used to any extent in this country. They possess the advantage of containing a minimum of impurities and a maximum of phosphoric acid in a soluble form.

In stating the composition of superphosphates, the three forms of phosphoric acid are all recognized. The sum of the soluble and reverted forms is called the "total available," because these, as already stated, are regarded as immediately useful to the plant. In commercial transactions in mineral superphosphates, the total available only is regarded,—the content of insoluble being ignored.

CHEMICAL COMPOSITION OF SUPERPHOSPHATES

As already stated, the composition of the superphosphates varies according to the richness in phosphoric acid of the phosphates used, and according to the character of the material. Bone-ash and bone-black superphosphates are more uniform in composition than those derived from the mineral phosphates, and the phosphoric acid is practically all in the soluble form. They contain on the average about 16 per cent of total available phosphoric acid. The mineral or rock superphosphates differ from these in being more variable in their total content of available, and in showing wider variations in the proportions of reverted, the latter depending upon the skill in manufacture, as well as the character of the original material. Well made South Carolina rock superphosphates contain from 12 to 14 per cent of total available, of which 1 to 3 per cent is dicalcic, or reverted. There are several grades of the Florida rock superphosphates, due to the variation in the composition of the various raw phosphates. The pebble superphosphates are the richest, often containing as high as 16 or 17 per cent of total available, with varying percentages of reverted and insoluble. The Tennessee superphosphates also vary from the same cause, the richest showing as high as 16 to 18 per cent of total available. The concentrated, or double superphosphates, may contain as high as 45 per cent of available, practically all of which is soluble. The superphosphates made from animal bone are usually more variable in their composition than those made from bone-black, bone-ash or mineral phosphates, and the variation is due both to the variability of the raw materials and the difficulties involved in their change into superphosphates. The usual guarantee on an animal bone superphosphate is 12 per cent available, and from 3 to 5 per cent of insoluble. These superphosphates also differ from the mineral superphosphates in containing nitrogen in addition to their phosphoric acid. They are, therefore, really ammoniated superphosphates.

Well Made Superphosphates Contain no Free Acid

In the earlier history of the use of acid phosphates, or rock superphosphates, objections were urged against them, and are to some extent at the present time, because of the supposed deleterious effects of the acids contained in them, and these objections were undoubtedly encouraged,—certainly not discouraged,—by those manufacturers who used only genuine bone superphosphates. While the objections on this ground may have had some basis in earlier times, before their manufacture was well understood, there can be no rational objection to their use at the present time, when they are properly made; for while in fresh superphosphates a portion of the phosphoric acid may be in the form of "free" phosphoric acid, this form in ordinary superphosphates is practically all combined with lime or other minerals before it is placed upon the market, and there is really no more "free" acid in the rock superphosphate than in any other. It is quite likely this erroneous impression arose from the fact that strong sulfuric acid was used in the manufacture, and the belief existed that it remained as such. No free sulfuric acid exists in well made superphosphates. The sulfuric acid is combined with the lime to form gypsum, as already described, and the free phosphoric acid combines with the lime to form either a soluble or a reverted form.

Phosphoric Acid Remains in the Soil Until Taken Out by Plants

The phosphoric acid in superphosphates, though soluble in water, is not readily washed from the soil. The real object of making it soluble is to enable its better distribution. If it were possible to as cheaply prepare the dicalcic or reverted form as the soluble, it would, perhaps, be quite as useful from the standpoint of availability. After the soluble is distributed in the soil, it is fixed there by combining with the lime and other minerals present. It is believed that it assumes, first, by the larger relative proportion of lime usually present in soils, the dicalcic form, though it is not positively certain that in the presence of an abundance of lime, or that in time, it may not assume the insoluble tricalcic form. The soluble phosphoric acid may also combine with the iron and alumina in the soil, and form phosphates of these elements, though recent investigations lead to the conclusion that these conditions are much more rare than was at one time supposed. The time required for the fixing of the phosphoric acid, as well as the form it may eventually assume, depends chiefly upon the character and composition of the soil. In those rich in lime, the fixation is most rapid, though in no sense is the fixation immediate, and in such soils the fixation is probably largely completed in the course of a week. On clay soils, containing a low percentage of lime, and in light soils that contain little clay or organic matter, the fixation is much slower, though even in these the chances are that no serious loss of phosphoric acid occurs. Seldom do we find more than traces of phosphoric acid in drainage waters, even when heavy applications of soluble phosphoric acid are followed by heavy rains. The fact that the fixing power of soils practically prevents the loss of phosphoric acid should, however, not be used as an argument in favor of the careless use of superphosphates.

POTASH SALTS

Until the discovery of the mines of crude potash salts in Stassfurt, Germany, in 1859, and which have been worked since 1862, the chief source of potash for farm plants, other than that contained in yard manures, was wood ashes. The supply from this source now, however, is sufficient to meet all immediate as well as future demands, since the deposits are practically inexhaustible, though notwithstanding the abundance of the supply and the improvements made in the methods of utilizing the various salts, other than potash, contained in the deposits, it is the only fertilizer constituent which has remained practically constant in price during the past fifteen years. In this period not only have wide fluctuations occurred in prices of nitrogen and phosphoric acid from the different sources, but they are much lower now than formerly.

The Importance of Potash as a Constituent of Fertilizers

It has been attested that potash is of relatively less importance than either nitrogen or phosphoric acid, inasmuch as good soils are naturally richer in this element, and because a less amount is removed in general farming than of either nitrogen or phosphoric acid, as the potash is located to a less extent in the grain than in the straw, which is retained upon the farm. It is, however, a very necessary constituent of fertilizers, being absolutely essential for those intended for light, sandy soils and for peaty meadow lands, as well as for certain potash-consuming crops, as potatoes, tobacco and roots, since these soils are very deficient in this element, and the plants mentioned require it in larger proportion than do others. In fact, it is believed by many careful observers,—and the belief has been substantiated in large part by experiments already conducted,—that the average commercial fertilizer does not contain a sufficient amount of this element. It is a particularly useful constituent element in the building up of worn-out soils, because contributing materially to the growth of the nitrogen-gathering legumes, an important crop for this particular purpose.

Forms of Potash

Potash, as has already been stated in the discussion of phosphoric acid and nitrogen, exists in various forms, but it differs from the other elements in that its chemical form or combination seems to exert but relatively little influence upon the availability of the constituent. For example, it may be in the form of a muriate or chlorid, of a sulfate or of a carbonate, and while there is a difference in the diffusibility of these different compounds,—that is, a difference in the rate at which they will distribute in the soil before becoming fixed,—there seems to be very little difference in the rate of the absorption of the potash by the plant. Nevertheless, the form of potash must be observed, because of the possible influence that the substances with which it combines may exert in reducing the marketable quality of the crop to which it is applied. This influence has been very distinctly observed, particularly in the growing of tobacco, sugar-beets and potatoes, and it has been shown that the potash in the form of a chlorid (or muriate) does exert a very deleterious effect, especially on tobacco. In fact, tobacco manures should not contain potash in the form of a muriate. For such crops as the various clovers, Indian corn (maize), and the various grasses, no particular difference has been observed, and the form of potash that may be procured at the lowest price per pound of the constituent is the one, other things being equal, to use for these crops.

Kainit

In the next place, the potash salts that may be obtained are divided into two classes; first, the crude products of the mines, and second, the manufactured products. Of the crude products, kainit is the one more largely used in this country than any other. The potash contained in it is practically all in the form of a sulfate, though its effect is the same as if it were in the form of a muriate, because of the large quantities of other salts, chiefly sodium chlorid, or ordinary salt, and magnesium chlorid, with which the sulfate of potash is associated. It contains on the average 12.5 per cent of actual potash, or equivalent to about 23 per cent of sulfate of potash and 33 per cent of ordinary salt, and smaller percentages of magnesium chlorid and magnesium sulfate. Because of its low content of potash as compared with the manufactured products, the cost of the actual potash is usually greater than in these, owing to the increased cost of shipping and handling per unit of potash. It is more generally used near the sources of supply, rather than at a distance, unless the substances, as ordinary salt, also exert a beneficial indirect influence upon the soil, as is very frequently the case. It is not advisable to apply it immediately preceding the planting, nor in the hill or row, because of the danger to the young plant from the excess of both the chlorids of sodium and magnesium, which are injurious to the tender rootlets. Where its use is intended to benefit the immediate crop, it should be applied a considerable time before the crop is planted, in order that it may be well distributed, and that a portion of the chlorids, which are extremely soluble, may be washed into the lower layers, or into the drains.

Sylvinit

Sylvinit is somewhat similar to kainit in composition, in that it does not contain a large amount of actual potash, and the potash is associated with other substances, as sodium and magnesium chlorids, though less than is the case with kainit. The potash in the sylvinit, however, exists both in the form of a sulfate and of a chlorid. It is not as largely exported to this country as the kainit, and contains on the average about 16 per cent of actual potash. Its effect as an indirect manure is very similar to that of kainit, the salts associated with the potash having a beneficent effect in dissolving and making other substances in the soil available to the plant, particularly phosphates, as well as aiding in the improvement of the physical character of soils.

Muriate of Potash

Of the manufactured products, the muriate (chlorid) of potash is more generally used than any of the others. It varies somewhat in composition, according to the method of manufacture, though practically only three grades are offered. That most commonly met with in this country contains about 50 per cent of actual potash, equivalent to 80 per cent muriate. The chief impurities are common salt, or sodium chlorid, and insoluble matter, which are not deleterious substances. The lower the content of potash the higher the content of impurities, though in all cases this form of potash is sold upon the basis of 80 per cent muriate.

Recently a Scotch kiln-dried muriate of potash has been offered, which is much richer in actual potash than the other grades, containing over 98 per cent of pure muriate. The chief advantage of this higher grade is that the cost of handling per unit of actual potash is reduced, a point of considerable importance at points distant from sources of supply The actual potash is no better than in the lower grades.

High-grade Sulfate of Potash

High-grade sulfate of potash is usually sold on a purity basis of 98 per cent, or an equivalent of 53 per cent actual potash. It naturally varies somewhat in its composition, owing to possible impurities, either introduced or imperfectly removed. It is, however, regarded as preferable to the muriate for some crops, for the reasons already given (page 94), though until recent years it has been much more expensive, and thus not so largely used by the manufacturers of fertilizers. It is rather less diffusible than the muriate, though it is not believed to be inferior to it as a source of actual potash.

Double Sulfate of Potash and Magnesia

This is a lower grade in its content of potash, though similar to the high grade in its effect, as it contains no deleterious substances, and in many cases the sulfate of magnesia with which it is associated is believed to be of considerable service. The potash contained in it is equivalent to about 26 per cent of actual potash, though lower grades are made. These are known under the name of double-manure salts. The cost of the actual potash in the double sulfate is also greater than in the muriate.

Upon standing, all of the potash salts have a tendency to become hard, though, with the exception of kainit, they are easily pulverized, and thus readily distributed, either broadcast or in drills.

Fixation of Potash

Potash, like phosphoric acid, is readily fixed in the soil, though the chlorids with which it is combined when applied may form soluble compounds that are readily leached from the soil. For example, the chlorin combined with the muriate may be combined with lime or soda, forming soluble chlorids of lime or soda; hence, heavy applications of muriate of potash may result in the exhaustion of lime in the soil. The fact that the potash is fixed, and that the chlorids remain soluble, enables the application of a large quantity, which might otherwise be injurious. That is, if muriate of potash is applied a considerable time before the crop that may be injured by excess of chlorids is planted, the chlorids are washed out, while the potash remains.

Another point of importance should be observed in this connection: the rapidity of fixation on many soils, especially those of an alluvial character, which explains the recommendations frequently made to apply potash salts broadcast and immediately cultivate in, otherwise the fixation would take place at points of contact, and the distribution be incomplete.

CHAPTER VI

MISCELLANEOUS FERTILIZING MATERIALS

In addition to the specific fertilizer materials described in the previous chapters, which constitute the standard sources of supply, a number of other products exist, and should be considered here. Certain of these may serve in the manufacture of fertilizers, and certain others, which are not suitable for this purpose, may be used to advantage either because they furnish the constituents in considerable quantities, or in other ways assist in improving the fertility of the soil. They are often a cheap source of nitrogen, phosphoric acid or potash, besides contributing toward "condition" of soil, which exercises a decided influence in making possible the best use of commercial fertilizers.

Furthermore, while a consideration of these products may not be regarded as strictly pertaining to the subject of commercial fertilizers, a discussion of them is valuable, in order that certain impressions now existing concerning them may be corrected. These impressions, while not entirely erroneous, are not wholly in accord with scientific facts, particularly as to how far they may substitute the better products; and on this point information as full and exact should be had as the limited knowledge that we have of the subject will permit. These various products cannot be strictly classified into the three main groups: nitrogenous, phosphatic and potassic. They are, as a rule, rather general in their effect; they contain small amounts of all the essential constituents rather than large amounts of one or two, and many of them are useful, practically altogether because of their indirect action.

TOBACCO STEMS AND STALKS

Tobacco stems consist of the waste stems or ribs of the leaves, and parts of the leaves themselves, which result from the stripping of tobacco for the manufacture of cigars, or for smoking and chewing tobacco. The stalks include the main stem and branches of the plant. The stems are frequently ground and sold as a fertilizer, and the product is chiefly valuable for its nitrogen and potash — the nitrogen ranging in content from 2 to 3 per cent and the potash from 6 to 10 per cent. They contain but small amounts of phosphoric acid. The nitrogen exists in both the nitrate and organic forms. The nitrate form constitutes from one-third to one-half of the total nitrogen, and its presence is due both to the fact that nitrogen exists as such in the tobacco plant, and to the fact that saltpetre (nitrate of potash) is frequently added in order to improve the marketable quality of the lower grades of

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NOTE.— Full discussions of stable manures are contained in Roberts' "Fertility of the Land;" and that book also has a table of compositions of very many materials which are used for fertilizing the land.

tobacco. The potash occurs largely in the soluble form, and is free from chlorids. The tobacco stalks are somewhat richer in nitrogen than the stems, ranging from 3 to 4 per cent, and are poorer in potash—about 4 to 5 per cent of potash—though the forms of these two constituents are similar in the case of both to those contained in the stems. Both stems and stalks may be frequently obtained in the vicinity of towns where tobacco manufacture is carried on, and while more variable in their content of nitrogen and potash than the ground stems and stalks, due largely to the variations in the content of moisture, they are a useful and often a very cheap source of nitrogen and potash.

These waste tobacco products are free from deleterious compounds, and for this reason alone are highly valued as a fertilizer for tobacco, as well as for small fruits, for which they are especially useful, because of their known insecticidal value. A ton of tobacco stems of good quality contains nitrogen equivalent to the amount contained in 500 pounds of nitrate of soda, and potash equivalent to the amount contained in 200 pounds of high-grade sulfate of potash. They, therefore, possess a distinct value as a source of these constituents.

CRUDE FISH SCRAP

It frequently happens that farmers are so situated as to be able to procure directly from the fishermen the fish scrap from which dried ground fish is made.

Very large amounts are used in this crude form in our coast states, particularly New England and the middle states. This material, while chiefly valuable for its nitrogen, is not uniform in its content of fertilizing constituents, owing to the wide variation in the content of moisture, or water, which may range from as low as 25 to as high as 75 per cent. The nitrogen, of course, varies with the dry matter, and ranges from 2.5 to 8 per cent. The scrap also contains considerable amounts of phosphoric acid, ranging from 2 to 6 per cent. The fish scrap in this form, too, is less valuable as a source of nitrogen than the dried ground material, because of its coarser condition, requiring a longer time for decay.

The whole fishes (menhaden) are also used either directly or in a composted form in many instances, and the excellent results obtained are mainly due to the rapidity of decay of the nitrogenous substances. The economical purchase of these products depends largely upon the judgment of the farmer. He should be guided in determining their value by the amount of water contained in them. As they approach dryness, they become richer in the constituents of fertility. In any case, products of this sort should be obtained at so low a price per ton as to guarantee to the purchaser a maximum quantity of the fertilizing constituents for his money, when measured by the market value of the materials of known composition.

For example, if crude fish scrap, which contains as a minimum 2.5 per cent of nitrogen, can be purchased for $5 per ton, it will furnish nitrogen at 10 cents per pound, or at two-thirds the cost of this element in nitrate of soda at $48 per ton. Besides, the scrap contains phosphoric acid in good forms. At this price, the purchaser could afford to take the risk incident to the variability of the product.

WOOL AND HAIR WASTE

Wool and hair waste have already been described in part, though more largely from the manufacturers' standpoint, as representing materials that may be utilized in the manufacture of commercial fertilizers. These products may frequently be obtained in large quantities and at a low price per ton in towns in which the original products are used in manufacturing, and thus occur as wastes. Both are extremely variable in their composition, the wool, particularly, being very liable to change in this respect, owing both to the admixture of non-nitrogenous substances, such as cotton, and to the source of the waste itself, whether it consists of the clippings and tags from the original fleece, or whether it is in part the manufactured product. Different samples show a wide range in the content of nitrogen and potash, from 2 to 10 per cent in the former, and from 1 to 3 per cent in the latter. The nitrogen in the waste is extremely slow in its action in the soil, though it may be made directly useful, both as an absorbent of other wastes, as in liquid manure, and as an ingredient of composts. Excessive quantities must be applied in order to obtain a marked immediate result.

The hair waste is also variable, both on account of the content of moisture, as well as the admixture with it of other substances.

Lime often occurs as a waste product in some industries, and as such it is frequently wet and pasty, and not easily handled.

These wastes, when they can be purchased at a low price per ton,—and frequently they may be obtained as low as two or three dollars,—serve an excellent purpose as absobrents, and for use in orchards and pastures, or in gradually building up the fertility of poor soils.

POULTRY AND PIGEON MANURES

These products accumulate in considerable amounts on many farms, and are often more highly valued than their composition warrants. Many believe that they can be favorably compared with high-grade commercial fertilizers. The good results obtained are doubtless due to the readily available form in which the nitrogen exists, since the examination of these products does not show them to be particularly rich in nitrogen, or in the mineral elements of fertility, phosphoric acid and potash.

Chicken manure in the fresh state contains from 50 to 60 per cent of water, from 1 to 1.5 per cent of nitrogen, and about .50 to 75 each of phosphoric acid and potash. When brought to the air-dry state,—that is, if allowed to thoroughly dry in the air,—it contains from 10 to 20 per cent of water, and the content of the fertilizing constituents is about doubled. Thus, even in the best condition, these products compare favorably with commercial fertilizers only in their content of nitrogen. Naturally they also vary in their composition, according to the character of food used in their production.

Pigeon manure differs but little from hen manure in composition, though usually it is much drier and somewhat richer in nitrogen.

These products should be cared for, since the constituents in them serve quite as well in the feeding of plants as those contained in the more concentrated forms, though a higher estimation should not be placed upon the constituents than upon those contained in commercial forms which are quite as good.

SEWAGE

In recent years, great progress has been made in the handling of sewage from cities, and there is now a product called "sewage sludge," which is obtained in many towns, as a result of its chemical treatment. Such examinations as have been made of this product show it to be very poor in the fertilizing constituents, showing less than .20 per cent nitrogen, .05 phosphoric acid, and .05 potash. It is seldom worth the handling. The untreated sewage and garbage wastes are also obtainable in large quantities, and while the constituents contained in them act quickly, and while they are considerably richer in these than the sludge wastes, it seldom pays the farmer to handle them, owing to their offensive character and the enormous amount of useless moisture contained in them.

MUCK AND PEAT

"On many farms there are low, wet places, where the conditions are favorable for the collection of partially decayed vegetable matter. The material thus formed is called muck or peat. The thickness of the deposit, and its character, depend upon the time during which it has been formed, and the character of the climate." *

Muck is used mainly as a source of humus, and serves an excellent purpose as an absorbent in cattle stalls or yards. Fresh muck, while varying in composition according to its source, may be said to contain on the average 75 per cent of water and about .75 per cent of nitrogen, and only traces of potash, phosphoric acid and lime. Air-dry muck also varies in composition, largely owing to the different proportions of vegetable and mineral matter contained in the different products, as well as the amount of water absorbed in its dry state. The richer it is in vegetable dry matter, the richer in nitrogen. The value of the muck as a source of humus is measured by its content of nitrogen, while its value as an absorbent depends upon its content of organic matter. The value of muck for either of these purposes is further modified by the labor necessary to secure it in

* Voorhees, "First Principles of Agriculture."

a dried condition. This product is of doubtful value as a source of immediately available nitrogen.

"The usual method of securing it is to throw it out of the bed into heaps, and allow it to dry before it is used, either upon the field or in the stables. Where a muck bed exists upon a farm, it should first be studied in reference to its possible drainage. If it can be drained, it is liable to prove more useful where it lies than for the other purposes mentioned."*

KING CRAB, MUSSELS AND LOBSTER SHELLS

King crab, already described in the discussion of nitrogenous fertilizing materials (page 43), is also used in many sections of New Jersey in its green or fresh state, either directly on the land or in the form of a compost, and because of its nitrogenous character, and its tendency to rapid decay, is a valuable source of this element, of which, in its fresh state, it contains from 2 to 2.5 per cent.

In certain sections of the coast states farmers have access to an almost unlimited supply of mussels, which may be had for the carting. Analyses made at the New Jersey Experiment Station show them to contain, in their natural state, a very considerable amount of fertilizing constituents, the nitrogen reaching .90 per cent, the phosphoric acid and potash .12 and .13 per cent, respectively, and the lime 15.84 per cent. The organic portions of the mussels decay rapidly,

* "First Principles of Agriculture.'

and serve as a fairly good source of nitrogen; and since this product is twice as rich in this constituent as average yard manure, it is well worth the expense of handling.

Lobster shells are also a waste of considerable importance, since they can be obtained at a very low cost, often for the carting. They contain, in their dry state, an average of over 4 per cent of nitrogen, 3 per cent of phosphoric acid, and about 20 per cent of lime.

These products, of course, are not to be depended upon for the entire supply of constituents to crops; they are mainly useful in improving the natural quality of the soil by building it up in vegetable matter containing nitrogen. Their best use requires the addition of the minerals from other sources.

SEAWEED

In the coast states, seaweed is held in high esteem as a manurial product. In Connecticut, Rhode Island and New Jersey, the use of seaweed as a fertilizer is very general. In Rhode Island the annual value of the manure from this source has been estimated to be as high as $65,000.*

In its fresh state it contains from 70 to over 80 per cent of water, and is thus economically used in that condition only near the shore. It is frequently spread out in thin layers and dried, in which condition it can be profitably transported considerable distances.

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* Bulletin 21, Rhode Island Experiment Station.

Seaweeds of different kinds differ in their content of the fertilizing constituents. Certain of them show a relatively high content of nitrogen, and others of potash, and they furnish more of these constituents than of phosphoric acid. All seaweeds contain considerable salt, though if they are not used in too large quantities, no serious injury is liable to follow. In fact, salt in some instances is a substance of considerable indirect manurial value. Seaweed manure is certainly worthy of consideration where it can be obtained in quantity for the expense of carting.

WOOD ASHES AND TAN-BARK ASHES

Wood ashes contain potash in one of the best forms, and were, in the early history of manuring, practically the only semi-artificial source of this element. At the present time, however, the supply is limited, and the average content of potash in the commercial article is much lower than was formerly the case.

The pure ash is not a uniform product. That from the different varieties of wood varies in composition. As a rule, the softer woods are poorer and the hard woods richer in potash than the average, the range being from 16 to 40 per cent.

"Ashes also contain lime in large quantities, while phosphoric acid is contained in much smaller quantities. Wood ashes, as usually gathered for market, however, contain very considerable proportions of moisture, dirt, etc., which cause a variability in composition not due to the character of the woods from which they are derived. The average analysis of commercial wood ashes shows them to contain less than 6 per cent of potash, 2 of phosphoric acid and 32 per cent of lime. Leached wood ashes contain on the average 30 per cent of moisture, 1.10 of potash, 1.50 of phosphoric acid and 29 per cent of lime.

"Ashes are probably one of the best sources of potash that we have, so far as its form and combination are concerned, being in a very fine state of division, and in such a form as to be immediately available to plants. Ashes also have a very favorable physical effect upon soils, the lime present, of course, aiding in this respect. Canada is now the main source of wood ashes, the substitution of coal for wood making the supply in this country for commercial purposes very limited. Owing to the variability of this product, it should always be bought subject to analysis, and to a definite price per pound for the actual constituents contained in it, which should not be greater than the price at which the same constituents could be purchased in other quickly available forms." *

Tan-bark ashes are much poorer in fertilizing content than those obtained from the regular commercial sources of supply. They seldom contain more than 2 per cent of potash, 1.5 per cent of phosphoric acid and 33 per cent of lime.

Lime-kiln ashes are obtained in the burning of lime with wood, and are also relatively poor in potash, containing less than 1.5 per cent of potash and 1 per

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* "First Principles of Agriculture."

cent of phosphoric acid. The product is, however, much richer in lime than the average wood ashes, often containing as high as 50 per cent of calcium oxide.

COAL ASHES

It is believed by many that coal ashes, because of their favorable effect upon many soils, also possess considerable fertilizing value, whereas analyses show them to contain only traces of soluble potash and of phosphoric acid. The good results from their use is undoubtedly due to their beneficial indirect effect in improving the physical character of heavy soils.

COTTON-HULL ASHES

Cotton-hull ashes were formerly made in considerable quantities in the southern states, where the hulls were used as fuel in the furnaces connected with gins and presses. This product, while exceedingly variable in composition, is usually very rich in potash, besides containing a very considerable amount of available phosphoric acid. A large number of samples have been examined at the Connecticut Experiment Station,* and the results of the study show that no average percentage composition is a sufficient guide as to their quality. They can be safely purchased only on the basis of their actual composition. They are an excellent source of potash and phosphoric acid,

*Annual Report for 1897 (Part II.), Connecticut Experiment Station.

because free from chlorids and other deleterious substances, but are not so rich in lime. They are especially useful for such crops as are injured by the presence of chlorids.

MARL*

Marl may contain one or more of the constituents, phosphoric acid, potash and lime. Shell marls are usually very rich in lime, but contain only traces of phosphoric acid and potash. The green sand marls of New Jersey often contain very considerable amounts of phosphoric acid and potash, though they vary widely in composition. They contain, on the average, 2.20 per cent of phosphoric acid, 4.70 per cent of potash, and 2.90 per cent of lime. These constituents, particularly the potash, are, as a rule, slowly available.

Marl, however, is an important amendment to soils, not only because of its content of mineral constituents, but because these constituents are associated with products that exert a very favorable mechanical effect upon soils. Large areas of land in the state of New Jersey, formerly unproductive, chiefly because of physical imperfections, have been made very productive mainly through the application of marl.

The use of marl is now less general than when the fertilizing constituents from artificial sources were dearer, and when the labor of the farm was more abundant and cheaper. The quicker effect of more soluble fertilizer constituents has had an influence in

* "First Principles of Agriculture."

reducing the use of marl where quick returns are desirable. Where farmers have deposits of marl upon their own farms, or within short distances of them, and can secure it at a low price per ton, its application is a desirable method of improving land.

The results from the use of marl are frequently due quite as much to the improvement given to the physical condition of soils as to the increase in fertility furnished by the essential mineral constituents. Marl may be carted and spread upon the land when other work of the farm is not pressing, thus making it possible to get a considerable addition of fertility at a small expense.

LIME

"Lime, as it is generally known, is an oxide of calcium, and is produced by burning limestone, or carbonate of lime. The lime loses the carbonic acid when burned in the kilns, and the oxide of lime remains behind; this is termed 'burned lime,' 'quicklime,' or 'stone lime,' and is usually slaked before it is applied to the soil. This is done by adding water, which the lime absorbs, and falls to a powder. Slaked lime, also called caustic lime, is a calcium hydrate.

"The more completely limestone is burned, the better the quicklime, and the more completely it slakes. We have, when we speak of lime, three forms: limestone, quicklime and slaked lime, each differing from the other in composition.

"Quicklime absorbs moisture, and slakes when exposed to the atmosphere. Lime thus slaked is called 'air-slaked lime,' and is usually less completely changed to a hydrate than when water is added. Quicklime also absorbs carbonic acid from the air, and changes back to the limestone form. Lime in the carbonated form, if finely pulverized, is better for liming light lands than the caustic lime, while for heavy lands, the caustic is preferable to the carbonate." *

What is termed "marble lime" is made from pure limestone, and the burned lime thus obtained is practically pure oxide of lime. Limestone, so called, is not always pure. It is a mixture of lime and magnesia, in which case it is the mineral "dolomite," and is termed "magnesian limestone." A very large quantity of the lime used in the eastern states is the magnesian form. The burned lime from the magnesian limestone contains from 50 to 60 per cent of calcium oxide, and 30 per cent or over of magnesium oxide. In some instances, the magnesia is of value, though it is rather inert in its effect, and is less useful than the lime. A safe rule in the purchase and use of lime is to adjust the price to the proportionate percentage of actual lime present, or practically in the ratio of 10 to 7

Oyster shells are nearly pure carbonate of lime, and oyster shell lime, while practically pure lime, so far as this element is concerned, is usually mixed with

* "First Principles of Agriculture."

more or less dirt and other impurities, and is, therefore, not as rich in lime as that derived from pure limestone.

"Gas lime is also frequently used as manure; in gas works, quicklime is used for removing the impurities from the gas. Gas lime, therefore, varies considerably in composition, and consists really of a mixture of slaked lime, or calcium hydrate, and carbonate of lime, together with sulfites and sulfides of lime. These last are injurious to young plant life, and gas lime should be applied long before the crop is planted, or at least exposed to the air some time before its application. The action of air converts the poisonous substances in it into non-injurious products. Gas lime contains on an average 40 per cent of calcium oxide, and usually a small percentage of nitrogen."*

Where it can be used to advantage, its cost should, as in the case of the other, be based on the proportion of actual lime present.

Gypsum is a sulfate of lime, containing water in combination. Pure gypsum contains 32.5 per cent of lime, 46.5 per cent of sulfuric acid, and 21 per cent of water.

Plaster of Paris is prepared from gypsum by burning, which drives off the water it contains.

Gypsum, like other forms of lime, furnishes directly the element calcium, and also exerts a favorable solvent effect upon the soil. It was formerly used in large quantities, particularly for clover, and it is believed

* "First Principles of Agriculture."

that its favorable effect was due, not so much to the direct addition of lime, as to its action upon insoluble potash compounds in the soil, in setting free potash. Thus the application of plaster caused an increase in crop, because of the potash made available.

We have in the eastern states two main sources of gypsum, namely, Nova Scotia and Cayuga, N. Y. Nova Scotia plaster contains on the average over 90 per cent of sulfate of lime, and is, therefore, purer than that obtained from Cayuga, which often shows as low as 65 per cent of pure sulfate; the latter, however, frequently contains appreciable amounts of phosphoric acid.

In many places it is possible to obtain plaster which is a waste in the manufacture of phosphorus. This waste contains the plaster in a precipitated form, and frequently also contains considerable amounts of phosphoric acid. The disadvantage of this waste lies in the fact that it is frequently wet and lumpy, and thus not easily handled and distributed. Its advantage lies in its content of phosphoric acid, which ranges from 1.5 to 2 per cent, though as a rule, it can be purchased at a lower price per ton than that from the regular sources.

AGRICULTURAL SALT

Agricultural salt, which is chiefly common salt, is also frequently used as a manure. "It supplies no essential plant-food constituents, and its value is still a disputed point, though it is admitted that where its use is favorable, it is due to indirect action in aiding the decomposition of animal and vegetable matter, increasing the absorbing power of soils, and, by its reaction with lime, acting as a solvent for phosphates."*

There would seem to be no good reason for paying from $4 to $6 per ton for this substance, when practically the same effect can be obtained from the salt contained in the crude potash salt, kainit, one-third of the total weight of which is common salt. This, too, may be had free of charge, or for the handling, as the market price of the kainit is based upon its content of potash.

POWDER WASTE

Powder waste also consists largely of common salt, though frequently containing appreciable percentages of nitrogen in the form of a nitrate. Its use can only be recommended when it can be obtained at a low price per ton, or for the handling, and upon soils that show a marked benefit from its application.

GREEN MANURES

A great deal of misconception is prevalent concerning the value of what are termed "green manures." These do possess a distinct value, and a proper understanding of their place in farm management will undoubtedly result in their larger and better use, and

* "First Principles of Agriculture."

in the consequent improvement of agricultural practice. By green manures is meant any crop that is grown primarily for the purpose of improving the soil, and not for the harvested product.

"Nitrogen Gatherers" and "Nitrogen Consumers"

In this sense any crop will serve as a green manure, yet certain crops possess a greater value than others for this purpose, because they are able to obtain certain of their constituents from sources not accessible to all crops. In other words, the one class of plants can obtain the nitrogen necessary for their growth from the air, as well as from the soil; the other, as far as we now know, can obtain it only from the soil. These two groups of plants are, therefore, classified as "nitrogen gatherers" and "nitrogen consumers."

The nitrogen gatherers belong to the legume, or clover family, and do not depend solely upon soil sources, but rather gather the element from outside, and thus do not reduce the content of soil nitrogen. Distinguishing features of the plants of this order are that the seeds are formed in a pod or legume, and that they have the power of acquiring at least a large part of their nitrogen from the air. These, when plowed down as green manures, add directly to the crop-producing capacity of soils poor in nitrogen, because increasing their content of this element. In order that the plant may obtain its nitrogen from the air, however, the soil must originally contain, or must be inoculated with, a specific germ, the presence of which is manifested by the growth of nodules upon the roots, through which it is believed the nitrogen is obtained. Most well-tilled soils contain these germs in abundance.

The "nitrogen consumers" are those which can obtain their nitrogen only from the soil; these consume the nitrogen existing there, and their growth and removal exhausts the soil of this element.

Notwithstanding the very great advantages of the "nitrogen gatherers" as green manures, they cannot be solely depended upon to increase the crop-producing capacity of the soil. That is, soils that are very poor, both in their content of nitrogen and of the essential mineral elements, cannot be made very productive by the sole use of green manures. In fact, the green manure crops cannot be grown with advantage unless they are supplied with an abundance of the mineral elements, phosphoric acid and potash; hence helpful green manuring for such soils must be preceded and accompanied by liberal fertilization with the minerals, phosphoric acid, potash and lime. With these added in sufficient amounts, and with the specific bacteria present in the soil, their use results not only in the addition of nitrogen to the soil, which may be useful for other plants, but by the accumulation of vegetable matter, which improves the physical character, usually imperfect in this class of soils. The nitrogen thus introduced into the soil is also in a very good form; that is, it has a tendency to decay rapidly and thus supply the needs of other plants, but the helpful additions to the soil are limited to organic matter and nitrogen. The mineral constituents absorbed by the crop may be more available for other crops, but they formerly existed there. No additions of these are made by the growing of the crop; hence no system of green manuring can be made successful unless there is a previous abundance in the soil of the mineral elements, or unless these have been directly applied.

The Most Useful Crops

Of the crops most useful for green manures, red clover, crimson clover, cow peas and soja beans are first in order; first, because of their capacity to gather nitrogen, and second, because of their period and time of growth. Whether these plants will gather all of the nitrogen of their growth from the air, other conditions being good, depends upon whether the soil is rich or poor in nitrogen, since it has been shown that these plants will gather at least a part of the nitrogen from the soil in preference to that from the air, unless they are starved in respect to soil nitrogen. The amounts that may be gathered from the air, therefore, are not measured by the total content of nitrogen contained in the plant grown (which may, in the case of good crops, amount to as much as 200 pounds per acre, sufficient for the use of several good crops of wheat, or other cereal grains), but apparently by the poverty of the soil in this element. The fact that an accumulation of nitrogen does occur has been distinctly shown, and their continuous growth, therefore, would have a tendency to over-enrich the soil in this constituent, unless accompanied by an abundant supply of minerals, particularly in the improvement of light lands and in orchards and vineyards, for which their right use is very beneficial.

Experiments conducted in this as well as other countries, show that the nitrogen so gathered and stored in the soil may be readily obtained by cereal and other nitrogen-consuming crops. In experiments conducted by the New Jersey Experiment Station, on a poor, sandy soil, in which the mineral elements, phosphoric acid, potash and lime, only, were added, a crop of cow peas gathered, in the roots and tops, 75 pounds of nitrogen, equivalent to that contained in 470 pounds of nitrate of soda, which when turned under was capable of feeding a rye crop with sufficient nitrogen to produce a most excellent crop, quite as good as that grown on land long under cultivation and well-manured. Further experiments conducted with crimson clover* show that the nitrogen gathered was capable of supplying the needs of fruit trees quite as well as when the nitrogen was applied in the immediately available form contained in nitrate of soda.

If it were necessary to do so, numerous experiments might be cited to show that the nitrogen is gathered from the air by these plants, and that it is capable of providing that required for those other crops which can obtain it only from the soil.

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*Annual Report for 1894, New Jersey Experiment Station.

Green Manure Crops that Consume the Nitrogen in the Soil

In addition to the legumes, other crops are used as green manures, chief of which are rye, buckwheat and mustard, not because they are capable of directly gathering nitrogen, but because their period and time of growth are such as frequently to enable them to serve a very useful purpose in preventing losses in fertility. In the growth of these crops, however, the only real addition to the soil is the amount of non-nitrogenous organic matter contained in them. The nitrogen gathered is in direct proportion to the amount contained in the soil and the relative feeding capacity of the plant. The nitrogen is not obtained from the atmosphere, and the soil has not accumulated nitrogen by virtue of their growth, and is not richer in this element, except in so far as by their growth they prevent the escape of readily available nitrogen into the drainage waters. The nitrogen gathered is "soil nitrogen," and its conversion into a crop simply results in changing its form and place. The specific use of these crops, therefore, so far as directly contributing to the fertility of the soil is concerned, is to prevent the possible loss of nitrogen and other constituents by leaching, which is more liable to occur on uncropped soils, though they further contribute toward soil improvement by accumulating stores of non-nitrogenous vegetable matter.

These crops, too, in order that they may produce largely, must be freely supplied with the mineral elements, as well as with nitrogen in some form, and cannot be regarded as a substitute for the leguminous crops, or as a substitute for commercial fertilizers in the permanent improvement of the soil, in the sense that they actually contribute to its content of fertility elements,—an opinion apparently held by many who have observed the good results that often follow their use.

Furthermore, these crops contain, as a rule, less nitrogen, and besides, that contained in them is apparently less available than the nitrogen contained in the green manures from the leguminous crops. In their growth, too, they appropriate the immediately available nitrogen of the soil, and convert it into the less available organic form; hence the crop that follows is frequently unable to obtain its food as readily as would have been the case, provided the green manure crop had not been grown. Therefore, while the practice of using green manures is a desirable one when properly understood, it should not be regarded as a means by which soils may be directly enriched, except in the case of the plants of the legume family, where nitrogen is really added to the soil. In the case of all other crops, the benefit is indirect, and is in proportion to the amount of minerals added.

CHAPTER VII

PURCHASE OF FERTILIZERS

COMMERCIAL fertilizers, in the form in which they are obtained by farmers, are made up of varying proportions of one or more products from each class of fertilizing materials described. That is, every manufacturer is obliged to go to these sources of supply, whatever may be the name given to the finished product or mixture. Hence the fertilizing materials described are not regarded as commercial fertilizers in the same light as those which they are able to purchase under brand names from their local dealers. In the first place, a specific fertilizing material, as distinct from a manufactured fertilizer, contains, as a rule, but one of the essential fertilizing elements, and its use under average conditions would be far different from one which contains two or all of the essential fertilizing elements. The materials, therefore, are classed as nitrogenous, phosphatic and potassic, according to whether the material contains nitrogen, phosphoric acid or potash as its chief or its only constituent element; and these different classes, too, may be again sub-divided into two distinct groups, the first including "standard," or high-grade materials, and second, "general," or low-grade materials. This classification is of the utmost importance.

STANDARD HIGH-GRADE MATERIALS

Nitrate of soda, sulfate of ammonia, and dried blood are, for example, standard or high-grade nitrogenous materials, and belong to the first group. They are "standard" because they do not vary widely in their composition. A definite quantity can be depended upon to furnish not only practically the same amount of the specific constituent, but to furnish it in a distinct and definite form, which is identical, from whatever source derived. For example, commercial nitrate of soda does not vary materially in its composition, and the nitrogen in it is always in the form of a nitrate. The same is true of sulfate of ammonia. One ton will furnish practically as much nitrogen as any other ton, and it is always in the form of ammonia. It is also practically true of high-grade dried blood. Each lot contains this specific form of organic nitrogen, and will always decay at practically the same rate, if used under the same conditions. They are also high-grade products because they are richer in the constituent element, nitrogen, than any other, and because this element is immediately or quickly available.

The South Carolina, Florida and Tennessee rock phosphates differ from the nitrogenous materials mentioned, inasmuch as, in their raw state, they are not directly useful as fertilizers,—they are not sources of available phosphoric acid. Hence the standard supplies of phosphoric acid are derived from these materials after they are manufactured into superphosphates. The various kinds of these may be regarded as high-grade in the sense that they always possess a high content of available phosphoric acid. They are standard, too, not only because of this, but because they do not vary widely in their composition. A definite amount from each class can be depended upon to furnish practically the same amount of available phosphoric acid. For example, a ton of South Carolina rock superphosphate, from whatever manufacturer obtained, will not vary widely in its content of phosphoric acid, and will always act in the same way under similar conditions. The various German potash salts are also standard and high-grade, since the composition of each grade and kind is practically uniform in its content of potash, which will always act in the same way under the same conditions, and since they are richer in the specific element, potash, than other potassic compounds suitable for the manufacture of fertilizers.

These various standard, high-grade products, when used in the manufacture of fertilizers, make what are called "chemical fertilizers," because they are really crude chemical compounds, and furnish the particular fertilizer elements in their most concentrated and active forms.

FERTILIZING MATERIALS WHICH ARE VARIABLE IN COMPOSITION

The products which are included in the second group differ from the others, in that they not only vary in their content of the specific constituent, or in their composition, but they are also variable in the sense that the constituents contained in them do not show a uniform rate of availability. For example, ground bone varies in its composition owing to its source and the method of treatment, and the availability of the constituents, nitrogen and phosphoric acid, also varies because of these conditions, and because of its mechanical condition or degree of fineness. Different samples of bone derived from the same source, treated in the same way, and ground to the same degree of fineness, would be regarded as standard, but because these conditions differ, bone from different sources cannot be depended upon to act in the same way under the identical climatic and soil conditions. This is also true of tankage, which varies, not only in the total amount of the constituents contained in it, but in the proportion of its two chief constituents, nitrogen and phosphoric acid, and in the rate at which they become available to plants. In this class belong, in addition to the bone and tankage, ground fish, and the various miscellaneous products. They cannot be depended upon, either in respect to their composition or their availability of the essential constituents—important advantages possessed by the standard products.

HIGH-GRADE AND LOW-GRADE FERTILIZERS

The fertilizers manufactured from these two classes of raw materials will, therefore, differ. Those made from the first class are always high-grade, both in reference to the quality and quantity of the constituents that may be contained in a mixture. Those manufactured from the second group are not high-grade, so far as the form of the constituent is concerned, though they may be high-grade in the sense that they contain large amounts of them. In the manufacture of fertilizers, too, as a rule, all three of the essential constituents are introduced, and the buying of a fertilizer is really the buying of the three constituents, nitrogen, phosphoric acid and potash. Hence, the more concentrated the product, or the richer it is in these constituents, the less will be the actual cost of handling per unit of the constituents desired, and the higher the grade of the materials used, the greater the proportionate activity of the constituents.

The "Unit" Basis of Purchase

In commercial transactions in fertilizing materials, two systems of purchase are used. The first is known as the "unit" system, in which case the quotations, or prices are based on the unit. A unit means one per cent on the basis of a ton, or 20 pounds. For example, a unit of available phosphoric acid means 20 pounds, and a quotation of $1 per unit would be equivalent to a quotation of 5 cents per pound. In the trade, sales are always made on this basis. The system is also applied to such nitrogenous products as blood, meat, hoof meal, concentrated tankage, etc. The price is fixed at so much a unit of ammonia.

This system is probably the most perfect, and certainly cannot but be satisfactory to both the dealer and the consumer. It results in the consumer receiving exactly as much as he pays for, and the producer is paid for exactly what he delivers. The number of units in each material sold is fixed in each case by the chemist to whom the samples are referred..

The "Ton" Basis of Purchase

The other method of purchase is known as the "ton basis," and is used almost exclusively in the sale of other materials than the standard products mentioned, and manufactured fertilizers. This system works well with standard high-grade products, since the ton price is, in this case, a fair guide as to the cost of the constituents, though it cannot be as satisfactory as the other, since even the best materials may vary sufficiently to cause a difference in actual cost of the constituents, even though the price per ton remains unchanged. In this method, the products are usually accompanied by a guarantee, the purpose of which is to indicate the minimum amount of the constituents contained in the material.

The Necessity of a Guarantee

In the purchase of mixtures, consumers should demand that they be accompanied by a guarantee, because they are unable to determine the kind and proportion of the different materials entering into the mixture, either by its appearance, weight or smell. In mixing, too, an opportunity is afforded for disguising poor forms of the constituents, particularly nitrogen. That is, in a mixture of nitrogenous materials, potash salts and superphosphates, it would be a difficult matter to determine, by mere physical inspection, the proportion of the nitrogen which had been supplied in the form of horn meal and of blood, and the statement of the manufacturer on this point would be valuable in proportion to his reliability. The fact that in mixtures it is impossible for the consumer to distinguish or determine the proportions, amounts or kinds of the constituents is so fully recognized that it has resulted in the enactment of laws in most states, which require that manufacturers or dealers in fertilizers shall state the actual amounts of the different constituents contained in their products, as well as the sources from which they were derived, and which fix a penalty for any failure to comply with the law in this respect. A chemical control is in these cases provided for, and it has been of great service both to the good manufacturers, because it tends to reduce the number of low-grade brands which would naturally come into competition with them without such protection, and to the consumers, because it protects them from fraudulent products.

Laws Alone do not Fully Protect

Laws alone, however, are not sufficient to fully protect the farmer in this respect. He must possess, in addition, a knowledge of what constitutes a good fertilizer, and must be able to determine from the analysis whether there is a proper relation between the guarantee and the selling price, and whether the materials that have been used are of good quality. The fact that there is a very decided lack of the right sort of intelligence on this point, is shown by the results of the work of the different fertilizer control stations. These demonstrate clearly that farmers do, in many cases, pay exorbitant prices for their fertilizer constituents, not because the manufacturer did not sell what he claimed to sell, but because the price charged by the dealer was far in excess of that warranted by the guarantee. For example, it has been repeatedly shown that of two farmers in the same neighborhood, the one who studies the matter and understands the relation of guarantee to selling price, may pay 15 cents per pound for his nitrogen, while the other, who does not study the matter, buys on the ton basis, and does not know that there should be such a relation between the two, may pay 30 cents per pound for the same quality of the same constituent. This may be illustrated by the following examples:

Two brands are offered, made up from the same kind and quality of materials. No. 1 is guaranteed to contain:

Nitrogen	1 %
Phosphoric acid (available)	6 %
Potash	1 %

and sells for $20 per ton; and No. 2 is guaranteed to contain:

Nitrogen	4 %
Phosphoric acid (available)	8 %
Potash	2 %

and sells for $22 per ton. The farmer who buys on the ton basis, or is guided only by the ton price, will be induced to purchase the No. 1 brand, because by so doing he apparently saves $2 per ton. The one who studies the relation of guarantee to selling price will purchase the No. 2 brand, because he finds, from a simple calculation, that it furnishes the constituents at just one-half the cost per pound of the No. 1 brand, notwithstanding the higher ton price, which is shown by the following calculation:

No. 1

		Lbs. per ton	*Cts. per lb.*	
Nitrogen	1% × 20 =	20 @	30 =	$6 00
Phosphoric acid (available)	6% × 20 =	120 @	10 =	12 00
Potash	1% × 20 =	20 @	10 =	2 00
				$20 00

No. 2

		Lbs. per ton	*Cts. per lb.*	
Nitrogen	4% × 20 =	80 @	15 =	$12 00
Phosphoric acid (available)	8% × 20 =	160 @	5 =	8 00
Potash	2% × 20 =	40 @	5 =	2 00
				$22 00

In reality, the fertilizer at $22 per ton is cheaper than the one at $20 per ton.

Cost per pound of constituents in:

	No. 1	No. 2
Nitrogen	$0 30	$0 15
Phosphoric acid (available)	10	05
Potash	10	05

This may seem an extreme case, but it is well within the facts, which may be ascertained by consulting the bulletins on fertilizer analyses, as published by the different states.

Method of Statement of Guarantee Sometimes Misleading

Guarantees, too, are sometimes rendered confusing to the purchaser, because of the method of their statement, though the different methods used are, in one sense, entirely legitimate, because the terms used are in accordance with the facts. From a chemical standpoint, at any rate, it is quite as legitimate to guarantee the percentage of phosphoric acid equivalent to bone phosphate of lime, as it is to guarantee the percentage of actual phosphoric acid. It is because the consumer believes that the "equivalent" in combination means that he is obtaining something more than when actual constituents only are guaranteed, that he is led to purchase more freely, or to pay a higher price. Nitrogen may be properly stated in its equivalent of ammonia, phosphoric acid in its equivalent of bone phosphate, and potash in its equivalent of muriate of potash, and it is the business of the purchaser to understand the relations of the two methods of statement, in order that he ıay not be misled in his purehases. The following ıble shows the terms used, their equivalents, and ıe faetor to use in multiplying, in order to convert ıe one into the other:

convert the guarantee of			Multiply by
mmonia	into an equivalent of	Nitrogen	0.8235
itrogen		Ammonia	1.214
itrate of soda		Nitrogen	0.1647
one phosphate		Phosphoric acid	0.458
hosphoric acid		Bone phosphate	2.183
uriate of potash		Actual potash	0.632
ctual potash		Muriate of potash	1.583
ılfate of potash		Actual potash	0.54
ctual potash		Sulfate of potash	1.85

Discussion of Guarantees

It is shown in this table that, in order to convert nmonia into its equivalent of nitrogen, the percent-ge of ammonia should be multiplied by 82 per eent, : divided by the faetor 1.214, beeause ammonia is 2 per eent nitrogen, and beeause one part of the itrogen is equivalent to 1.214 parts of ammonia.

In order to determine the eost per pound of nitro-en in dried blood, which is quoted, for example, at 2 per "unit,"—20 pounds of ammonia,—the unit 20 ounds is multiplied by 82 per eent, which gives 5.40 as the pounds of nitrogen offered for $2, or 2.14 cents per pound.

Bone phosphate of lime is, in round numbers, 46 er cent aetual phosphorie aeid. Henee, by multi-lying the bone phosphate by 46 per cent, the per cent of actual phosphoric acid is obtained. Ground bone, for example, guaranteed to contain from 48 to 52 per cent bone phosphate, contains, in round numbers, 22 to 24 per cent of phosphoric acid. Sulfate of potash is 54 per cent, and muriate of potash is 63 per cent "actual" or potassium oxide, respectively. Hence, to convert the percentages of these forms into their equivalents of "actual," they are multiplied by the factors given.

In such raw materials as nitrate of soda, muriate of potash, and sulfate of potash, a method of guaranteeing is used which is based upon their purity as chemical salts. That is, when pure they contain 100 per cent of the specific salt, and the guarantee accompanying the commercial product is simply a statement indicating their purity For example, when nitrate of soda is guaranteed to contain from 95 to 97 per cent pure nitrate, it means that it is 95 to 97 per cent pure, or that 3 to 5 per cent of the substance consists of impurities ; it is not absolutely pure nitrate of soda. Hence, the minimum percentage of nitrogen guaranteed is 15.65 per cent, or 95 per cent of 16.47, the per cent or pounds per hundred of nitrogen contained in pure nitrate of soda. When muriate of potash is guaranteed 80 per cent muriate, it means that 80 per cent of the salt consists of pure muriate of potash, and because pure muriate of potash contains 63 per cent of actual potash, or potassium oxide, the actual content of potash is derived by multiplying the 63 per cent, which the pure salt contains, by 80 per cent, and the result, 50.5 per cent, represents ıe amount of actual potash guaranteed. Sulfate of otash, high-grade, is usually guaranteed to be 98 er cent pure, and since pure sulfate of potash conıins 54 per cent of actual potash, the content f actual potash, or potassium oxide, guaranteed is ›und by multiplying the 54 per cent by 98 per cent. he following illustrations show the two methods of ;ating the guarantees of raw materials and of mixed ›rtilizers :

Raw Materials

GUARANTEE ON BASIS OF PURITY

itrate of soda .	98 %, or containing		98 %	pure	nitrate
uriate of potash	80 %,	" "	80 %	"	muriate
ılfate of potash .	98 %,	" "	98 %	"	sulfate
ainit	25 %,	" "	25 %	"	sulfate

GUARANTEE ON BASIS OF ACTUAL CONSTITUENTS

itrate of soda, total nitrogen	16.00 %
uriate of potash, actual potash	50.50 %
ılfate of potash, actual potash	53.00 %

Mixed Fertilizers

GUARANTEE ON BASIS OF EQUIVALENTS IN COMBINATION

itrogen (equivalent to ammonia)	3 to 4 %
vailable phosphoric acid (equivalent to bone phosphate of lime)	18 to 22 %
otash (equivalent to sulfate of potash)	10 to 12 %

GUARANTEE ON BASIS OF ACTUAL CONSTITUENTS

itrogen (total)	2.50 to 3.25 %
hosphoric acid (available)	. 8.00 to 10.00 %
otash (actual)	. 5.50 to 6.50 %

The guarantees of the raw materials mean practically the same in the first as in the second case. In the first, the percentages given indicate the purity of the chemical salt; while in the second, the figures given indicate the actual content of the constituent contained in the chemical salt. In large commercial transactions, the sales are frequently made on the basis of certain purity percentages; as, for example, muriate of potash is sold at so much per ton on the basis of 80 per cent muriate. If the analysis shows it to contain less than 80 per cent, then the price paid per ton is less in proportion to such deficiency. If it is shown to contain more than 80 per cent, the purchaser pays for the excess at the same rate. In round numbers, a ton of muriate on the 80 per cent basis contains 1,000 pounds of actual potash; if the price is $40 per ton, the cost per pound is 4 cents. If analysis shows but 900 pounds instead of 1,000, the price paid per ton, at 4 cents per pound, is $36. If, on the other hand, it is shown to contain 1,100 pounds, the price paid per ton is $44. Purchase made when this method of guaranteeing is used is practically equivalent to the "unit" basis, though, as already stated, unless it is thoroughly understood, it is likely to be misleading.

What has been said of the different statements of guarantees of the raw materials, is also true in the case of the mixed goods. In the first, the percentages of the elements that are given represent the amounts when they exist in combination with other elements: nitrogen, as ammonia; phosphoric acid, s bone phosphate, and potash, as sulfate. While n the other, the percentages given indicate the content of the actual constituents: namely, nitrogen, hosphoric acid and potash.

The Advantages and Disadvantages of Purchasing Raw Materials and Mixed Fertilizers

In the purchase of fertilizers, therefore, two methds may be adopted: First, the buying of fertilizng materials, as distinct from fertilizers, which furish single constituents like the standard high-grade roducts, or which furnish one or two of the contituents, like ground bone, tankage, fish, and the misellaneous products; these are called "incomplete," ecause they do not furnish all of the three essential onstituents. Second, the purchase of the mixed nanufactured brands, which contain all of the three ssential constituents, nitrogen, phosphoric acid, and otash, which are prepared to meet the demands of ifferent soils and crops, and are called "complete," ecause containing all of the essential manurial contituents, or those liable to be lacking in any soil. The relative advantage of these different methods f purchase depends, first, upon the cost of the contituents, and second, upon the use that is to be nade of them.

It may be urged that, on theoretical grounds, there re no good reasons why nitrate of soda, sulfate of mmonia, dried blood, superphosphates and potash ompounds should be mixed, as the manufacture of these does not improve or change the quality of the constituents—it consists chiefly in simply grinding, mixing and bagging. There are, however, advantages and disadvantages in both methods of purchase, the chief of which are stated below

The advantages in the purchase and use of raw materials are:*

1. A better knowledge of the kind and quality of plant-food obtained. That is, these products as a rule possess characteristics which distinguish them from others and from each other, and they are more likely to be uniform in composition than mixtures.

2. It enables the use of one or more of the constituents as may be found necessary, thus avoiding the expense of purchasing and applying those not required for the particular crop or soil. The farmer is also enabled to adjust the forms and proportions of the various ingredients to suit what he has found to answer the needs of his soil or crop.

3. A saving in the cost of plant-food, since in their concentrated form, the expenses of handling, mixing and rebagging are avoided.

The chief disadvantages are:

1. The materials are not generally distributed among dealers, and thus not so readily obtained.

2. It is difficult to spread evenly and thinly products of so concentrated a character, particularly the chemical salts, which, unless great care is used, may

* "First Principles of Agriculture.'

ıjure by coming in immediate contact with the roots f plants.

3. The mechanical condition or degree of fineness less perfect than in the manufactured products.

The advantages in the purchase and use of complete manures are:

1. They are generally distributed, and can be purıased in such amounts and at such times as are conenient.

2. The different materials may be well proporoned, both as to form of the constituents and their lative amount for the various crops.

3. The products are, as a rule, finely ground and ell-prepared for immediate use.

The chief disadvantages are:

1. That it is impossible to detect in a mixture hether the materials are what they are claimed to be.

2. That without a true knowledge of what constiıtes value, many are led to purchase on the ton basis, ithout regard to the quantity and quality of the lant-food offered.

There is no question that the actual cost of ıe constituent is less when purchased in the fertilizıg material than in the manufactured brand, as not ıly the expenses of mixing and bagging are saved, ıt the cost of handling the product per unit of lant-food is much less in the highly concentrated aterials than in mixtures made up of both classes fertilizing materials.

In the purchase of fertilizers by the second method, ıe cost of the constituents is not only higher on the average, but the variations in their cost are very much greater, due to the differences in the charges made by the different manufacturers for handling and selling their products.

HOME MIXTURES

The fact that fertilizing materials are a regular article of trade, and may be purchased as such, and the fact that a complete fertilizer, so-called, is really only a mixture of the various manufactured fertilizing materials, has suggested the use of what are called "home mixtures,"—that is, their mixing by the farmer himself. This has proved to be very satisfactory under proper conditions, since, as already stated, the cost of the constituents is much less than if secured in the average manufactured brand (often from 25 to 50 per cent), and the mixing can be performed by the regular labor of the farm, and thus not add directly to the cost of the constituent.

This matter of home mixtures has been carefully studied by a number of the experiment stations, notably Connecticut, Rhode Island and New Jersey. The results of their studies are published in their regular reports, and show that the materials can be evenly mixed on the farm, that the mechanical condition is good, and that the results obtained from their use are entirely satisfactory. It must be remembered, however, that whatever method of purchase is used, the object should be to obtain the kind and form of constituent best suited to the conditions ıder which they shall be used, at the lowest price ɘr pound.

In any method of purchase which contemplates ıe use of a mixture, care should be taken in the ·lection of the brand or of the formula, since in ixtures as well as in the raw materials, there are vo grades, the high-grade and the low-grade—.gh-grade in the sense that in quality the conituents are all good, and in the sense that maxium quantities are contained; and second, high-:ade only in that constituents of good quality ·e furnished. They may be low-grade in the sense ıat both the quality and amount of constituents ›ntained are low, and also in the sense that only ıe quality of the constituents is low, the quanty being sufficiently high.

Formulas

The following formulas are used for the sole pur-›se of illustrating the differences that may exist ɘtween high-grade and low-grade mixtures, and not ; indicating what should be used to make a good · poor mixture:

FORMULA NO. 1

.trate of soda	500	lbs.	furnishing	80	lbs.	nitrogen
igh-grade super-phosphate	1,100	"	"	180	"	phos. acid avail.
uriate of potash,	400	"	"	200	"	potash
Total	2,000	"	"	460	"	total plant-food

With a guaranteed composition of:

Nitrogen	4 %
Phosphoric acid (available)	9 %
Potash	10 %

FORMULA NO. 2

Nitrate of soda.	250 lbs.	furnishing	40 lbs.	nitrogen
High-grade superphosphate	1,000 "	"	160 "	phos. acid avail.
Muriate of potash,	80 "	"	40 "	potash
Make-weight	670 "	"		
Total	2,000 "	"	240 "	total plant-food

With a guaranteed composition of:

Nitrogen	2 %
Phosphoric acid (available)	8 %
Potash	2 %

FORMULA NO. 3

Tankage	600 lbs.	furnishing	30 lbs.	nitrogen
			90 "	phosphoric acid
Kainit	400 "	"	50 "	potash (actual)
Make-weight	1,000 "	"		
Total	2,000 "	"	170 "	total plant-food

With a guaranteed composition of:

Nitrogen .	1.5 %
Phosphoric acid	4.5 %
Potash (actual) .	2.5 %

FORMULA NO. 4

Tankage	1,200 lbs.	furnishing	60 lbs.	nitrogen
			180 "	phosphoric acid
Kainit	800 "	"	100 "	potash (actual)
Total	2,000 "	"	340 "	total plant-food

With a guaranteed composition of:

Nitrogen	3 %
Phosphoric acid	9 %
Potash	5 %

Formula No. 1 shows a high-grade product, both respect to quality of plant-food and concentration, le No. 2 is high-grade only in respect to quality. order that the plant-food may be distributed oughout a ton of material, it is necessary to add it is called "make-weight," or a diluent. These usu- consist of substances that possess no direct fer- zing value. High-grade mixtures cannot be made n low-grade materials, and low-grade mixtures not be made from high-grade materials without ing "make-weight." The advantages of high- de products are concentration and high quality plant-food.

It will be observed that formula No. 1 contains rly twice as much plant-food as No. 2, or, in er words, it will require about two tons of a fer- zer made according to formula No. 2 to secure the ie total amount of plant-food as is contained in ton of No. 1. Now, the material in No. 2, other n the actual plant-food, is of no direct ferti- ig value,—it is of no more value as a fertilizer n the soil to which it is applied,—but the ial cost of the constituents is considerably in- ised, because the expenses of handling, bagging shipping are just double what they would be No. 1.

Formula No. 3 illustrates a low-grade fertilizer in the sense that it contains the poorer forms of the constituents, and furnishes a comparatively small total amount of plant-food. The nitrogen is all in the organic form, and is derived from tankage, which, while not the poorest, is poorer than other forms of organic nitrogen. The phosphoric acid is also in organic combination, and, while useful under many conditions, is less useful for certain other conditions than the soluble in Nos. 1 and 2. The potash, while soluble, is derived from kainit, which, because of its large content of chlorin, is regarded as less desirable for certain crops than the more concentrated materials, muriate, or the high-grade sulfate, which is free from chlorids. It would require more than 2½ tons of a mixture made according to this formula to furnish as much total plant-food as would be contained in a mixture made according to formula No. 1, besides the disadvantage of the lower quality of the constituents.

Formula No. 4 illustrates a mixture which, while rich in total constituents, is not high-grade in its quality.

All of these considerations should, therefore, be carefully observed in the purchase of mixtures, or even in the purchase of raw materials for home mixtures, and the analysis, if properly made, will give positive evidence on these points.

The expensiveness of low-grade fertilizers, as represented by formulas Nos. 2 and 3, is not fully appreciated by the purchaser in all cases. He does not stop to think that it is quite as expensive to handle the

ıterial which contains no plant-food as it is to
ndle material which is rich in plant-food.

The Cost of Handling "Make-weight"

A comparison of the advantages of low-grade and gh-grade mixtures in this sense of total quantity of ınt-food may be illustrated as follows:

It has been shown by continued studies at the New rsey Experiment Station that the charges of the ınufacturers and dealers for mixing, bagging, shipıg and other expenses are, on the average, $8.50 per ı; and also that the average manufactured fertilizer ntains about three hundred pounds of actual ferizing constituents per ton. A careful study of the :tilizer trade indicates that these conditions are also actically true for other states in which large quantis of commercial fertilizers are used.

A mixture of formula No. 1 would contain 460 unds of actual available fertilizing constituents per ı—160 pounds, or over 50 per cent more than is ntained in the average manufactured brand. That a farmer purchasing a brand similar to formula). 1 would secure in 2 tons as much plant-food would be contained in 3 tons of the average manactured brand. Assuming that the charges per und of plant-food at the factory, and the expense arges, are the same in each case, and also that the ality of plant-food in the one is as good as in the ıer, the consumer would save $8.50 by purchasing o tons of the former instead of three tons of the latter In a few states the consumption of fertilizers reaches nearly 100,000 tons annually, while in many it ranges from 30,000 to 50,000 tons.

Thus is shown the very great saving that may be effected in the matter of the purchase of fertilizers from the standpoint of concentration alone, or, in other words, the importance of a definite knowledge of what constitutes value in a fertilizer. This saving may be accomplished, too, without any detriment to the manufacturer, since the difference to him between making high-grade or low-grade goods, in reference to concentration, is largely a matter of unskilled labor. The manufacturers are in the business to cater to the demands of the trade. If consumers are intelligent, high-grade rather than low-grade goods will be provided by the manufacturers. Furthermore, as already indicated, high-grade in the matter of concentration means high-grade in quality, for high-grade mixtures cannot be made from low-grade products.

GENERAL ADVICE

As farmers understand more fully the question of fertilization, and as intensive methods of practice are adopted, the tendency in the purchase of fertilizers will undoubtedly be toward the first method, or the purchase of fertilizing materials, rather than mixtures, or at any rate, of high-grade special mixtures, rather than what are now termed "standard brands," which are, as a rule, low-grade in the concentrated sense. This tendency will come, first, because intensive pracce requires a larger use of all of the constituents, id second, a greater need in the growth of certain 'ops of specific or dominant elements, and thus better sults are obtained from the application of single onstituents, or the use of special formulas, than in extensive" practice, in which the object is more to ipplement the soil supplies than to fully provide r all the needs of the plants for food.

The tendency toward coöperative buying on the art of small farmers will increase as it has done in iose countries in which there is a larger use of rtilizers than here, though the method is already in iccessful operation in certain sections of the country, id with very gratifying results. In this method of irect purchase, the manufacturer and the consumer re brought into closer relations with each other. ransactions are based upon the transfer of a definite umber of pounds of a specific kind and form of lant-food, rather than upon some mysteriously re-iarkable qualities that are claimed, and are by many ipposed to be inherent in certain mixtures.

CHAPTER VIII

CHEMICAL ANALYSES OF FERTILIZERS

A COMPLETE chemical analysis of a fertilizer shows not only the total amount of the different constituents contained in a brand, but the form in which they exist, and in most cases, the source of the materials used is also indicated.

THE INTERPRETATION OF AN ANALYSIS

An analysis may show simply the total amount of the constituents. This is not a sufficient guide as to the value of a mixture, for while it is not possible to indicate absolutely by analysis whether the organic nitrogen, for example, is derived from blood (which is one of the best forms), or from horn meal (one of the poorer forms), it is possible to show whether the nitrogen is derived from nitrate or from ammonia, whether the phosphoric acid is derived from a superphosphate or a phosphate, and whether the potash present is in the form of a sulfate or of a muriate. A high-grade or a low-grade fertilizer, for example, may be distinctly indicated by the analysis, since it is of a high-grade if the three forms of nitrogen are present, if the total phosphoric acid is chiefly soluble in water, and if the potash has been derived from a sulfate or from a ıriate. On the other hand, if the analysis shows at the nitrogen is all in the organic form, that only minimum percentage of the phosphoric acid is ailable, though not soluble, and that a high conıt of chlorin accompanies the potash, it is a lowade product, in so far as the form of the constituents concerned. The following statements of analyses two brands, showing the same total content of nstituents, illustrate this point:

Analysis No. 1

Nitrogen, as nitrate	1 %	
" " ammonia	1 %	
" " organic matter	1 %	
Total		3 %
Phosphoric acid, soluble	8 %	
" " reverted	1 %	
" " insoluble	1 %	
Total available		9 %
Potash		5 %
Chlorin		0.50 %

Analysis No. 2

Nitrogen, as nitrate		
" " ammonia		
" " organic matter	3 %	
Total		3 %
Phosphoric acid, soluble		
" " reverted	2 %	
" " insoluble	8 %	
Total available		2 %
Potash		5 %
Chlorin		10 %

A study of these two statements of analyses shows at the total contents of the constituents are identical, 3, 10 and 5, respectively, in each case. That is, so far as the total amounts are concerned, one brand furnishes as much as the other, and from that standpoint alone it is as good as the other; but it has been already shown that the value of a fertilizer depends not only upon the total content of its constituents, but upon the form in which they exist. In the first brand it is found that two-thirds of the total nitrogen exists in the soluble form, equally divided between nitrate and ammonia; the remaining third is in the organic form, and may be derived from blood, or from some low-grade materials. It is to be fairly presumed, however, that when thus associated with so high a proportion of soluble nitrogen, it is in a good form, as the manufacturer has given evidence of his intent by his liberal use of other good forms.

In the case of the phosphoric acid, it is shown that of every 100 pounds of the total, 80 pounds are soluble, 10 reverted, or nine-tenths of the whole is available; 10 pounds of every hundred only are insoluble, which is not only an indication, but positive proof, that the phosphoric acid is derived from a superphosphate.

In the case of potash, the chlorin associated with it is but ½ per cent, indicating that it has been drawn from high-grade sulfate, since kainit and muriate are rich in chlorin, while in a high-grade sulfate no appreciable amounts of chlorin are present.

In the second statement, all of the nitrogen is shown to be in the form of organic matter. It may be derived from blood, though it is not likely to have n drawn from this source, since of the total ›sphoric acid but 20 pounds per hundred, or oneh, is available, and that is reverted rather than ıble, indicating that the phosphoric acid must have n drawn from tankage or from bone, or other maals which contain reverted but no soluble phos›ric acid, and which also contain a considerable centage of nitrogen. The phosphoric acid was cerıly not drawn from a superphosphate, or it would 'e shown a higher percentage of available, a cerı proportion of which would have been soluble, and percentage of insoluble would have been very much ;. In the case of potash, it is quite evident that vas drawn from kainit, inasmuch as the percentage chlorin exceeds the percentage of the potash, as ıld be the case if the potash had been drawn from t source.

Thus it is that a complete chemical analysis of a ;ilizer indicates very clearly the source of the terials by the form in which the constituents exist the mixture.

THE AGRICULTURAL VALUE OF A FERTILIZER

It is obvious, from what has already been pointed , that the value of a fertilizer to the farmer ›ends not so much upon what is paid for it as upon character of the materials used to make it. This ue is termed the "agricultural value," and it is ısured by the value of the increased crop produced its use. It is, therefore, a variable factor, depending first, upon the availability of its constituents, and second, upon the value of the increased crop produced.

For example, in the first place, the agricultural value of a pound of soluble phosphoric acid is likely to be greater than that of a pound of insoluble when applied under the same conditions as to soil and crop, because in the one case the element is in its most available form, while in the other it is least available. In the second place, the soluble phosphoric acid may exert its full effect and cause a greatly increased yield on a certain crop, and still not cause an increase in its value sufficient to pay the cost of the application, while for another crop the same application may result in a very great increase in the value of the crop. The character or form of the materials used in a mixture, as well as their suitability for the crop must, therefore, be carefully considered in the purchase of fertilizers. Slow-acting materials cannot be expected to give profitable returns, particularly upon quick-growing crops, nor expensive materials such profitable returns, when used for crops of relatively low value, as for crops of relatively high value.

THE COMMERCIAL VALUE OF A FERTILIZER

This agricultural value is, however, separate and distinct from what is termed "commercial value," or cost in market. This value is determined by market and trade conditions, as the cost of production of the crude materials and the cost of their manufacture and sale. Since there is no strict relation between

;ricultural and commercial or market value of a fer-
rlizer constituent, it frequently happens that an
ement in its most available form, and under ordi-
ıry conditions of high agricultural value, costs less
market than the same element in less available
rms and of a lower agricultural value. The cost of
oduction in the one case is lower than in the other,
ough the returns in the field are far superior.

It is manifestly impossible to fix an agricultural
.lue for any of the constituents that will be true
ıder the varying conditions of soil, crop and season,
ıd method of use, though the relative value of the
fferent forms under uniform conditions of use may
fairly indicated, and the analysis is the guide as
their form. The commercial value of the different
nstituents in their various forms may, too, be fairly
dicated, and will vary according to variations in
ade conditions. If the wholesale jobbing price of
trogen as nitrate is 15 cents per pound, available
ıosphoric acid 5 cents per pound, and potash 4 cents
r pound, these are the prices which the manufacturers
.y. Their increased cost in manufactured brands,
erefore, is in proportion to the cost of this work;
nce their cost to the consumer at factory should
.ry within reasonably narrow limits, due to varia-
ɔns in cost of manufacturing in different localities.

An illustration of the commercial value is shown
the following example: Suppose that nitrate of
da costs or can be purchased at retail, in ton lots,
r $48 per ton, which is, then, its commercial value.
ıe commercial or trade value of the nitrogen is,

therefore, 15 cents per pound, since a ton contains on the average 320 pounds of nitrogen. Or, suppose that the retail price of available phosphoric acid in superphosphates is $1 per unit; this is its commercial value, and hence the commercial or trade value of the available phosphoric acid would be 5 cents per pound, since a unit contains 20 pounds. It does not follow that the application of a pound of nitrogen, costing 15 cents, and, therefore, having a commercial value of 15 cents, will result in an increased crop worth 15 cents, or that the application of a pound of phosphoric acid costing 5 cents per pound will result in an increased crop worth 5 cents. The increased returns in crop from their use may be very much greater or much less than the cost of the constituents, depending upon the kind of crop and the skill of the user. In the purchase of materials, however, a commercial valuation is a guide as to the cost of the constituents from different manufacturers or dealers; and in many states a system of commercial values for mixed fertilizers has been fixed, which, when properly understood, is a useful method of comparison of the different brands.

This method is based upon the fact that at points of supply a pound of nitrogen, in the form of nitrate, of ammonia, or of definite organic compounds, or a pound of available phosphoric acid, or of potash in the form of muriate or sulfate, is practically the same to all manufacturers. That is, these cost prices, or trade values, when applied to the constituents in the mixture, represent their commercial value before they

mixed to form complete fertilizers. Henee, the
erence between the valuation of a brand on this
s and the eost to the consumer represents the
ges, including profit, for mixing, bagging, ship-
g and selling the goods.

The commercial or trade value for each of these
stituents is obtained, as already indieated, by
ply ealculating the eost, using two faetors, —
wholesale priees for the different materials con-
ing them, and their average composition. To
cost is added a eertain pereentage, to represent
cost of handling and distribution in small lots.
s the trade value eorresponds as nearly as may
with the eost of the eonstituents to the farmer.
t is, the price fixed represents what the farmer
ld have to pay the manufaeturer for the eon-
ients in the material before it is mixed.

For example, suppose the wholesale price per ton
nitrate of soda for the six months preeeding Mareh
shown to be $40 ; the wholesale eost of nitrogen
his form is, therefore, 12.5 cents per pound. To
wholesale price may be added a eertain sum to
r the expenses of handling, usually 20 per eent,
making the retail price per ton $48, and the
e or eommereial value of the nitrogen 15 eents
pound. That is, the $48 per ton, or 15 eents
pound, represents the retail cost per pound of
ate nitrogen. This, if applied to the nitrogen as
ate, in the mixed fertilizer, will show what it
ld have been bought for as nitrate in the unmixed
ilizer. The values for the other constituents are

erived in the same way These, together, make the hedule of trade or commercial values of the conituents which are used in the computing of the ommercial values of mixed fertilizers. The schedule f values is revised annually, and, as nearly as posble, at the same time in the year. The following hedule, used as an illustration of this point, was dopted for 1898 by the states of New York, Conecticut, Rhode Island, Massachusetts, Vermont and lew Jersey:

SCHEDULE OF TRADE VALUES ADOPTED BY EXPERIMENT STATIONS FOR 1898

	Cts. per lb.
itrogen, as nitrates	13.0
" " ammonia salts	14.0
rganic nitrogen, in dried and fine-ground fish, meat and blood, and in mixed fertilizers	14.0
rganic nitrogen, in fine-ground bone and tankage *	13.5
" " " coarse bone and tankage †	10.0
hosphoric acid, soluble in water	4.5
" " " " ammonium citrate ‡	4.0
" " insoluble, in fine bone and tankage *	4.0
" " " " coarse bone and tankage†	3.5
" " " " mixed fertilizers	2.0
" " " " fine-ground fish, cotton-seed meal, castor pomace and wood ashes	4.0
otash, as muriate	4.25
" " sulfate, and in forms free from muriates (or chlorids)	5.0

* Finer than 1-50 inch.

† Coarser than 1-50 inch.

‡ In New Jersey, the price for the soluble and reverted is identical; viz., .5 cents, owing to the different method used in the determination of the 'reverted.'

It will be observed that the schedule gives the
st per pound of the different forms of nitrogen,
d of high-grade organic nitrogenous materials; of
rogen and phosphoric acid in ground bone and
ıkage; of available phosphorie acid in superphos-
ates, and of actual potash in the potash salts, and
a useful guide also in showing that the nitro-
n, phosphoric acid and potash contained in these
terials can be purchased in ton lots for the
ces mentioned. *The valuations of mixed fertilizers,
ained by the use of this schedule, are entirely
nmercial; they are not intended to indicate even a
sible agricultural value.* This point needs to be
phasized, as many are inclined to interpret them
not only guides as to agricultural value, but as
sitive statements of such value. It can be said,
wever, that those who do so do not familiarize
mselves with the discussions that usually accom-
ny reports of analyses. The different trade values
en for the nitrogen and phosphoric acid in the
grades of bone represent their value in the form
ground bone and of bone meal, products which
distinctly recognized in the market, and which are
oted at different prices. The coarser ground bone
lower in price than the finer bone meal.

The accuracy of the schedule of values can be
own by comparing it with the actual prices paid
the constituents in the different materials, and
h comparisons as have been made from year to
r, by a number of the institutions exercising an
dysis control, show that manufacturers and dealers

re willing to sell to farmers at prices corresponding ery closely with the schedule.*

A value is placed upon the insoluble phosphoric cid in mixed fertilizers, not because all insoluble costs he price given, but because in mixtures it is assumed hat the phosphoric acid is drawn from organic sources, which do cost, at least, the price given.

There are arguments both in favor of and in oppo-ition to this method of comparing the commercial alues of mixed fertilizers. The chief arguments in pposition may be stated as follows:

First, that the prices of these materials vary, and ence in order to represent the actual commercial value t the time the sales are made, they should be changed s the markets change.

Second, the valuations are misleading, because the armer does not clearly understand their meaning, and s thus guided in his judgment of the usefulness or gricultural value of a fertilizer by the stated com-ercial value, as shown by this method, rather than by he kind, form and proportion of constituents that ay be contained in it, and upon which its agricultural alue should be based.

Third, the chemical analysis does not show abso-ıtely the sources of the materials, and thus it is ifficult to place a true commercial value upon a mix-ure. This is especially true of organic nitrogen, ince because it is impossible to separate the amounts hat may be derived from different materials, a uniform

*See Bulletins Connecticut and New Jersey Experiment Stations.

alue is placed upon the total nitrogen found, whether ; is derived from the best forms, as dried blood and ried meat, or whether derived from horn meal, ground eather, or other low-grade forms of nitrogenous naterial. This encourages the use of low-grade roducts by unscrupulous manufacturers, to the real etriment of the trade as a whole.

Fourth, that the commercial value so fixed militates against the use of certain kinds of good materials, nd in favor of certain kinds of poorer materials. 'hat is, a valuation of 2 cents per pound for insoluble hosphoric acid in complete fertilizers, for example, is direct encouragement to include in the mixture a onsiderable proportion of the insoluble phosphoric cid from South Carolina, and other rock phosphates, he value of which is ignored in commercial transacions; while that price (2 cents) does not give a fair alue to the phosphoric acid contained in bone, tankage nd natural guanos, products in which the commercial alue of the insoluble is recognized,—that is, mixtures which contain bone and tankage, and which furnish hosphoric acid largely in an insoluble form. The aluation fixed for this form is too low to fully epresent the commercial value of these goods. It is lso said that the trade value for available phoshoric acid in the mixtures encourages the use of uperphosphates from the rock phosphates, and disourages the use of superphosphates from bone-black, one-ash and dissolved bone, because the trade or ommercial values represent the average cost of available phosphoric acid in the superphosphates from all of these, while the latter materials, because of actual commercial conditions, cost more than the superphosphates from the former.

The chief arguments in favor are:

First, that it is not asserted that the system shows absolutely the commercial value of each brand at the time the sales are made, but the comparative commercial value.

Second. They are not misleading. The commercial valuations are not intended to be a guide as to the agricultural value of a fertilizer. It is distinctly stated in the reports of analyses that the comparative values are purely commercial.

Third. It is a system which more nearly approaches perfection than any other that has been devised, is educative in its tendency, and is a safe guide, in the majority of instances, as to the charges made for mixing, handling and selling plant-food contained in the different brands. If the analysis is properly interpreted, as already indicated, it is the purchaser's fault if he buys poor forms of plant-food at a high price. It is certainly a safer guide than mere name of brand, and does not encourage the use of poor materials.

Fourth. Any system of comparison of brands must leave a great deal to the judgment of the purchaser. He must interpret for himself whether he would rather that his phosphoric acid were derived from one source or another, whether he would prefer to pay a higher price for insoluble phosphoric acid in acid phosphate, and have the remainder soluble, than to pay the same r a greater price for the insoluble phosphoric acid in ›one, and have the remainder of it in the reverted orm. These conditions are again indicated by the nalysis which accompanies the valuation ; the valua- ions are, therefore, not to be used in total disregard f the composition. If they are so used, it is not the ault of the system. That it militates against the use f high-priced superphosphates, if they are no better han the lower-priced ones, is no argument against he system, but rather for it, since it tends toward a eadjustment of the prices, a condition that must be net in all competitive trades. Furthermore, the valua- ion system has been effective in driving out materials hat are either fraudulent in their character or of very ow-grade. It is impossible to obtain a high valuation n poor materials, and in the majority of cases de- endence upon valuations alone would be a safe guide s to the comparative agricultural value of brands of he same general composition.

CALCULATION OF COMMERCIAL VALUES

The following examples illustrate how commercial alues of complete fertilizers and of ground bone are alculated. The mixed, or complete fertilizer, contains he three forms of nitrogen, three of phosphoric acid, nd the two forms of potash. In the bone, it is ssumed that 50 per cent of the meal is finer than -50 inch, and is, therefore, regarded as fine, and that 0 per cent is coarser than 1-50 inch, and is, therefore, egarded as coarse ; and it is also assumed that the proportions of the nitrogen and phosphoric acid in the fine and coarse is the same; also, that the analysis shows the bone to contain 4 per cent of nitrogen and 20 per cent of phosphoric acid.

A Complete Fertilizer

	1 % or lbs. per 100	2 Lbs. per ton	3 Value per lb. cts.	4 Estimated value per ton of each constituent
Nitrogen, as nitrates	1 × 20 =	20 ×	13.0 =	$2 60
" " ammonia salts	1 × 20 =	20 ×	14.0 =	2 80
" " organic matter	1 × 20 =	20 ×	14.0 =	2 80
Phosphoric acid, soluble	8 × 20 =	160 ×	4.5 =	7 20
" " reverted	1 × 20 =	20 ×	4.5 =	90
" " insoluble	1 × 20 =	20 ×	2.0 =	40
Potash, as muriate	5 × 20 =	100 ×	4.25 =	4 25
" " sulphate	5 × 20 =	100 ×	5.0 =	5 00
Total estimated value per ton				$25 95

The first column shows the per cent of the contituents contained, which, multiplied by 20, gives the pounds per ton in the second column, which, multiplied by the schedule prices per pound, gives the valuation per ton, as shown in the fourth column.

Ground Bone

	1 % or lbs. per 100	2 % of fineness	3 % or lbs. per 100	4 Lbs. per ton	5 Value per lb. cts.	6 Estimated value per ton
Nitrogen	4 ×	50 =	2 in fine. × 20 =	40 ×	13.5 =	$5 40
	4 ×	50 =	2 in coarse. × 20 =	40 ×	10.0 =	4 00
Phosphoric acid	20 ×	50 =	10 in fine. × 20 =	200 ×	4.0 =	8 00
	20 ×	50 =	10 in coarse. × 20 =	200 ×	3.5 =	7 00
Total estimated value per ton						$24 40

The first column of figures shows the per cent, · pounds per hundred, of the constituents, which is ultiplied by the pereentage of fineness, whieh gives e pereentage or pounds per hundred of fine or arse in the third column. The calculation is then ished as in the case of complete fertilizers.

THE UNIFORMITY OF MANUFACTURED BRANDS

Another point which consumers of fertilizers are terested in is the reliability of the various brands. hat is, they desire to know whether a brand that ows good forms of nitrogen, of phosphoric acid, and potash in one year may be depended upon to fursh approximately the same the following year, or hether the manufacturers change their formulas from ar to year to conform to the relative cost of the fferent materials: that is, whether when nitrogen relatively expensive and phosphoric acid is relavely cheap, they introduce a larger proportion of osphoric acid and a smaller percentage of nitrogen; hether when organic nitrogen is cheap and nitrate d ammonia nitrogen are dear, they change the proortions of these to correspond with the difference price, in order to retain the same selling price.

This is an important point, since after a certain and has been shown to be better suited than other to their conditions of soil, to change the rmula, both in reference to the character and proortions, may mean to the purchaser the difference tween profit and loss.

Evidence on this point can be obtained from the ports showing the results of the analyses of the differ rent brands from year to year, and a careful udy of these shows that genuine manufacturers of rtilizers,—those who make it their sole business, ther than a side issue or an adjunct to another busiess,—can be fully depended upon in this respect. hey know that the farmer's interest is their interest, nd that their sales will depend, other things being qual, upon the increased crop results that the farmer ecures; that the permanency and success of their usiness will depend upon the successful and profitable se of their product; and that they cannot afford to nd do not change their formulas from year to year, ither in proportion or quality of constituents, to correspond with the changes in price of the materials. heir brands can be depended upon to furnish practically the same amount, kind and proportion of lant-food from year to year.

The value of a fertilizer depends upon the kind, uality and form of plant-food, as shown by the nalysis. Value does not depend upon who the manuacturer is, or what the statements may be concerning he usefulness of special manipulation, nor to any reat extent upon special formulas, unless the farmer as positive knowledge of the character of his own onditions. Formulas derived both in kind and proortion from the same materials will do equally well nder the same conditions. So far as the matter has een investigated, there is no specific virtue added by hat is claimed to be the "blending" of the materials.

In the whole matter of the purchase of fertilizers, no guide, however good, can take the place of intelligence on the part of the purchaser. This intelligence must be exercised in the selection of forms of plant-food, in the preparation of formulas, in the interpretation of guarantees and of commercial values, and in the method of using the fertilizer.

CHAPTER IX

METHODS OF USE OF FERTILIZERS

THE primary object in the use of a commercial fertilizer is to receive a profit from the increase in the yield of crops from the land to which it is applied; and this may be derived either from the immediate crop, or from the larger yield of a number of crops. That the greatest immediate or prospective profit may be gained, a wide knowledge of conditions which have either a direct or indirect bearing upon the result is essential.

CONDITIONS WHICH MODIFY THE USEFULNESS OF FERTILIZERS

In fact, the controlling conditions surrounding the matter are so numerous and so various that it is impossible, with our present knowledge, to lay down positive rules for our guidance. At best, only suggestions can be offered.

We may possess a full knowledge of both the kind and form of existing fertilizer supplies, their cost and the action under known conditions of the constituents contained in each, as well as their maximum capability for increasing the crop, but together with this knowledge, it is essential that we should know how these acts and principles must be applied to each individual rop, soil and condition, and yet even with this, absoute certainty of profit is not guaranteed. A few of he more important conditions which control the rofitable use of fertilizers are, therefore, briefly disussed, in order to arrive at a better understanding of he practical suggestions and concrete examples given n subsequent chapters.

Derivation of Soil a Guide as to its Possible Deficiencies

The first consideration is the soil itself, and its nfluence. It is well known that a wide difference xists in soils, both in reference to their chemical haracter or composition, and to their physical properies, each having a direct influence in determining the ffect of any specific application of fertilizers. These lifferences in soils are due to changes which were vrought in the surface of the earth during its formaion, and which are continuing in a small way at the resent time. It is believed that the original earth rust contained all the minerals now found in it, but hat in the beginning they were distributed more uniromly throughout its mass, and that the soils as they xist at the present time, and as a result of the direct lisintegration of the original rock, represent a very mall area of the earth's surface. They are not now onstant, but variable in their character. The various hanges that have taken place during geologic time nave resulted in the breaking up of the original rocks, a part having been separated mechanically and being represented by various sizes of particles, and a part rendered soluble. The fragments and the soluble portions thus separated have not been deposited again in the same proportions as they existed in the original rock, which has caused a very wide variation in the chemical composition of the different soil deposits. The process and its results may be shown at the present time in the wearing away of rocks. The harder, sandy particles separate mechanically, and because of the difference in the size of the particles, the coarser are deposited as gravel or sand, in one place, and the finer particles are deposited in another, making the clay The lime enters partly into solution and is deposited in another place, and so on, thus giving us sandy soils, clayey soils and limy soils, all differing from each other in their amount and proportion of the essential fertilizing constituents, as well as in their physical qualities,—the sandy and gravelly making the poorest soils because the particles consist very largely of quartz, and the remainder being poor in phosphoric acid or potash. The clay soils are frequently rich in minerals containing potash, and poor in those containing lime and phosphoric acid; and the limestone soils are poor in potash and rich in lime, and frequently in phosphates. In addition to these soils, there are those that are made up largely of vegetable matter, due to the accumulation of decaying growths. These are frequently rich in nitrogen and poor in all of the essential mineral constituents.

Hence it is that in the use of a commercial fertilizer, ıt least for certain crops, a knowledge of the nature)f soils in respect to the possible deficient element is mportant, in order that those which exist in abun- lance may not be added to, but that they may be sup-)lemented by such an abundance of the deficient ele- nents as to permit the acquirement by the crops of hose necessary for a maximum growth. As a rule,)otash is a very essential constituent of manures for andy soils, not only because all crops require potash,)ut because they require it in relatively large amounts, ınd because in sandy soils it is liable to exist in ninimum amounts. Potash fertilization, therefore, is specially useful on sandy soils. On the other hand, n clay soils, which, as a rule, contain a very con- iderable proportion of potash as compared with sandy oils, the deficient element may be either phosphoric .cid or lime; and if these are supplied in abundance, he plant will be able to secure the necessary potash. n a limy soil, the lime and phosphoric acid, and per- ıaps the potash, may be in sufficient abundance to ause a normal growth of plant, yet the nitrogen may e so deficient as to prevent a normal growth.

Physical Imperfections of Sandy Soils

If it were possible to distinctly classify soils in espect to their lack of one or more of the essential onstituents, it would be an easy matter to formulate ules for our guidance in the fertilization of these oils; but such is not the case. Even sandy soils vary videly in their chemical composition, as well as in heir mechanical or physical properties, and certain f them possess such a physical character as to make ; impossible to grow maximum crops even though he essential elements are all supplied in sufficient bundance. The constituent particles are too coarse, nd thus make the soils so open and porous that hey too freely admit the air, water and warmth, and hus results a very rapid drying and heating of the oil, with a premature ripening and burning of the rops. The phosphates or the potash compounds aplied are not readily fixed, and suffer an immediate)ss as soon as rain falls in such amounts as to ause a leaching from them.

Physical Imperfections of Clay Soils

In clay soils, the physical conditions are quite the everse. All clay soils do not have the same general omposition, and they differ widely in their physical ualities. Certain of them possess a reasonably good exture, and permit the absorption of the food applied, s well as its gradual distribution throughout the nass by the percolation of the water through them; while certain others are so compact, owing to the nely divided particles, that even though they were bundantly supplied with all or the necessary mineral onstituents, profitable crops could not be grown ecause the roots could not readily penetrate, and ecause the water falling upon the land would not eadily pass through, but remain upon the surface.

In the case of soils with an abundance of lime, ıhysical qualities also exercise a very considerable nfluence, even though there is a sufficient supply of all f the fertility elements. Certain of them are too cold, thers are too dry, and the mechanical condition is uch as to prevent the proper and uniform growth of ılants. It must be remembered, then, that only genral rules apply in the use of fertilizers upon soils of he different classes, and that they are modified by oth the chemical composition and the mechanical conlition of the soils. The best use of a fertilizer,—that s, the greatest proportionate return of plant-food in the rop, all things considered,—is obtained from its apılication upon soils that possess "condition," or that re well cultivated or managed. Full returns cannot e expected when they are applied upon soils that are oo wet or too dry, too porous or too compact, or too oarse or too fine. It is important that even the best oils should be properly prepared, and it is infinitely nore important that those which possess poor mechanical condition should be improved in this respect, efore large expenditures are made for fertilizers.

The Influence of Previous Treatment and Cropping

In the next place, the previous treatment and ropping of soils should guide in the use of ferilizers, since soils of the same natural character, ocated equally well, will not always show the same esults from the application of fertilizers, because in he one case the cropping has been such as to result n the rapid exhaustion of one, rather than the three ecific fertilizer elements; while in the other, the opping may have been quite as severe, but has been lpful because judicious rotations have been used and nproved methods practiced. It may be that in the ne case, there may have been a continuous cropping wheat, for example, and only the grain sold from e farm, in which case there would be a much more pid exhaustion of the nitrogen and phosphoric id than of the potash; and if this continuous heat-cropping has been continued for a long time, n application of the phosphates only may result in iite as large an increase in crop as if both phosnates and potash salts were applied, because the otash exhaustion has been less rapid than that the phosphoric acid, and the addition of potash ould simply add to the probably abundant quantities ready there. On the other hand, if the cropping as been timothy hay, the removal of the potash ould have been greatly in excess of the phosphoric id, and consequently a fertilization with a greater roportion of potash, or even this element alone, of e minerals, may result in quite as large returns if the fertilization had consisted of both phosphoric id and potash. In fact, if the land had been opped continuously with tobacco, cotton, potatoes, other crop, there is likely to be a much larger moval proportionately of some one element, rather ian proportionate amounts of all. This practice sults in a disproportionate removal of the constituits, and in order to bring the land back to its ipacity for maximum production, or to equalize matters in this respect, it is necessary to add to the soil the constituents removed in amounts in excess of the others. On the other hand, the cropping may have been such as to be fully as exhaustive in the sense that the total quantity of constituents removed is quite as great, though since they are removed in more uniform proportions, the period of profitable cropping is extended, and the fertility needed includes all the essential elements, rather than one or two. That is, the grain, hay and potatoes may have been grown in rotation, each removing one or the other in greater proportion, but because they differ with each crop, no one is exhausted before the other; and thus when the land reaches the time when it would no longer profitably grow those crops, an application then of all of the constituent elements would result in a greater and more profitable increase in crop than if the fertilizer contained one constituent only. The previous treatment and cropping of soils, therefore, is an important guide in determining the most economical method of fertilization.

Furthermore, in this matter of cropping as a guide to possible need of fertilization, it must be remembered that a continuous one-crop practice is more productive of total loss of constituents than a practice which includes such renovating crops as clover, or one which permits of a more constant occupation of the land, since in the former, the introduction of clover reduces the need for nitrogen fertilization, and in the latter, the vegetable matter is not so rapidly used up, and the loss of mineral constituents by nechanical and other means is very much reduced, ecause of the constant occupation of the land.

The Influence of Character of Crop

The financial result from the application of fer-ilizers is also influenced in a very large degree by he character of the crop itself, whether the value f an increase in crop as great as can be expected rom a definite application is high or low; and on his basis, crops may be classified into two general roups: first, those which possess a high fertility, and vhich, as a rule, possess a relatively low commercial alue; and second, those which possess a low fertility alue and a relatively high commercial value. In the irst class are included the cereal and forage crops, s corn, oats, wheat, hay. buckwheat, cotton and obacco, and in the second are included the various egetable and fruit crops. This classification, and ts importance, may be illustrated by the following xamples:

A ton of wheat, at $1 per bushel, will bring 33.33. Its sale removes from the farm 38 pounds f nitrogen, 19 of phosphoric acid, and 13 of potash. At prevailing prices for these constituents, it would ost $6.50 to return them to the farm.

A ton of asparagus shoots, at 10 cents per pound unch, will bring $200. Its sale removes from the arm 6 pounds of nitrogen, 2 of phosphoric acid and of potash. which could be returned for but little nore than $1.

A ton of timothy hay will bring $10. Its sale removes from the farm 18 pounds of nitrogen, 7 of phosphoric acid and 28 of potash, amounts that would cost $4.

A ton of apples will bring in an ordinary season $20. It removes less than 3 pounds of nitrogen, 1 of phosphoric acid and 4 of potash, which would cost less than 60 cents to return to the land.

It is thus shown that crops like wheat and hay possess a relatively low commercial value, and yet carry away, when sold, a very considerable amount of the fertilizing constituents, while vegetables and fruits, as illustrated by the asparagus and the apples, have a high commercial or market value, and carry away but minimum amounts of the fertilizing constituents. This distinctive character of crops, while not an absolute guide as to the profits that may be obtained from the use of fertilizers,—since the cost of production varies widely for each class,—is instructive in showing that those of a low commercial value are more exhaustive than the other class, or those of a high market value, and is certainly suggestive, pointing out the necessity for judgment in the application of fertilizers that shall be made in the case of crops of the different groups.

The Kind of Farming, Whether "Extensive or Intensive"

Another very important consideration, and one which exercises an influence, is whether the farming engaged in is "extensive" in its character, or "intensive;"

whether the purpose or idea is to simply supplement the stores of plant-food in the soil, or whether the object is to ensure an abundance of all forms of constituents under all reasonable conditions, in order that a maximum production may be secured.

PLANTS VARY IN THEIR POWER OF ACQUIRING FOOD

In the next place, the character or feeding capacity of the plant and its season of growth should be considered, that systematic methods may be adopted, and thus not only that waste of fertilizing materials may be avoided, but that the applications may be made at such times and in such amounts as will, other things being equal, promote the greatest increase per unit of applied food.

While each plant possesses individual characteristics which distinguish it from all others, for our purpose they may again be classified into general groups which possess somewhat similar characteristics, particularly as to their method and time of growth and their capacity for acquiring food from soil sources.

Characteristics of the Cereal Group

The cereals possess distinct characteristics of growth. The roots branch just below the surface, and each shoot produces feeding roots, which distribute themselves in every direction, and thus absorb food from the lower layers of the soil as the plant grows older. Because of their wide root system, and because of the character of their feeding rootlets, they are able readily to acquire food from the insoluble phosphates and potash compounds of the soil, though they are unable to feed to any extent upon the insoluble nitrogen. Furthermore, inasmuch as the most rapid development of many of these crops takes place early in the summer, before the conditions are favorable for the rapid changing of organic nitrogen into nitrates, they are, with the exception of Indian corn (maize), specifically benefited by early applications of nitrogen in the form of nitrate. The corn, on the other hand, which makes its most rapid growth after the other cereals are harvested,—in July or August,—when the conditions are particularly favorable for the development of nitrates, do not usually require as large proportions of nitrogen as of the mineral constituents, particularly the phosphates. That is, wheat, rye, oats and barley are specifically benefited by the early application of quickly available nitrogen.

Characteristics of Grasses and Clovers

Forage crops, including both the grasses and clovers, constitute another group, in so far as their use is concerned, though possessing marked distinguishing characteristics. Of the grasses, nearly all species are perennial, though their length of life depends upon the method of cropping and upon the character of the soil. They send their fibrous roots into the surface soil in the same manner as the cereals, though they differ from them in forming a set of buds which become active in the late summer and develop new roots and shoots. They resemble the cereals in their power of acquiring mineral food, and are even more benefited by the application of nitrogen, since the chief object in their use is to obtain the nitrogenous substances contained in leaf and stem in the form of pasture, forage or hay, rather than the matured grain. Hence, nitrogen, which promotes this form of growth, is an important constituent, and under any conditions there should be a liberal supply provided.

The clovers, on the other hand, are not perennial, with the partial exception of "white" or "Dutch" clover, and with this exception they all possess a tap-root, which penetrates downward, and as it descends, throws out fibrous roots into the various layers of soil. They are capable of readily acquiring their mineral food, both because of their large root systems and because of the character of the roots. They, however, differ in one very important particular from the cereals and grasses, in that under proper conditions, as already pointed out (p. 118), they are capable of acquiring their nitrogen from the air. Thus with liberal dressing of only phosphoric acid and potash, maximum crops may be secured. They are "nitrogen gatherers," and the tendency of their growth is to improve the soil for the nitrogen consumers, or for those that obtain their nitrogen only from soil sources.

Root Crops

Another class of plants, differing from those already described, includes the root crops, as beets, mangels, turnips and carrots. These plants cannot make ready use of the insoluble mineral constituents of the soil. Hence, in order to insure full crops, they must be liberally supplied with available food. Of the three classes of fertilizing constituents, the phosphates are especially useful for turnips, while the slower-growing beets and carrots require that the nitrogen shall be in quickly available forms. The proper fertilization of sugar beets, for example, is of great importance, since not only is the yield affected by fertilization, but the quality of the beet for the production of sugar.

White potatoes and sweet potatoes, the one a tuber, the other an enlarged root, constitute another class which does not possess strong foraging powers. They require their food in soluble and available forms, and with suitable soils potash is the ingredient that is especially useful in the manures applied.

Market-garden Crops

Another group of crops is distinguished as a class, not so much because of their peculiar habits of growth as because of the objects of their growth, though this latter fact has a very important bearing upon economical methods of fertilization. This class includes what are called "market-garden crops," as lettuce, beets, asparagus, celery, turnips, cucumbers, melons, sweet corn, beans, peas, radishes, and various others. The particular object in raising these is to secure rapidity in growth, and thus to insure high quality, which is measured by the element of succulence. In order that this may be accomplished, they must be supplied with an abundance of available plant-food, and since nitrogen is the one element which more than any other encourages and stimulates leaf and stem growth, its use is especially beneficial to all of these crops. They must not lack for this element in any period of their growth, though, of course, a sufficiency of minerals must be supplied in order that the nitrogen may be properly utilized. Because of their high commercial value, the quantity of plant-food applied may be greatly in excess of that for any other of the groups, and profits, as a rule, are measured by this excess rather than by the proportion of the elements.

Fruit Crops

Another distinct class of crops, though differing materially in their individual characteristics, as well as in their time and period of growth, are the fruits. These differ from most other crops, in that a longer season of preparation is required, in which the growth may be so directed as to prepare the plant or tree for the proper development of a different kind of product, namely, fruit, as distinct from grain or seed in the cereals, or succulence in the vegetable crops. The fruit differs in its characteristics from the ordinary farm crops, in that its growth and development require a little different treatment, since it is necessary that there shall be a constant transfer of nitrogen from the tree to the fruit throughout the entire growing season. The growth of each succeeding year of tree and fruit is dependent, not altogether upon the food acquired during the year, but as well upon that acquired in the previous year, and which has been stored up in bud and branches. A knowledge of the habits of growth, the period of growth and the object of the growth of this class is, therefore, useful as a guide to the economical supply of the essential elements of growth. These crops must be provided with food that will encourage a slow and continuous rather than a quick growth and development.

SYSTEMS OF FERTILIZING SUGGESTED

A careful review of the foregoing facts furnishes abundant evidence of the impracticability of attempts to give information concerning the use of fertilizers that will apply equally well under all of the conditions of farming that may occur. Nevertheless, there have been a number of methods or systems of fertilization suggested, each of which possesses one or more points of advantage.

A System Based Upon the Specific Influence of a Single Element

The one which has perhaps received the most attention, doubtless largely because one of the first presented, and in a very attractive manner, is the system advocated by the celebrated French scientist, George Ville. This system, while not to be depended upon absolutely, suggests lines of practice which, under proper restrictions, may be of very great service. In brief, this method assumes that plants may be, so far as their fertilization is concerned, divided into three distinct groups. One group is specifically benefited by nitrogenous fertilization, the second by phosphatic, and the third by potassic. That is, in each class or group, one element more than any other rules or dominates the growth of that group, and hence each particular element should be applied in excess to the class of plants for which it is a dominant. In this system it is asserted that nitrogen is the dominant ingredient for wheat, rye, oats, barley, meadow grass, and beet crops. Phosphoric acid is the dominant fertilizer ingredient for turnips, Swedes, Indian corn (maize), sorghum and sugar cane; and potash is the dominant or ruling element for peas, beans, clover, vetches, flax and potatoes. It must not be understood that this system advocates only single elements, for the others are quite as important up to a certain point, beyond which they do not exercise a controlling influence in the manures for the crops of the three classes. This special or dominating element is used in greater proportion than the others, and if soils are in a high state of cultivation, or have been manured with natural products, as stable manure, they may be used singly to force a maximum growth of the crop. Thus, a specific fertilization is arranged for the various rotations, the crop receiving that which is the most useful. There is no doubt that there is a good scientific basis for this system, and that it will work well, particularly where there is a reasonable abundance of all of the plant-food constituents, and where the mechanical and physical qualities of soil are good, though its best use is in "intensive" systems of practice. It cannot be depended upon to give good results where the land is naturally poor, or run down, and where the physical character also needs improvement.

A System Based Upon the Necessity of an Abundant Supply of the Minerals

Another system which has been urged, notably by German scientists, is based upon the fact that the mineral constituents, phosphoric acid and potash, form fixed compounds in the soil, and are, therefore, not likely to be leached out, provided the land is continuously cropped. They remain in the soil until used by growing plants, while the nitrogen, on the other hand, since it forms no fixed compounds and is perfectly soluble when in a form useful to plants, is liable to loss from leaching. Furthermore, the mineral elements are relatively cheap, while the nitrogen is relatively expensive, and thus that the economical use of this expensive element, nitrogen, is dependent to a large degree upon the abundance of the mineral elements in the soil. It is, therefore, advocated that for all crops and for all soils that are in a good state of cultivation, a reasonable excess of phosphoric acid and potash shall be applied, sufficient to more than satisfy the maximum needs of any crop, and that the nitrogen be applied in active forms, as nitrate or ammonia, and in such quantities and at such times as will insure the minimum loss of the element and the maximum development of the plant. The supply of the mineral elements may be drawn from the cheaper materials, as ground bone, tankage, ground phosphates and iron phosphates, as their tendency is to improve in character; potash may come from the crude salts. Nitrogen should be applied chiefly as nitrate of soda, because in this form it is immediately useful, and thus may be applied in fractional amounts, and at such times as to best meet the needs of the plant at its different stages of growth, with a reasonable certainty of a maximum use by the plants. Thus no unknown conditions of availability are involved, and when the nitrogen is so applied, the danger of loss by leaching, which would exist if it were all applied at one time, is obviated.

This method also possesses many advantages, particularly where the "intensive" system is practiced, though it is also useful in quickly building up worn-out soils, or those naturally poor, because in any case these must be provided with liberal supplies of the minerals, and when these only are applied, the immediate outlay is far less than if the expensive element, nitrogen, were included; and a greater economy in the use of nitrogen is accomplished if it is added in small amounts when required. Besides, in the improvement of soils, the liberal application of the minerals is conducive to an abundant growth of the legumes, which are able to acquire their nitrogen from the air, thus reducing to some extent the outlay for this expensive element. This system is strongly recommended where cheap phosphatic and potassic materials are readily accessible, as is the case in those countries where it is successfully used.

A System Based on the Needs of the Plants for the Different Elements as Shown by Chemical Analysis

Another system of fertilization is based upon the theory that the different plants should be provided with the essential elements in the proportions in which they exist in the plants, as shown by chemical analysis. Different formulas are, therefore, recommended for each crop, the constituents of which are so proportioned as to meet its full needs. This method, if care is taken to supply an abundance of all the necessary constituents, may result in a complete though perhaps not an economical feeding of the plant, since it assumes that a plant which contains a larger amount of one constituent than of another requires more of that constituent in the fertilizer than of the others. It does not take into consideration the fact that the plant which contains a larger amount of one element than another may possess a greater power of acquiring it than one which contains a smaller amount.

Neither does this system take into consideration, as already pointed out (p. 178), that the period or time of growth of the plant also exercises a considerable influence in indicating the capability of the plant to acquire its necessary food from the stores of the soil, as may be illustrated by wheat and Indian corn, which both contain a relatively high content of nitrogen. Under good conditions of soil, wheat is specifically benefited by heavy dressings of quickly available nitrogen. Corn is not, and one reason is, that they possess different powers of acquiring food, due, to a considerable extent, to the difference in their time of growth, as well as to the period or time of their most rapid growth.

This method may, however, be applied with very great advantage in greenhouse work, or in growing market-garden crops, where the amounts in the soil are not regarded as of importance, and excessive amounts of all are added. The system has been elaborated to a great degree of nicety for the growing of greenhouse crops, flowers, and foliage plants, so much so that now artificial manure cartridges are prepared, which contain the amounts and kinds of food shown by the analysis of the different plants to be needed for their growth and full development. "The manure has the form of a fine powder, enclosed within a metallic wrapper, and firmly compressed into the shape of a cartouche or capsule, cylindrical in form, about three-fourths inch across and one-half inch in depth. It is simply thrust into the soil of the pot to a depth of one-half or one inch, and allowed to remain. After a time it is found that the fertilizer gradually disappears, and at length nothing is left but the little pill-box-like wrapper, which originally contained the mixed fertilizing powder."*

* "The Gardener's Chronicle," London, England.

A System in Which the Fertilizer is Applied to the "Money Crop" in the Rotation

Another system is also recommended, which is well adapted for "extensive" farming, where the majority of crops which are grown in rotation possess a high fertility value and a low commercial value, and where one crop is regarded as the chief "money-maker." The system demands that to this crop shall be applied such an abundance of plant-food as to insure a continuous feeding, and a consequent maximum production, even though adverse conditions intervene. Thus by a liberal supply of food, a money crop is secured which is as large as climate and seasonal conditions will permit, though which does not require all of the food applied. Hence the residue may be depended upon to fully nourish the remaining crops in the rotation, or at least the immediately succeeding ones, thus saving direct outlay for them. This system may be illustrated as follows:

On soils in good physical condition, and naturally well adapted for growing potatoes, this crop is selected as the "money-maker" in the rotation, which consists of corn, potatoes, wheat, clover and hay. The potato crop is fertilized so liberally, say with 1,500 pounds per acre of a fertilizer containing—

Nitrogen	4%
Phosphoric acid	6%
Potash	10%

as to insure its maximum growth under average conditions. The removal of a large crop would still leave a large residue of plant-food, which would provide the following wheat crop with at least all of the mineral elements necessary to produce a maximum crop. If the wheat does not show vigorous growth in the spring, it is lightly top-dressed with nitrate of soda, which not only feeds it directly with nitrogen, but strengthens and invigorates the plant, enabling it to secure the minerals needed. The removal of a large crop still leaves an unused residue, upon which the clover crop following is also able to make a maximum growth, and thus three crops are fertilized with the one application. The hay is either fertilized with both the minerals and nitrogen, or lightly top-dressed with nitrogen early in the spring. The yard manure, accumulated from the residue of straw, hay and corn, is applied to the corn, which, being a gross feeder, is able to obtain from this an abundance. Thus, by the heavy application of fertilizer upon the "money crop," all the crops in the rotation are benefited.

This method possesses many valuable features, and is, perhaps, quite as well adapted as any other for this system of farm practice.

An Irrational System

The most expensive and irrational system of all, and one more commonly practiced than any other in general farming, may be termed the "hit or miss" system; if a "hit" is made, there is a profit, if a "miss," the loss is trifling. In this system, no special thought is given to the character of the crop or its needs. If the farmer can afford it, he purchases a fertilizer, without regard to its composition, and applies it in very small amounts. If it happens to contain that element which is particularly needed for the plant to which it is applied, a profit is secured. In too many cases, however, the constituents added are already in abundance in the soil, or so little of the fertilizer is used as to preclude any profit.

SUMMARY

With the exception of this last system, there are good features in all of these suggested methods of use, and it rests with the farmer to select the best points from each, or rather to use the suggestions in each which are in his judgment more applicable to his conditions. They are all based upon underlying principles, and pre-suppose a knowledge of them on the part of the farmer. They are, at best, but guides or sign-posts pointing toward better methods in the use of fertilizers, rather than absolute rules to be blindly followed.

The suggestions here and in subsequent chapters, in reference to the use of fertilizers, are formulated from the best information obtainable by the writer, and mainly from two sources: First, the results of experimental inquiry, and, second, the results of the observation and experience of practical men. In no case can absolute rules be laid down. Farmers may safely rely on the well-established principles, but each must remember that the use of the principles must be modified according to his own conditions.

CHAPTER X

FERTILIZERS FOR CEREALS AND GRASSES

It has already been pointed out (p. 175) that these crops are classed as possessing a relatively low commercial value and a relatively high fertility value, and that, from a practical standpoint, in any fertilization of them a possible profitable return should be borne in mind. This is, of course, necessary in all cases, but is particulary necessary where an increased yield, as great as can be expected from an application of proper fertilizing materials, cannot possibly result in an extraordinary profit, a result quite possible with certain crops of the opposite class. The possible increase in yield, too is, dependent on the conditions of soil and season, and if these latter are such as to forbid a maximum increased yield, the immediate profits from the application are considerably reduced.

It has been shown, too, by careful experiments, that, on the average, at least one-third of the nitrogen applied to these crops, though contained in the best forms, is not secured in the crop, even under the most favorable conditions; that is, in any case certain amounts are lost through drainage, the growth of weeds and denitrification; and, further, that the minerals must exist in the soil, or must be supplied in sufficient excess, otherwise, the utilization of the nitrogen by the plant is still further reduced. The expense of fertilizer per unit of increase in these crops is, therefore, relatively greater, even under the best conditions of its use. A bushel of wheat, with its accompanying straw, will contain, for example:

Nitrogen	1¾ lbs.
Phosphoric acid	⅔ "
Potash	1¼ "

It will be observed that the amounts of fertilizer ingredients contained in the crop are such that, if the seasonal conditions are perfect, so that the maximum of the amounts applied are recovered in the crop, the cost of fertilizers per bushel of increase is still relatively high, thus showing that great care must be exercised in order that a direct and immediate profit may be secured. Nevertheless, since the cost of preparing the land and of harvesting the crop is but slightly greater for a large crop than for a small one, the larger returns for the labor very frequently pay well for the application of the material, even though the margin of money profit is small. In crops of this sort therefore, and especially when grown on the "extensive" plan, an important point to be determined is whether the land is deficient in all of the constituents for grain and hay growing, or whether only one or two are lacking, in order that in the applications made, only those constituents are supplied that are necessary, and adding to an excess already present is thus avoided, with a consequent saving in the cost of the fertilizer.

EXPERIMENTS TO DETERMINE THE LACKING ELEMENT

The lacking element cannot be fully determined, except by direct experiments by the farmer himself. That is, no general principle can be depended on as an absolute guide. He should learn whether his soil is deficient in any of the elements, and, if so, which ones should be applied to the different crops in his rotation. A careful study along this line, too, will show whether it is fertilization that is required to meet seeming deficiencies, for it frequently happens that the needs of the soil are not so much for added plant-food as for better management of the soil in other respects, in order that natural supplies may be made more available.

It may seem, at first glance, that experimenting should be left to the experiment stations, and that farmers should be advised by them in respect to the needs of their soils in respect to plant-food. This is partly true, but the proper function of experiment stations is to establish principles, the application of which must be left, in large part at least, to the intelligence of those who are to utilize them. The farmer must study his own conditions. Scientific inquiry has established the facts that soils differ in their content of the different plant-food elements, and that those of practically the same chemical composition differ in respect to their physical qualities, both of which conditions exercise an important influence upon the availability of the constituents.

This experimenting may also seem to be a troublesome operation, yet, if thoughtfully managed, it will mean but little extra labor, and the resulting gain may be far in excess of the cost of the work. For example, if it is shown that fertilization under certain conditions is not the thing needed, and, therefore, not profitable, it saves possible outlay at once; if it shows that the application of certain of the constituents is a profitable practice, it enables the adoption of a systematic scheme of fertilization.

A Scheme for Plot Experiments

The following simple scheme of plot experimenting has been suggested, and it admits of determining many of the points involved. This scheme includes ten plots, in which three are to be cropped without manure, as check plots, in order to show the productive capacity of the unmanured land. The plots may vary in size, though it is desirable that they should contain at least one-twentieth of an acre, and that they should be long and narrow, in order to include as many inequalities of the soil as possible, though in any case land as uniform as possible in physical and chemical qualities, and fairly representative, should be selected. The following plan permits of a study of the effect of the application of individual constituents, and of their various combinations. If desired, in order to simplify the work in the beginning, only the first four plots need be taken. This will reduce the labor, and, at the same time, permit a study of the soil's deficiencies in respect to single elements of plant-food, and the relative needs of the different crops for the various constituents.

PLAN OF EXPERIMENTS — SIZE OF PLOTS, $\frac{1}{20}$ OF AN ACRE

Plot I.	Check. No fertilizer.			
" II.	Nitrate of soda		8	lbs.
" III.	Superphosphate		16	"
" IV	Muriate of potash		8	"
" V.	Check. No fertilizer.			
" VI.	Nitrate of soda, 20 lbs.	Superphosphate.	16	"
" VII.	Nitrate of soda, 20 "	Potash	8	"
" VIII.	Phoshoric acid, 40 "	Potash	8	"
" IX.	Nitrate of soda, 8 "	Superphosphate,	16	"
	Potash		8	"
" X.	Check. No fertilizer.			

The rate of application per acre is greater than would naturally obtain in practice, in order both to facilitate the distribution of the fertilizer, to furnish a sufficient abundance of the constituent, and to provide against unfavorable conditions.

Preferably, the application should be made broadcast, and before planting, if an uncultivable crop, though for cultivable crops it may be applied later and harrowed in.

It will be observed that the amounts of fertilizer are one pound per square rod, or multiple thereof. Thus, in order to insure an equal distribution over the entire area, it may be roughly divided into plots of a square rod, and the required material for each rod applied separately Careful weights should be made of the yields of the different plots, as a basis of comparison. The same fertilizers should be used on the different crops of the rotations, and, as interest is increased in the work, different forms and amounts of the various constituents may be introduced.

Results That May Be Attained

If it is found that for a certain crop only one of the applied constituents profitably increases the yield, then that should be used until the need of the others is apparent. If two are needed to accomplish the results, use two, and so on; though in the long run, or as the practice approaches the "intensive" system, all will doubtless be required. In "extensive" farming this is a very desirable line of experimentation, and can be carried out by individual farmers. It is useful not only in showing the deficiencies of the soil for the various crops, but is educative in its character, as it familiarizes the farmer with the materials that are used in making fertilizers, and encourages exact methods of work. Since, as already stated, the need very frequently is not so much for added fertility as it is for better preparation and cultivation of the soil, or for amendments such as lime, it would be a desirable practice to include in the number of plots here indicated one or two in which the cultivation of the soil was made more perfect, in order to determine whether the need is for more fertility elements or whether it is for better tillage, the effect of which is to render more of the soil constituents available to the plant. One or two to which lime is added may be advisable, in order to determine whether this substance is needed either to correct acidity or to make available otherwise unusable compounds. This method, while particularly desirable where "extensive" methods of practice prevail, is of less importance where the aim is to grow maximum crops, in which case both the crop and its rotation are to be considered, and the needs of the plant rather than the deficiencies of the soil require first attention.

The results of experiments which have been conducted with great care in a number of states show that where "extensive" methods are practiced certain elements need not be added in the fertilizers; that is, that the soil contains such an abundance of them that the plant is able to obtain a full supply, at least, for a long time. For example, it has been shown that on the chief sugar-producing soils of Louisiana and Mississippi, and the cotton soils of Georgia and Texas, the addition of potash has been of less importance in the past than the other elements, and it frequently does not need to be included in the fertilizer, while phosphoric acid is always needed.

The results of field experiments on this plan in New Jersey, on reasonably good, loamy soils, indicate that phosphoric acid and potash are of much more importance in fertilizers for corn than nitrogen, whereas upon sandy soils, nitrogen and potash are of relatively more importance than phosphoric acid; that is, even where "extensive" practice is used there are conditions where one or more of the elements are not required in order to secure maximum crops, which eliminates the necessity for an immediate outlay for those constituents that are not lacking. Where experiments of this sort have not been carried out and the specific needs determined, *it becomes necessary to assume that all of the constituents are required*, and to apply the amounts and proportions of those which the general considerations of the soil, season, climate and crop would seem to demand.

As already pointed out, the methods of fertilization here suggested, though in many instances apparently positive, are not to be interpreted as absolute rules, but rather used as guides, based upon the best information that it has been possible to obtain, both as a result of scientific inquiry and of practical experience.

THE IMPORTANCE OF SYSTEM IN THE USE OF FERTILIZERS

The following rotation is assumed, in order to show the necessity of a definite system of work, which is quite as important in this branch of farming as in many others in which system is apparently more essential,—though in fact it is quite as necessary to observe a definite system in the feeding of plants as in the feeding of animals with the plants:

ILLUSTRATION OF A ROTATION

First year	Maize (corn).
Second year	Oats.
Third year	Wheat.
Fourth year	Clover and timothy
Fifth year	Timothy hay.

Indian Corn Exhaustive of the Fertility Elements

Since in rotations of this sort a fair number of live stock is usually kept, a considerable amount of manure is made, which should be carefully cared for and used, as it contributes materially to the success of the plan. The manure may be used in part on land for corn, and should be spread broadcast, practically as fast as made during the fall, winter and early spring. This plant, because it is a gross feeder, and also because it makes most of its growth during the summer season, when activities in the soil are most rapid, is able to appropriate from the coarse manures a larger proportion of the constituents than would be possible for crops which make their greatest growth earlier or later in the season. In the summer, too, the conditions are most favorable for nitrification, and soils which possess a fair content of vegetable matter are usually able to furnish the nitrogen needed in addition to that supplied in the organic manures, particularly in the middle and southern states. The considerable amounts of potash required for the growth of stalks, and the phosphoric acid for the formation of grain, demand that a liberal supply of these constituents be provided, and the fertilizer for the corn should, therefore, contain an abundance of available phosphoric acid and of potash.

A crop of 50 bushels of shelled corn per acre, with the accompanying stalks, will remove, on the average, 80 pounds of nitrogen, 29 pounds of phosphoric acid, and 55 of potash. It is an exhaustive crop. A fertilizer, therefore, that would furnish 30 pounds of phosphoric acid and 40 of potash would be regarded as a fair dressing for land of medium quality. A part of the phosphoric acid, at least, should be in a soluble form, in order to supply the early needs of the crop. The remainder may consist of ground bone or tankage, if the phosphoric acid in these can be obtained more cheaply, since they will decay rapidly enough to supply the demands for the later growth. The potash may be either muriate of potash or kainit, though the former is preferable if it is applied in the drill, which is, if used in these amounts, a perfectly safe practice so far as injury to the plant is concerned; though fertilizers containing large amounts of potash salts are preferably applied broadcast on raw ground of a clayey nature, and well worked into the soil, thus insuring a good distribution. The cost of an application of this sort will be relatively small, and the minerals added will be more than sufficient to provide for a considerable increase in crop. If the land is light and sandy, nitrogen should be added, even though it has received a good dressing of yard manure, as these lands are usually deficient in this element, and organic forms are usually quite as useful as the soluble nitrate or ammonia, since the seasonal conditions during the period of growth are favorable for the rapid change of the nitrogen in materials of good quality, like blood, concentrated tankage, or cotton-seed meal, into nitrates. The amounts of nitrogen needed would, under ordinary conditions, be supplied by 100 pounds of high-grade blood, or 200 pounds of cotton-seed meal. The nitrogen may also be obtained by substituting tankage for the superphosphate, though it is not so desirable a practice.

In this matter of fertilizing, it must be remembered that weeds appropriate plant-food quite as readily as the corn, wherefore in order to obtain the best results from the fertilizers added, clean cultivation should be practiced.

Oats

For the oat crop that follows corn, and which makes its best growth early in the season, before nitrification is rapid, quickly available forms of nitrogen are very desirable; and inasmuch as the oats require an abundance of phosphates, a fertilization with phosphoric acid is also essential. Hence, fertilizers consisting of mixtures of nitrate of soda and superphosphates have proved of great value for this crop. If mixed at home, they should be applied immediately after preparation, for a loss of nitrogen may result if the mixture is allowed to stand for any length of time. An application of 8 pounds of nitrogen and 18 of phosphoric acid, or 200 pounds per acre of a mixture of 50 pounds of nitrate of soda and 150 of acid phosphate, has proved quite as profitable on medium soils as heavier applications, mainly because the oat crop is a less certain one than corn; besides, it frequently suffers severe losses in harvesting, which increase the risk from an expensive fertilization. The application of potash is not so necessary if added in the fertilizer for corn, as suggested, except on light, sandy soils.

Wheat

For the wheat crop following oats, the rest of the farm manure on hand may be applied after plowing, well harrowed into the surface soil, and a fertilizer applied which shall be rich in available phosphoric acid, and which shall contain only a sufficient amount of nitrogen in quickly available forms to insure a good fall growth. When the land has been well fertilized for previous crops, a dissolved animal bone superphosphate is an excellent fertilizer for wheat, because containing the elements, phosphoric acid and nitrogen, in good forms and proportions. If more nitrogen is needed than is provided by 200 to 300 pounds of this fertilizer in order to mature the crop, which is frequently the case, particularly if the winter has been severe, or if the land is light, it may be applied in the spring, and preferably in the form of a nitrate, which distributes readily, and is immediately available, advantages not possessed by other forms. At this period of its growth, the crops need to make a rapid appropriation of nitrogenous food, though the conditions are not yet favorable for the change of nitrogenous organic compounds in the soil into the available nitrate. The top-dressings should be made as soon as the crop has been well started, and should range from 75 to 150 pounds per acre, according to the character of the soil and previous fertilization. The better the natural character of the soil and its treatment, the larger the dressing that may be applied with possible profit, though in no case should it exceed the larger amount.

Clover

For the clover which follows the wheat, only the minerals, phosphoric acid and potash, need be applied. An increased return is likely to follow such an application, as the clover is not able to utilize to the fullest extent the nitrogen from the air except when the soil is supplied with an abundance of mineral food. An application which will furnish 12 pounds of phosphoric acid and 25 pounds of potash per acre marks the minimum dressing, and it may be applied with advantage immediately after the wheat is harvested.

Timothy

The timothy, the next crop in the rotation, is a member of the grass family, and is especially benefited by nitrogenous fertilization, and top-dressings in the spring with nitrate of soda have proved of great value on soils well supplied with minerals, though experienced farmers have learned that better results are obtained if the minerals are applied with the nitrate, thus insuring a better growth and development of plant. A mixture made up of 150 pounds of nitrate of soda, 100 of acid phosphate and 50 of muriate of potash, at the rate of 300 pounds per acre, is now used by many successful hay growers. The application should be made as soon as the crop has well started in the spring.

The system of fertilization here outlined is not to be advocated except under circumstances where it is not possible or practicable to supply such an abundance of plant-food as will guarantee a maximum production, as in "intensive" practice, in which the yield is measured by climatic and seasonal rather than soil conditions, but rather such additions as will return a profit and at the same time tend toward the improvement of soil. This system is economical in the use of nitrogen, the most expensive element. It provides a sufficient amount of available plant-food to insure a reasonable increase in crop, and it is well adapted to lead the farmer by easy steps from the "extensive" to the "intensive" system of farming.

A Gain of Fertility by the Rotation System

Assuming that the increased yield of corn is 20 bushels, with accompanying stalks, of wheat 10 bushels per acre, of oats 15 bushels, of clover ½ ton, and of timothy ½ ton, the amounts applied will be practically sufficient to furnish all of the potash contained in this increase, and more than sufficient to meet the demands for phosphoric acid. That is, by this system, there has been applied in the materials 30 pounds of nitrogen, 64 of phosphoric acid and 80 of potash. While, if this increased crop was secured, the following amounts would be required: 71 pounds of nitrogen, 31 of phosphoric acid and 79 of potash. The considerable amounts of plant-food contained in the yard manure, and the gain from the roots and stubble of the clover, serve to supply the balance of nitrogen required, and to provide a store of unused residue for future crops.

The method, if adopted, would be more rational, and likely to result in more satisfactory returns than the one now generally practiced, namely, to purchase without particular regard to the character of the materials furnishing the constituents, or their proportions, and to apply, on the average, even less per acre than is here recommended. Assuming that 200 pounds per acre of the average corn fertilizer, showing a composition of 2.5 per cent nitrogen, 8 of phosphoric acid and 5 of potash, were applied only to the crops corn, oats and wheat, omitting both clover and timothy, there would have been added 15 pounds of nitrogen, 48 of phosphoric acid and 30 of potash, amounts of each too small to provide for a large increase in crop, provided all were needed.

The Necessity of Adding More Plant-food than is Required by a Definite Increase in Crop

It may be asked, why add more of the constituents than is necessary to provide for a definite increase in crop? Assuming that the average yield of the land is twenty bushels of wheat per acre, and the aim is to secure thirty bushels, why not add the constituents in the amounts and proportions necessary to provide for this extra increased yield, rather than any excess of these amounts? The answer is, that in order that such a result may be accomplished, the conditions would need to be absolutely perfect, so that the plant would have at its command the amount of food needed each day. If a period in the growth of the plant should be so wet or so dry as to prevent the plants from acquiring the food necessary for their continuous growth, there would be no opportunity for them to gather food faster, when the better conditions followed the unfavorable conditions, and thus to overcome the ill effects of the period of partial starvation. In other words, if there were only sufficient food to supply the plant under normal conditions of season, the plant, after a period of time during which there was no growth, could not grow faster than it did before, hence it could not catch up in its growth and make a full crop. Furthermore, the plan of applying only that needed for the increase must necessarily assume that the plant-food is in the best forms, and that the physical conditions of soil are so perfect as to cause it to absorb and retain all the food applied, and in such a manner as to permit it to be readily obtained by the plant. A further advantage is to enable the clover plant in the rotation to fully exercise its power of acquiring nitrogen from the air. Moreover, if properly carried out, it fulfils the idea of successful agriculture; viz., the production of profitable crops, while at the same time not reducing, but increasing, the potential fertility of the soil.

The System Should Be Modified if no Farm Manures are Used

In this rotation, if no manures are available, as indicated, then the amounts and kinds of fertilizers should be somewhat changed. For example, if it was necessary to supply the corn crop with a sufficient abundance of all the elements in artificial forms, then the proportions of nitrogen should be somewhat greater and the total amounts of the constituents applied to the different crops considerably increased. For corn, a mixture consisting of 20 pounds of nitrogen, 30 of phosphoric acid and 50 of potash should be applied, and if grown upon raw ground rather than upon sod, it would be desirable to still further increase the nitrogen. The oats could be fertilized, as before recommended, while the wheat should have an increased supply of both nitrogen and phosphoric acid,—double the amounts recommended when used with manure,—besides an addition of at least 10 pounds per acre of potash. The fertilizing of the clover and timothy need not be changed. If, in a rotation of this character, barley were substituted for oats and rye for wheat, the fertilization need not be materially changed, though the rye possesses a slightly greater power of acquiring phosphoric acid than wheat, and the nitrogenous top-dressings may be omitted, unless the crop is grown primarily for straw rather than for grain. The barley is also less able to acquire its phosphoric acid than the oats, and is especially benefited by nitrogen, though care should be exercised to regulate the amounts applied in order to prevent lodging, which affects both the yield and quality of the grain. If in the rotation the timothy hay is omitted, then the fertilization for the corn may be reduced, as on good soils the yard manure, together with the plant-food stored in the surface in the clover sod, will furnish an abundance.

FERTILIZERS FOR A SINGLE CROP GROWN CONTINUOUSLY

When it is desirable to grow any one or all of these crops continuously (and this practice may be followed with advantage, particularly when a leguminous catch-crop is seeded with the main crop, which insures a continuous occupation of the land and also provides vegetable matter and nitrogen), the fertilization would naturally be somewhat different, and, as a rule, would require more nearly even quantities of the different constituents. For corn, a fertilizer supplying 20 pounds of nitrogen, 40 each of phosphoric acid and potash, would provide for a liberal increase in the yield from year to year. The nitrogen should preferably be in good organic forms, which would decay rapidly enough to supply the needed available nitrogen during the growing season. The phosphoric acid may be drawn partly from superphosphates and partly from organic compounds, as ground bone and tankage, provided these latter may be secured at as low a price as the superphosphate, and the potash applied in the form of a muriate or kainit. Fertilizers may be applied broadcast and well harrowed into the soil, or part may be distributed in the row at time of planting.

If a catch crop were seeded to be used as green manure, as, for example, crimson clover, the application of nitrogen may be very materially reduced. This practice has been followed with advantage in the middle and southern states.

For continuous wheat growing, a fertilizer may be used at time of seeding which supplies 10 pounds of nitrogen, 40 of phosphoric acid and 20 of potash. A small part of this nitrogen would better be in the form of a nitrate, which will encourage a good top-growth in the fall, as well as a deep root system; the phosphoric acid should be soluble, in order to supply the immediate needs of the young plant, and the potash in the form of a muriate. Such an application would provide for a very considerable increase in crop, particularly if followed in the spring by a top-dressing of 100 pounds per acre of nitrate of soda.

The top-dressing with nitrate of soda is, however, not always advisable. The chief objection to its use is that it does not encourage, but frequently seems to retard, the growth of clover, though its very great advantage is that it encourages the deeper rooting of the wheat and the more rapid growth of grasses. If continuous cropping of wheat is practiced, clover should be seeded with it, in order that the ground may be constantly occupied, and thus prevent leaching, as well as mechanical losses of fertility, and also to supply vegetable matter containing nitrogen for the succeeding crop. When a system thus outlined has been continued for a few years, the nitrogen in the fertilizer may be largely omitted.

The same considerations apply to rye as were indicated for wheat. Oats are seldom grown as a continuous crop, though if it should be desirable, a fertilizer furnishing at least 20 pounds of nitrogen, 25 of phosphoric acid and 10 of potash would be a good dressing, care being taken that a large portion of the nitrogen exists as nitrate or as ammonia, in order to stimulate and strengthen the early growth of the plant. For the grass crop, or continuous mowing land, a fertilizer rich in nitrogen and potash should be applied. A good application in the spring may consist of 25 pounds of nitrogen, 15 of phosphoric acid and 25 of potash, and immediately after the hay is harvested a further application of at least 20 pounds of nitrogen and 30 each of phosphoric acid and potash should be applied. The nitrogen in this case may consist partly of organic forms, though the soluble nitrogen is to be preferred as top-dressings where it can be procured at such a price as to make it comparable with other forms. The nitrogen of bone, tankage and other slower-acting forms is excellent for the grasses, though these should be preferably applied and well worked into the soil previous to seeding. The early spring application should consist largely of soluble nitrogen, both to encourage a rapid appropriation of this element by the plant early in the season, as well as a deeper root-system, and consequently a greater drought-resisting power, and also to provide the elements necessary for the increased crop. The summer or later application stimulates and strengthens the roots for the coming season. If an aftermath crop is removed, or if it is pastured, a further application may be made, which may consist largely of the mineral elements. This fertilization of the hay crop will also result in a richer product, for an abundant supply of nitrogen encourages a larger proportion of leaf growth, and consequently a smaller proportion of stem, containing the less valuable woody matter. Lands that are well fertilized in this way, if properly seeded in the first place, may make profitable mowing crops for a long series of years, and good crops cannot be expected unless liberal fertilization is practiced.

Fertilizers for Meadows

For meadows used as pastures, a more liberal application of the mineral elements is recommended, since an abundance of these encourage the growth of the clovers, which make a richer herbage than the grasses. Heavy nitrogenous fertilization is expensive, and encourages the growth of the grasses rather than the clovers. Pasturing, while less exhaustive than hay cropping, nevertheless results in the gradual depletion of fertility, and an abundant growth of rich pasturage can only be secured where there is an abundant supply of available plant-food. Mixtures made up of acid phosphate, ground bone and muriate of potash in equal proportions, make very good dressings, if applied in sufficient quantity, three hundred to five hundred pounds per acre annually. The ground bone is recommended because it decays slowly, and thus furnishes a continuous supply of nitrogen and of phosphoric acid. The application should preferably be made both in spring and in late summer, in order to secure a good growth, as well as to encourage the introduction of the clovers. In any system of continuous cropping, or in fact in any system of rotation-cropping, in which an abundance of organic matter is introduced in the way of green crops, or in decaying vegetable matter contained in roots, the land should occasionally receive a dressing of lime, both to supply that which the plants need, as well as to correct possible acidity of soil.

WILL THIS SYSTEM of FERTILIZING PAY?

That fertilization will pay if carried out, as is pointed out here, and upon lands not now producing paying crops, depends, of course, very largely upon the price of the crops, the cost of the materials, and the method of farming practiced. At the prices which have prevailed in the recent past, for both crops and fertilizing materials, there is no doubt that this reasonable fertilization, together with a good system of practice in other respects,—that, is, good plowing good harrowing, good drainage and good cultivation, —will result in very satisfactory returns. In fact, it has been shown by repeated experiments (see bulletins and reports of New Jersey Experiment Station) that the yields on land which is capable of producing an average crop of 15 bushels of wheat per acre, 30 of corn and 30 of oats, may be more than doubled by an abundant supply of fertilizing materials. Such an increase results in an actual direct gain, as well as in the saving of labor per unit of product, which is accomplished when the larger crop is secured.

The main point in this whole matter of fertilization is to understand that a fertilizer is a fertilizer because of the kind and form of plant-food contained in it; and that its best action, other things being equal, is accomplished when the soil possesses good physical qualities, when the management is also good, and when systematic methods are planned and adopted. "Hit or miss" fertilization, even for these crops, may pay, and doubtless, on the average does pay as well as some other things that farmers do, but does not pay as well as it might if better methods were used.

CHAPTER XI

POTATOES, SWEET POTATOES, TOMATOES AND SUGAR BEETS

These crops differ from the cereals and grasses in that they are products of high commercial value, and are less exhaustive of plant-food constituents per unit of money value. As field crops they are usually grown in a rotation, and constitute one at least of the chief money crops. In sections near large markets these crops are, with the exception of sugar beets, divided into two classes, early and late, the early crop being regarded as the most profitable; hence greater efforts are made, both in the way of fertilization and of management, to secure a large and early crop, than is the case with the late crop. For the early crop the natural supply of plant-food in the soil is not a prime consideration. In districts distant from markets, the late crop is the only one grown to any extent, and because it has the whole season for its growth, greater dependence is placed upon the natural resources of the soil. While, as already stated, these crops are not regarded as exhaustive of plant-food elements in the same sense as the cereal crops are, because it frequently happens that a bushel of potatoes, or of sweet potatoes, or of tomatoes, will bring as much as a bushel of corn, or sometimes as a bushel of wheat, yet the amount removed in the entire crop may be quite as great as in the grain crop, because of the much larger number of bushels grown per acre.

FERTILIZERS FOR POTATOES, EARLY CROP

It has been demonstrated, both by experiment and practical experience, that good crops of early potatoes require an abundance of plant-food, and that on soils of good character a heavy fertilization is usually more profitable than a medium or light application.

The plant-food removed by a fair crop — 200 bushels per acre of tubers — will, on the average, consist of 27 pounds of nitrogen, 12 pounds of phosphoric acid and 60 of potash. Even though the increase from the application of fertilizers is less than 100 bushels per acre, it is always advisable to add plant-food in considerable excess of these amounts: first, because the crop must be grown quickly; and second, because a large part of its growth must be made in the early season, before the natural conditions are favorable for soil activities. A study of the fertility composition of the potato shows that of the three essential constituents, the potash is contained in the greatest amount and the nitrogen next, while the amount of phosphoric acid contained in it is comparatively small. Most fertilizer formulas for potatoes are, therefore, prepared with the idea of furnishing a greater amount of potash than of nitrogen or phosphoric acid. A study recently made by the Geneva Experiment

Station* shows that the formulas prepared to contain the plant-food in nearly the proportions used by the entire potato plant, excepting that the phosphoric acid is in considerable excess, were less useful than those containing very different proportions of the constituents, and which were based upon the experience of observing growers. That is, a formula of the first class, furnishing—

Nitrogen	6½ %
Available phosphoric acid	5 %
Potash	10 %

gave less satisfactory returns for the same amount applied than one furnishing—

Nitrogen	4 %
Available phosphoric acid	8 %
Potash	10 %

This latter formula is very generally used in sections where early potatoes are an important crop.

The Time and Method of Application

These are matters of considerable importance. It has been urged, particularly by German experimenters, that the potash salts, when used in such excess as seems desirable, should be applied more largely to the crop preceding, rather than directly to the potato crop. This method has not been adopted in this country to any extent, and it is believed that

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*Bulletin No. 137, N. Y. State Exp. Sta.

our climatic conditions are such as to cause a very general distribution of the salts throughout the soil, if applied, in part at least, just before planting and thoroughly distributed by cultivation. At any rate, very satisfactory returns are secured from the direct application to the crop of fertilizers of this composition. In reference to the method of application, while very good results are secured from the application of the fertilizers directly in the row, this is to some extent influenced by the character of the soil. Where the soil is somewhat heavy, and the circulation of water is not perfectly free, it is less desirable than where the soils are open and porous, and free circulation is not impeded; though where the amounts applied are considerable, it is recommended that at least one-half of the fertilizer should be applied broadcast and worked into the soil, and the remainder placed in the row at the time of planting. Naturally, when the soils are poor, a concentration of the constituents is more desirable than when the surrounding soil possesses reasonably abundant supplies of available food.

The Amount to be Applied

As already stated, the amount of the different constituents to be applied should be in considerable excess of that required by the actual increase in crop, both for the reasons already given, and because it is desirable in crops of this sort to insure a continuous and abundant feeding of the plant. Where "intensive" practice is general, the amounts applied very frequently reach a ton per acre of the high-grade fertilizer already mentioned, though the necessity for so large an application as this has been questioned, particularly if it is expected to give rise to a profitable return in the crop to which the application is made, and though it can be readily seen that if conditions should not be favorable the larger amounts would be preferable. The result of investigations of this point by the Geneva Experiment Station* showed that an addition of fertilizers above 1,000 pounds per acre, or 40 pounds of nitrogen, 80 of phosphoric acid and 100 of potash, was not as profitable as 1,000 pounds. It must be remembered, however, that these experiments were conducted upon light soils, and on these entire dependence must be placed upon added plant-food.

In the best potato sections of New Jersey, the application of a fertilizer of this composition ranges from 1,000 to 2,000 pounds per acre, while the majority of the growers use the smaller rather than the greater quantity. Many use the larger, and are of the opinion that it is a profitable practice, because of the greater certainty of securing a good potato crop, and because the unused residue provides for large yields of the subsequent crop without further applications. The growers of potatoes in the vicinity of Norfolk, as well as farther south, also find it profitable to be generous in the use of fertilizer for this as well as for other crops of high commercial value.

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*Bulletins 93, 112, 137, N. Y. State Exp. Sta.

Form of the Constituents

In the growing of potatoes, sulfate of potash is generally recommended in preference to the muriate, owing to the supposedly deleterious effect on the quality of the tubers resulting from the large quantities of chlorids contained in the muriate, though the different forms, when properly applied, do not seem to materially influence the yield. That is, if muriate or kainit is applied previous to the planting of potatoes, the deleterious chlorids may be washed from the soil. There is no doubt that the sulfate improves the appearance of the potatoes, making them more clean and uniform in size, though experiments that have been conducted do not show a material difference in the chemical composition of the tubers grown with any of the forms. The tendency on the part of the muriate seems to be to diminish the amount of dry matter, and inasmuch as the dry matter is mostly starch, the latter is thereby slightly reduced, though it has not yet been demonstrated that the good quality of the potatoes is measured by the content of starch.*

In reference to the form of nitrogen, both theoretical considerations and the experience of growers confirm the belief that for the early crop, a portion of the nitrogen should exist in the form of nitrate or ammonia and the remainder in quickly available organic forms, although no definite experiments have been conducted to determine this point, nor the one

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* Bulletin No. 137, N. Y. State (Geneva) Exp. Sta. Bulletin No. 80, N. J. Exp. Sta.

as to whether all of the nitrogen in the form of nitrate should be applied at the time of planting. A top-dressing after the potatoes have come up is a very desirable method of practice on light soils which have been liberally supplied with the minerals.

On good potato soils, therefore, a good fertilization would consist of 800 pounds per acre, as a minimum, of a mixture containing:

Nitrogen	3 to 4 %
Phosphoric acid	6 to 8 %
Potash	8 to 10 %

The nitrogen is to be in quickly available forms; the phosphoric acid, also, is to be available, and the potash to be derived from sulfate, particularly if fine quality of crop, as indicated by appearance, is desired. If only yield is considered, the muriate is quite as serviceable.

LATE POTATOES

For late potatoes, the considerations in reference to the form of the constituents and the amount of the application, as suggested for early potatoes, do not always hold good, since in many cases the crop is able to secure a larger proportion of its plant-food from soil sources,—due, first, to the longer period of growth of the plant, and second, to the fact that the crop is usually grown upon soils naturally richer in the plant-food elements, though the proportion of potash, as in the formulas already indicated, should be relatively large. The nitrogen may be reduced, and the form of nitrogen may be derived largely from organic sources. Good formulas for late potatoes may consist of —

Nitrogen	2½ %
Phosphoric acid	6 %
Potash	8 %

and the application may be from 600 to 800 pounds per acre.

Where potatoes are grown in rotations with the cereal crops mentioned in Chapter X, the unused residue from the rather heavy application of fertilizers to the potato crop is depended upon to very materially aid the growth of these, thus reducing the outlay for fertilizer for crops of a low commercial value. This practice is advantageous, though the prime object should be to feed the *crop* rather than the *soil*—that is, apply the fertilizer with the idea of securing a profit from it in the potato crop, rather than a possible profit in subsequent crops.

SWEET POTATOES

In the growing of sweet potatoes, the quality of the product is more important than in the case of the white potato. The northern markets distinctly recognize quality in this crop, and it is measured by size, shape, and results in cooking. The potato that brings the best price in the different markets is small, about the size of a white potato; in shape round, rather than oblong, and is dry and mealy when cooked.

This characteristic of the crop is influenced both by the character of the soil and of the manures and fertilizers applied. The soils best adapted are dry, sandy loams, and the most useful fertilizers are those which contain an abundance of minerals,—phosphoric acid and potash,—and not too large supplies of quickly available nitrogen. It is also true that the yields of sweet potatoes of this character are not as large as those that may be obtained when quality is not a prime consideration, and which are grown for the general market.

Fertilizer Constituents Contained in an Average Crop

This crop is very similar to the white potato in regard to food required. Two hundred bushels of sweet potatoes, not including vines, contain, on the average, 30 pounds of nitrogen, 10 of phosphoric acid and 45 of potash; and since the yield of the general crop is larger on the average than one of white potatoes, a liberal supply of the minerals must in all cases be provided. The studies made of this crop have not yet established the best proportions of the constituents in fertilizers, though such experiments as have been conducted show that those that contain a very considerable excess of potash over the other elements are preferable. While nitrogen is needed, too much, particularly in soluble forms, seems to encourage too large a growth of vine, which contributes to yield, but at the expense of quality, which is a very important consideration. The best growers use fertilizers containing a small percentage of nitrogen and a high percentage of phosphoric acid and potash. Applications that furnish 20 pounds of nitrogen, 50 of phosphoric acid and 80 of potash per acre have given excellent results in regions in New Jersey in which market quality up to a certain point is quite as important as increase in yield, though, of course, yield is also considered. Any excess of nitrogen over this amount seems to contribute toward a larger, rather oblong, rooty growth of tuber, and to injure cooking quality. In growing crops for the general market, however, larger applications of nitrogen are demanded, and experiments have shown that organic forms are preferable to soluble forms, though the climate and season largely influence this point. In northern sections, and in cold seasons, the soluble forms are more useful than in the warmer climate and longer seasons of the South.

There is no question, however, that commercial fertilizers can be depended upon to produce maximum crops of sweet potatoes, and at much smaller cost than with yard manure.* Results reported by the Georgia Experiment Station† indicate the following formula as an excellent one for sweet potatoes, though, as there stated, "the amounts that can be used vary considerably, depending upon the character of the soil—the richer the land in humus, the greater the quantity that can be safely used." "Thin soils will, of course, only stand very moderate manuring,

*Bulletin P, New Jersey Exp. Sta.

†Bulletin No. 25, Georgia Exp. Sta.

and necessarily produce a very small yield." The formula consists of —

Acid phosphate	320 lbs.
Cotton-seed meal	360 "
Kainit	640 "

This formula will furnish about 25 pounds of nitrogen, 50 of phosphoric acid and 80 of potash, and, according to the bulletin, will produce a yield of potatoes of from 200 to 400 bushels per acre, depending upon the season and variety of potatoes planted. Experiments at the Georgia Station also show that organic nitrogen (cotton-seed meal) is preferable to nitrate of soda as a source of nitrogen.

In making mixtures which furnish these proportions of plant-food, other nitrogenous organic materials, furnishing an equivalent of nitrogen,—as blood or concentrated tankage,—may be substituted for the cotton-seed meal, if they can be purchased quite as cheaply; and muriate of potash, furnishing an equivalent of potash, may be substituted for the kainit, if it can be more readily obtained.

As already stated, however, this fertilizer is too rich in nitrogen for the production of the best quality of potatoes, as for example "Vineland Sweets," which command the highest prices in northern markets. The growers in that district use a fertilizer richer in the minerals; one containing —

Nitrogen	3 %
Phosphoric acid	7 %
Potash	12 %

is very generally used, though reasonably heavy dressings of this are often further supplemented by applieations of from 200 to 300 pounds of acid phosphate and 100 to 150 pounds of muriate of potash per aere.

The Application of the Fertilizers

Owing to the faet that the sweet potato is grown from plants or slips, rather than from seed, and the fact that the best quality of potatoes is produeed upon rather light, sandy land, it is desirable that the fertilizer should be applied some time before the putting out of the plants. The praetiee on this light land is to apply the fertilizer when making up the hills, which usually oeeurs from two to three weeks before the plants are set. That is, in making up the hills, the soil is ridged, and during the preparation of the ridge the fertilizer may be distributed in it and well mixed with the soil. Where the land contains more clay and humus it is frequently advocated that the potash manures be applied broadeast the previous year, and only the nitrogenous fertilizer and superphosphate be applied immediately to the plant. On soils of this latter eharaeter, this is doubtless the best system. If kainit,—which has been found to be preferable to muriate in the Georgia experiments referred to,—is used as the souree of potash, it is very neeessary that it be well mixed with the soil before setting out the plants. Heavy applications of this salt in the spring proved injurious in the experiments eonducted at the New

Jersey Station.* The effect of fertilizers upon the chemical composition of the tuber was chiefly to reduce dry matter, and not apparently to affect edible quality, though the experiments were carried out upon the general crop rather than upon those grown for high quality.

TOMATOES

Tomatoes are largely grown as a field crop, and the object of their growth, whether for the early market or for the canneries, is a factor that must be considered in the adoption of systems of fertilization.

Field Experiments with Fertilizers for Tomatoes

The impression is very prevalent among growers that the tomato does not require heavy manuring. Studies made at a number of experiment stations† show, however, that the tomato is a plant that quickly and profitably responds to the use of manures or fertilizers, and that the maturity and yield are very largely influenced by the method of manuring and fertilizing. Experiments were conducted by the New Jersey Station upon three farms located in different parts of the state, and during four seasons, the object of which was to test the effect on maturity and yield of the early crop

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* Bulletin P, New Jersey Experiment Station.

† Bulletins Nos. 21 and 32, Cornell Experiment Station (Ithaca). Bulletin No. 17, Georgia Experiment Station. Annual Report for 1891, Maryland Experiment Station. Bulletin No. 11, Virginia Experiment Station. Bulletins Nos. 63, 79 and O, and Report for 1892, New Jersey Experiment Station.

of the use of nitrate of soda in different quantities and at different times, both with and without the addition of the mineral elements, phosphoric acid and potash, and to make a comparison of these with barnyard manure. The results showed:

First. That nitrate of soda was one of the best nitrogenous fertilizers for this crop, and that its use in small quantities (160 pounds per acre), or in large quantities (320 pounds per acre) in two applications, increased the yield materially, but not at the expense of maturity, and that this was equally true when used alone and when used in connection with phosphoric acid and potash.

Second. That nitrate of soda, when used in large quantities (320 pounds per acre) in one application, in the presence of a sufficient excess of phosphoric acid and potash, did increase the yield, but at the expense of maturity.

Third. That when properly used, nitrate of soda was a profitable fertilizer for the crop.

It was shown, furthermore, that nitrate of soda was superior to both barnyard manure and mineral fertilizers alone, and on the whole, was but slightly less effective than the complete fertilizers.

Fertilizers for the Early Crop for Different Conditions of Soil

These results have been practically confirmed both by the experiments of the stations referred to, and also in actual practice on soils similar in character;

namely, those which were well adapted for the early tomato — light, well-drained sandy loams — and which had been previously well manured for crops entering the rotation. The results do not apply in the case of very poor soils, or upon heavy clay soils, which are not adapted for the early crop.

The statement that it pays to fertilize early tomatoes, and that nitrate of soda is one of the best fertilizers for the crop, must, therefore, be accompanied by statements regarding the condition of soil and the purpose of growth. With the conditions clearly understood, a scheme of fertilization for early tomatoes may be outlined which, when the conditions are observed, will be likely to give much better results than methods of fertilization which do not take into consideration the habits of the plant and the special object of its growth.

For example, on soils which have been well supplied with the mineral elements, phosphoric acid and potash, by previous manuring or fertilizing, a fertilizer very rich in nitrogen derived from nitrate of soda, or nitrate of soda alone, should be used; the application at the time of setting the plant to be equivalent in nitrogen to from 80 to 100 pounds of nitrate of soda, with a second application of an equivalent amount made from three to four weeks later. A single application of the amount here suggested at the time of setting the plants would, perhaps, under good seasonal conditions give results quite as good, though the heavier application of nitrate at one time may result, in certain cases, in the loss of nitrogen by leaching, since it is an extremely soluble salt. In this case a deficiency of food would result, and thus prevent the normal development of both plant and fruit.

On soils which possess only good mechanical condition, and are very poor in plant-food, a heavier application of both nitrogen and the mineral elements will be required, in which case the following fertilization is recommended:

Previous to setting the plants, or at the time they are set, apply 50 pounds per acre of phosphoric acid, preferably derived from superphosphate, and 100 pounds of potash, derived from muriate, and thoroughly harrow or cultivate into the soil; and at the time of setting apply around the hill 100 to 150 pounds per acre of nitrate of soda. Three to four weeks later, make another application of from 100 to 150 pounds per acre of nitrate of soda. Owing to the small bulk of nitrate, it should be mixed with dry soil or sawdust, in order to insure even distribution. The only precaution to be observed is to prevent its immediate contact with the plant roots. If these methods are practiced, the plant secures its nitrogen in an immediately available form at a time when it is needed,—when it is set in the field. There is thus no delay in growth, and because of the presence of an abundance of the mineral elements no excessive growth of vine is encouraged by the use of the nitrate, as would be the case were the mineral elements absent. Inasmuch as the nitrogen is applied close to the plant, it is within the immediate reach of its roots; and because it is all in an immediately available form, which is used up rapidly, the tendency to late plant growth, which would be caused by a continuous supply of nitrogen, is not encouraged, and a normal and rapid growth and development of fruit results.

It is not stated that by this method of fertilization maturity is increased in the sense that the date of the first picking is earlier, but that a larger number of fruits is picked earlier. It was not shown in any of the experiments that the date of picking was made earlier by virtue of the nitrate, for, in fact, the earliest tomatoes were picked upon land where the minerals only had been applied. Here the yield was not satisfactory, but where the nitrate was applied, because of the larger crop, a larger proportion of early tomatoes was secured. It is obvious that, inasmuch as the price of the fruit rapidly declines as the season advances, receipts from the proportionately larger quantity of early fruit will be materially increased.

The Use of Fertilizers with Yard Manures

When it is desirable to use yard manures with fertilizers for tomatoes, because of the abundance and cheapness of the former, they should be applied broadcast, and the nitrate applied at the time of planting, as already described, rather than both together in the hill. The tendency in the latter case will be to cause a loss of nitrogen from the nitrate, depending upon the amount of organic matter in the manures. That is, experiments and experience have shown that under these circumstances more or less of the nitrogen in the nitrate may be lost.

In the use of yard manures for early tomatoes, the application of excessive quantities should be avoided, as they are virtually nitrogenous manures, which, because of their organic character, feed the plant in proportion to their rate of decay. Hence, the presence of large quantities will encourage not only an undue growth of plant, but a late growth as well. The mineral fertilizers, as acid phosphate and muriate of potash, can be used with the yard manures with perfect safety, in fact, with great advantage, because supplementing their proportionate lack of the mineral constituents. It is also desirable, where it is the practice to use manure, particularly if it is coarse, to spread it during the winter, in order that the soluble portions may become thoroughly distributed throughout the soil. As soon as the land is ready to work in the spring, it should again be plowed shallow and then deeply tilled, in order both to thoroughly warm up the soil, and to incorporate with it coarser portions of the manure.

Fertilizers for Late Tomatoes

In manuring and fertilizing for the late crop, the character of the crop and the season of its growth should be remembered. In the first place, the plants for this crop are not put in the soil until summer, when the conditions are most favorable for the rapid change of organic forms of nitrogen into nitrates. Thus, if the soil has been manured or is naturally rich in vegetable matter, the additional application of nitrogen in immediately available forms is not so important. In the second place, the object of the growth is not early maturity, but the largest yield of matured fruit; hence it is more desirable to grow a larger plant than in the case of the early tomatoes. The fertilization should, therefore, be such as to furnish an abundance of all the elements of plant-food; and, inasmuch as the tomato belongs to the potash-consuming class of plants, any fertilization should be particularly rich in this element. It is not to be understood, however, that it is not necessary to apply nitrogen, for frequently soils are used that are either not well adapted for the plant or are poor, not having been previously well supplied with vegetable matter containing nitrogen. On such soils, additional applications are very important, and nitrate of soda is one of the best forms to use, as it is absorbed freely by the roots, encouraging an early and vigorous growth of plant and a normal development of fruit. Slow-acting organic forms of nitrogen, on the other hand, frequently begin to feed the plant and cause its rapid growth when the energies should be concentrated in the growth and maturity of fruit. Fertilizers that have proved very excellent are those which contain a relatively smaller amount of nitrogen than is required for early tomatoes, and are richer in phosphoric acid and potash.

A study of the composition of both the fruit and vine of the tomato will serve to guide us in this respect, though the amounts and proportions of food removed by any crop are not absolute guides, inasmuch as the soil may furnish more of one constituent than another, and because the plant may have the power of acquiring certain of its constituents more readily than others. The analyses of the fruit and vines of tomatoes show that one ton contains:

	Nitrogen lbs.	*Phosphoric Acid lbs.*	*Potash lbs.*
In fruit	3.20	1.00	5.40
Vines (green)	6.40	1.40	10.00

Ten tons of the fruit, with the accompanying vines, which would probably reach four tons, would contain 57 pounds of nitrogen, 16 of phosphoric acid and 94 of potash. On a good soil, therefore, which without manure would produce five or six tons, there should be added a sufficient excess of the constituents to provide for a maximum production, and the materials should be relatively richer in nitrogen and potash than in phosphoric acid. A mixed fertilizer composed of:

Nitrate of soda	400 lbs.
Bone tankage	700 "
Acid phosphate	400 "
Muriate of potash	500 "

would contain, approximately, 95 pounds of nitrogen, 144 of phosphoric acid and 250 of potash in each ton. An application of 500 pounds per acre of this mixture would furnish half as much nitrogen as is contained in a crop of ten tons, nearly as much immediately available phosphoric acid, and two-thirds as much potash. Hence a dressing containing the amounts, kinds and proportions of plant-food here shown would be regarded as very desirable, since one-half of the nitrogen is in the form of a nitrate, which would contribute to the immediate growth of the plant. The amount of soluble and available phosphoric acid is sufficient to satisfy the needs of the crop throughout its entire growth, and such an abundance of potash as to contribute to the normal development of both plant and fruit. Formulas of this character have been used with good results, though the large proportion of salts sometimes make mixtures of this sort too moist to handle well, in which case a part of the potash, or even of the nitrate, may be applied separately with advantage. On poorer soils, the artificial supply of plant-food should be proportionately greater, or sufficient to provide for the entire needs of a fair-sized crop, since as a rule the relative power of the plant to acquire food is somewhat slighter on poor soils than on good soils; or, stated in another way, the results from the use of fertilizers are proportionately better upon soils in good condition than upon those not well cared for. A good formula for these may consist of:

Nitrate of soda	500 lbs.
Bone tankage	500 "
Acid phosphate	. 400 "
Muriate of potash	600 "

One ton of this mixture would furnish, approximately, 105 pounds of nitrogen, 120 of phosphoric acid and 300 of potash. The application of 1,000 pounds, therefore, would furnish the food in sufficient abundance and in good proportions to meet the demands of a fair crop.

The advantage of using so large a proportion of nitrogen in the form of nitrate of soda in this case is, that it is immediately available, inducing the immediate and rapid growth of plant, and preventing a too late growth by furnishing a minimum of organic nitrogen, which would become available late in the season. The cost of the fertilizer suggested in these cases is high, and the necessity of so expensive a dressing could be materially reduced by decreasing the need for nitrogen, particularly in organic forms, which may be accomplished by sowing crimson clover with or after the previous crop of, say, corn or tomatoes. If weather conditions are favorable, crimson clover may be sown in the tomato fields in August, after cultivation has ceased, or at the last cultivation, and a crop of clover grown which will provide nitrogen for the next year's crop. This method is now practiced with advantage by many growers. The late crop, like potatoes and sweet potatoes, is usually grown in rotations in which it is the chief money crop; hence the unused residue from fertilizers applied in large amounts, as here indicated, contributes largely to the economical growth of subsequent crops.

SUGAR BEETS

The purpose in the growth of sugar beets is to obtain the largest total yield of sugar per acre; and inasmuch as the sugar content of the beet, as well as its right growth and development, is very largely influenced by the character of the fertilization, this matter becomes of very considerable importance, in view of the promising development of the sugar beet industry in this country. Thus far, information concerning the use of fertilizers is derived largely from the results obtained in other countries, where it has been a prominent crop, and where great attention has been paid to this factor in its production.

The Demands of the Crop for Plant-food

The sugar beet draws heavily upon the soil for the nitrogen and potash constituents. A minimum yield of 10 tons of topped beets contains 44 pounds of nitrogen, 20 of phosphoric acid and 96 of potash. On medium loamy soils, which by their character are well adapted for the growth of the sugar beet, heavy fertilization with potash, however, has not been found to be desirable; while on light soils, which are also well adapted for the crop, liberal manuring with potash becomes absolutely necessary.

As in this crop, the object of the growth is to secure not primarily beets, but sugar, and since the sugar formation is not perfected until the absorption of the necessary food from the soil has been in large part completed, any fertilization which promotes a too rapid or too long continued growth has a tendency to reduce the percentage of sugar; and inasmuch as the maturation takes place largely in the months of early fall, the growth must be forced early in the season. That is, it is essential that a large and rapid leaf growth be made early, in order that the food from the air may be acquired. It has been demonstrated that for this early and rapid growth of the beet, phosphoric acid is one of the most essential constituents, which explains the need for phosphoric acid in larger proportion than is indicated by the composition of the beet. The crop requires a considerably greater supply of phosphoric acid at this stage of its growth than other farm crops which are quite as exhaustive, and it is also evident that in order that the crop may obtain the phosphoric acid at this period, it must be soluble and immediately available; hence the larger portion of this element applied should be derived from superphosphates. In the matter of fertilization with nitrogen, the object of the growth must also be kept in view. An application which would encourage steady and continuous growth, rather than an early and rapid growth, while contributing to a large yield, causes a reduction in the sugar content of the beet. Hence it is strongly urged by those who are in a position to give sound advice, that the early nitrogen fertilization should consist of the quickly available forms, nitrate or ammonia, and that the organic or slower-acting forms should not be applied in such excess as to encourage a late growth. Hence it is, that upon medium and light lands the use of commercial fertilizers has proved of greater service in the growing of this crop than the exclusive use of yard manure, and in such quantities as to supply the entire needs of the plant. In the use of fertilizer, not only the total supply of the constituents, but their form, may be regulated to the needs under different conditions, thus permitting a full feeding of the plant, and at a time most suitable to accomplish the object in view,—advantages which are not possessed by the natural manures.

A fertilization which would meet the needs both in respect to quantity and kind of fertilizers, may be as follows:

On good soils, the application or a fertilizer containing from 40 to 50 pounds of nitrogen, from 50 to 60 of phosphoric acid and from 40 to 50 of potash, would be sufficient to meet the demands of the plant. The nitrogen supplied should be derived largely from nitrates or ammonia, or both, and the phosphoric acid from a superphosphate, while the potash may be derived from sulfate or muriate of potash. The former is preferable if applied during the spring preceding the planting of the beets. While it is frequently desirable, for convenience and economy of labor in applying, that the fertilizer should be mixed, in order to prevent any waste of soluble nitrogen, it should be applied in fractional dressings. For example, a mixture of 250 to 300 pounds of nitrate of soda (or, the nitrogen may be derived partly from nitrate and partly from ammonia). 400 to 500 pounds superphosphate, and 80 to 100 of muriate or high-grade sulfate of potash, should be applied in two or three dressings. A part only should be applied previous to sowing, for both the nitrate and the potash salts have a depressing effect upon germination. They are preferably applied, say, one-third of the mixture as soon as the plants have come up, another third immediately after or before the first cultivation, and the remainder immediately after or before the second cultivation. The application of the fertilizers in these forms and at the times indicated insures the rapid and early growth and development of the plant; and by reason of the solubility of the nitrates and ammonia salts, a late feeding of the plant with nitrogen is obviated.

On light or medium soils, the amount of plant-food should be increased by at least one-third, though fractional applications should be made as previously recommended. On soils rich in vegetable matter, a part of the nitrogen may be omitted, though the phosphoric acid should not be reduced.

The Influence of Previous Deep Cultivation of Soil

Another point to observe in the growing of beets for sugar,—and it also has an immediate bearing upon fertilization,—is the character of the previous cultivation. If the soils have not been deeply and well cultivated, so large a dressing as is here recommended would be likely to be deleterious, as with a shallow and poorly prepared soil plants would have less opportunity to penetrate deeply, and thus too great a growth above the surface of the ground would be encouraged, with a consequent lowering of sugar content as well as yield.

The best practice in our country will have to be developed by the experience of our own growers, though in the absence of such experience, the recommendations here made may be relied upon. In many of the sections of this country in which the soils and climate are well adapted for the sugar beet industry, the needs as yet are quite as much for improved methods of cultivation as for added fertility. They have not been exhausted of their essential elements of fertility.

An epitome of the soil conditions for sugar beet culture will be found in the second edition of Roberts' "Fertility of the Land," p. 405.

CHAPTER XII

GREEN FORAGE CROPS

A LARGE number of crops is included in this class. In dairy districts they are grown for summer feeding, mainly to supplement or to entirely substitute pasturage, as well as to provide a succulent ration of roughage in winter. Any crop which grows quickly, is palatable, and makes a reasonably large yield, is adapted for the purpose. For convenience of study, these crops may be further classified into three groups :

1. Cereals and grasses. 2. Clovers and other legumes. 3. Roots and tubers.

In the case of those included in the first group, the purpose or object is to obtain as large a growth of leaf and stem as possible. Thus the character of the fertilization may differ from that recommended when the same crops are grown for the primary purpose of obtaining the largest yield of seed or grain. These crops, too, may in all cases be considered as only well adapted for the "intensive" system of practice—that is, when the management is such as to encourage the largest yield possible per unit of area under the existing conditions of climate and season. The natural fertility of the soil thus becomes a less important factor; indeed it cannot be relied upon altogether, as the largest yield of succulent food is dependent upon a rapid and continuous growth, and hence the supply of plant-food must be relatively much greater than is the case when the cereals are grown for their seed. That is, forage crops, because succulence is a factor influencing quality, must, as a rule, be grown quickly, and in order that large yields may be obtained in a short period of time a relatively greater abundance of plant-food must be at their disposal than when the growth is distributed through a longer period. Besides, larger amounts of all of the food constituents are required for the production of the same amount of dry matter per acre than when grown for the mature crop, because the dry matter of the mature crop is richer in the constituents derived from the air and poorer in those derived from the soil, than the dry matter of the immature crop.

Maize (Corn) Forage

A valuable forage crop of the first group is maize (Indian corn), because it grows quickly, is well adapted for a wide variety of soils and climates, is extremely palatable, and is capable of producing large yields. The fertilization which has been recommended for the field crop is less desirable than one which furnishes a greater proportion of nitrogen, because of the greater need of this element, and because it encourages a larger leaf and stalk growth; and the greater the proportion of these in a corn crop the richer will be the dry matter in the important compound protein, and nitrogen is the basic element in this group of nutrients.

When the crop is grown on good land on clover sod, which has been liberally manured, the fertilizers applied should be particularly rich in the mineral elements, phosphoric acid and potash. An application of 500 pounds of a mixture containing—

Nitrogen	2 %
Available phosphoric acid	6 %
Potash.	8 %

would provide an abundance of food, even should unfavorable conditions intervene, but when grown on light, unmanured soil without sod, a larger amount of nitrogen should be used in connection with the minerals. An application of 25 pounds of nitrogen, 35 of phosphoric acid and 50 of potash is as small a fertilization as should be recommended on soils of this character, since a yield of 10 tons per acre, containing 25 per cent of dry matter — which is only a fair crop —would remove 60 pounds of nitrogen, 25 of phosphoric acid and 70 of potash. Hencc, very large increases in yield could not be expected from smaller dressings, unless conditions were absolutely favorable throughout the entire period of growth. The nitrogen, as in the case of field corn, may be derived from organic sources, as the season of growth is the same—the summer—which is the most favorable for encouraging a rapid change of the organic nitrogen into the soluble nitrates. The phosphoric acid should be in large part derived from superphosphates, though since the season of growth and the character of the crop and of its cultivation are conditions all of which favor a rapid change of insoluble into available forms, a portion may be supplied by ground bone or tankage. The potash may be kainit or muriate, though if kainit is used, it should be broadcasted and well worked into the soil before planting.

Silage Corn

Corn grown for the silo, while distinctly a forage crop, is, in its management, very similar to the field crop, and is not planted so thickly as to prevent the formation of ears. The object in its growth is, however, to obtain a large yield of dry matter, somewhat richer in nitrogenous substance and poorer in starch and woody fiber than field corn. Hence the fertilizers for the crop on medium soils should be richer in nitrogen than for the field corn, where the primary object is the grain, and where heavy fertilization with nitrogen would encourage a disproportionate stalk growth. An application of 30 pounds of nitrogen (equivalent to 250 pounds of dried blood or 450 of cotton-seed meal), 40 of phosphoric acid (equivalent to 300 pounds of acid phosphate), and 60 of potash (equivalent to 120 pounds of muriate of potash), would provide for a marked increase in yield.

Wheat and Rye Forage

In the growth of cereal grains, the object is to secure as large a yield of grain as is possible under the conditions of climate and season, and only such development of leaf and stem as will contribute to a maximum yield of grain. Hence a too liberal nitrogenous fertilization which encourages this form of growth may result in too great a proportionate yield of straw This objection becomes an advantage when the cereals are grown for forage.

The cereal crops, wheat and rye, if seeded in the fall, should, therefore, receive a fertilizer which shall especially promote leaf and stem growth; and to accomplish this purpose in the best manner, a rapid early fall growth, and a consequent deep rooting system, as well as an early and rapid spring growth, should be encouraged. Fertilizers most suitable are rich in nitrogen and phosphoric acid, and should contain potash also, if the land has not been previously well supplied with this element. The larger proportion of the nitrogen, however, should be applied in available forms as a top-dressing in the spring, rather than at time of seeding, thus reducing the possible loss of this element during the winter and early spring through leaching, besides providing the plant with it when most needed, and producing a crop richer in nitrogenous substance.

The ranker growth and somewhat coarser product resulting from this method of fertilization, while not desirable for grain crops, is not a detriment when the product is cut in its green stage for feeding, and the larger growth is accompanied by greater succulence.

Where these cereal grains are sown mainly as catch crops following a corn crop which has been liberally fertilized with the minerals phosphoric acid and potash, the application at time of seeding may be light, and may consist only of nitrogen and phosphoric acid,—for example, from 200 to 400 pounds per acre of a dissolved bone; and the top-dressing in the spring need not exceed 100 pounds of nitrate of soda per acre for the wheat, and 75 pounds per acre for the rye. For lighter soils, or for those not previously well fertilized, much heavier applications not only are required, but all of the constituents should be included, and the top-dressings should be made in spring, as already pointed out.

Spring Rye

For spring rye, an application of a fertilizer furnishing 10 pounds of nitrogen, 20 of phosphoric acid and 10 of potash per acre would be a sufficiently liberal dressing for the crop on good soils, since the plant possesses good foraging powers, though it is not so desirable a forage crop for northern climates as the winter rye. The nitrogen, in any case, should be in quickly available forms.

Oats

Oats and millet are also suitable crops for forage purposes, and are largely grown; the first, because it is adapted for cool, moist weather, and makes a rapid early growth, and the second, because adapted for late spring seeding and for summer conditions.

The oat crop for forage purposes is even more generally benefited by manuring than when grown for the grain, and the constituents particularly useful are nitrogen and phosphoric acid, though on sandy soils, and on those of medium fertility and not previously fertilized with potash, this element should also be added.

A good dressing, keeping in mind the value of the possible increased yield, may consist of 12 pounds of nitrogen, 20 of phosphoric acid and 10 of potash,—the nitrogen largely in the form of a nitrate and the phosphoric acid in soluble and available forms.

The oat crop is peculiar in that shortly after the germination of the seed, there usually occurs a period of a week or ten days during which the growth is extremely slow, which experienced farmers call the "pouting" period. While the exact cause of this well-known habit is not understood, it is believed to be due in part to the absence of available plant-food of the right sort early in the season, since liberal applications of nitrates and superphosphates seem to shorten the period of "pouting," if not altogether preventing its occurrence. Its avoidance for grain crops, while important, is not so important a matter as in the case of forage crops, since an extension of the period of growth simply delays ripening, while in the latter, delays not only prevent maximum growth within a certain time, but seriously interfere with rotations.

Winter oats, which are successfully grown in the southern sections of the country, should be fertilized at time of seeding practically in the same manner as wheat; that is, dressings furnishing small amounts of nitrogen and considerable phosphoric acid, to be followed in spring with a top-dressing of nitrate of soda, not to exceed 100 pounds per acre

Oats and Peas

Where oats are grown with field peas for the purpose of supporting the vines, as well as to obtain a larger yield than from either alone, the fertilizer should also contribute toward the increase in the pea crop, and hence a greater abundance of the minerals should be applied, though it is very desirable in this case, too, to encourage the rapid growth of the oats by reasonably liberal supplies of available nitrogen.

Barley and Peas

The growth of this combination of plants is a desirable one when late fall forage is needed, and as a crop is well adapted for fall conditions. The fertilization should be liberal, in order to encourage a rapid and large appropriation of food, which may be elaborated after light frosts occur. An application of 200 pounds per acre of a mixture of 100 pounds of nitrate of soda, 175 of acid phosphate and 25 of muriate of potash, will furnish sufficient and good proportions of the plant-food constituents.

Millet

The various kinds of millet are eminently surface feeders, and are particularly benefited by liberal applications of all the fertility elements. In fact, maximum forage crops of this plant cannot be obtained except when there is present in the soil such an abundance of all of the fertility elements as to enable a continuous and rapid growth. Both the nitrogen and phosphoric acid should be largely in immediately available forms; hence nitrates and superphosphates are recommended. The potash may be in the form of muriate. A crop of ten tons per acre of millet forage, of any of the Japanese varieties, which are very suitable for this purpose, will remove 50 pounds of nitrogen, 25 of phosphoric acid, and 110 of potash, practically all of which food is absorbed from the immediate surface soil. Good crops frequently reach this assumed yield; hence, unless the land is in a high state of fertility, or has been previously fertilized, it is necessary, in order to obtain a fair crop, to furnish by direct application at least one-half of the nitrogen and potash, and as much phosphoric acid, as are contained in the crop. These amounts and kinds of plant-food could be practically supplied by a dressing of 450 pounds of a mixture made up of 150 pounds of nitrate of soda, 200 of acid phosphate, and 100 of muriate of potash, and such dressings have given excellent satisfaction in the New Jersey experiments with forage crops.

CLOVERS AND OTHER LEGUMES

These are among the most valuable of our summer forage crops: first, because of the time of their growth, they furnish food before spring-sown crops are ready; second, because of their power of acquiring food from sources inaccessible to the cereals, they are less exhaustive; and third, they are especially rich in the compound protein, the most useful substance contained in feeds. Since these crops generally grow well on soils of medium fertility, many are inclined to regard them as able to subsist and make a good crop without liberal fertilization. It should be remembered, however, that the power which these plants possess of acquiring nitrogen from the air depends largely upon the supply at their command of the mineral elements, phosphoric acid, potash and lime; the presence of these is of primary importance, and good crops cannot be grown on land deficient in these elements. In any event, therefore, liberal supplies of the minerals should be provided, in order that maximum yields may be obtained. On soils of medium fertility which are fairly well supplied with vegetable matter, the need for nitrogen is not marked, even in the early growth of the plant. On lighter soils, however, a nitrogenous fertilization is often serviceable, because supplying nitrogen before the plant has acquired the power of obtaining it from the air. This practice enables the plant to make an early start, and prevents the delay in growth which sometimes occurs, particularly on light soils, during the period immediately after germination, when the plant is unable to obtain its nitrogen from sources other than the soil. A green forage crop averaging 10 tons per acre requires, on the average, about 30 pounds of phosphoric acid and 100 of potash, and the nitrogen which necessarily accompanies these amounts of minerals will reach, on the average, 100 pounds. If this element is drawn from the air, because provided with an abundance of minerals, it is manifestly economy to supply the full amount of these required, rather than omit them, and thus to limit the plant's power of acquiring this expensive element, since the value of the 100 pounds of nitrogen gained is greater than the cost of both the phosphoric acid and potash required.

Cow Pea and Soy Bean

The clovers, which range in their length of life from annuals to perennials, are, too, able to obtain their necessary supplies of minerals more readily from soil sources than the distinctly summer crops, as the cow pea and soy bean, because of the longer period of preparatory growth in the case of the former. That is, clover or vetch, while it does make a very rapid growth through a short period, does not obtain all of its food during that period. In its preparatory stage of growth—fall and early spring—a very considerable amount of food, the larger proportion, in many instances, is obtained, which in its later stages of growth, is simply distributed throughout the entire plant; while the cow pea and soy bean, on the other hand, must obtain the entire amount of food needed for their growth and development during a short period, and these crops reach their best stage of development for forage in two and one-half to three months from time of planting. Hence, these crops, which possess apparently greater foraging powers, and make their development during the season when conditions are most favorable for rapid change of insoluble to soluble food in the soil, require, when the conditions of the land are the same in each case, a relatively greater abundance of the mineral elements than do the clovers, which can acquire food through a longer period.

An application of 300 pounds per acre of a mixture of 200 pounds of acid phosphate and 100 of muriate of potash, which supplies 25 pounds of phosphoric acid and 50 of potash, would, on medium soils, be regarded as a sufficient annual dressing for clover crops; whereas, in the case of the purely summer crops, the application could be increased one-half with profit. In the case of the summer crop, the phosphoric acid should be in a soluble form, because it is not economy to depend upon the conditions of climate, soil and season to change insoluble forms rapidly enough to provide for the continuous feeding of the plant, while for the clovers, less available forms may be used with advantage.

Alfalfa, or Lucerne

This valuable crop, which was not formerly regarded as well adapted for the eastern states, can be successfully and profitably grown if the soil is sufficiently deep and open and naturally well drained, and provided it is supplied with an abundance of mineral food, consisting of phosphoric acid, potash and lime. Its habits of growth are such as to enable the harvesting of three or four green forage crops, and at least two hay crops annually. In order to meet the large plant-food demands thus made, the fertilization previous to seeding must be not only liberal, but frequent top-dressings should be made. The phosphoric acid for these dressings should preferably be drawn from superphosphates, in order that ready distribution may be accomplished, while a large portion of that contained in the preparatory dressing may consist of the less soluble forms, as ground bone, natural phosphatic guanos, and fine ground rock phosphates.

Twenty tons of alfalfa green forage, which may be regarded as a good annual yield for this plant from the two to four cuttings that may be made, will contain 250 pounds of nitrogen, 50 of phosphoric acid and 275 of potash. Assuming that the demands for soil nitrogen are confined to a short period immediately subsequent to the germination of the seed, the total required plant-food is still considerable, and is especially severe upon the potash compounds of the soil. Hence, the fertilizers supplied should be particularly rich in this element. For eastern conditions, where soils possess a medium rather than a high potential fertility, heavy dressings of the minerals should always be made. A good preparatory fertilizer may consist of 20 pounds of nitrogen, equivalent to 125 pounds of nitrate of soda; 75 of phosphoric acid, equivalent to 600 of acid phosphate; and 200 of actual potash, equivalent to 400 pounds of muriate of potash per acre; and annual top-dressings should provide at least 30 pounds of phosphoric acid and 100 of actual potash for the same area.

Inasmuch as careful preparation of soil is necessary previous to seeding, and since this can preferably be accomplished by the growth of cultivable crops, the fertilizers may be also partly applied to these rather than all at once immediately preceding the seeding, thus limiting danger of injury to germination by an application of so large a proportion of salts.

Need of Lime for Legumes

Another point that should be remembered in the fertilization of the leguminous plants is their need for lime. This is true of the clovers particularly, not only for the purpose of providing the plants with a sufficient amount of this element, but in order that any possible acidity of soil may be corrected, since the bacterial life in the soil, which is essential in order that the plant may acquire its nitrogen from the air, is discouraged rather than encouraged by the presence of acid. Hence, all soils that are used for the frequent growth of leguminous crops should receive a dressing of lime, preferably in the fall; 25 bushels of stone lime per acre, once in four or five years, is a sufficient amount for medium soils.

The necessity for fertilization, and the method employed in "intensive" practice, are illustrated by the following scheme of growing soiling crops, now practiced at the Experiment Farm in New Jersey. If an abundance of food is not supplied, the continuous feeding and consequent constant and rapid growth of the plants, which are primary necessities of the system in order to maintain the rotation and to obtain maximum yields, are prevented. With proper management in other respects, the scheme of rotation and fertilization will result in a gradual increase in the fertility of the soil.

Scheme of Soiling Crops

No. of Acre	*Crop Rotation*	*Time of Seeding*	*Amount of Fertilizer Applied*	*Time of Harvesting*
1	Crimson Clover	Aug. 11,'97	100 lbs. Acid phosphate 50 lbs. Muriate of potash	May 20,'98
	Corn	June 20,'98	100 lbs. Acid phosphate 50 lbs. Ground bone 50 lbs. Muriate of potash	Aug. 20,'98
	Barley and Peas	Aug. 25,'98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Oct. 25,'98
2	Crimson Clover	Aug. 24,'97	100 lbs. Acid phosphate 50 lbs. Muriate of potash	May 10,'98
	Corn	June 10,'98	100 lbs. Acid phosphate 50 lbs. Ground bone 50 lbs. Muriate of potash	Aug. 10,'98
	Barley and Peas	Aug. 25,'98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Oct. 25,'98
3	Corn	May 20,'98	50 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Ground bone 50 lbs. Muriate of potash	July 20,'98
	Millet	Aug. 1, '98	75 lbs. Nitrate of soda 150 lbs. Acid phosphate 75 lbs. Muriate of potash	Oct. 1, '98

No. of Acre	*Crop Rotation*	*Time of Seeding*	*Amount of Fertilizer Applied*	*Time of Harvesting*
4	Corn	May 10,'98	50 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Ground bone 50 lbs. Muriate of potash	July 10,'98
	Barley and Peas	Aug. 10,'98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Oct. 10,'98
5	Wheat	Sept. 28,'97	150 lbs. Acid phosphate 50 lbs. Ground bone 25 lbs. Muriate of potash	June 5, '98
	Oats and Peas	April 20,'98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 25 lbs. Ground bone 50 lbs. Muriate of potash	June 20,'98
	Soy Beans	Aug. 1, '98	200 lbs. Acid phosphate 100 lbs. Muriate of potash	Oct. 1, '98
6	Rye	Sept. 29,'97	150 lbs. Acid phosphate 50 lbs. Ground bone 25 lbs. Muriate of potash	May 1, '98
	Millet	May 1, '98	75 lbs. Nitrate of soda 150 lbs. Acid phosphate 75 lbs. Muriate of potash	July 1, '98
	Cow Peas	July 20,'98	200 lbs. Acid phosphate 100 lbs. Muriate of potash	Sept. 20,'98
7	Oats and Peas	April 10,'98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 25 lbs. Ground bone 50 lbs. Muriate of potash	June 10,'98
	Soy Beans	July 1, '98	200 lbs. Acid phosphate 100 lbs. Muriate of potash	Sept. 1, '98
	Barley and Peas	Sept. 1, '98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Nov. 1, '98

No. of Acre	*Crop Rotation*	*Time of Seeding*	*Amount of Fertilizer Applied*	*Time of Harvesting*
8	Oats and Peas	April 1, '98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 25 lbs. Ground bone 50 lbs. Muriate of potash	June 1, '98
	Cow Peas	June 15, '98	200 lbs. Acid phosphate 100 lbs. Muriate of potash	Aug. 15, '98
	Barley and Peas	Aug. 20, '98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Oct. 20, '98
9	Rye and Vetch	Sept. 10, '97	25 lbs. Nitrate of soda 150 lbs. Acid phosphate 75 lbs. Muriate of potash	May 5, '98
	Corn	June 1, '98	100 lbs. Acid phosphate 50 lbs. Ground bone 50 lbs. Muriate of potash	Aug. 1, '98
	Barley and Peas	Aug. 15, '98	25 lbs. Nitrate of soda 100 lbs. Acid phosphate 50 lbs. Muriate of potash	Oct. 15, '98

This scheme, which provides for two or three crops each season, has proved entirely practicable and successful when liberal fertilization is practiced, as here indicated.

ROOT CROPS

These crops are, as a class, exhaustive of plant-food elements, much more so, in proportion to the dry matter contained in them, than the cereals or legumes. It will require, for example, 20 tons of topped fodder beets or turnips to furnish as much total food as is contained in 10 tons of corn forage or silage, as the former seldom contain more than 10 per cent of dry matter, whereas the latter frequently contain more than 20 per cent; yet on the average, 20 tons of roots will contain 60 pounds of nitrogen, equivalent to 400 pounds nitrate of soda, 35 of phosphoric acid, equivalent to 300 pounds of acid phosphate, and 150 of potash, equivalent to 300 of muriate of potash, which amounts are far in excess of those contained in a corn crop, particularly of the minerals, phosphoric acid and potash. The nitrogen demands for the two crops are practically identical. In the case of both kinds of crops, these fertility constituents are obtained entirely through the roots from soil sources.

In respect to fertilization, however, the root crops may be divided into two groups, very similar in their demands for plant-food, the first to include mangel-wurzels, fodder beets, sugar beets and carrots, and the second turnips, swedes (ruta-bagas) and rape.

Fertilizers for Fodder Beets, Sugar Beets and Carrots

The first group requires that the fertilization with nitrogen and phosphoric acid shall be liberal, and that these constituents shall be applied in readily soluble forms, in order to meet the large and early demands of the plant for them. Potash is also a very essential constituent, particularly upon soils of a light, sandy character; upon clay loams, the plant is better able to obtain this element.

In order to obtain a large amount of actual food by the growth of these crops, a large tonnage must be secured, and a large yield cannot be obtained unless provision is made for a continuous and rapid growth, and this again cannot be accomplished without an abundant supply of nitrogen and phosphoric acid, which, as already stated, are the elements which, more than any others, seem to rule the crop.

In the case of sugar beets, the suggestion for fertilization when grown for sugar (Chap. XI), may be followed in large part. That is, particular attention should be given to the supply of nitrogen and phosphoric acid, though when grown for forage it is important not only to secure sugar, which constitutes a large proportion of the dry matter, but that the gross yield shall be much greater than in the former case. Hence, a liberal use of yard manure need not be avoided, and heavier dressings of nitrogen, which stimulates early leaf growth, may be made.

For both fodder beets and sugar beets, an application per acre of 40 pounds of nitrogen, 50 of phosphoric acid and 100 of potash, or 1,000 pounds of a fertilizer, containing—

Nitrogen	4 %
Available phosphoric acid	5 %
Potash	10 %

should insure a very considerable increase in yield on soils of medium fertility. provided the elements are drawn from the best materials. On light soil the fertilization should be still heavier, and the proportion of nitrogen increased. In fact, on soils poor in fertility and possessing good physical qualities, the contributions of plant-food by them may be largely ignored, and the dressings made large enough to supply the entire amount of food required by the crop. On such soils the nitrogen should preferably be applied in fractional dressings and in quickly available forms, because it is essential that this element should be quickly absorbed by the growing plant. The minerals may be all applied in one dressing, though preferably in two, in order that the constituents may be well distributed throughout the surface soil. To better accomplish this, cultivation should follow each application.

Turnips, Swedes and Rape

In the case of the second class of crops, it has been shown that they are able to extract their phosphoric acid from combinations not readily accessible to other plants. In fact, they respond so promptly to applications of this element, that frequently too little attention is given to the supplies of the other elements; yet in order to obtain satisfactory yields, these must also be added. An analysis of the turnip, for example, shows it to be rich in potash; hence it must naturally be a voracious feeder upon compounds containing this element, and while it seems to obtain it more readily from soil sources than many other plants, these supplies should not be depended upon, even on good soils, to meet its entire needs in this respect. A liberal supply of nitrogen is also demanded, particularly during the early growth. An application of a fertilizer containing 20 pounds of nitrogen, derived in part from nitrate, 40 of phosphoric acid, derived in large part from phosphates, and 40 of potash, derived from muriates, would be a fair dressing on soils of good character. On the poorer soils, the application of the constituents of the same kind and forms should be very largely increased.

In these crops, as in those already mentioned, it is essential—and success depends upon this as much as upon any other factor—that the growth should be continuous; and in order that there shall be no delay in this respect, there must be an abundance of available food always at their command.

TUBER CROPS

In many sections the potato and sweet potato are grown for roughage. For these crops no different fertilization is recommended than that already outlined (Chapter XI) for the crops when grown for market, though in the case of sweet potatoes, soils not adapted for the growth of marketable tubers may be used.

CHAPTER XIII

MARKET-GARDEN CROPS

A KNOWLEDGE of the principles of plant nutrition is perhaps more serviceable in market-gardening than in any other line of farming. This branch of farming cannot be profitably conducted either without suitable soils or without an abundant supply of plant-food. Both of these conditions are essential for the growth of high-class products.

THE YIELD AND QUALITY DEPENDENT UPON CONTINUOUS AND RAPID GROWTH

In these days, it is not only the yield of a definite area that must be considered, but the edible quality of the products that are put upon the market. Quality depends upon, or is measured by, both appearance and palatability; and palatability is determined by the succulence and sweetness of the vegetable, or its freedom from bitterness, stringiness, and other undesirable characteristics which frequently exist, and which can be largely eliminated, provided the grower is thoroughly familiar with his business, assuming, of course, that varieties are the same in each case. It has been demonstrated that market-garden crops of the best quality are those which are grown under conditions which permit of a continuous and rapid development. Any delay in the growth of a radish or of lettuce is largely responsible for the sharp taste and pungent flavor of the former, and the bitterness and toughened fiber of the latter. The same principles hold true of early table beets and turnips. The beets become stringy and wiry in character, and are less palatable if during the period of normal growth there has been any delay In a time during which there has been no progress the fibrous portion of the vegetable is toughened, and exists in too great proportion. In the case of the early turnip, if any delay in growth occurs, the quality is injured, and the peculiar, pleasant flavor, a characteristic of the perfect vegetable, is changed; it becomes unpleasant. The unfavorable conditions of growth seem to cause more or less reversion to the character of the original plant from which the improved type has been derived, mainly through selection and improved methods of cultivation.

All these conditions of growth are not absolutely under the control of the grower; as, for example, a lack of sufficient moisture and sunshine, the latter of which is certainly beyond his power to control. But given good natural conditions in respect to soil, and a favorable season, the one thing that more than any other controls the yield and quality of market-garden products is plant-food of the right amount and kind. In other words, in crops of this sort, any limitation in this respect usually results in a disproportionate reduction in profits. Only under exceptional circumstances is it economical to depend upon natural soil conditions for profitable crops, however favorable such conditions may be, because in successful practice the cropping is in the highest degree "intensive," and even the best soils are liable to be deficient in some essential feature.

It might seem from the discussion thus far, that for these crops the recommendations as to methods of fertilization might be briefly though fully expressed as follows:

Apply a reasonable excess of all of the essential fertilizer constituents to all of the crops. Nevertheless, because of the peculiarities of growth of the different plants, as well as the different objects of their growth, distinctions should be made in reference to the kinds and amounts of plant-food applied, and these distinctions should be borne in mind, in order that the most profitable returns may be secured. Market-garden crops may, however, be grouped according to similarity, both in character and object of growth, and each group fertilized in a similar manner, which obviates the necessity of extra labor in the preparation of fertilizers.

ASPARAGUS

Asparagus is one of the very important vegetable crops, and perhaps no other renders so profitable a return for proper manuring and fertilizing. It differs from the majority of the others in two essential particulars. First, it is a perennial, the length of life of a bed depending largely upon the treatment; and second, only one crop can be obtained in a season—it occupies the land to the exclusion of other crops. Hence, special efforts should be made to obtain as large a crop as the conditions of season and climate will permit. With this plant the yield and market quality of the crops depend upon the number and size of the shoots. In respect to quality, the demands of the different markets vary. Some of them require that the shoots shall be bleached and so cut as to present only a green tip, the remainder being perfectly white, while others demand that the shoot shall be green. But in both cases, the size of the shoot determines salability, and the size is largely measured by the methods observed in feeding the plant when other conditions are favorable; that is, if not injured by disease or insects. Small, spindling shoots usually indicate that the crop has not been well cared for, or that the plant has been imperfectly nourished.

The root is enlarged and invigorated by the character of the growth of the tops, or summer growth of the plant after cutting is finished, and it is obvious that the manuring should be such as to encourage not only a rapid growth of shoots early, but a large and vigorous growth of tops later, which assists the growth of the roots in which energy is stored up for the production of the crop in the following year. Hence, not only the character but the method of fertilization is important, and it differs from that recommended for those plants which grow from the seed in one season and which must depend upon what they are able to acquire during their short period of growth.

The Use of Salt

It was formerly believed that one of the most important ingredients of manures for the asparagus plant was common salt, and that in any fertilization this substance should occupy a prominent part. Experience has shown, however, that while salt may not be harmful, there is no real fertility value in it. The crop may be profitably grown without its application, though it does no harm, and there is no objection to its use except on the ground that it adds no essential fertility element, and its indirect benefit may be obtained more cheaply by the use of other materials, which contain salt as a normal ingredient,—for example, kainit, the crude potash salt, which is one-third salt, though its market price is based solely upon its potash content.

Fertilizers that Have Proved Useful

Fertilizers which have been found very useful for asparagus are those which contain food both in immediately available and in gradually available forms. During the early growing season, the available food may be appropriated rapidly enough to cause an increase in the yield of shoots of that year; and inasmuch as the plant continues to grow until winter, the food that becomes gradually available is appropriated later, and contributes to the strength and vigor of the roots upon which the next year's crops depend. Furthermore, because the crop is gathered from the early shoots, which are continuously removed for from one to two months, the root is continuously drained of its stored-up material, and at the end of the cutting season it has been very much reduced in vitality; wherefore it is particularly desirable that available food be applied at this time also, in order to encourage a rapid and vigorous growth of the top, which aids in the storing up of food in the root. A fertilizer containing —

Nitrogen	4 %
Phosphoric acid	8 %
Potash	10 %

the nitrogen to be drawn from both soluble and organic sources, and the phosphoric acid from both superphosphate and ground bone, or tankage, and the potash from muriate, may be applied previous to setting the crowns, at the rate of 1,000 to 1,500 pounds per acre, and thoroughly worked into the soil.

A Basic Fertilizer for Market-garden Crops

For market-garden crops, a fertilizer of the above composition may be regarded as a basic mixture, which may be applied to all of the crops, leaving the specific needs of the different plants to be met by top-dressings, or applications of the other constituents. The fertilizer ingredients, nitrogen and phosphoric acid, should preferably consist of the different forms, rather than to be all of one form, though the cost of the element will naturally regulate this point to some extent.

That is, a part of the nitrogen should be nitrate or ammonia, and a part organic; a part of the phosphoric acid should be soluble (from superphosphates), and a part insoluble (from ground bone, tankage or natural phosphates). The soluble portions of both nitrogen and phosphoric acid contribute to the immediate needs of the plant, and the less soluble to its continuous and steady growth, and to the potential fertility of the soil.

For asparagus, this basic fertilizer may be applied at this same rate,—1,000 to 1,500 pounds per acre,—at the time of setting the crowns, or even in greater amounts from year to year, preferably early in the spring, in order that the plant may have the whole season for the appropriation of the food.

The specific fertilizer, in addition, should contain immediately available forms of food, and should be applied preferably immediately after or during the latter period of the cutting, in order to feed at once, and thus stimulate and strengthen the plant in its condition of lowered vitality, due to the continuous and large removal of the shoots. This application should also be liberal, since, as already indicated, limitations at this time may result in a greatly decreased yield and a poorer quality of product the next year, and hence a reduction in profit. The best growers apply, in addition to the fertilizer recommended, and after cutting, not less than 250 pounds of nitrate of soda, 300 of superphosphate, and muriate of potash, or kainit, equivalent to 100 pounds of actual potash.

These recommendations as to the amounts of fertilizers may seem rather large to those who have been accustomed to light applications, but they are the minimum rather than the maximum amounts, as many growers have learned that the extra amounts applied are preferable to the smaller amounts, contributing not only to the length of life of the plant, but also to the total yield and size of the shoots, as well as to their edible quality, which is measured by their succulence and flavor.

These suggestions as to fertilizers are for conditions where large amounts of organic or natural manures are not readily obtainable. When these are used, they may serve instead of the basic fertilizer, but cannot well substitute the special applications of artificial fertilizers made after cutting is finished.

PEAS AND BEANS

Peas and beans of the various kinds and varieties belong to the legume family, and possess the power of acquiring nitrogen from the air; they are, therefore, ordinarily placed in a separate class in respect to their fertilization with nitrogen. When they are grown as market-garden crops, however, it is frequently the wiser economy to apply nitrogen, particularly if they are raised upon land which has not been previously planted with these crops, and thus may not possess the specific nitrogen-gathering bacteria: because it is imperative that the plants should not only have an abundance of all of the food constituents, but that their food should be such as to cause as long a cropping period as possible, and nitrogen will contribute to this end. Hence, in the fertilization of these crops, while the minerals are the primary constituents needed, nitrogen should also be applied, and it should preferably be in the organic forms, which encourage a longer period of growth, rather than in the single, active-form nitrate, more generally recommended for the quick-growing market-garden crops, because its complete solubility and immediate availability encourage a rapid growth and short period of development. The basic fertilizer recommended, if applied at the rate of 500 to 600 pounds per acre, will usually furnish sufficient nitrogen, and may, if necessary, be supplemented by the application of amounts of superphosphate and potash salts which will add from 20 to 30 pounds of phosphoric acid, and 60 to 75 of potash.

BEETS AND TURNIPS

The early table beet and the early turnip are very important market-garden crops. Wherever grown, whether in the South for the northern market, or in the middle states for the near-by market, earliness is a primary consideration; and the earliness of the crop is determined largely by the amount and availability of the nitrogen and phosphoric acid applied. These are the two elements which, more than any others, modify and dominate the growth of these plants, and contribute to their profitable production as early market-garden crops. In the case of early turnips particularly, a difference of two or three days in the beginning of the harvest will often determine the profit or loss upon the crop. The experience of many growers confirms the view that for no other crop is the necessity for right fertilization more important. Since the early growth of these crops takes place before active nitrification begins in the soil, dependence for this element must be placed upon the nitrogen applied, and it is desirable not only that the soils should be well supplied at the time of planting with all of the constituents, but that frequent top-dressings of the soluble nitrate shall be made. Top-dressings are recommended because the application of a sufficient amount of the nitrogen in this form at the time of seeding might result in its considerable loss, since at this season rains often occur which are frequently so heavy as to cause a leaching of the nitrates into the drains or into the lower layers, and thus prevent the continuous feeding of the plant, and a consequent delay in growth.

An application, therefore, of from 1,000 to 1,500 pounds of a high-grade fertilizer, one of the composition of the basic fertilizer already suggested (p. 267), is frequently employed at the time of seeding, followed by a top-dressing of from 50 to 100 pounds of nitrate of soda per acre once every week or ten days, for at least three or four weeks after the plants have well started. It will meet the requirements for added fertility. Such a practice, under average seasonal conditions, insures a continuous and rapid growth, and obviates to some extent the dangers liable to follow from too much rain or from drought. The frequent applications prevent losses from leaching if heavy rains follow, and, except in case of excessive and prolonged drought, the nitrate remains in solution, and is ready to be immediately absorbed by the plant. The advantage of earliness which is gained by the use of apparently excessive amounts of nitrogen is two-fold: a higher price is received for the product, and the cost of labor per unit of income is less. Quite as large yields may be obtained by smaller dressings, but the net income is reduced as the time necessary for the growth of a marketable beet or turnip is increased. See also Chapter XII, in reference to this subject.

CABBAGE, CAULIFLOWER AND BRUSSELS SPROUTS

These large-leaved plants are all voracious feeders, and are specifically benefited by large applications of nitrogen and of phosphoric acid. Heavy applications of the basic fertilizer (p. 267). which is excellent, should be supplemented upon good soils with additions of nitrogen and phosphoric acid, and upon light soils, potash may also be added. Notwithstanding the fact that these crops are particularly benefited by nitrogen, the character of the edible portion or head of the different plants is very largely influenced by the nature of the growth. Too rapid an early growth, due to an excess of nitrogen, frequently results in an abnormal development of leaf, which is not accompanied by a proper formation of the head; hence a part of the nitrogen essential for the growth of the plant after the head has begun to form should be applied at this time in an immediately available form, and a part in forms which will gradually feed the plant. A good method of fertilization, in addition to the application of from 1,000 to 1,500 pounds per acre of the basic fertilizer, therefore, may consist of a top-dressing of 100 pounds of nitrate of soda and 200 of superphosphate per acre, after the plants have begun to make growth after transplanting. After the heads begin to form, another top-dressing of 200 pounds of nitrate of soda may be applied, which will contribute toward a rapid and continuous growth of head, provided an abundance of the minerals is present, as already indicated.

A number of crops belonging to this group of plants require, in addition to a sufficient supply of plant-food, peculiar climatic conditions for their best crop development. Cauliflower, particularly, not only seems to be so influenced, but great skill and experience are required on the part of the grower. It must be remembered, that while proper fertilization is essential, it is only one of the primary conditions of successful culture.

CUCUMBERS, WATERMELONS, MUSKMELONS, PUMPKINS AND SQUASHES

All these belong to one botanical group of plants, and are usually adapted for similar climatic and soil conditions, though watermelons and muskmelons of good quality are successfully grown only upon light, warm, sandy soils. The pumpkins, cucumbers and squashes may be readily grown to perfection upon the colder and more compact clayey soils. All of these crops seem to require an abundance of vegetable matter in the soil, in order to make their best growth. Hence, upon soils deficient in this respect, manures should be applied which are rich in vegetable matter. Composts in the hill have proved of especial advantage, as they seem to encourage an immediate feeding, and prevent delay in early growth. In the best growth of these plants it is also necessary that the mineral elements shall be available, and that the nitrogen shall be of such a character as to encourage a continuous rather than a quick growth of vine. That is, unless the quick-acting nitrates are applied very frequently, they are less desirable than organic forms of nitrogen. Hence, with the usual broadcast application of the basic mixture at the time of planting, together with a compost in the hill, further applications of organic nitrogen should be made, its character to be such as to promise a relatively rapid change into nitrate. The basic mixture may be re-enforced by any one of the following materials: 200 to 300 pounds per acre of cotton-seed meal, 100 to 200 of dried blood, or 300 to 400 pounds of fine-ground tankage. Any organic substance whose greater part will decay in one season will generally give better results than the nitrate, unless the latter is applied in frequent small top-dressings, because organic forms of nitrogen provide for a continuous growth of vine and fruit, while too great an abundance of immediately available nitrogen as nitrate is liable to cause too rapid and large growth of fruit of poor quality This does not apply in the case of cucumbers for pickling, where a large setting of immature fruits is desired. In this case, nitrogen in the form of a nitrate, if properly applied, will contribute to a large setting and a rapid growth of the fruits.

CELERY

Celery is another plant that luxuriates in a soil rich in vegetable matter, though the peculiar advantage of this natural condition of soil may be largely met where it is possible to secure an abundance of water and plant-food in soluble forms. In the absence of an abundance of water, even the best judgment in application of fertilizers will not result in satisfactory growth. A heavy application of the basic mixture (p. 267)—a ton per acre, used at time of setting the plants—may be followed with advantage by frequent and reasonably heavy top-dressings of nitrate of soda, 100 pounds per acre or more, and well worked into the soil. This abundance of soluble nitrogen will contribute toward that rapidity of growth which is accompanied by the peculiar crispness and sweetness that gives edible quality to this vegetable. In the absence of sufficient water and food, not only is the growth of the plant retarded, but the quality of that obtained is materially influenced, since the development of the bitter flavor and fibrous character that frequently cause a reduced consumption of this valuable plant is apparently encouraged.

What has already been said concerning this vegetable is true of a number of others: the main thing is to see to it that such an abundance of available food of the right kind is provided as to make possible a rapid growth when other conditions are favorable. This is one of the primary necessities, if a high yield of good quality product is obtained.

SWEET CORN

In the case of sweet corn, the early crop is usually the most profitable. The recommendations that are made for the fertilization of the field crop do not apply to this, because the object is not the matured crop, which makes its greatest development in July and August, the most favorable season of growth, but the early green product, which is often harvested before the field crop has fairly begun to grow. This early and rapid growth, therefore, cannot be attained by methods of fertilization suitable for the field crop (Chapters X and XII). It can be accomplished only when an abundance of the mineral foods is present, and when the nitrogen is in part, at least, in forms which may be directly absorbed, as much growth must be made previous to the time that nitrification takes place in the soil.

The large quantity of well-rotted manure which, until recently, was practically the only manure used for this crop, while extremely valuable, can be in part substituted by a liberal dressing of the minerals, phosphoric acid and potash, and further supplemented by nitrogen in readily available forms. The use of the basic formula (p. 267), reënforced by an application of nitrogenous materials, partly in the form of nitrate, and partly in quickly available organic forms, as blood, cotton-seed meal, or tankage, may be practiced with advantage.

EGG-PLANT, SPINACH, LETTUCE AND RHUBARB

The egg-plant belongs to the same botanical family as the potato, and while specifically benefited by the fertilizers recommended for that crop, is improved by the further addition of nitrogen, which stimulates an early leaf growth. Good organic forms are quite as useful as the nitrates or ammonia, unless the latter are used frequently as top-dressings.

Spinach and lettuce, grown for their tops or the edible portion of the leaf, are encouraged in their development by an abundance of available nitrogen, as this element is the one which contributes more than any other to formation of leaf. Abundant growth of the right sort is only accomplished when it is present in such quantities and in such forms as to continuously supply the plant with its needs. Reasonably heavy dressings of the basic formula (p. 267), 1,000 pounds per acre, or over, at time of planting, should be followed by a top-dressing of 100 pounds per acre of nitrate after the plants are well started. The late fall and winter growth of the spinach is especially benefited by the application of nitrates.

Rhubarb is a crop somewhat similar to asparagus, in that it is a perennial, and that the best fertilization is one which not only provides food for the growth of the immediate crop, but which encourages the growth of top after the regular crop is harvested, and thus restores the vitality of the plant,—which has been weakened by the continuous removal of the stalk and leaf,—and enables it to store up energy for the subsequent crop. An annual application of 1,500 pounds of the basic formula (p. 267) early in the spring, preferably plowed in, may be followed with advantage by a top-dressing of 150 pounds per acre of nitrate of soda in about two weeks after harvesting has begun, and a similar dressing after harvesting has ceased. These dressings should be cultivated into the soil, unless immediately followed by rain, which will distribute the salt into the lower layers of soil. Plants of this sort, from which only one crop can be secured, should be stimulated to the largest possible production.

ONIONS, ONION SETS AND SCALLIONS

The growing of onions, either from seed or from sets, and the growing of sets according to "intensive" systems of practice, requires a soil of a suitable physical character, and also that it shall be well supplied with all of the essential constituents of fertility The minerals should be supplied in abundance by superphosphates and potash salts, while the nitrogen should be supplied in the most active forms, and in even larger amounts than for many other crops. The present systems of growing these crops require that the sets shall be planted and the seed sown more thickly than was formerly believed to be desirable, which permits of a larger yield per unit of area, though it requires better culture and a very much larger quantity of available plant-food than was the case under the former rather "extensive" systems of culture. Except in the case of very early onion crops, immediate rapid growth after setting is not so essential as in the case of many other market-garden crops, and in the growing of onion sets, when the soil is richly provided with food, great care in management is necessary in order to secure a development of bulb that shall not be too large, in which case the salable quality of sets will be reduced. Hence, to avoid this, the seed should be spread thickly, in rows about 3 inches wide, and the cultivable portion between the rows about 8 inches wide. With so large a portion of the surface area occupied with the crop, the danger of too large development from heavy fertilization is greatly reduced.

In growing scallions, the soil should not only be richly provided with minerals and organic forms of nitrogen, as in the case of the other, but should be supplied early with soluble nitrate, in order to meet the demands for this element before it is available from soil sources. In the growing of crops which require so much hand labor as onions, fertilizers are also preferable to yard manures, because they are free from weed seed. Further, fertilizers do not contribute toward the development of insects or diseases, as is sometimes the case with manures, particularly with the product derived from city stables.

A good general fertilizer for onion sets for soils of fair fertility may consist of about 50 pounds per acre of nitrogen in organic forms, as dried blood, cottonseed meal or tankage, 60 of phosphoric acid, which may be partly in organic forms, as bone or tankage, and 100 of actual potash, derived from a muriate. The application of a formula containing—

Nitrogen	5 %
Phosphoric acid	6 %
Potash	10 %

at the rate of 1,000 pounds per acre, and well worked into the soil previous to planting, would furnish these amounts, and this application, together with a top-dressing of from 75 to 100 pounds per acre of nitrate of soda, or 60 to 75 pounds of sulfate of ammonia, two or three times at intervals of about three weeks, the first after the crops have well started, would provide not only an abundance of food of the right sort, but the nitrogen when needed, without danger of loss.

If the soil has been well dressed with a general fertilizer, as above described, the scallions should receive a dressing of nitrate just as soon as growth begins in the spring, as rapid and early growth at this season will, other conditions being equal, depend upon the supply of available nitrogen, and nitrogen in available forms is not usually present in the soil in sufficient quantities so early in the season.

In all of the suggestions made as to the fertilization of market-garden crops, not only has the question of yield been kept in mind, but also the quality of the product, which is a measure of salability. The question is often raised as to whether the forcing of these crops by means of active fertilizers may not result in too coarse and one-sided a growth. Such growth does frequently follow a heavy fertilization with nitrogen, if accompanied by too light a fertilization with minerals. The tendency of the plant is to make a normal development when a sufficiency of all of the fertility elements are present, but in these crops the object is really a one-sided growth in many cases, since that growth is usually better adapted for the purpose than that obtained under what may be regarded as normal conditions. It must be remembered, too, in the growing of certain vegetables, such as radishes, celery, etc., or those in which the roots are the edible portion, that commercial fertilizers do not contribute any undesirable flavors. In fact, they are often largely responsible for those peculiar characteristics which give quality; whereas, when these vegetables are grown by the exclusive and necessarily excessive applications,—if large yields are to be secured,—of natural manures, undesirable qualities are frequently contributed by them.

CHAPTER XIV

ORCHARD FRUITS AND BERRIES

It is not until within recent years that the question of manuring or fertilizing fruit trees and berries has come to be of particular interest. This is due primarily to the fact that demands for fruit and berries have been relatively limited as compared with the staple crops. Hence, fruit-growing as a business, or on a commercial scale, is comparatively new, though the opinion is quite prevalent among fruit-growers that trees, particularly, are indigenous to most soils, and grow freely like weeds, and that, therefore, orchard crops are not as exhaustive of the fertility elements as others. They cite, as an argument on this point, the fact that lands from which timber has been recently removed are much more productive than those upon which many regular farm crops have been grown. Scientific investigation and practical experience, however, teach that forest growth and fruit growth are quite different in respect to the needs of fertilizing elements, and that progressive fruit-culture demands that quite as much attention shall be given to the matter of providing proper plant-food as is now known to be desirable for the other and more common crops of the farm grown for profit.

FRUIT CROPS DIFFER FROM GENERAL FARM CROPS.

It is obvious that suggestions as to the character of the fertilization of the cereal crops, grasses and vegetables, must be somewhat different from these fruits, because the former differ from the latter not only in their habits of growth, but in the character and composition of the crop produced, and in their relation to soil exhaustion. General farm crops, with few exceptions, require but one year for the entire processes of vegetation and maturation. Fruit crops, as a rule, require a preparatory period of growth of tree or bush before any crop is produced, which is longer or shorter according to the kind of fruit. Furthermore, after the fruit-bearing period begins, the vegetative processes do not cease, but are coincident with the growth and ripening of the fruit. The crop product, or the fruit, also differs materially in its character from the general farm crop, or from vegetables, which reach their harvesting stage and die in one season, because for many kinds a whole season is required for growth and development.

That is, in fruit-growing it is necessary that there shall be a constant transfer of the nutritive juices from the tree to the fruit throughout the entire growing season, while the growth for each succeeding year of both tree and fruit is dependent upon the nutrition stored up in buds and branches, as well as upon that which may be derived directly from the soil.

"In the next place, the relation of fruit-growing to soil exhaustion is very different from that in general-crop farming, because in orchards there is an annual demand for specific kinds and definite proportions of soil constituents. It is really a continuous cropping of the same kind, and there is no opportunity, as in the case of ordinary farm crops, to correct the tendency to exhaustion by a frequent change of crops, or the frequent growth of those which require different kinds and amounts of plant-food constituents." *

THE SPECIFIC FUNCTIONS OF THE ESSENTIAL FERTILIZING CONSTITUENTS

It must be admitted, however, that the general principles of manuring, as applied to farm crops, also apply to fruit and berry crops; that is, the essential manurial constituents must be the same.

"A fruit tree will not make normal growth in a soil destitute of nitrogen. That nitrogen encourages leaf growth is a recognized fact, and since trees grow by means of both leaf and root, its presence is required in the soil in order to promote the growth and extend the life of the tree. It is very evident, too, that potash is an essential constituent in the growth of fruits, not only because it constitutes a large proportion of the ash of the wood of the apple, pear, cherry and plum, and more than 50 per cent of the ash of fruit, but because it forms the base of the well-known fruit acids. Phosphoric acid is also very essential in order to

* Voorhees, "Manuring Orchards.' Lecture before Massachusettes Horticultural Society, 1896.

nourish a tree properly, as well as to insure proper ripening, though it is apparent from such investigations as have been made that this constituent is relatively of less importance than for the cereals.

"It is also a matter of common observation, that in the prodnction of stone-fruits, particularly, lime is an important constituent. Its functions seem to be to strengthen the stems and woody portion of the tree, to shorten the period of growth, and to hasten the time of ripening. Fruit trees growing on soils rich in lime show a stocky, steady, vigorous growth, and the fruit ripens well, while those on soils which contain but little lime, particularly the clays, appear to have an extended period of growth, the result of which is that the wood does not mature and the fruit does not ripen properly." *

THE CHARACTER OF SOIL AN IMPORTANT CONSIDERATION

Soils which possess good mechanical condition, are rich in the essential constituents—nitrogen, phosphoric acid and potash—contain a good proportion of lime, and are well drained and cultivated, are naturally well adapted for fruit trees, as well as for other crops, and the exhaustion of such soils will not become apparent for a long time. But soils of this character are the exception rather than the rule, and the growth of fruit on those which possess the opposite characteristics cannot be continued for any considerable period without an artificial supply of the fertility

*"Manuring Orchards.' Massachusetts Horticultural Society, 1896.

elements. In fact, it is doubtful whether it ever pays to attempt to grow fruits on soils of the latter character without supplying them with an abundance of the essential fertilizer elements.

In the matter of berries, which are crops especially well adapted to soils which possess a light, open character, but which are not naturally supplied with the essential plant-food constituents, proper manuring becomes of even more importance than for the tree fruits; though, because of their shorter period of life, one or two good crops may be secured without heavy fertilization.

On the whole, however, for all of these crops the great need at the present time is for a larger use of fertilizing materials, not only because a larger yield may be obtained thereby, but because the quality of the product is far superior to that grown under conditions which are not perfect in this respect. Quality, which is determined by size and appearance, is, other things being equal, largely dependent upon an abundant supply of plant-food. It is manifestly impossible to include all fruit and berry crops in one general group, though possessing points of resemblance, because the different ones vary more or less in their character. The trees of certain of them are long-lived —40 years or more,—while others are comparatively short-lived—10 years or less. In certain of them the cropping period is short; the fruit ripens at once, while in others the ripening period extends over a considerable time. They also differ in reference to their demands for plant-food, certain of them requiring an abundance of available food, while others can readily absorb the food necessary for their growth from relatively insoluble compounds. In the discussion, similar recommendations may be made in many cases, though it is desirable that each class of fruits shall be considered separately, and also that distinctions should be made between what are regarded as good soils, as medium soils and as poor soils, in respect to their content of plant-food.

THE GENERAL CHARACTER OF THE FERTILIZATION

It must be borne in mind, also, that inasmuch as the fruit crop is not derived from annual plants, but from perennials, the character of the feeding may be very different from that in which the entire plant serves as a crop, as is the case with the cereals and most vegetables. Hence, the fertilizers applied need not all be of such a character as to be immediately available. That is, the fertilizing materials may be such as to provide for a gradual and continuous feeding. Those forms which decay relatively slowly are, perhaps, quite as good, if not better, for many kinds of fruits than those which by virtue of their solubility and immediate availability are more stimulative in their character. Those fertilizers which do not contribute to the immediate feeding of the tree or plant, but rather add to the reserves of potential plant-food in the soil, should, however, in many cases be supplemented by those which act more quickly, in order to supply an abundance of available food at special times and seasons. In general, therefore, a basic formula, the chief claim of which is that it furnishes large percentages rather than specific proportions or forms of plant-food, may be more reasonably adopted for fruits and berries than for other crops, because it may be applied with advantage to all of the fruits, the amounts to be applied to be adjusted to meet the requirements of the different kinds of crop and the different kinds of soil. Fertilizers which have been found to be very serviceable for fruit crops have been made according to the following formulas, the materials of which are familiar to all, and may be readily obtained from dealers: (1) One part, or 100 pounds each, of ground bone, acid phosphate and muriate of potash; or (2), a mixture of one and one-half parts, or 150 pounds, of ground bone, and one part, or 100 pounds, of muriate of potash; the mixture of either to be applied in all cases. For fruit trees on soils of good natural character, further additions of more active forms of the various constituents may not be needed, while on light soils, or those of a medium character, or for berries, they should be added.

The chief point to observe is that an excess of nitrogen must be avoided, and that if this element is applied in active forms it should be used at such times as to enable the plant to appropriate it early in the season, and thus become assimilated before the beginning of winter, the danger from too great an excess of nitrogenous fertilizers being that it causes a too rapid growth of both wood and fruit, which do not ripen well.

THE APPLICATION OF FERTILIZERS FOR FRUITS

A point which should be carefully observed in the fertilizing of orchards is the method of application. The fertilizers should, as far as possible, be distributed throughout the lower layers of soil, where the feeding roots are located. If applied wholly on the surface of the soil, the tendency of the root is to go to that point, or where the food is, and trees which have the larger proportion of the feeding roots near the surface are more liable to suffer from drought than those which have them distributed at greater depths in the soil. Hence, in the application of fertilizers to orchards, particularly in the early life of the trees, they should, as far as possible, be well worked into the soil, which may be readily accomplished by applying upon the surface before plowing. The after-fertilization, if it seems desirable to leave the orchard in sod, may be upon the surface, though in that case the soluble fertilizers are preferable, since they would rapidly descend, while the insoluble would do so more slowly, or only as rapidly as they became soluble.

THE FERTILIZATION OF APPLES AND PEARS

The necessity for the application of fertilizers in the growing of apples and pears is largely due to the fact that it is really a continuous cropping of the same kind, and, therefore, more exhaustive than a cropping which removes more plant-food in the same period of time. While upon good soils the trees may be able to acquire sufficient food to mature maximum crops for a considerable period, the life of the tree, as well as the character of the fruitage, will be very favorably influenced by the fertilization.

An experiment* bearing upon this point is very instructive, as indicating the need of manures for fruit trees, not only in reference to the amount removed, but also in reference to the proportions of the essential constituents required. This study shows that the plant-food contained in 20 crops of apples, of 15 bushels per tree, and 35 trees per acre, and in the leaves for the same period, amounts, in round numbers, to 1,337 pounds of nitrogen, 310 of phosphoric acid, and 1,895 of potash. These amounts of plant-food are compared with the amounts that would be removed by 20 years' continuous cropping with wheat, assuming an average yield of 15 bushels of wheat per acre, and 7 pounds of straw to 3 bushels of grain; viz., 660 pounds of nitrogen, 211 of phosphoric acid, and 324 of potash. By this comparison it is shown that the 20 crops of apples remove more than twice as much nitrogen, half as much again of phosphoric acid, and nearly three times as much potash as the 20 crops of wheat.

These results are valuable in indicating the rate of soil exhaustion by apple-growing. It is to be remembered, however, that the larger root development of the tree would enable it to draw its nourishment from

* Cornell Exp. Sta., Bulletin No. 103, "Soil Depletion in Respect to the Care of Fruit Trees."

a larger area of soil than is the case with wheat, and thus probably permit of normal growth for a longer period.

Too many are satisfied with short crops of medium fruit, with off-years and with short-lived trees, largely because they do not know that all of these conditions may be improved by a proper feeding of the tree, and that such feeding will usually result in a very largely increased profit.

Statistics gathered in the state of New Jersey* show that over 90 per cent of the commercial apple-growers in the southern and central sections use fertilizers or manures for their orchards, whereas, in the northern section about 70 per cent use manures. In the northern section the orchards are usually located upon soils of a very high natural strength, and which are peculiarly well adapted for the growing of fruits, while in the central and southern sections, the soils in many sections are of medium, if not of very low fertility. Hence, while the larger proportion of the growers use fertilizers or manures upon the poor soils, a very considerable number use manures for orchards located upon soils which are regarded as of the best; yet all claim that it is a paying practice.

There is also a difference in the time at which manuring or fertilizing should begin. When the soil is naturally good the fertilization need not begin with the setting of the tree, as the food obtainable is usually sufficient to provide for a good growth of leaf and

*Bulletin No. 119, New Jersey Experiment Station.

wood, and in many cases maximum crops of fruit for a number of years, though even here fertilization should preferably begin as soon as large crops are produced, whereas, on the lighter soils, fertilization should begin when the tree is set.

The Amounts to be Applied

For these crops, either of the basic mixtures suggested (p. 288) will provide a sufficient proportion of nitrogen, except possibly upon the more sandy soil. On light soils, the necessity for liberal fertilization with nitrogen is frequently apparent, in which case it may be applied in organic forms, preferably from materials that do not decay too rapidly, as tankage, or wool waste, and other waste nitrogenous materials, because they may be obtained more cheaply, and because they furnish the nitrogen quite as rapidly as is needed by the tree. In many cases it is possible to obtain the necessary nitrogen from the growing of leguminous crops, as crimson clover, though when these are used they should be plowed down early in the spring, in order that their growth may not interfere with the growth of the tree. If they are allowed to remain until mature, they absorb not only the food that may be necessary for the growth of tree and fruit, but the moisture also, and thus they frequently injure rather than improve the crop prospects.

On soils of good natural character, the fertilization of apples and pears should begin as soon as the trees reach the bearing period, and an annual application of

400 pounds per acre of either formula 1 or 2 should be made, preferably in early spring, and plowed in. As they grow older and the yield of fruit is larger, the amounts should be increased. While no definite rules can be laid down as to the most profitable amounts to apply, the best growers find that it pays to use from 1,000 to 1,500 pounds annually of mixtures which furnish practically the amounts and kinds of plant-food contained in the formulas suggested. The profit is found, not only in the larger yield, but in the quality of the fruit and in the increased tendency toward continuous crops, and in longer life of the tree. On soils of medium character the fertilization should begin earlier, and the amounts of the basic fertilizer should be larger. In many cases, too, nitrogen, in addition to that contained in the basic formula, should be added, the kind and form depending, perhaps, upon the relative cost more than upon any other one thing, the minimum amount to be 20 pounds per acre, or an equivalent of 125 pounds of nitrate of soda.

On poor soils, the necessity for fertilization is naturally greater than for either of the others. In fact, on these liberal fertilization — 500 pounds per acre of basic formula No. 2—should precede the setting of the trees, and be continued annually On these soils, too, green manuring as a source of nitrogen can be practiced with safety for a longer period than in the preceding case. In the presence of an abundance of minerals, the need for nitrogen is indicated by the color of the foliage. If it lacks vigor and is yellow in the spring, rather than green, a dressing of from 100 to 150 pounds of nitrate of soda will supply the needs to better advantage than any other form.

PEACHES

Peaches differ from apples and pears in respect to fertilization, because the period of development of the tree, preparatory to bearing, is shorter, and because the cropping is usually much more exhaustive. Hence, the demands for added plant-food are proportionately greater in the early life of the tree, and are different, because of their more rapid growth. That is, forms of nitrogen that are more available are preferred to the slowly available materials recommended for apples and pears.

The Need of Fertilizers

The results of an experiment conducted by the New Jersey Experiment Station* are interesting and valuable, as bearing upon this point. They show the value of fertilization, not only in increasing the yield of crops, but in extending the period of life of the trees, and in overcoming unfavorable crop conditions. The soil upon which the experiment was conducted possessed only medium fertility, good mechanical condition, and was fairly representative of soils naturally well adapted for peach-growing. The fertilized plots received annually—

*Annual Reports of New Jersey Experiment Station, 1884–94.

Nitrate of soda	150 lbs.
Bone-black superphosphate	350 "
Muriate of potash	150 "

per acre, whereas the manured plot received manure at the rate of 20 tons per acre.

The following tabular statement shows the results obtained:

I. The Yield without Manure

	Baskets per acre
1884–1891, inclusive, 8 years, average per year	65.7
1884–1895, " 10 " " "	60.3
1887–1891, " (5 crop years), average per year	105.0
1887–1893, " 7 " " " "	86.2

II. The Yield with Complete Chemical Manure

	Baskets per acre
1884–1891, inclusive, 8 years, average per year	164.2
1884–1893, " 10 " " "	183.4
1887–1891, " (5 crop years), average per year	262.8
1887–1893, " 7 " " " "	262.0

III. The Yield with Barnyard Manure

	Baskets per acre
1884–1891, inclusive, 8 years, average per year	169.5
1884–1893, " 10 " " "	194.7
1887–1891, " (5 crop years), average per year	271.3
1887–1893, " 7 " " " "	276.8

IV. The Relative Yield in an Unfavorable Season

	Baskets per acre
1889, unmanured	10.9
1889, fertilized	152.5
1889, manured	162.5

"The first point of importance and value observed is in reference to the number of crops that were secured. On the unmanured land, the crops secured after eight years were so small as to materially reduce the average for the whole period, while for the manured land the average for the whole period was not only not reduced, but very materially increased; that is, the crops secured on these after the trees on the unmanured land had practically ceased to bear were greater proportionately than those secured previous to that time. This was true both for the fertilized and manured land.

"In the next place, it is shown that the yield was very materially increased by the use of manures, either in the form of artificial or natural supplies, and the differences in yield derived from these two forms are very slight, indicating that very much smaller amounts of actual plant-food in quick-acting forms were quite as useful as larger amounts of the less available forms in which the food exists in natural manure products.

"For the ten years, the fertilized plot received 250 pounds of nitrogen, 560 of phosphoric acid and 750 of potash, while the yard manure plot received — assuming the average composition of yard manure — 2,000 pounds of nitrogen, 2,000 of phosphoric acid and 1,600 of potash; yet with eight times as much nitrogen, nearly four times as much phosphoric acid and more than twice as much potash, the yield was but 113 baskets greater, or an average of 11 baskets per acre.

"In the third place, it is interesting to observe—and it is a point of great importance—the effect of an abundance of food in overcoming unfavorable weather or seasonal conditions. The year 1889 was extremely unfavorable, and the crop throughout the state was small. In this experiment the unmanured plot yielded at the rate of 10.9 baskets per acre, while the manured and fertilized plots both showed a yield exceeding 150 baskets per acre. The manure strengthened and stimulated the trees, and enabled them to successfully resist such conditions as were fatal to the crop on the unmanured land.

"This point is one that is seldom considered in calculating the advantages to be derived from proper manuring, though it is of extreme value, since the expenses of cultivation, trimming, and interest on investment are quite as great in one case as in the other." *

Methods of Fertilization

On soils of good natural character, the necessity for fertilizing peaches is seldom apparent until after the first or second year of growth. That is, good soils will provide sufficient food for a normal development of leaf and wood, and any additional fertilization would have the tendency to unduly increase the tree growth. On medium and poor soils, the setting of the trees should be preceded by a fer-

* "Manuring Orchards." Massachusetts Horticultural Society, 1896.

tilization with one or the other of the basic mixtures (p. 288), on the better soils No. 2, and on the poorer No. 1, at the rate of 400 to 600 pounds per acre, which should be followed by the application of the more soluble fertilizers immediately the trees begin to bear. The need of nitrogen is often very marked, and is shown by a lack of vigor of the tree. The soluble nitrates have proved very valuable as a source of this element, since from these the nitrogen may be appropriated by the roots during the early season, and which, if a sufficient abundance of the minerals is present, enables a normal development of leaf and branch. If the quick-acting nitrogenous fertilizers are applied late, or if too large applications of the slower-acting nitrogenous materials are applied early, the tendency is to provide for a continuous feeding on nitrogen, and thus encourage an undue development of leaf and branch, which does not permit the ripening of the wood before the beginning of winter. Thus on these soils, in addition to an annual application of the basic formula, from 100 to 150 pounds of nitrate of soda, 200 pounds of acid phosphate and 100 of muriate of potash should be applied early in the season and carefully worked into the soil.

For peach crops, too, green manuring with leguminous crops should be carefully carried out, since if too much nitrogen is added by this means, an abnormal growth of wood is encouraged, and a late ripening of the fruit occurs; and injury to the tree may follow if the manuring crop is not used at the proper time, as already indicated.

Many orchardists use much larger amounts of fertilizer than is here recommended, though if the suggestions concerning the method of use are carried out, the quantities named will be found sufficient to supply all the needs of maximum crops.

PLUMS, CHERRIES AND APRICOTS

The fertilization of these fruits, when grown on the different classes of soils, need not differ materially from that recommended for peaches under the same conditions, though cherries, particularly, require in addition to the essential constituents, nitrogen, phosphoric acid and potash, a relatively greater supply of lime, and this substance should be applied in addition to the regular fertilization. Care should also be exercised in the application of nitrogen, in order to prevent a too great development of leaf and branch. Unless these trees show a decided need for nitrogen, a medium application of the second basic formula (p. 288) will furnish sufficient for their needs.

CITROUS FRUITS

These products—the oranges, lemons, and the like—belong to a distinct class of fruits, and the experience already gained in their fertilization is such as to make applicable the suggestions concerning peaches, plums and apricots. On the lighter sandy soils of Florida, which are naturally well adapted for oranges, growers have found potash to be a specially important element in manures. The nitrogen and phosphoric acid should be accompanied by a larger proportion of potash than is recommended for the stone fruits. Great care should be exercised in the use of nitrogen, though in the case of these semi-tropical crops, the danger from immature growth, as in the case of fruits for the more northern climates, is not so marked.

SMALL FRUITS IN GENERAL

These crops do not differ from those already discussed in reference to their needs for liberal fertilization, yet because of their different character of growth, the method of fertilization should be somewhat different. They are, as a rule, crops which require a shorter preparatory season, and have a shorter period of bearing life. The strawberry, for example, does not advantageously bear more than two crops without re-setting, whereas the blackberry and raspberry may range in life from four to eight years, and the gooseberry and currant are relatively long-lived, provided they are supplied with an abundance of food. In respect to their general character, they correspond more nearly with the vegetable crops than with the cereal grains, in that they possess a relatively higher market value and a lower fertility value than these, and the period of growth and development of the fruit is much shorter. Therefore, natural sources of plant-food may be largely ignored in their growth, and the more quickly available — particularly nitrogenous and phosphatic — materials supplied.

STRAWBERRIES

In the case of the strawberry, the preparatory period of growth of the plant before bearing is but one year, and the crop that may be obtained is largely dependent upon the strength and vigor of plant which has been acquired during this period. Hence, it is desirable that the soil in which the plants are set should be abundantly provided with the mineral elements, particularly with soluble and available phosphoric acid; hence an application of from 500 to 800 pounds per acre of basic formula No. 1 (p. 288) is recommended. The nitrogen should also be in quickly available forms, and should be supplied in sufficient quantities at time of setting the plant to enable it to mature, and thus to withstand the rigors of winter. Hence, an additional application of 100 pounds of dried blood, or its equivalent in nitrate of soda or ammonia, is advisable, particularly on soils not previously well enriched with organic nitrogenous matter. In the spring of the season during which the first crop is harvested, an application of a quick-acting fertilizer rich in nitrogen is desirable, since it not only provides for an early and strong growth of plant, but a better setting of fruit, if other conditions are favorable; and frequently, with a full setting, top-dressings with nitrate of soda are useful, in order to insure the full development of the crop. Many growers, therefore, who have supplied the soil liberally with minerals and nitrogen, both at time of setting the plants and in the following spring, make top-dressings of nitrate of soda (about 100 pounds per acre), preferably after the plant has blossomed, in order to insure a sufficiency of this element. This should be applied at this time rather than later in the season, since later applications have a tendency to cause a soft growth of fruit, and thus injure shipping qualities.

RASPBERRIES AND BLACKBERRIES

Raspberries and blackberries also require a soil well enriched with the mineral elements, which insure an abundant and strong growth of canes. The need for nitrogen, while apparent, is less marked than in the case of the strawberries, and the slower-acting forms serve a good purpose, provided they are not applied in too great quantities, so as to encourage a late growth of plant, which does not fully mature. The main object is to obtain strong, well-ripened canes, and this can be accomplished with the slowly available nitrogenous substances, provided an abundance of the minerals is present. An annual application in spring of 500 pounds per acre of basic formula No. 2 (p. 288) will furnish sufficient food on soils of good character, though on lighter soils additional nitrogen should be supplied, preferably in forms not too active. The practice of applying quick-acting nitrogen early in the spring, after plants have blossomed, has been followed with great success, particularly upon the lighter soils, as it encourages a more complete development of fruit, though it should be used with caution, since the fruit canes of both the present year and those which provide the plant for the next year naturally grow in the same bed, and the young canes may not mature properly if too heavy applications of nitrogen are made.

CURRANTS AND GOOSEBERRIES

These are crops which, under average conditions, are seldom heavily fertilized, though fertilizing is usually followed with great profit. They are less likely to need nitrogen than the other crops mentioned, and a too heavy fertilization with this element has a tendency to encourage the development of mildew, the disease so common to these crops. In common with the other crops mentioned, they should be abundantly supplied with the minerals, phosphoric acid and potash, and the basic formula already recommended (p. 288) may be used in all cases with profit at the rate of 500 to 1,000 pounds per acre. The additional nitrogen needed may be provided by the slow-acting materials. Many growers find such waste products as wool and hair of great advantage in the growing of these crops.

GRAPES

Grapes are more exhaustive as a crop than most of the fruit crops, largely because of the larger total crop harvested, and the special need is for phosphoric acid and potash. These elements may be supplied by the basic formula (p. 288), and very liberal dressings are recommended,—from 1,000 to 2,000 pounds per acre annually,—after the bearing period begins. On light soils, an annual spring dressing of nitrate of soda, at the rate of 200 pounds per acre, is also desirable, in order to encourage rapid and large early growth of leaf and vine, though this dressing may be omitted if the growth of clover as a green manure is practicable. The latter, however, as when used in connection with the other fruits mentioned, should not be allowed to mature, but rather be plowed down early in the season.

The main point in the fertilization of all fruits is to provide an abundance of the mineral elements, and to give particular attention to fertilization with nitrogenous materials. It must be remembered that it is the fruit, not the wood, that constitutes the crop, and that all the energies should be directed toward the development of such a tree or vine as will best contribute toward this end.

CHAPTER XV

FERTILIZERS FOR VARIOUS SPECIAL CROPS

In addition to the generally familiar crops already described, there are certain special ones, not distinct from the others because they are of less importance, but rather because they are only grown in certain localities.

COTTON

Among these special crops, cotton takes first rank, because it is one of the leading crops of the country, occupying wide areas, and exercising fully as great an influence upon our agricultural prosperity as any other of our American staples.

The climate suitable for the growing of cotton is confined to about one-quarter of the area of the country, and in this area it occupies a more important position than any other crop grown there.

In the earlier history of its cultivation, the methods employed were not such as to encourage the largest yield. In the first place, it was grown on the poorer soils rather than the more fertile, and after it had been grown consecutively upon the same lands for a number of years, and thus rapidly exhausting them, the planter, instead of attempting to improve the lands, either by better methods of culture or by the use of manures, extended the areas under cultivation. After the civil war, when it became still more necessary to change methods, fertilizers were looked to as the main reliance, rather than the improvement of the character of the soil, either by judicious rotation or by manuring. The results secured from the use of fertilizers at this time were so generally satisfactory that their large and indiscriminate use was encouraged, and this, without proper attempts at the improvement of the soil in other respects, hastened the time when such use did not give profitable returns. The very great importance of the crop to the agriculture of the leading cotton states, and the necessity of better methods of culture, were so fully appreciated that a scientific study of the crop was then entered upon, and the states largely interested planned, through the aid of their colleges and experiment stations, a wide series of experiments, which were directed toward the solution of the problems connected with the feeding of the plant. The results of these experiments have been fruitful of such valuable information as to warrant practical and specific suggestions which have a wide application, and which, if followed, will result in the improvement of the soil and in the economical increase in crop.

As already stated, the cotton crop is not an exhaustive one in one sense, though the methods of practice used in its growth have been wasteful, and thus have given rise to that belief. That is, a large crop of cotton does not remove from the soil a very considerable amount of the fertilizer constituents.

The following amounts are contained in a crop yielding 300 pounds of lint per acre :*

Nitrogen	46 lbs.
Phosphoric acid	12 lbs.
Potash	30 lbs.

Fertilizers for Cotton

In regard to its need for fertilizing, cotton may be classed with the cereals rather than with the crops already discussed ; and like the cereals, its best growth is attained when properly introduced into a rotation with other crops, and the annual food supply arranged in such a manner as to contribute to the larger yield of the immediate crop, as well as to furnish an unused residue which will provide for an increase in the yield of the succeeding ones. Of the constituents, phosphoric acid seems to exercise a greater influence upon the growth and development of the cotton plant than any other element, notwithstanding the fact that smaller amounts are contained in it than of either nitrogen or potash. That is, it appears that the plant must have an abundance of available phosphoric acid at its command in order that the other constituents necessary for a full crop may be freely absorbed, though on the soils adapted for the crop, which naturally vary widely both in their general and special physical characteristics, but are poor in the fertility elements, both nitrogen and potash must be applied, in order that maximum crops may be obtained.

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*Farmers' Bulletin No. 14, Department of Agriculture.

On the whole, therefore, though the "intensive" system is not generally practiced, fertilizers furnishing all of the constituents are superior to those which furnish but one or two; yet when proper rotations are practiced and leguminous crops are grown for the purpose of improving the physical character of the soil, as well as increasing its content of nitrogen, the percentage of this element introduced into the fertilizer may be very largely reduced.

The conclusions that have been arrived at by the experiments conducted in the various states have been very fully set forth in various publications,* and the following statements drawn from these indicate what are believed to be the advantages derived from the right use of fertilizers, and the best methods to be observed:

"The cotton plant responds promptly, liberally and profitably to judicious fertilization. The maturation of the crop may be hastened, and the period of growth from germination to fruiting may be so shortened as to increase the climatic area in which it may be profitably grown. It should be assigned to a place in a rotation system. One of small grain, corn (with peas) and cotton, is well suited for the conditions prevailing in the cotton belt, and, as with other crops, the results derived from the use of fertilizers for this crop are much enhanced by the proper preparation of the soil. It pays to bring

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*Farmers' Bulletins, Nos. 14 and 48, Department of Agriculture. Office of Experiment Stations, Bulletin No. 33, Department of Agriculture. Various bulletins issued by the Georgia, South Carolina and Louisiana Experiment Stations.

up the cotton lands by mechanical treatment, and especially by introducing organic matter. The renovating crops, especially the cow pea, are very profitably employed as adjuncts to the fertilization of the crop itself. On the majority of soils, too, it is advisable, and more generally proves profitable, to use a complete fertilizer, rather than one containing one or two of the constituents; and of the forms of nitrogen, organic (vegetable and animal) is best suited to the cotton, if one form alone be used, although nitrate of soda is probably nearly, if not quite, of equal value. The relative advantages of various proportions of the different forms have, however, not yet been fully determined; hence the use of a mixture of the best is a safe plan, the proportions to be determined by their relative cost. In the case of phosphoric acid, superphosphate is to be preferred to to materials of an organic or mineral nature, which are not immediately available. Of the potash salts, no particular difference is observed in the use of the different forms. The form to be secured is to be based upon the price of the different forms."

Formulas for Cotton Fertilizers

While the most judicious proportions of soluble phosphoric acid, of potash and of nitrogen in a complete fertilizer cannot be said to have been determined with entire accuracy, the carefully conducted experiments of both the Georgia and South Carolina stations indicate that for general use 1 part of nitrogen, 1 of potash, and 2¾ or 3 of phosphoric acid indicate the best proportions. The amount of fertilizer that may be profitably used very naturally varies widely, though medium rather than very large dressings are recommended, not so much because the plant under good soil conditions could not appropriate and use to advantage large amounts, but because on the whole, soils used for cotton are peculiarly lacking in those qualities which enable the proper distribution and appropriation of the larger quantity. For those soils, then, the amounts per acre indicated by the Georgia Experiment Station are, annually —

Nitrogen	20 lbs.
Available phosphoric acid	70 "
Potash	20 "

The South Carolina Experiment Station recommends an application per acre of —

Nitrogen	20 lbs.
Available phosphoric acid .	50 "
Potash	15 "

or, as suggested by the Georgia Experiment Station, perhaps a fertilizer containing —

Nitrogen .	3 %
Phosphoric acid (soluble)	9 %
Potash	3 %

applied at the rate of 700 pounds per acre, would be approximately the best amounts to use under ordinary circumstances.

Method of Application

The fertilizer should be applied in the drill at the time of planting, and at the depth of not more than three inches, and well mixed with the soil. In most cases it is best to apply all of the fertilizer in one application rather than in fractional applications, though with lands in superior condition profitable applications may be made again at the second plowing. Owing to the nearness of the cotton belt to the supplies of superphosphate, and to the cheap supplies of cotton-seed meal, the only fertilizer necessary to import is potash. Hence it has become a practice in most sections for the planter to make his own formulas, using his own supplies of phosphoric acid and nitrogen; and home mixtures, made up of acid phosphate, cotton-seed meal and muriate of potash, or kainit, are largely used to supply the demands. The following formula is an example of a good mixture:

Acid phosphate	1,200 lbs.
Cotton-seed meal	600 "
Kainit	200 "

The formula containing—

Nitrogen .	3 %
Phosphoric acid	9 %
Potash .	3 %

is also recommended, since an application of 700 pounds per acre will furnish the amounts and proportions of the elements indicated as the maximum by the Georgia station. This formula is also well suited for corn, if introduced into a rotation as previously suggested.

TOBACCO

Tobacco is another special crop grown only in certain localities, favored either by reason of climate or character of soil, or both. It is, however, a very important crop in this country, and one which requires very careful attention in reference to the amounts and kinds of fertilizers applied, because the fertilization exercises an influence upon both the yield and quality of the crop. It is an exhaustive crop, drawing heavily upon both nitrogen and potash. A crop yielding 1,000 pounds of leaf per acre will contain, in round numbers, 67 pounds of nitrogen, 9 of phosphoric acid and 85 of potash: amounts equivalent in nitrogen to over 400 pounds of nitrate of soda, of phosphoric acid equivalent to 75 pounds of acid phosphate, and of potash equivalent to 170 pounds of muriate of potash. It is a fact, too, that tobacco of the best quality, or that best suited for cigar wrappers, can be grown to advantage only on light, sandy soils,—those not naturally well supplied with the fertilizing constituents. Thus, if large crops are to be secured, the soil must receive liberal supplies of food from artificial sources.

The Influence of Fertilizers on the Quality of the Crop

A point of great importance in the fertilizing of tobacco, is the influence of the constituents applied on the marketable quality of the crop, as for certain purposes, especially for the manufacture of cigars and cigarettes, the tobacco must possess peculiar characteristics in order to bring the highest price in the market. In other words, in the growing of this crop, as is the case in many others, both the yield and quality must be taken into consideration, and frequently the latter point is of quite as much importance as the former, though a reasonable yield must be secured before the influence of quality is of practical significance. The quality of the leaf is believed to be influenced chiefly by the constituent potash, though many growers object to the use of various nitrogenous and phosphatic materials, believing that they, too, exercise a decidedly unfavorable influence upon the quality of the leaf. Careful experiments, however, do not justify many of the opinions of growers and dealers regarding the effect of the different materials upon the quality of wrapper tobacco.

The main points, therefore, in the fertilizing of tobacco, are to see to it that a sufficient quantity of plant-food is applied in order to secure the largest possible yield consistent with quality, and second, to avoid the use of such constituents as are positively injurious.

The Conclusions from Connecticut Experiments

Experiments in the application of fertilizers to tobacco have been carried out at the Connecticut Experiment Station with great care and skill for a number of consecutive years.* They lead to the conclusion that "there is no 'best' tobacco fertilizer, or 'best' formula for all seasons, even on the same soil. A formula or a form of plant-food which in one season gives the leaf a somewhat better quality than any other, may, perhaps the next year and on the same soil, prove inferior to others, for reasons which can only be surmised.

"Nevertheless, by comparing the effects of these fertilizers for a term of years, it appears that certain ones are, on the whole and generally speaking, more likely to impart a perfectly satisfactory quality to the leaf than certain others.

"It is doubtless true of tobacco, as of other crops, that the liberal but not greatly excessive supply of readily available plant-food yearly required to insure a paying crop may be given in a variety of forms with equally good results, on the average of one season with another, and that, indeed, occasional changes in the form of nitrogen and potash supplied may be a distinct advantage, avoiding always any considerable quantity of those things, as chlorin, and sulfuric or other free acids, which experience has shown may damage the leaf."

These conclusions in regard to the kind and quantity of fertilizing constituents required for the growing of tobacco of good quality confirm those arrived at by experiments elsewhere, and the suggestions made are sufficiently definite to guide in the use of fertilizers

*Connecticut Agr. Exper. Sta., Annual Report, 1897, Part IV., page 255.

for this crop. In brief, therefore, the tobacco cro] must be provided with an abundance of all of the fer tilizer elements derived from readily available forms and free from those constituents known to exercise aı unfavorable influence upon the quality of the product in order that satisfactory yields of good quality may b secured.

Form of the Constituents

It has not been shown that one form of nitrogeı is superior to another under all circumstances, or iı other words, that one form of nitrogen,—as, fo example, ammonia or nitrate, or any particular forn of organic nitrogen, vegetable or animal,—is superio to all others, but rather that any or all of the goo forms may be used in a mixture, provided a sufficien abundance is present to insure a maximum yield though not so large an amount in excess of th minerals as to encourage a rank, coarse growth. Th phosphoric acid should be in available forms, and i in these forms, must naturally be drawn largely fron superphosphates. The potash should in all cases b drawn from sources free from chlorids. A fertilizer therefore, which contains the nitrogen, either in goo organic forms, as cotton-seed meal or blood, or a mix ture of these organic forms with ammonia or nitrat in not too large amounts, which contains the phos phoric acid in a soluble form, and potash derive from products free from chlorids,—as from high-grad sulfate, or from a carbonate, or from cotton-hul ashes, if these are obtainable,—may be regarded as well adapted for the crop.

Amounts to Apply

An annual dressing which will furnish 100 pounds of nitrogen, 75 of phosphoric acid and 150 of potash per acre may be regarded as a minimum for soils of medium quality. On lighter soils heavier applications should be made, and on soils previously well enriched with the fertilizer constituents, the dressing may be somewhat less. It must be remembered, however, that it is not economical, from the standpoint of either yield or quality, to be too sparing in the application of fertilizers, because the plant requires large amounts of both nitrogen and potash, and because it is essential that the plant should have a reasonable excess of these at its command, in order to overcome as far as possible any unfavorable seasonal conditions that may occur.

In the Connecticut experiments already referred to, amounts greatly in excess of those suggested have been used with advantage. In Kentucky and Virginia, on soils naturally richer, smaller amounts have given quite as good results. It is likely, however, that upon the very light soils of certain of the states in which tobacco of high quality is grown, notably Florida, considerably increased amounts may be used with profit.

As sources of at least part of the nitrogen and potash in the southern states particularly, cotton-seed meal and cotton-hull ashes are recommended, because readily obtainable. These forms have been found to be good, and they may be obtained as cheaply as other forms as well as more conveniently

SUGAR-CANE

Another special crop, confined largely to one state, Louisiana, is sugar-cane, and perhaps no other one crop has in this country received such careful study in reference to its needs for plant-food. The Sugar Experiment Station of that state has for twelve years conducted a series of systematic experiments designed to answer the questions as to what the needs are for nitrogen, phosphoric acid and potash; and the results of this work thus far secured furnish suggestions in reference to fertilization, which will, if carefully followed, undoubtedly result in the production of better crops than are grown under present systems. Fertilizers are clearly needed, and their right use is a profitable practice, though, as stated by Doctor Stubbs, "many ascribe the failure from their use to the worthlessness of the fertilizer, when it should be ascribed to some defection of the soil, rendering it incapable of appropriating the applied fertilizer."

The chief conclusions in reference to fertilizers for sugar-cane in Louisiana, so clearly set forth by Doctor Stubbs in this report,* are here summarized, as it is believed that the underlying principles are

*"Sugar-Cane," Vol. I, Sugar Experiment Station, Audubon Park, New Orleans, La.

applicable elsewhere, though naturally their use must be modified to suit individual cases.

The Needs of the Plant as Indicated by the Louisiana Experiments

"An examination of the cane plant shows that a crop of 30 tons will remove, in round numbers, 102 pounds of nitrogen, 45 of phosphoric acid and 65 of potash. It is, therefore, a relatively exhaustive crop, and unless the physical conditions are perfect, even good soils should receive considerable dressings of the constituents, if the fertility is to be maintained.

"The results secured thus far in the experiments referred to demonstrate that the soil needs nitrogen and phosphoric acid particularly, in order to grow cane successfully, while thus far, no results of any character, either in the increased sugar content or tonnage per acre, have been visible from the use of any form of potash upon the alluvial lands of the lower Mississippi. Several forms of potash, notably the carbonate, and ashes of cotton-seed hulls, have rather decreased the yield of cane and injured the physical qualities of the soil by causing it to 'run together.'

"In reference to the form and amount of nitrogen, it has been shown that sulfate of ammonia gives slightly better results than any other form, though its higher cost gives no advantage over those costing less, while cotton-seed meal comes next, followed by dried blood and nitrate of soda. In reference to the amount of nitrogen to be applied, it is shown that not less than twenty-four pounds nor more than forty-eight pounds per acre should be applied. Naturally, different soils and different kinds of cane would vary in their requirements for this element, and the amount needed would also be influenced by the method of growing the crop: whether upon 'succession' land—that is, upon soils upon which a crop of stubble cane has just been taken off, and which has been in cane for a number of years without the intervention of a leguminous crop between to restore the nitrogen—or whether upon pea-vine land, upon which the plant cane is grown the first year, stubble cane the second, and corn and cow peas the third year. This system of rotation, which introduces a leguminous crop into it, not only improves the physical quality of the soil, but enables a considerable accumulation of nitrogen, frequently over one hundred pounds per acre. The pea-vine lands, put in plant cane on account of their excellent physical condition, not only yield up readily the nitrogen stored up by the pea, but can also assimilate larger quantities of plant-food applied as fertilizer. Hence, such cane usually makes large crops. Since nitrogen is the chief ingredient taken from the soil by a crop of cane, it follows that with each successive crop of cane grown on the land without the interjection of the leguminous nitrogen there arises an increased demand for nitrogen. Hence, stubble cane requires larger quantities than plant cane, and the older the stubble, the larger its requirements for this element."

In reference to phosphoric acid, the results so far indicate positively the value of this element in fertilizers for sugar-cane on these soils, but the demand for this ingredient is small in comparison to that for nitrogen, 36 pounds per acre being ample for the crop. The results further show that the soluble forms of phosphoric acid are preferred. Inasmuch as the leguminous crop does not add to the store of phosphoric acid in the soil, it is equally needed by both plant and stubble cane.

While potash has not been shown to be needed on the land upon which the experiments were conducted, because of the abundance of potash contained in the soil, after continuous cropping of these and on lighter soils this element should be included in the fertilizer.

The Application of Fertilizers

For plant cane, a small quantity of readily available fertilizer directly under and near the cane is highly beneficial, as it provides food also for the sucker, which, with food at hand, is greatly aided in developing a healthy sucker, and thus the entire plant is given a vigorous send-off in youth. It is necessary, to give a good start to a young plant, to withhold manures until a stand is secured, though when cane is planted during the fall and winter, as it is in Louisiana, the danger of loss by leaching must be reckoned upon, and the exact amounts to be applied at that time regulated by the judgment of the planter. Usually the more perfect the incorporation of a manure in the soil the better the results to be expected, but in this case it should be deposited in a drill and well mixed with the soil. In the spring, after the cane is closely off-barred, the fertilizer, if not applied at planting, should be scattered on both sides of the plant from the center of the row to the off-barred furrow. Hence, in reversing the furrow, the manure is covered, and subsequent cultivation will mix the latter with the soil. If the cane has received the first application at planting, the second one should be given in May, on both sides of the row. The stubble cane should not be fertilized very long before each sprout has sent out its own rootlets, since prior to this no good could be accomplished, and there would be a waste of manure.

MISCELLANEOUS CROPS

Other crops of importance for which the need of fertilizers is frequently apparent include sorghum, buckwheat, peanuts, roses and herbaceous plants, lawns, grasses, and plant-house vegetables. These are, of course, similar to those already described, since their best development requires that they shall be well supplied with the fertilizing constituents, nitrogen, phosphoric acid and potash, though their special needs in this respect have not been so fully investigated as the other crops dealt with in this chapter. The discussion of their requirements is, therefore, necessarily brief, and the suggestions made are of a general rather than a special character, though they may serve as a safe guide.

Sorghum

Sorghum is grown both for forage and for sugar, and its fertilization should be discussed from these two standpoints. If grown for forage, the fertilization should be more liberal and of a different character than if for sugar, as the object is the largest yield of succulent food rather than the highest yield of sugar, and the yield of sugar is not always consistent with the highest yield of cane. For forage, therefore, the fertilizer recommended for maize forage (p. 242) is well adapted for sorghum on soils in a good state of fertility, though since the plant is very slow to start, its early growth is stimulated if a larger amount of readily available nitrogen is used than is desirable for corn, particularly on soils of medium fertility, and which have not been previously well fertilized. If grown for sugar, too much nitrogen must be avoided, since an excess of this element in the fertilizer causes an imperfect ripening, and consequently a higher percentage of non-crystallizable sugar in the cane; though if quickly available forms are used, as nitrate, ammonia, or dried blood, which may be absorbed by the plant early in the season, a larger amount may be applied with safety than if the poorer forms are used. Of the three constituents, potash in the form of muriate seems to be the one exercising the greatest influence upon the yield of sugar, hence it should always be introduced in considerable amounts in fertilizers for sorghum.* A fertilizer furnishing 20

*Report for 1886, New Jersey Agricultural Experiment Station.

pounds of nitrogen, 35 of phosphoric acid and 60 of potash per acre will meet the needs on average soils.

Buckwheat

Buckwheat is frequently grown upon the poorer soils of the farm. It is a crop well adapted to mountain lands, and as a preparatory crop in the breaking of new lands. It has not been carefully studied in reference to its needs for plant-food, though phosphoric acid seems to be the constituent more particularly required than the others. Its need of nitrogen is marked, yet because its entire growth and development are made during the months of July and August, when conditions are most favorable for soil activities, heavy nitrogenous fertilization is not to be recommended, except when grown on very light soils, or those deficient in vegetable matter. The moderate use of fertilizers rich in minerals, and which contain nitrogen in quickly available forms, result favorably, not only in increasing the yield, but assist materially in maturing the crop, a matter of great importance. A fertilization with 25 pounds per acre each of phosphoric acid and potash and 10 of nitrogen may be regarded as a good one for soils of medium character.

Peanut

The peanut is a leguminous plant, and, like others of this family, is not specifically benefited by nitrogen, but responds readily to liberal dressings of phosphoric acid and potash. The fertilization suggested for green manure crops, namely, a mixture of three parts acid phosphate and one part muriate of potash, or equal parts of acid phosphate and kainit, may be used for this crop with great advantage. The applications, if frequently made, need not exceed 300 to 400 pounds per acre. Like other leguminous crops, it is specifically benefited by lime, medium dressings of which (20 bushels per acre) should be made at least once in four years. In the districts in which this crop is successfully grown, lime marls are frequently obtainable at slight expense, and may be used with great advantage.

Roses, and Other Flowering Plants

In the growing of roses and other herbaceous plants, of which the flowers constitute the crop, great care is usually taken in the preparation of the soil, and natural soils are seldom used. Notwithstanding the richness of the prepared soils, the crops are benefited by the addition of commercial fertilizers, particularly those phosphatic in their nature. Ground bone is especially useful, since it furnishes both nitrogen and phosphoric acid in slowly available forms, and usually sufficient nitrogen to meet the needs of the plant, as excessive quantities of this element cause a too vigorous and rank growth of foliage, which is not accompanied by profuse flowering. A good mixture for the prepared soils, therefore, may consist of four parts of ground bone and one part of muriate of potash, which may be applied at the rate of four pounds per square rod of area, and well worke into the soil previous to setting the plants. The after fertilization may contain a larger portion of the sol uble phosphoric acid, which is more readily distrib uted. The need for nitrogen is indicated by a yel low, rather than a bright green color in the foliage Nitrogen may be supplied by light dressings (½ to pound per square rod) of the active forms of thi element, preferably nitrate of soda, because of its read distribution. In the preparation of soils for thes plants in the house, the mixture may be applied at th rate of 2 pounds for every 100 square feet of surface the after application to consist of the more solubl forms as recommended for the hardy plants. An eve mixture of nitrate of soda and acid phosphate may b used at the rate of one pound for every 100 square fee of surface once in two weeks, if the plants do no show vigorous growth.

Lawn Grasses

The fertilization of lawns is also important in sense, because proper fertilizing obviates the necessit of the home manures, which, although excellent a sources of the constituents, are frequently offensive The use of manure also involves considerable labor both in the application and the consequent remova of the coarse part in the spring, besides resulting i the introduction of weed seeds. In the preparatio of the soil for a lawn, it must be supplied with a abundance of all of the necessary fertilizer ingredient previous to seeding, and of these phosphoric acid an nitrogen are especially important. Too great an excess of potash encourages the development of the clovers rather than the grasses. This preparatory fertilizer may contain the more slowly available forms of nitrogen and phosphoric acid. Ground bone is an excellent source of these elements, and a mixture of five parts of ground bone and one of muriate of potash makes an excellent dressing. This may be applied at the rate of five pounds per square rod, and thoroughly worked into the soil. The after-fertilization may consist chiefly of nitrogen, preferably as a nitrate, since its ready solubility permits of its free penetration into the lower layers, which encourages a deeper root system, and thus greater resistance to drought.

The top-dressings with nitrate of soda should consist of light fractional dressings, rather than of large amounts at one time. One-half pound per square rod, twice or thrice during the season — the first as soon as the grass is well started in the spring, and preferably immediately preceding a rain — will, if the land has been previously well prepared, be sufficient. To facilitate the distribution of the nitrate, as well as to supply a sufficient abundance of phosphoric acid, it may be mixed with equal parts of ground bone.

Forcing-house Crops

A rich garden loam, to which a considerable proportion of stable manure — one-third to one-half the bulk — has been added, is the usual type of soils for such crops as tomatoes, lettuce, radishes and cucumbers under glass. The addition of fertilizers to these is seldom advisable. It has been demonstrated, however, that such mixtures are not essential, and that the crops may be profitably and successfully grown in mediums which contain no plant-food,* if supplied with an abundance in available forms from artificial sources. In the absence of good manure, which is the chief expense, a reasonably fertile loamy soil may be used for filling the beds, in which at the time of filling may be mixed, for each 100 square feet of surface, one-half pound of nitrate of soda, one pound of acid phosphate, one pound of ground bone, and one-half pound of muriate of potash. This application will be sufficient to supply the needs of the plants for food until growth is well started, after which they should be fertilized at least once each week with one-quarter of a pound of nitrate of soda for every 100 square feet of surface area, and with the mineral fertilizers at the rate of one pound of acid phosphate and one-half pound of muriate of potash every two weeks. These may be applied in solution, or evenly distributed over the surface of the soil, and worked in before watering. The amounts to apply should always be governed by the judgment of the grower. There is less danger from the application of too much, if properly used, than is commonly supposed.

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*Connecticut State Experiment Station Reports for 1895, 1896 and 1897.

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