MANURES:

HOW TO MAKE AND HOW TO USE THEM.

SEMPERS.

HOME-MIXING. (*From photograph taken at Fordhook Farm.*)

MANURES:

HOW TO MAKE AND HOW TO USE THEM.

A NEW, PRACTICAL TREATISE ON THE CHEMISTRY
OF MANURES AND MANURE-MAKING.

WRITTEN SPECIALLY FOR THE USE OF FARMERS, HORTICULTURISTS
AND MARKET GARDENERS.

BY

FRANK W. SEMPERS,

DIRECTOR OF THE FORDHOOK CHEMICAL LABORATORY.

SECOND EDITION.

PUBLISHED BY

W. ATLEE BURPEE & CO.,

PHILADELPHIA, PA.

1893.

WM. F. FELL & CO.,
Electrotypers and Printers,
1220-24 Sansom Street, Philadelphia.

PREFACE.

The object of this little volume is to place in the hands of farmers the accumulated results of trustworthy research in the science of soil fertilization and manure-making. Much of the recent literature in this department of agricultural chemistry is found only in the technical writings of professional chemists, or is scattered through innumerable scientific and agricultural periodicals, many of which are not accessible to the farmers of America.

The work of collecting and reducing to a system this vast literature has involved an enormous amount of labor and has enforced upon the author not only a close study of late scientific investigation in America and England, but has also made necessary a careful review of the literatures of other lands in which agriculture rests upon a sure and advanced scientific foundation.

It will be observed that the book contains much about manure-making upon the farm and that considerable space has been given to formulas for the mixing of chemical manures by farmers themselves. Some terms of chemical technology which farmers should clearly understand are explained and simple methods are given for converting one chemical compound into an equivalent of some other chemical compound ; brief rules are also given for determining the commercial values of unmixed chemicals, raw materials, and commercial fertilizers ; and the closing chapter is given up wholly to the subject of soil-tests with fertilizers on the farm.

In these and several minor particulars the work differs from any other upon the subject hitherto published in America.

In the formulas for special crops great care has been taken to indicate those forms of raw materials and of agricultural chemicals which by practical field trials have been demonstrated to be the best. The numerous formulas found throughout the book are based upon no theoretical estimations, but are in all cases the results of carefully conducted experiments by investigators of the highest scientific attainment and repute.

Care has been taken to exclude all questions in controversy among chemists, and to advocate no particular system of culture or of farm management.

In writing this treatise every available source of information has been brought into service. The writings of American, English, French, and especially of German agriculturists have been freely consulted and used, but in all instances the author has conscientiously endeavored to trespass on the domain of none; on the other hand, he has aimed to give full acknowledgment to every authority from which materials have been drawn.

In the preparation of the work the Annual Reports of the United States Department of Agriculture and the reports of the various State experiment stations have been of inestimable value. Recent reports of every experiment station in the country have been carefully examined and much suggestive information has been drawn therefrom. And, in the acknowledgment of a great personal obligation to these institutions the author would take advantage of this opportunity to urge upon farmers everywhere the importance of familiarizing themselves with the work and literature of the State agricultural experiment stations. In emphasizing the manifest importance of mutual coöperation between the farmer and his State experiment station no more fitting reasons can be given than those recorded in the THIRD ANNUAL REPORT of the SECRETARY of AGRICULTURE. In this report the work and purpose of the State agricultural experiment station is thus defined:—

"(1) *It acts as a bureau of information regarding all questions of practical interest to the farmers of its locality;* (2) *it seeks by practical tests to devise better methods of agriculture and to introduce new crops and live stock, or to establish new agricultural industries;* (3) *it aids the farmer in his contest with insects and with diseases of his crops and live stock;* (4) *it defends the farmer against fraud in the sale of fertilizers, seeds, and feeding stuffs*; (5) *it investigates the operations of nature in the air, water, soil, plants, and animals, in order to find out the principles which can be applied to the betterment of the processes and products of agriculture.*"

The limitations of the present volume have made necessary the omission of many interesting details, but the author has labored faithfully and to the best of his ability to exclude no important researches that would add to the practical value or scientific accuracy of the work. His aim has been to place before the great body of intelligent American farmers, in simple language, the pregnant results of accumulated experience in agricultural science as recorded in our own and foreign literatures.

A list of the authorities used and quoted from in the preparation of this work is appended on a subsequent page.

F. W. S.

FORDHOOK FARM, *December*, 1892.

CONTENTS.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

PAGE

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

LIST OF WORKS USED AND QUOTED FROM.

Praktische Düngerlehre. By Dr. Emil Wolff.
Aschen-Analysen. By Dr. Emil Wolff.
Zur Kali-Phosphat, nach Schultz-Lupitz. By Dr. Paul Wagner.
Anleitung zu einer rationellen Düngung mit Phosphorsäure. By Dr. Paul Wagner.
Die Kali-Düngung auf leichten Boden. Schultz-Lupitz.
Untersuchungen über die Stickstoffnährung der Graminen und Leguminosen. By Prof. H. Hellriegel and Dr. H. Wilfarth.
Centralblatt der Agricultur-Chemie. By R. Biedermann.
Jour. de l'Agriculture. May and June, 1887.
Bull. Soc. Nation. d'Agriculture. 1887.
Bull. Soc. Horticulture de Soissons. 1888.
Etudes sur le Vin. By M. Louis Pasteur.
Ann. de Chemie et de Physique, Series 3, Vol. 58.
Comp. Rend. de l'Acad. des Sciences, Vols. 50, 75.
Comp. Rend. Sciences, Vol. 104, No. 19, Vol. 115, '92, No. 1.
How Plants Grow. By Prof. S. W. Johnson.
How Plants Feed. By Prof. S. W. Johnson.
Peat and its Uses. By Prof. S. W. Johnson.
Agriculture in some of its Relations with Chemistry. By Prof. F. H. Storer.
The Chemistry of the Farm. By Prof. R. Warington.
A Treatise on Manures. By Dr. A. B. Griffiths.
Farming with Green Manures. By Dr. C. Harlan.
Report on the Manurial Value of Basic Cinder. By Prof. J. Wrightson and Dr. J. M. H. Monro.
Fertilizers. By J. J. H. Gregory.
Annual Reports U. S. Department of Agriculture. 1889, '90, '91.
Annual Reports Maine State College Agricultural Experiment Station. 1889, '90, '91.
Annual Reports N. Y. State Board of Agriculture. 1889, '90, '91.

Reports N. Y. Agricultural Experiment Station. Ninth and Tenth Annual Reports.

Reports N. J. State Agricultural Experiment Station. Ninth, Tenth, and Eleventh Annual Reports.

Reports Connecticut State Agricultural Experiment Station. 1889, 1890, 1891.

Reports Mass. State Agricultural Experiment Station. Eighth and Ninth Annual Reports.

Reports R. I. Experiment Station. Second, Third, and Fourth Annual Reports.

Reports Cornell University Agricultural Experiment Station. 1890, '91, '92.

Jour. Chem. Soc. 1886, '87, '88.

Chem. News, Vols. 55, 56.

Files of the American Agriculturist.

Files of The Rural New Yorker.

Files of The American Cultivator.

Files of The New England Homestead.

Experiment Sta. Record, Vol. iv, 3 and 4.

"*In the plant lies the principle of life; in the environment are the conditions of life. Without the fulfilment of these conditions, which are wholly supplied by environment, there can be no life.*—HERBERT SPENCER.

MANURES.

How to Make and How to Use Them.

CHAPTER I.

THE CHEMICAL ELEMENTS.

The materials of which the earth, the air, and the waters of our globe are composed have been found by chemists to consist of about seventy distinct elementary bodies or primary forms of matter. These elementary or primary bodies are known as the **Chemical Elements**, and are so called because they cannot, by any known chemical process, be separated into two or more different kinds of matter. The common metal, iron, is an element; so is the invisible gas, nitrogen, of the atmosphere. Both of these very unlike substances are elements because when in their pure condition we can by no means known to chemistry find in them anything but iron and nitrogen.

To chemical analysis we are indebted for all that is known about the elementary composition of the earth and of its life, and of the vast stores of knowledge which we now possess the last one hundred years have contributed more than all the preceding ages of history. Less than eighty years ago not a single vegetable substance had been accurately analyzed, and the use of artificial fertilizers was practically unknown. The rapid growth of accurate knowledge of plant chemistry began about the year 1840, when the celebrated German chemist, Justus von Liebig, published the results of his researches in the relations of Chemistry to Agriculture.

A few elementary bodies form the structural basis of our planet and of its life, and out of these are built up all the multitudinous forms of matter with which we are familiar,—the rocky crust of the earth, the great continental seas, the invisible air, and, lastly, the complex animal and vegetable life of the globe.

It is believed that the number of different kinds of plants growing upon the earth somewhat exceed 200,000. Of this large number only a few have been subjected to careful chemical analysis, but in that number are included all our familiar farm-plants. And from what is known of the uniform methods of nature in plant building, it may be safely asserted that the structural composition of plants has been quite definitely determined.

Only fourteen, or about one-fifth, of the total number of elements appear to be essential to the perfect growth and development of plants. These elements are :—

CARBON,	HYDROGEN,	OXYGEN,	NITROGEN,
PHOSPHORUS,	SULPHUR,	CHLORINE,	SILICON,
CALCIUM,	IRON,	MAGNESIUM,	MANGANESE,
POTASSIUM,		SODIUM.	

The elements, *aluminium*, *fluorine*, *barium*, *bromine*, *iodine*, and a large number of the rarer elements, occur in miuute quantities in plants, but the presence of these elements is not regarded as of practical importance, nor are they known to be essential to the life of plants.

ORGANIC AND INORGANIC ELEMENTS.

For many years writers on agricultural chemistry have divided the plant-forming elements into two classes :—

First, *the Organic Elements*, or those which appear to be destructible by fire ; and,

Second, *Inorganic Elements*, or those which after combustion remain as a residue or ash.

But the barriers between organic and inorganic chemistry have, in recent years, been rapidly giving way, and it is now universally admitted among chemists that an element may be organic or inorganic, according as it is or is not a part of an organized body.

The plant-forming elements naturally group themselves into two distinct classes, which are marked by clearly defined and widely differing characteristics :—

The **first** are those elements which are derived exclusively from the **air**, and the **second** are those furnished exclusively by the **soil**. Thus we have two distinctive classes of elementary substances entering into the composition of plants, both of which are equally essential to their life and growth. In this little work we shall classify the elements according to the sources from which they are derived by plants. We have, therefore—

First,—Elements derived from the Air.

Second,—Elements derived from the Soil.

The elements derived from the air are **Carbon, Hydrogen, Oxygen,** and **Nitrogen.** These elements, long known in agricultural chemistry as the organic elements, are derived exclusively from the air, either directly or indirectly; they constitute the greater part of plants, forming from ninety-five to ninety-nine per cent. of their entire weight. In the processes of combustion or burning, the air-derived elements mostly pass off into the atmosphere in the form of gases. It must not, however, be supposed that the elements furnished by the air are always derived by plants directly from the atmosphere. Plants do obtain large quantities of food directly from the air, but the air-derived elements are always present in soils, and, in combination with other elements form chemical compounds which are gathered as food by the roots of plants.

The elements furnished to plants exclusively by the soil are also known as the *inorganic elements.* They are **phosphorus, sulphur, chlorine, silicon, calcium, iron, potassium, sodium, magnesium,** and **manganese.**

The soil-derived elements all occur in small proportions in plants, varying in quantity from a fractional part of one per cent. to ten or twelve per cent. Though present in such small proportions, the soil-derived elements are just as important as the more abundant air-derived elements; both are essential and equally important in the elaboration of plant tissue.

When plants are burned, the soil-derived elements remain as a residue, or ash. Slight traces of chlorine, phosphorus, and sulphur may be driven off as gases in the combustion, and in the ash there always remain minute quantities of carbon, oxygen, and nitrogen; but the quantities, in either case, are very small.

We have, thus far, seen that out of a few primary or elementary bodies the whole vegetable kingdom of nature has been elaborated; that over ninety per cent. of all the parts of plants are built up from the four air-derived elements, carbon, oxygen, hydrogen, and nitrogen, and that the total number of elements actually necessary to the vegetation of the globe is about fourteen, or one-fifth of all the elementary substances known to chemists.

We find that the atmosphere and the air-derived elements are most important agencies in vegetable physiology, but, as we proceed with the study of plant life and plant nutrition, we must not assign to these elements an undue importance, nor presume them to be more important factors in vegetable nutrition than the less abundantly occurring soil-derived elements. We soon discover that the life-functions of plants are twofold; that the atmosphere, after all, is a kind of aëriform soil, from which the leaves of plants absorb nutrition just as truly as the roots gather in food from the soil; that both are essential to life and healthy growth, and that one is not less important than the other.

With the single exception of nitrogen, which is the most elusive and costly element of plant-food, it is with the soil-derived elements, phosphorus and potassium, and with the soil itself, that man has mostly to deal. These and other elements are taken from the land in crops and are not returned by nature, and, unless restored to the soil by man, the time comes when the land is exhausted and cannot furnish the necessary food to crops. We must not lose sight of the fact that the deepest and richest soil is but as a mere film of dust on the rocky crust of the earth; yet from the soil all the animal and vegetable life of the globe must be fed. And, hence, the most important problems in agriculture to-day are economy in soil management and the maintenance of soil fertility. In virgin soils there is usually an abundant supply of plant-food, for the elements taken from the soil are returned to it when plants decay. As soon as land is brought under cultivation, however, animal and vegetable products are taken from the soil in the form of farm animals, grain, hay, fruits, vegetables, etc. Under this drainage the land, in time, becomes infertile and refuses to yield its increase. On very poor soils it is sometimes necessary to make a complete return of the elements of plant food taken in crops, but, fortunately, in most soils there is an abundant supply of some of the elements and, consequently, only a partial return is necessary.

It will be found generally that a poor or worn soil will be deficient in one, two, or all three of the elements, nitrogen, phosphorus, and potassium; and sometimes the soil will contain these elements in forms that cannot be taken up by plants. In most all soils, rich or poor, the elements, sulphur, magnesium, sodium, iron, etc., are found in abundance. Calcium or lime is sometimes deficient, but in most cultivated soils lime is rarely deficient as a plant food.

The Plant-forming Elements are generally Combined with Oxygen in the Soil.

The food elements which plants take from the soil are usually combined with oxygen, and, therefore, instead of using the names of the elements we use the names of their oxides. We say phosphoric acid instead of phosphorus because plants take up this element in the form of an oxide of phosphorus; or, we use the term potash instead of potassium because the element potassium is never used by plants in the elementary form, but is combined in the soil with oxygen or with an acid.

And for like reasons we say lime instead of calcium, soda instead of sodium, and magnesia instead of magnesium.

CHAPTER II.

METALS AND METALLOIDS.

ACIDS, SALTS, AND BASES, OR METALLIC OXIDES.

The chemical elements are divided into two classes, known as **metals** and **metalloids**,* or **non-metals**. Of those essential to plant nutrition, seven are metals and seven are metalloids. They are :—

Metals.	*Metalloids.*
Hydrogen.	Carbon.
Calcium.	Oxygen.
Potassium.	Nitrogen.
Sodium.	Phosphorus.
Iron.	Sulphur.
Magnesia.	Chlorine.
Manganese.	Silicon.

Until recently, it has been the custom to include hydrogen among the metalloids, but this element is now known to be a metal, several of its alloys with other metals having been obtained by chemists. Long before actual proof had been obtained, chemists were of the opinion that hydrogen was the gaseous form of a metal.

The seven metalloids and the metallic element, hydrogen, are the acid-forming elements.

Acids. *An acid is a chemical compound formed by the union of an acid-forming element with hydrogen and oxygen, or, in some instances, with oxygen alone.*

Thus, the three elements, nitrogen, hydrogen, and oxygen, unite to form nitric acid. Chlorine and hydrogen combine to form hydrochloric acid (muriatic acid, or the old spirit of salt).

In ordinary usage, an acid is believed to be any substance having a sour taste. It is true that all sour bodies are acids, but all acids are

---

* The term, metalloid, is from the Greek, *metallon*, a metal, and *eidos*, likeness, that is, likeness to metals, but the name is inappropriate, for these elements have no likeness to the metals.

not sour. Some are sweet to the taste, some are bitter, and others have no appreciable effect on the nerves of taste at all.

Nitric, phosphoric, sulphuric, and hydrochloric acid are all very sour and corrosive bodies.

Salts.

A salt is a chemical compound formed by putting a metal in the place occupied by the hydrogen of an acid. Thus, we take the nitric acid formed by the union of nitrogen, hydrogen, and oxygen, we put the metal, sodium, in the place of the hydrogen, and we have the salt, nitrate of sodium. An impure form of this salt, known as nitrate of soda, or Chili saltpetre, is familiar to every farmer.

Again, we may take phosphoric acid, which is composed of phosphorus, hydrogen, and oxygen, we replace the hydrogen by the metal, calcium, and we have the calcium salt, phosphate of calcium, or what is more commonly known as phosphate of lime. Or if we take sulphnric acid, which is a compound of sulphur, hydrogen, and oxygen, and replace the hydrogen by the same metal, calcium, we have sulphate of calcium, or sulphate of lime, gypsum, or land plaster. If we replace the hydrogen with potassium we have the sulphate of potassium, or if we replace the hydrogen of hydrochloric acid by the metal, sodium, we have a compound of chlorine and sodium, called chloride of sodinm, muriate of soda, or common salt.

And so it is with all salts known to chemistry, they are all substances in which some metal has taken the place of hydrogen in an acid.

Bases.

Bases may be regarded as just the opposite of acids, or, a base is simply another name for metallic oxide. When soluble the strongest bases have a bitter, biting taste, and a caustic or corrodiug effect on the skin. Lime, soda, potash, and ammonia are soluble bases. Magnesia, silica, and oxide of iron are insoluble bases.

PLANT-FOOD AND FERTILIZERS.

Plant-food is a general term under which all substances that increase crop-production may be included.

Fertilizers.

The term **fertilizer**, as used among farmers, is generally applied to the artificial commercial fertilizers, while the word **manure** is indiscriminately given to such natural fertilizers as farm-yard manure, composts, marls, muck, and night soil.

The original meaning of the word **manure** was **manœuvre**, in allusion to tillage, or the working of the land, and, hence, probably came the old farm proverb, "He who tills his land, manures it."

Plant-food is, therefore, **anything that contributes to the growth of plants**, and it is obvious that all plant-food must be derived from one or both classes of elementary bodies or their compounds, since it is from the air and the soil that plants obtain all their food.

The wood burned in our fires furnishes both classes of elements to nature for use in the elaboration of vegetation. In combustion, which is the union of the carbon of the wood with the oxygen of the air, the air-derived elements pass off into the atmosphere in forms of carbon dioxide (carbonic acid), watery vapor, nitric acid, ammonia, etc., and are at once ready to be re-appropriated by plants and used in building up vegetable forms.

The soil-derived elements, or rather their compounds, potash, lime, phosphoric acid, magnesia, etc., remain in the ash, and if applied to the land are taken up by plants and become parts of a new vegetation.

Plant-food when added to a soil increases its fertility, and consequently becomes a **fertilizer**. But, because plant-foods are fertilizers, it does not follow that fertilizers are always plant-foods.

The soil is a great field of chemical activity, in which nature is constantly at work tearing apart and building up innumerable chemical compounds that may or may not promote plant growth ; and in this marvelous soil-chemistry plants play a most important part themselves. In the intelligent practice of husbandry man not only feeds the growing crops by applications of plant-food to the land, but he mixes with the soil a variety of substances which may not be plant-foods at all, but which, both by their mechanical and chemical action upon soils, induce a higher degree of fertility, and thus act indirectly as fertilizers.

A fertilizer is, then, any substance added to a soil for the purpose of inducing a larger and better growth of plants. And plant growth may be defined as the transformation of inorganic matter into organic bodies.

Fertilizers are divided into—

First, Direct Fertilizers, and,

Second, Indirect Fertilizers.

Direct Fertilizer.

A **direct fertilizer** is a plant-food in which there are elements of plant nutrition at once available for the use of crops.

To be available plant-food must be **soluble**, that is, in such condition that the roots of plants can take it readily in solution.

A large proportion of the plant-food present in soils is not in available or soluble form, that is, it is food held in reserve in such condition that the roots of plants cannot make use of it; such **locked-up** food is said to be **unavailable** or **insoluble.**

By the action of air, water, carbon di-oxide (carbonic acid), **lime,** gypsum, etc., unavailable plant-food is gradually converted to the available or soluble form; it then becomes a **direct fertilizer,** immediately ready for the use of plants.

Indirect Fertilizer.

An indirect fertilizer is not necessarily a plant-food at all, nor does it furnish any needed plant-food to the soil. It acts upon compounds already present in the soil in the forms of unavailable plant-food, uniting with them or changing them from unavailable to available forms. **Lime** is an example of an **indirect fertilizer.** It is present in almost every cultivated soil in sufficient quantities for all the wants of vegetation; so that the addition of lime to a soil, except in rare instances, cannot be regarded as a needed application of plant-food. Yet lime often has an almost magical influence on crop production, and on no soils are its effects more noticeable than upon those in which its compounds exceed all the requirements of vegetation. Lime not only acts chemically upon the organic and mineral constituents of soils, but it also exerts a very powerful influence upon their mechanical or physical condition.

Direct fertilizers may be divided into two classes, viz.:—

1st. *Natural fertilizers*, or those furnished by the solid and liquid excrement of animals, refuse vegetable matter, green crops when intended for plowing under, castor pomace, cotton seed, muck, peat, marl, etc.

2d. *Artificial or chemical fertilizers*, which are the commercial preparations made from different fertilizing materials found as natural deposits in the earth, and from the waste-products of many manufacturing industries.

Artificial fertilizers are also subdivided into (*a*) *complete fertilizers*, or those which contain nitrogen, phosphoric acid, and potash, and (*b*) *incomplete or special fertilizers*, which contain one or two of the three constituents, nitrogen, phosphoric acid, and potash.

CHAPTER III.

ELEMENTARY PARTS OF PLANTS DERIVED FROM THE AIR.

CARBON AND CARBON COMPOUNDS.

Carbon.—The word is from *carbo*, coal, which is chiefly composed of carbon. In the free condition carbon is a solid substance without odor or taste. It occurs in several modified forms which exhibit great differences in physical properties, and which, under ordinary circumstances, are extremely indestructible.

Carbon.

Anthracite and bitnminous coal, coke, lignite, wood charcoal, lamp-black, bone-black or animal charcoal, and graphite or plumbago, principally consist of carbon. The diamond is pure carbon. Some forms of carbon, notably wood-charcoal and bone-black, have the remarkable property of absorbing gases and coloring matter, and for these purposes are used in refining sugars and in purifying chemicals. Charcoal is much used for destroying noxious odors and for purposes of disinfection.

Carbon may be regarded as the great central element characteristic of all vital organism. Wherever the **life force** is tangible, whether in the simplest microscopic cell or in the full-grown plant or animal, the element, carbon, is always found as an essential and constant constituent.

The source of the carbon of vegetation is the carbon dioxide (commonly called carbonic acid) gas present in the atmosphere.

Carbon Dioxide.

When carbon is burned in the air or in oxygen gas, carbonic acid is formed, and an enormous amount of heat is disengaged. This is witnessed in the combustion of coal or wood in our household fires, and also, to a less extent, in the fermentation of manure, which is but a slow combustion or oxidation of the carbonaceous materials contained in the manure.

At ordinary temperatures carbonic acid dissolves in about its own volume of water, forming solution of carbonic acid, which has a sharp, slightly acid, and pleasant taste. The volume of carbonic acid dissolved in water diminishes as the temperature rises, and at the boiling point (212° F.) is entirely expelled. The so-called soda water is, in most cases, merely water holding in solution several volumes of carbonic acid forced into solution by mechanical pressure.

Decomposition of Carbonic Acid in the Green Leaves of Plants.—The green leaves of plants decompose carbonic acid in sunlight—the oxygen of the carbouic acid is set free while the carbon is retained in the plant. It is in this way that carbon is being uninterruptedly taken from the atmosphere and used in the elaboration of vegetable forms. Little is known as to the precise manner in which this decomposition is effected ; it is known to be in some way intimately connected with chlorophyl, which is the cause of the green color of the leaves ; and also that light is necessary to the decomposition. Indeed, the agency of light is most important, and the fixation of carbon by plants from the carbonic acid of the air has been found by the experiments of several chemists to be most rapid in the yellow rays of the solar spectrum, and to diminish in passing from the yellow part of the spectrum toward either of its ends.

The electric light very sensibly affects the growth of some forms of vegetation. A few plants are greatly assisted in their growth while others are injured by its use, but in just what manner the electric light promotes the fixation of carbon and assists in the general life functions of plants is not known.*

"It was found," says Prof. L. H. Bailey in a most interesting report upon experiments in electro-horticulture, conducted by the Cornell University Experiment Station, "that the electric light profoundly affects many plants, some injuriously and a few beneficially. Lettuce appeared to be greatly assisted by the light, and some ornamental plants produced earlier and brighter flowers under its influence. The experiments were all made with an arc lamp which hung inside the house, and it was found that better results were obtained when the arc was screened by an opal-globe or even by a pane of window glass. . . . . . It is thought that plants grow mostly at night, using up the materials which they have manufactured during the hours of sunlight. The question then arises when the lighted plants grew. Did they grow more rapidly than the others during their fewer hours of darkness, or did they grow when the electric light was burning?"

In these experiments care was taken to measure and record the periodical growth of the plants, and it was shown that lettuce, "under normal con-

In the entire absence of light, plants cease to exhale oxygen, and give off carbonic aoid. Plants are not only unable to decompose carbonic acid in the dark, but this gas is then generated in them and given off into the air. Carbonic acid is also given off in considerable quantities from the roots of plants.

In spite of the enormous consumption of carbonic acid by vegetation, there is always a never-failing supply in the atmosphere. It is constantly being poured forth by the combustion of our fires, by the respiration of animals, and by the slow combustion or decay of organic matters. This gas is also exhaled by volcanoes, by the waters of mineral springs, and from fissures in the crust of the earth. It is likewise abundant in the pores of soils—in fact, the carbonic acid of the air is largely derived from the oxidation of organic matters in the soil.

And yet the proportion of carbonic acid in the air is only about 1 part by volume in every 3300 parts of air, or about twenty-eight tons is floating in the air over each acre of the earth's surface. Chevandier has calculated that an acre of thrifty beech trees may assimilate in a year from nineteen hundred to two thousand pounds of carbon or three and one-half tons of carbonic acid, which is about the amount of carbonic acid produced by the burning of one ton of anthracite coal. "Yet so large," says Prof. Storer, "is the amount of carbonic acid in the air, that if the whole earth was covered with a forest of the kind specified, it would take eight years for the forest to consume an amount of carbonic acid equal to that now actually contained in the air."

We have good reason to believe there was a time in the history of our planet when there was a much larger proportion of carbonic acid in the air. In the earlier geological periods, when the earth had cooled from its molten condition, the atmosphere probably contained carbonic

---

ditions, grows about as much in daylight as in darkness; and the periodicity of growth was very irregular."

In the case of lettuce the leaves matured more quickly under the influence of the light. The electric light is now used commercially in forcing lettuce.

Says Prof. Barley in the same report of Mr. W. W. Rawson, the well-known horticulturist of Arlington, Mass., who now uses the electric light in the commercial forcing of lettuce: "Mr. Rawson calculates that he receives a gain of five days in a crop of lettuce by the use of these lamps, and as he grows three crops during the winter the total gain is over two weeks of time. The gain from one crop is estimated to pay the cost of running the lights all winter. The effect of the light is said to be marked at the distance of 100 feet." (*See Bulletins* 30 *and* 42 *Cornell University Agr. Exp. Station.*)

acid greatly in excess of that of historic times, and the vegetation of those remote ages was, probably, capable of decomposing carbonic acid with greater rapidity than the plants that have succeeded them.

Much of this prehistoric carbon is stored away in the earth in the forms of coal, lignite, and peat; and even the carbon of limestones and of other rocks probably existed once as the carbonic acid of the atmosphere.

Carbonic Acid a Manure.

Notwithstanding the fact that carbonic acid is a fertilizer of paramount importance, we have no reason to believe that the use of manure, yielding by its decomposition carbonic acid or other carbon compounds to the soil, is of much practical value as a direct fertilizer to most crops. If the necessary amounts of nitrogen and mineral constituents are present in the soil in available forms, most plants are practically independent of the carbon supplied in manure, and will assimilate from the atmosphere all the carbon needed for their perfect growth. Root crops, however, appear to profit greatly by a supply of carbon from decaying organic matter, but it is highly probable that the carbonaceous materials of such manure may favor the growth of micro-organisms which add to the soil fertility, or the presence of the carbonaceous manure may act as a mulch, increasing the supply of water, or, finally, the conjoint action of both may account for the increased production in the case of root crops.

Carbonic Acid of the Soil.

"The air of soils," says Prof. Johnson ("How Crops Feed"), "is usually richer in carbonic acid and poorer in oxygen than the normal atmosphere, while the proportion (by volume) of nitrogen is the same or nearly so." The investigations of Boussingault and others show that in cultivated soils taken to a depth of fourteen inches there was as much carbonic acid gas as existed in the same horizontal area of the atmosphere through a height of 7 to 110 feet.

While the carbonic acid present in soils may be of little or no direct use as a source of carbon to plants, this acid gas is believed to be of great importance in dissolving and disintegrating the components of most soils.

Carbonic acid is dissolved in water to a greater or less degree according to temperature and pressure; in rain-water it never amounts to one per cent., but varies between 5 and 90 parts, by volume, in 10,000; in soil-water the amount of carbonic acid held in solution is determined in great measure by the presence of other gases in the soil.

At 60° F. water is capable of dissolving its own bulk of carbonic acid, but in soil-water, at this temperature, only about two per cent. of carbonic acid is usually found. This might seem strange were it not known that the relative proportions in which the several aëriform ingredients of gaseous mixtures are absorbed by water depend not only on the relative solubility of each gas by itself, but also on the proportions in which each exists in the gaseous mixture. Associated with the carbonic acid in the pores of soils are large quantities of nitrogen and oxygen, which help to prevent the carbonic acid from being taken up in greater quantity by the soil-water. The carbonic acid is fifty times more soluble than atmospheric air—a mere mixture of oxygen and nitrogen—but the latter gases may be present in fifty times the quantity of the carbonic acid. But the long-continued action of carbonic acid in the capillary water of soils, extending, as it does, over large surfaces, accomplishes most astonishing results. In the soil-water carbonic acid exists chiefly in chemical combination as bicarbonates of ammonia, lime, magnesia, etc., and these extremely weak solutions greatly exceed either pure or carbonated waters in their solvent and disintegrating action upon rocks and soils. Within certain limits saline solutions acquire increased solvent power by increase in number and amount of dissolved matters which they contain. Soda, potash, lime, and magnesia are dissolved from their silicates. Some carbonates, notably those of lime and magnesia, are also dissolved, and from insoluble calcium phosphate lime is slowly removed and soluble acid phosphate of lime formed.

Solvent Action of Carbonic Acid.

In chemical combination with lime, carbonic acid is an important agent in producing **flocculation** or coagulation of the finest particles of soils, that is, in loosening the texture or rendering friable the cohesive particles of clays and fine loams. The lime of such soils is slowly dissolved and bicarbonate of lime formed, which renders the soil more friable and prevents the puddling of clay.

CHAPTER IV.

ELEMENTARY PARTS OF PLANTS DERIVED FROM THE AIR.

OXYGEN, HYDROGEN, AND NITROGEN.

Oxygen.—This element is a colorless gas without taste or odor, and is the most abundant substance in all nature. The name is from *oxus*, acid, and "*genesis*," generation, and means generator of acids. When first discovered oxygen was believed to enter into the composition of all acids. In combination with other elements oxygen forms eight-ninths, by weight, of the waters, and nearly one-half of the solid crust of the globe. It also forms about one-third of all animal and vegetable substances. About one-fifth of the bulk of the atmosphere is oxygen gas diluted chiefly with nitrogen. This element is essential to all organic life. Even the fishes of the sea breathe oxygen, and cannot live without it; sea water contains about three per cent. of dissolved oxygen.

Oxygen.

The warmth of the body in animals is due to the continuous burning of their tissues by the oxygen of the air taken into the lungs in breathing. The product of this combustion in the bodies of animals is carbon-dioxide (carbonic acid) gas, the poisonous compound of carbon with oxygen, which we have already considered in Chapter III. Oxygen is the great supporter of combustion. In a pure atmosphere of this gas wood or coal burns with intense heat and with great brilliancy and rapidity. Iron is incombustible in the air, but if a piece of iron wire be heated to redness, and then plunged into a jar of oxygen gas, the wire bursts into brilliant, scintillating flame, and burns more readily than a match does in air. Oxygen was discovered by Dr. Joseph Priestley in 1774.

Hydrogen is an invisible, odorless, and tasteless gas. It does not support combustion but burns with a pale yellow flame, combining with oxygen to form water.

Hydrogen was discovered in 1766 by Cavendish, who, from its combustibility, called it inflammable air. The name is from the Greek "*hudor*," water, and "*genesis*," generation, that is, generator of water. The element is obtained from water, which is its commonest compound, and also by the action of acids upon metals.

Hydrogen.

Substances employed for the production of artificial light, like oil, tallow, and illuminating gas, contain hydrogen as a prominent and important constituent. It is the lightest substance known, atmospheric air being about fourteen and a half times heavier than hydrogen.

Alloys of hydrogen with several metals have been obtained, thus confirming an opinion long held by chemists that this element is a gaseous metal.

Hydrogen combines with oxygen to form water, of which it forms one-ninth by weight. It is present in all animal and vegetable substances and forms an essential constituent of acids. Hydrogen does not occur in the free state in nature, except in the gaseous emanations of volcanoes and boiling springs.

Nitrogen, like hydrogen, is an inodorless, invisible, and tasteless gas. It constitutes about four-fifths of the bulk of the earth's atmosphere. Nitrogen was discovered by Rutherford in 1772, but its properties were more particularly investigated about 1775 by the great French chemist Lavoisier, who lost his life during the French Revolution.

Nitrogen.

Lavoisier estimated the quantity of nitrogen in the atmosphere and gave to the newly discovered element the name of *azote*, because it did not support life. The present name, nitrogen, from "*nitron*," nitre, and "*genesis*," generation, was given to the element by Chaptal.

In its free condition nitrogen manifests no positive or active properties. Its most striking characteristic in the uncombined state is its chemical indifference to most other elements or their compounds. Nitrogen does not support combustion nor maintain respiration; animals and plants cannot live if confined in an atmosphere of this gas. The nitrogen and oxygen of the air are not in a state of chemical union, but form a mere mechanical mixture in which the office of nitrogen appears to be to dilute the energetic and ever active oxygen.

Nitrogen is an essential and constant constituent of all animals and plants. The atmosphere is the great natural reservoir of this element, yet there are but few plants that can appropriate atmospheric nitrogen. It is also present in soils, but much of the soil nitrogen exists in an inert and comparatively useless state. The humus of soils always contains nitrogen; peat contains from one-half to two or three per cent.

When the chemist speaks of nitrogen in manures he does not mean that the element exists in the simplo form of nitrogen gas. In manures and soils nitrogen is combined with other elements or their compounds, and may be present in the form of nitrates, in compounds of ammonia, or in combinations with organic matter. In artificial fertilizers nitrogen may exist as nitrate of soda, sulphate of ammonium, dried blood, or flesh, guano, hair, horn, cotton-seed meal, tobacco stems, etc.

Plants appropriate nitrogen in three different forms, viz.:—

1. *As the free nitrogen gas of the atmosphere.*

2. *In the form of ammonia.*

3. *In the form of nitrates.*

The nitrogen of the atmosphere exists practically in inexhaustible quantity, but there are only a few leguminous plants, such as beans, peas, clover, etc., that can use the uncombined nitrogen of the air.

Some plants obtain nitrogen through the power which their leaves have of absorbing ammonia directly from the air, and others through their roots take up nitrogen from the ammonium compounds existing in the soil. **Ammonia** is a colorless gas formed by the chemical union of nitrogen with hydrogen. *Spirits of hartshorn* is ammonia gas dissolved in water.

The chief source of the nitrogen obtained by vegetation is the soil, from which it is taken up by the roots of plants in the form of **nitrates.**

A **nitrate** is a salt formed by the chemical union of nitric acid with a metal, such as potassium or sodium. Nitrates are mostly formed by what is known as nitrification, a process by which ammonium compounds and organic substances in the soil are converted into nitrates. Nitrates are the most available form in which many plants take up nitrogen. Nitrogen deepens the color of the foliage of plants and greatly promotes the growth of stem and leaves, but it retards the growth of buds and flowers, and if used in available form at that period of growth when plants cease to produce stems and leaves, and begin to produce flowers, the growth will be transferred back to the leaves and stems, and should flowers be produced they will be sterile and without seed.

Ammonia compounds and nitrates dissolve readily in water, and hence we might suppose there would be danger of these valuable constituents washing away in drainage water or of their sinking to a depth in the soil beyond the reach of plants. Ammonia compounds, however, are largely retained in the soil, but the nitrates are liable to be carried away and lost if the land is allowed to lie in bare fallow. When the soil is covered with vegetation there is little loss, for the roots of growing plants absorb or gather up the nitrates. A small quantity of nitrogen is also lost to the soil by the decay of organic matter, the nitrogen escaping in the free state into the atmosphere.

These losses of nitrogen are partly counterbalanced by the nitric acid and ammonia dissolved in dew and rain, by the decay of organic matter on the surface of the soil, and by the conversion of the air-nitrogen into forms that can be appropriated by plants.

But the natural additions of nitrogen are not sufficient to make good the loss in waste and crop consumption from cultivated lands, and unless nitrogen be replaced in the form of nitrogenous manures, a time comes when the soil ceases to yield paying crops. Following are some of the forms of nitrogen used in making artificial fertilizers or manures :—

Nitrate of soda, sulphate of ammonia, guano, dried blood, tankage, meat scrap, fish scrap, azotin or ammonite, dried fish, horn dust, wool-waste, cotton-seed meal, castor pomace, etc.

Chemical Terms relating to the Nitrogen and Ammonia of Fertilizers.—In agricultural reports and in the analytical tables of experiment station bulletins farmers often see the terms "**Determined as Nitrogen**" and "**Nitrogen equivalent to Ammonia.**"

It is important to clearly understand the meaning of these terms

Nitrogen is never present in a fertilizer in the form of nitrogen gas. It is always present in combination with some other element or elements ; but the chemist in his analysis simply determines, without regard to the form, how much this combined nitrogen would amount to if it were present in the form of pure nitrogen gas. It may be in the form of ammonia as sulphate of ammonia, in the form of nitrate as nitrate of soda, or as organic nitrogen in such forms as dried blood, meat or fish scrap, or cotton-seed meal. The official chemical analysis does not attempt to determine or to state in which form or forms the nitrogen is present; so that by *determined as nitrogen* is simply meant to state *the amount of nitrogen present without regard to the form in which it is present.*

"Nitrogen equivalent to Ammonia."—We have already defined ammonia as a compound formed by the chemical union of nitrogen with hydrogen. By the laws of chemical union—

14 lbs. of nitrogen unite with
3 " " hydrogen, to make
17 " " ammonia,

or one pound of nitrogen will make 1.214 lb. of ammonia.

By the term, **equivalent to ammonia**, the chemist simply means *how much ammonia would be present in a fertilizer if its nitrogen was all in the form of ammonia.*

The published guarantee of the manufacturer most generally states the amount of nitrogen only in the form of ammonia : to determine how much nitrogen the ammonia contains we have simply to multiply the percentage of ammonia by .8235, for one pound of ammonia contains .8235 pound of nitrogen.

Simple Rules for the Use of Farmers in Estimating the Nitrogen and Ammonia of Fertilizers.—**1st. To convert nitrogen into an equivalent amount of ammonia, multiply the amount of nitrogen by 1.214.**

2d. To convert ammonia into an equivalent amount of nitrogen, multiply the amount of ammonia by .8235.

Examples: A high grade **complete fertilizer** contains 4.30 per cent. of nitrogen, that is, in each one hundred pounds there are 4.30 pounds of nitrogen. We wish to know how much ammonia this nitrogen would be equivalent to if it were in the form of ammonia—

$$4.30 \times 1.214 = 5.22, \text{ the equivalent to ammonia.}$$

Suppose this fertilizer to have been the complete chemical manure of some manufacturer, it is more than probable that the nitrogen would have then appeared in the printed analysis as ammonia; then, to determine the actual equivalent of nitrogen, we would have had—

$$5.22 \times .8235 = 4.30 \text{ nitrogen.}$$

Less simple rules are :—

1st. To convert any given percentage of nitrogen to its equivalent of ammonia, divide the given percentage of nitrogen by 14 and multiply the quotient by 17. Thus :—

$$4.30 \div 14 = .3071 \times 17 = 5.22.$$

2d. To convert any given percentage of ammonia to its equivalent of nitrogen, divide the given percentage of ammonia by 17 and multiply the quotient by 14. Thus :—

$$5.22 \div 17 = .3070 \times 14 = 4.30.$$

In purchasing nitrogenous manures farmers should not lose sight of the fact that a pound of ammonia is not a pound of nitrogen, but that it contains .8235 pound of nitrogen.

Each pound of ammonia contains a little less than two-tenths of a pound of hydrogen, which is of no value to the farmer except in so far as its combination with nitrogen forms a compound more readily assimilated by some plants. In the guaranteed analyses of the manufacturer the amount of nitrogen is commonly given in the equivalent to ammonia. The fertilizer may then appear to the farmer to contain more nitrogen, but farmers should remember that nitrogen and ammonia are different things; that a pound of ammonia contains but about eight-tenths of a pound of nitrogen.

Total Nitrogen.—By this term is meant *all* the nitrogen present in a fertilizer, without regard to the form in which it exists.

CHAPTER V.

ELEMENTARY PARTS OF PLANTS DERIVED FROM THE SOIL AND THEIR COMPOUNDS.

PHOSPHORUS, POTASSIUM, AND SULPHUR.

Phosphorus means *light-bringer* or *light-bearer*.

Phosphorus.

This element was discovered by the alchemist, Brandt, of Hamburg, in searching for an "essence for ennobling silver into gold." By the dry distillation of urine solids, Brandt obtained a wax-like, phosphorescent solid that readily ignited and burned with a brilliant light, evolving suffocating fumes and yielding a snow-like solid. The discovery of Brandt excited universal interest, but the new element was destined to remain a chemical curiosity until nearly a century later, when Scheele (1771) proved that bone-ash was the lime salt of an acid identical with the one formed in the combustion of phosphorus. With slight modification, the method of Scheele for the manufacture of phosphorus is used to this day.

In the manufacture of phosphorus either the mineral phosphate of lime, such as the well-known South Carolina rock or the bones of animals, may be employed. Mineral phosphates are, however, rarely used ; it is from the bones of animals that commercial supplies of phosphorus are obtained. Phosphorus is always present in the bones and tissues of animals and in the tissues of plants as phosphates of calcium, potassium, sodium, and magnesium. The bones of animals contain about ten per cent. of this element, mainly in combination with calcium, forming normal phosphate of lime. Phosphorus compounds are also found in the brain, muscles, nerves, blood, saliva, and tissues.

Two kinds of phosphorus are known to chemists. One is of a light yellow or translucent, wax-like consistency, which is intensely poisonous, very inflammable, and luminous in the dark. The other form, red or amorphous phosphorus, is a dark red, infusible, opaque solid, somewhat altered in its chemical properties by heat or by the long-continued action of sunlight on phosphorus kept under water. The commercial article so largely used in the manufacture of friction matches is made by heating phosphorus in iron pots, which communicate with the outer air by means of iron tubes, through which the atmosphere is admitted and rapidly deoxygenated.

When phosphorus is burned in oxygen gas or in air free from moisture a dense, suffocating white vapor is produced. This is phosphorus anhydride (phosphorus pentoxide). It is without sensible acid properties, readily dissolves in water with some of which it combiues, evolving much heat aud yielding phosphoric acid.

Anhydrous Phosphoric Acid.

By the chemical union of phosphoric acid with certain metallic bases of calcium, potassium, magnesium, sodium, etc., phosphates are formed. But the term phosphoric acid, as used by chemists in agricultural reports, does not apply to phosphoric acid at all.

What is really meant is the combination of phosphorus and oxygen known in chemistry as *phosphorus anhydride*, or *phosphorus pentoxide.* By the term phosphoric acid is meant the amount of phosphorus pentoxide equivalent to phosphoric acid in the form of phosphate of lime existing in a fertilizer.

Three distinct phosphates of calcium (lime) known to chemists figure iu the State Experiment Reports. These are called—

1. *Soluble Calcium Phosphate.*
2. *Insoluble Calcium Phosphate.*
3. *Reverted or Precipitated Calcium Phosphate.*

These three phosphates of calcium are all combinations of phosphoric acid, but they differ from each other in regard to the proportions of calcium, phosphorus, oxygen, and hydrogen which they contain.

Soluble calcium phosphate or superphosphate of lime is made by treating insoluble calcium phosphate with sulphuric acid. The result of this treatment is that a part of the calcium leaves the phosphate to unite with the sulphuric acid forming calcium sulphate (sulphate of lime or gypsum). The resulting mixture of calcium phosphate and calcium sulphate is known as *superphosphate of lime.*

Soluble Calcium Phosphate.

Soluble or superphosphate of lime is so called because it readily dissolves iu pure water, and hence is immediately available as food for plants. Of the three phosphates of calcium the soluble phosphate contains the least calcium and the most phosphorus, oxygen and hydrogen.

Insoluble Calcium Phosphate is known also as normal phosphate of lime, insoluble phosphate of lime, etc. This form of calcium phosphate, as its name implies, does not dissolve in water, and consequently cannot, without undergoing chemical change, be appropriated by the roots of plants.

Insoluble Calcium Phosphate.

Insoluble calcium phosphate is found everywhere in the soil. The mineral phosphates, South Carolina rock, apatite, phosphorite, phosphatic guanos, contain insoluble calcium phosphate. It also constitutes about eighty-five per cent of the ash of bones. Insoluble calcium phosphate is made available for plant food by treating it with sulphuric acid, thereby converting it into soluble calcium phosphate.

Reverted (Biphosphate), or Precipitated Calcium Phosphate.

Reverted phosphate of lime, while insoluble in water, is readily dissolved by the weak acids of the soil, or by water containing ammonium salts or carbonic acid. The term "*reverted*" is intended to express the idea that the phosphoric acid in this form has once been soluble, but that it has gone back or "*reverted*" to an insoluble state. It is always a constituent of the commercial superphosphates, for these cannot be kept on hand any considerable length of time without suffering a reversion of soluble phosphoric acid.

This form of calcium phosphate is made in large quantities in Europe as a product incidental to the manufacture of gelatine from bones.

Available phosphoric acid means the amount of phosphoric acid present in a fertilizer in the forms of both soluble and reverted calcium phosphates.

Insoluble phosphoric acid means the amount of phosphoric acid that is present in the form of insoluble calcium phosphate.

Total phosphoric acid is the sum of all the phosphoric acid present in *available* and *insoluble* calcium phosphates, regardless of the form in which it may exist; that is, it is the entire amount of phosphoric acid present in a fertilizer.

The following table, showing the chemical differences in the three phosphates of calcium, is taken from *Bulletin*, No. 27, new series, page 421 (February, 1891), New York Agricultural Experiment Station :—

		Calcium.	Phosphorus.	Oxygen.	Hydrogen.
1	Soluble calcium phosphate or superphosphate of lime..............	17.1	26.5	54.7	1.7
2	Reverted calcium phosphate or precipitated phosphate of lime........	29.4	22.80	47.0	0.8
3	Insoluble calcium phosphate.........	38.7	20.00	41.3	0.00

From the above table it will be seen that the soluble calcium phosphate contains the largest amount of phosphorus, which is the most valuable constituent in the phosphates of lime. It also contains more oxygen and hydrogen, but less calcium than either of the other phosphates. The reverted and insoluble phosphates rank, respectively, second and third in regard to the content of phosphoric acid.

Phosphoric acid is slowly fixed, that is, converted to the reverted form, in the soil. According to Dr. Voelcker's experiments in England with superphosphate of lime, the absorption of phosphoric acid is more rapid and complete in soils rich in carbonate of lime than in soils of a clayey or sandy character. Were it not for this fixation in the soil of the phosphoric acid of the soluble superphosphate in the form of reverted phosphate of lime, much of the valuable phosphoric acid would be washed away in drain water.

Potassium.

Potassium, also called *kalium*, is from the Arabic word *kali*, meaning ashes, the source from which potashes were first obtained.

The name potassium is from *potash*, so called from the evaporation of the lye of wood-ashes in iron pots.

Potassium is a bluish-white metal which, at ordinary temperatures, can be kneaded between the fingers like putty. It was first obtained by Davy in 1807.

If a small piece of potassium be thrown upon water, it immediately catches fire, burning with a beautiful violet flame. The color is due to the diffusion through the flame of the vapor of potassium.

The ocean is an inexhaustible store of potassium salts ; but it is not from this source that commercial supplies are drawn.

The cheapest sources of potassium compounds are the Stassfurt minerals, which will be described later on (see page 121). Silicates of potassium occur most everywhere in the earth's crust, and their disintegration is the direct or indirect source of the soluble potassium salts found in all fertile soils. Many clay soils, which have been formed by the disintegration of feldsparic and other potash-bearing rocks, contain an abundance of potash combined with silica and alumina in forms that cannot be appropriated by the roots of plants. By the action of air, water, and frost, aided by good culture and the use of lime and gypsum, these locked up treasures of potash are released and transformed into compounds which are readily assimilated by plants.

Next to nitrogen and phosphoric acid, potassium compounds are the most important constituents of manures.

The term *potash*, as used in the analytical tables of the Experiment Station bulletins and in the writings of agricultural chemists, always has reference to a compound of potassium with oxygen, known as potassium oxide, a compound that does not exist in fertilizers at all ; but the use of this form of expression is found to be a convenience in expressing the results of analysis.

"Determined as Potash."—This term, so often seen in the analyses of agricultural bulletins, simply tells the farmer the amount of *actual potash* a fertilizer would contain, if its potassium compounds were present in the form of potassium oxide. The potash in fertilizers is generally present in the forms of carbonate, sulphate, or chloride of potash, all of which compounds are readily soluble in water, and are, hence, available forms of plant food. In determining the potash of fertilizers, only that which is available or soluble in water is considered in the analysis.

"Determined as Potash."

Potash does not accumulate so largely in the seeds and fruits of plants as phosphoric acid, and is, therefore, less liable to be sold off the farm. In the ashes of most plants over ninety per cent. of the total alkali is obtained as oxide of potassium.

Much of the potash taken from the soil is returned in the form of farm-yard manure, composts, and the refuse of crops.

In districts where the land gets but little farm-yard manure and where the rocks by their disintegration supply comparatively small quantities of potash, the benefit to be derived from the application of potassium manures are most manifest.

As a rule the new stems and twigs of plants are richest in potash. Grape-vine twigs are well worth saving for the compost heap. A ton of such twigs will contain about eighty pounds of potash, of bean straw about forty pounds, and of corn stalks, thirty-five pounds of potash.

There is but little loss of potash in drainage water. Most soils have the power of absorbing potash from its solutions and of converting it into insoluble forms, whereby it is stored away for the future use of crops.

Wood ashes, cotton-seed hull ashes, tobacco stems, sulphate of potash, muriate of potash, nitrate of potash, kainit, carnallite, sylvinite, and green sand marl are the chief potassium compounds used as manures.

Sulphur.—The name is from *sal*, a salt, and *pur*, fire, in allusion to its well-known combustibility. Brimstone is from the Saxon word "*bryne*," a burning fire, and stone. The old Saxon word was brynstone, that is, burn-stone.

Sulphur minerals occur in nature as metallic sulphates, like the hydrated sulphate of lime or gypsum, and as sulphides including the metallic ores, of which iron pyrites, or fool's gold, is an example; also as elementary sulphur, which occurs as a mineral in certain geological deposits, and as native sulphur in most volcanic districts. The sulphur of commerce comes chiefly from Sicily.

Sulphur.

Sulphur is an essential constituent of plants. It forms a component part of the albuminoids, a class of complex compounds contained in all animal and vegetable structures. The quantity of sulphur required by plants is small, and the supply of the element in most soils is practically inexhaustible. It is believed to be taken up by plants in the form of sulphates.

Sulphuric Acid.—With oxygen and hydrogen sulphur forms sulphuric acid, a compound of great importance in the manufacture of chemical manures.

CHAPTER VI.

CHLORINE, SILICON, CALCIUM.

Chlorine is a suffocating and very poisonous, greenish-yellow gas. It was discovered by Scheele in 1774, and was so named because of its color, by Sir Humphrey Davy, who first established its elementary character in 1810. This element has the peculiar property of bleaching vegetable colors; combined with lime it is much used in the arts for this purpose.

Chlorine.

Bleaching powder, or chlorinated lime, is a compound of hypochlorite and chloride of calcium. When exposed to air and moisture, it slowly yields hypochlorous acid, which soon breaks up into chloric acid, water, and free chlorine gas.

Chlorinated lime is much used in disinfecting sick rooms and in destroying noxious effluvia. It owes this property to its chlorine, which is one of the most efficient of all disinfectants.

The affinity of chlorine for other elements is so strong that this gas is never found uncombined in nature. With metals, chlorine forms chlorides or muriates. Chloride of sodium or muriate of soda, or common salt, has already been referred to.

Dissolved in water, chlorine forms a yellow solution, and if this solution be exposed to sunlight water is decomposed, the chlorine seizes upon the hydrogen, forming hydrochloric acid, and oxygen is set free. Muriatic acid or the old *spirit of salt* is a strong solution of hydrochloric acid in water. Combined chlorine is abundant in all soils, and is always present in the tissues of plants.

Silicon.—The word is derived from the Latin *flint*, which is an oxide of silicon. Silica, which is the dioxide of silicon, is widely diffused in the soils and rocks of the earth, both in the free and combined states. Free silica abounds in nearly all soils and in many rocks, such as quartz, granites, and sandstones. It is slightly soluble in pure water, but dissolves slowly in strong, hot solutions of soda and potash, forming soluble silicates. Ordinary glass is a mixed silicate of calcium,

Silicon.

sodium, and aluminium, with a large amount of silica. Feldspar, mica, hornblende, soapstone, slate, and common clay are all silicates.

In plants silica exists chiefly in the free state, but in their ashes, owing to the high heat of combustion, it is usually present in combination with sodium, potassium, or calcium.

Silicon enters into the composition of many plants, but its functions are not clearly understood, and it is believed by some chemists that silica, its compound usually existing in vegetable structures, is not an essential constituent of most plants.

Silica is found as a component of cereals, abounding especially in their straw, to which it seems to give firmness. Some experimenters, who have given much study to the subject, believe that silica is found in plants because they take up the soluble silicate of potash from the soil, the potash of which is an important factor in vegetable physiology, but that the silica, being useless, is excreted in the straw. M. Ville, on the other hand, says, "The omission of soluble silica is very prejudicial to vegetable activity."

Compounds of silica are abundant in all soils.

Calcium is a brilliant malleable and very ductile metal of light yellow color. The name is from *calx*, meaning lime, the oxide of the metal. Calcium tarnishes readily in moist air, and decomposes water with evolution of hydrogen, forming hydrate of calcium or slaked lime.

Calcium.

The element is never found in the metallic state except in the laboratory of the chemist, but is very abundantly diffused through nature, existing in the forms of carbonate and sulphate of lime, and in the bones and shells of animals as carbonate and phosphate of lime. The carbonate in forms of limestone, marble, chalk, calcareous spar, etc., and the sulphate or gypsum form a large part of the crust of the earth.

Iceland spar is the purest form of the native carbonate. It is from the carbonate that calcium compounds are almost universally prepared.

Calcium oxide, commonly known as *lime* or *quicklime* is a compound of calcium and oxygen, made by burning lime-stone or oyster shells, or some other form of carbonate of lime, until the carbonic acid is driven off by heat, and quicklime remains. When exposed to the air, quicklime slowly absorbs moisture and carbonic acid, and is changed back into the carbonate, and into *air-slaked lime.*

Calcium Oxide.

With sulphuric acid, calcium forms calcium sulphate, or sulphate of lime. *Gypsum* or *land plaster* is a well known form of calcium sulphate.

Gypsum acts upon insoluble forms of potash and other elements in the soil, converting them into soluble and available forms of plant food ; it is known to aid in the formation of nitrates by the process of nitrification, and also to form compounds with ammonia. Gypsum or land plaster is much used for spreading over fermenting manure and compost heaps for the purpose of fixing ammonia which otherwise passes off into the air and is lost.

Quicklime and sulphate of lime are valuable indirect fertilizers. Most soils contain a sufficient supply of calcium compounds for the use of plants as food.

Lime is not only a direct and essential plant-food, but by its chemical activity the organic and mineral constituents of soils are decomposed, or are converted into compounds that can be assimilated by plants. When the chlorides or sulphates of potassium and sodium, as in the form of the Stassfurt salts, are applied to the land, carbonate of lime, if present in the soil in sufficient quantities, slowly decomposes these salts, forming carbonates of potassium and sodium, which have a better fertilizing action than the chlorides or the sulphates.

Carbonate of lime neutralizes the organic acids contained in peat or sour soils, and both carbonate and quicklime exert a mechanical influence upon soils deficient in lime, but the influence of the carbonate is less powerful than that of caustic or quicklime.

On heavy clays and soils rich in organic matter, the best results are obtained by the use of quicklime, while on light, sandy soils, or those poor in organic matter, carbonate of lime has been found most beneficial.

Calcium Sulphate.

Native gypsum is the hydrated sulphate of calcium. It occurs in various rocks, being especially abundant in deposits of tertiary formations. This salt as found in nature contains about twenty per cent. of water. At a heat of about 175° F., gypsum begins to part with its water of crystallization. In making plaster of Paris, gypsum is burned in kilns at about 250° F., and then reduced to powder. Gypsum not only acts as a plant-food, but it also has the power of absorbing ammonia and of holding it in the soil. It also prevents the waste of nitrogen during the fermentation of stable manure and composts, and, in some obscure manner, aids the process of nitrification by which organic nitrogen and ammonia are converted into nitric acid and nitrates. It decomposes insoluble potassium and magnesium salts, liberating potash and magnesia, thereby rendering these salts available for plants.

Leguminous crops, especially beans, peas, and clover, are in most instances greatly benefited by liberal dressings of gypsum. Quantity per acre, from 250 to 350 pounds.

In the manufacture of illuminating gas, quicklime is used to remove impurities before the coal-gas is fit for consumption. The gas-lime thus produced is a mixture of lime carbonate and hydrate, together with sulphite and sulphide of calcium. The last two compounds are poisonous to vegetation. Gas-lime should not be used as a fertilizer until it has been exposed for some time to the action of the air, by which the poisonous compounds are converted into sulphate of lime. If, on the addition of a weak acid, no odor of sulphur or of sulphuretted hydrogen is evolved, gas-lime is in proper condition for spreading on the land. Sulphuretted hydrogen can be readily distinguished by its odor, which is the same as that of decayed eggs. Gas-lime is by no means a valuable manure, and should not be used except it be near at hand and obtainable at a very low cost. It should never be used on farm-yard manure or compost heaps, nor spread upon light, sandy soils. The best time to apply it is in autumn, and at the rate of from three to five tons per acre.

Gas-lime.

The calcareous earths known as marls contain carbonate of lime, phosphoric acid, potash, and occasionally organic nitrogen. The percentage of carbonate of lime varies from less than five to more than eighty per cent. The agricultural value of marls depends practically on their richness in carbonate of lime, and not on the small amounts of phosphoric acid, potash, or nitrogen which they may contain.

Marls.

If a sandy marl, such as the green sand marls of New Jersey, be applied to stiff, clayey soils at the rate of from two to four tons per acre, the texture of such soils will be made sensibly lighter, and conversely, a similar dressing of clayey marl to sandy soils will give appreciable body to the land. In either case the effects of the dressing will be felt for from eight to a dozen years.

Professor Hilgard, writing upon the influence of lime on soils and crop production, says :—

"Other things being equal, the thriftiness of a soil is measurably dependent upon a certain minimum percentage of lime. The evidence I can present in support of this axiom is overwhelming. It is obvious to the eye in thousands of cases when the significance of the occurrence of certain trees esteemed by the old farmer as a certain sign of a productive soil is once understood. Almost all the trees he habitually selects as a guide to a good 'location' are such as frequent calcareous soils, using the term, however, with a somewhat different meaning from that usually given to it. That is, I find that in order to manifest itself unequivocally in tree growth the lime percentage should not fall below one-tenth of one per cent. in the lightest sandy soils; in clay loams, not below one-fourth of one per cent.; in heavy clay soils, not below one-half of one per cent.; and it may advantageously rise to one and even two per cent. as a maximum.

"Showing the advantages resulting from a certain definite amount of lime in a soil, we find that it effects—

"*First*, a more rapid transformation of vegetable matter into humus.

"*Second*, the retention of this humus against the oxidizing effects of hot climates.

"*Third*, whether through the medium of this humus, or in a more direct manner, it renders adequate for profitable culture percentages of phosphoric acid and potash so small that in case of a deficiency, or the absence of lime, the soil is practically sterile.

"*Fourth*, it tends to secure the proper maintenance of the conditions of nitrification, whereby the inert nitrogen of the soil is rendered available.

"*Fifth*, it exerts an important physical action on the flocculation, and, therefore, on the tillability of the soil.

"This controlling influence of lime renders its determination alone a matter of no small interest, since its deficiency can very generally be cheaply remedied."

CHAPTER VII.

IRON, SODIUM, MAGNESIUM, MANGANESE.

The word **Iron** is from the Saxon *iren*, and probably originally meant metal.

Iron.

Iron is so widely distributed in the rocks and soils of the earth, and is so well known by reason of its universal use in all the affairs of life that no detailed description of the metal is necessary here.

Magnetic iron-ore, red and brown hæmatite, iron-pyrites and bog iron are some of the commonest ores of this metal.

An oxide of iron (ferric oxide) is found in the ashes of all agricultural plants. Iron is necessary for the formation of *chlorophyl*, a name given to the substance which causes the green color in the leaves and other parts of plants. It is under the influence of iron that grains of chlorophyl are developed in the leaves, and the power of the leaf to decompose carbon-dioxide (carbonic acid) with fixation of carbon resides in the cells which contain chlorophyl, or rather in the chlorophyl itself.

Without iron there can be no formation of chlorophyl, no assimilation of carbon and consequently no healthy growth.

Combined with sulphuric acid iron forms sulphate of iron, more commonly known as copperas or green vitriol. This salt is sometimes used with marked success in agriculture. (See *Iron Sulphate*, page 190, Appendix.)

Sodium.

Sodium, also called *natrium*, is a soft, yellowish metal. The name is from soda-ash or sod-ash, the residue from the burning of masses or sods of sea-weed. From the lixivium of sod-ash, soda, in times past, was made. Natrium is from *natron*, an old name given to certain native deposits of sodium carbonate. Sodium does not occur in nature in the elementary condition, but its compounds are widely diffused through the crust of the earth and in the waters of the ocean. The element was first isolated by Sir Humphrey Davy in 1807.

Sodium decomposes water violently, but the evolved hydrogen does not ignite, as in the case of potassium.

Sodium burns with a deep orange-yellow flame, of great brilliancy. All soils contain compounds of this metal which have been derived from the disintegration of silicates, or that have been carried down in the rains.

Sulphate of sodium, also called *sulphate of soda*, *Glauber's salts*, and *salt cake*, is a compound of sodium and sulphuric acid.

It has a bitter, biting taste, and is used to some extent as a purgative for horses and cattle. In the crystallized state sulphate of soda contains nearly fifty-six per cent. of water. When exposed to the air it rapidly parts with its water of crystallization, and yields the **anhydrous** * salt. A good, commercial article should contain from ninety-four to ninety-eight per cent. of sodium sulphate.

Sulphate of Sodium.

Sulphate of soda has been found to be a good manure for cereal and leguminous crops.

When obtained as a bye-product in the manufacture of nitric acid from the Chilian nitrate, the sulphate contains small quantities of nitrate of soda, which increases its fertilizing value.

Sulphate of soda gives the best results on light soils, and is used with success on cereals, grass, clover, and potatoes, applied at the rate of from 175 to 250 pounds per acre. Lawes and Gilbert found a dressing of sulphate of soda to be of great benefit to red clover.

Chloride of soda and muriate of soda are terms often used for *sodium chloride* or *common salt*. In England and also in the United States common salt is used to some extent on grain crops, especially on wheat, to prevent excessive growth of straw, and also to brighten and toughen the straw, and to prevent rust.

Chloride of Sodium.

Until recently the peculiar actiou of salt upon soils very rich in nitrogen has not been clearly understood. It is now known that in many soils potash, lime, and magnesia can he made available for plants by an application of common salt. Its action is to decompose the double hydrous silicates of calcium, potassium, and magnesium, and thus serve indirectly a very useful purpose. Salt displaces, first, lime, then magnesia and potash and some phosphoric acid. Prof. Storer has suggested that the physiological action of salt in checking the growth of straw and stalks on lands highly charged with nitrogenous manures, may be due to the chlorine in the salt which acts to restrain the growth

* That is, without water.

rather than the sodium ; also that the salt may kill or hinder the development of the nitric ferment, or some other organism that makes the soil nitrogen active,—or that perhaps the effect of the salt may be due to a general weakening of the plant.

Some plants have the power to resist the injurious action of salt. It is a common practice to use salt as a manure on asparagus beds, but the opinion is gaining ground that the salt does more good in killing weeds than in furnishing food to the asparagus. Salt is much used in conjunction with land plaster on the cotton lands of the South to prevent rust.*

Like lime and other saline solutions, common salt has the power to flocculate fine earth, and thus it exerts an important mechanical influence on compact clay soils. Traces of common salt are always present in the atmosphere, even many miles inland from the sea.

When salt is used upon wheat to check and stiffen the straw, the practice in England is to spread it at the rate of from 300 to 600 pounds per acre. In the United States, about one barrel per acre is the quantity most usually applied.

After the introduction of Peruvian guano, it became a common practice to mix salt with guano before applying it to the land. Mixed in about equal proportions, the salt and guano mixture gave excellent results, much better than could be obtained by the use of guano alone. It is highly probable that salt when so mixed acts as an antiseptic, retarding the decomposition of the ammonium urate of the guano, and that more of the urate remains available as such for the feeding crop than would be the case if guano were used alone.

Magnesium.—So named from a city in Asia Minor near which native carbonate of magnesia was first found. The metal magnesium is of a silver-white color and readily tarnishes in a damp atmosphere. It is found in the shops in the form of a thin ribbon, known as magnesium-ribbon.

Magnesium.

When heated in contact with air, magnesium ignites and burns with characteristic brilliancy and intense heat, producing what is known as "magnesium light." The burning is simply the oxidation of the metal into magnesium oxide. Before the introduction of the electric light magnesium-ribbon was used for photographing at night.

The individual existence of magnesia as something distinct from lime was first proven by Dr. Joseph Black, of Edinburgh, a distin-

---

*At the rate of 300 pounds of salt and 200 pounds of land plaster per acre.

guished chemist of the last century. Magnesia is a constant constituent of the ash of plants. It is essential to healthy vegetable growth, and if excluded from the soil, crops cannot thrive. Magnesium compounds are abundant in most soils. Small quantities of magnesium silicate occur in granite, syenite, limestones, serpentine, soap-stones, talcose, slates, etc. So exceptionally rare are soils sterile through the absence of magnesia that comparatively little attention has been given to its use as a manure.

Sulphate of magnesium, or *Epsom salts*, is sometimes used as an ingredient in the preparation of special manures. Lawes and Gilbert have used this salt in their mixed manures for oats with marked success. M. Dejardin considers magnesia an important constituent in soils devoted to vine culture. According to this investigator, the French vine resists the attacks of phylloxera vastatrix in soils containing a high percentage of magnesia.

The experience of vine growers in this country confirms the opinion of M. Dejardin. Grape culture in America has flourished most in regions where the soils were rich in maguesium compounds.

Magnesia is found largely in the ashes of wheat, sugar cane, oats, clover, rice, and potatoes. Its compounds are usually abundantly present in soils for all the requirements of vegetation.

Manganese.—The name is regarded as a transposition of the letters of the word magnesia, with whose compounds those of manganese were long confounded.

Manganese. Manganese is a metal much resembling iron. It is sufficiently abundant in all soils for the use of plants and is rarely used as a fertilizer.

CHAPTER VIII.

NATURAL MANURES.

Farm-yard Manure consists of the solid and liquid excrement of farm animals mixed with the straw or other waste products used as litter. This, the first in importance among natural fertilizers, has been long regarded by farmers as a perfect manure, containing all the required constituents of plant nutrition in forms that insured plentiful crops and permanent fertility to the soil. Farm-yard manure does contain all the constituents of plant-food, and it also causes a certain amount of disintegration of the soil; it has a warming effect on cold, clayey lands, and retains moisture and ammonium compounds in the soil.

Farm-yard Manure.

If all the fertilizing materials taken from the soil were returned in the manure there would be no impairment of natural fertility, and the upper soil would slowly become richer, just as uncultivated lands are slowly improved in fertility by the annual growth and decay of natural vegetation. But much of the nitrogen, phosphoric acid, and potash of crops are contained in the seed and fruit, and these are sold off the farm or are converted into products which are not returned to the land in the manure. There is also much loss in fertilizing materials from faulty fermentation, and from the leaching action of storms when manure is not properly protected from the weather. Farm-yard manure, as produced in this country, is far from being a typical manure, and if experience in older countries is to be trusted, many soils would become almost barren if fertilized with farm-yard manure alone.

Its composition will vary according to (1) the age and character of the animals producing it; (2) the quality and quantity of the food; (3) the proportion and nature of the litter; (4) the method in which the manure has been prepared; and (5) the length of time it has been made.

Composition of Farm-yard Manure.

In the case of full-grown animals, neither gaining nor losing weight, the manure will contain exactly the same quantity of nitrogenous and mineral constituents as were present in the food.

Young, growing animals, or those taking on flesh, producing young, or furnishing milk or wool, will supply manure poorer in nitrogenous and ash constituents than that obtained from the former class.

In the case of growing animals and milch cows the amount of fertilizing materials in the manure will vary from fifty to seventy-five per cent. of all the fertilizing materials contained in the food.

The manure produced from fattening or working animals, provided all the urine and solid excrement are saved, will contain from ninety to ninety-five per cent. of the fertilizing constituents of the original food.

Horse manure ferments or decomposes quickly with the development of much heat, and hence is known as a "*heating*" or "*hot*" and rich manure.

Sheep manure usually contains more nitrogen and phosphoric acid but less potash than horse manure. It is ordinarily rich in solid matter and is a "*hot*" manure, but does not decompose so readily as horse manure.

Pig manure is generally very rich. It develops little heat in decomposing, and is, therefore called a "*cold*" manure. It is better to mix it with the manure of other animals than to use alone.

Cow manure decomposes slowly with the evolution of little heat, and is poorer in fertilizing constituents than the manures of other farm animals. It is a poor manure and contains less solid matter than any of those preceding it.

Poultry manure approaches guano in composition, though far less concentrated and less valuable. Much of the nitrogen in the excrement of fowls is in the valuable form of uric acid, which is directly assimilable by plants. To avoid loss by fermentation the fresh poultry manure should be composted with loam, peat, muck, or leaf-mould, and some one of these absorbents together with a little land plaster should be kept spread, in a thin layer, on the floors and under the perches of all poultry houses. For fermenting peat or muck the dung of poultry probably has a higher value than any other manure produced on the farm.

The following analyses of the fresh dung of poultry are given by Prof. Storer ("Agriculture," Vol. 1, page 367).

	FOWLS.	PIGEONS.	DUCKS.	GEESE.
Water	56.00	52.00	56.60	77.10
Organic matter	25.50	31.00	26.20	13.40
Nitrogen	0.80–2.00 say 1.60	1.25–2.50 say 1.75	1.00	0.55
Phosphoric acid	1.50–2.00	1.50–2.00	1.40	0.54
Potash	0.80–0.90	1.00–1.25	0.62	0.95
Lime	2.00–2.50	1.50–2.00	1.70	0.84
Magnesia	0.75	0.50	0.35	0.20

Horse and sheep manure are most effective when used on cold, clayey loams, or applied to moist soils rich in organic matter where decay will not be too rapid, and where these manures will help to warm the land. On the other hand the cold slowly fermenting cow and pig manures are preferable for light, warm soils.

Horse manure on light, sandy soils decomposes more rapidly and is a less lasting fertilizer. This is one reason why many farmers do not use horse manure by itself, but prefer to mix it with cow or pig manure. There is this decided advantage about the use of horse manure in early spring: the warmth of the fermenting manure is communicated to the soil upon which early vegetables are to be grown; the perceptible warming of the land is most marked when the manure is highly nitrogenous and in a condition fit for rapid fermentation.

In the case of any class of animals the value of the excrement is determined more by the quality of the food than by any other condition. A diet including a liberal allowance of cotton-seed meal or linseed meal, and the leguminous foods such as peas, beans, clover, etc., will yield a much more valuable manure than a diet of corn and straw-chaff or root crops.

The richest manures will be furnished by such highly concentrated foods as cotton-seed and linseed meal; next come the legumens, peas, beans, clover; then the grains, and, lastly, root crops.

The process of animal digestion adds nothing to the food.

The food materials are greatly changed and appear in the urine and solid excrement in widely differing forms from those existing in the original food ; but there can be in the manure no more fertilizing materials than were present in the food before it was eaten; the ingestion of food adds nothing in the form of fertilizing materials, but the changed materials are generally in more available form for plant food.

[See Appendix for Analysis of Farm Manures, page 204.]

The solid excrement of animals consists largely of the undigested parts of the food, which parts are mostly insoluble and, therefore, are not directly available for plant food. The urine contains that part of the food which has been digested ; it contains the most of the nitrogen and nearly all the potash, and its constituents are all in soluble form. Although the urine is usually much richer than the solid excrement, containing in most cases more nitrogen, phosphoric acid, and potash, it is, on many farms, allowed to run to waste or is lost by improper fermentation. To avoid this wasteful loss, straw, leaves, or sawdust, together with dry earth, peat, muck, or moss mixed with land plaster should be used to absorb the urine and to prevent its loss by drainage, and also to absorb any ammonia formed in the fermentation.

Fermentation of Farm-yard Manure.

The fermentation is the most important process in the preparation of farm-yard manure. Much has yet to be learned of the exact changes which take place in the decomposition or fermentation (rotting) of manure ; but we know the fermentation or rather the several fermentations are caused by minute living organisms (micro-organisms), some of which perform their normal life functions only in the presence of an abundant supply of air, while others flourish only when removed from the air. Some require a large amount of moisture and multiply most rapidly in the dark, others thrive where there is but little moisture. The fermentation, therefore, varies according to the kind of micro-organism at work, and these are determined by the presence or absence of air, light, heat, and moisture. In the fermentation or decomposition of farm-yard manure the carbon compounds undergo oxidation or slow burning, that is, some of the carbon present in the manure combines with the oxygen of the air, forming carbon dioxide (carbonic acid) which passes off into the atmosphere.

If the heap is kept sufficiently moist, ulmic, humic, and other organic acids are formed by the decomposition of organic matters.

The nitrogen combines with hydrogen, forming ammonia, and the ammonia unites with the ulmic, humic, and other organic acids, forming *ulmates*, *humates*, and other salts of ammonium, which are very soluble in water.

The temperature of fermentation should not be allowed to rise above

150° F., or some ammonia will be lost by volatilization. A considerable amount of water is driven off by the heat produced by fermentation, and if the manure heap is allowed to become dry, much ammonia combines with carbon dioxide, forming ammonium carbonate, which will escape into the atmosphere. The formation of ammonium carbonate is not desirable.

The late Dr. A. Voelcker, F. R. S., made analyses of fresh and rotted farm-yard manures. These analyses show a larger percentage of soluble organic matter in rotted than in fresh manure. The fresh manure contains more carbon and more water, while in the rotted manure the nitrogen is in more available form for root-absorption.

If the process of fermentation has been well managed, both fresh and rotted manures contain the same amounts of nitrogen, phosphoric acid, and potash.

Litter.

There should be a sufficient amount of litter to absorb and retain the urine and also the ammonia formed in the decomposition of the manure. Leaves, straw, sawdust, moss, etc., to which is added some peat, muck, or fine, dry, loamy earth, mixed with gypsum (land plaster), may be used for litter. The relative value of the manure is diminished by the use of too much litter, but on the contrary, if insufficient absorbent material is used, too much moisture prevents fermentation and the consequent chemical changes in the nitrogenous constituents of the manure.

Management of Farm-yard Manure.

The best method for the management of farm-yard manure is to make and keep it under cover, in sheds, or better still, in covered pits from which there can be no loss by drainage. It should also be kept sufficiently moist, and by the addition of charcoal, peat, or vegetable refuse and gypsum the volatilization of ammonia may be reduced to a minimum. Manure so made is worth fifty per cent. more than that thrown into a heap in the barnyard to be leached by the storms of months before being spread upon the land.

Where pits cannot be provided the manure pile should rest upon a hard, clay bottom, or on a thick layer of peat or vegetable refuse, which acts as an absorbent and prevents the loss of much liquid manure.

The time-honored custom of hauling manure upon the land and of dumping it in small heaps from two to three feet in height, is a wasteful and clumsy practice that should be abandoned by every farmer.

CHAPTER IX.

NATURAL MANURES.

NIGHT SOIL.

About the best thing to do with night soil is to get it under ground as speedily as possible. When fresh it is a highly concentrated and most valuable manure, but it is liable to rapid deterioration, and, as shown by the analyses of Prof. S. W. Johnson and others, may speedily undergo changes which render it of little value in agriculture. To obtain the full effects of night soil it must be used fresh, as is the custom among the Chinese and Japanese, or be composted with peat or treated as suggested by Fusselmann and Müller, whose processes are described later on. The methods of using this manure as practiced in China and Japan are so offensive that they can never meet with favor in America. Nearly all the advantages, without the unpleasant features, of the former methods are derived by composting night soil with large quantities of peat or muck.

Says Prof. Johnson in "Peat and Its Uses" (page 68): "When the night soil falls into a vault, it may be composted by simply sprinkling fine peat over its surface, once or twice weekly, as the case may require, *i. e.*, as often as a bad odor prevails. The quantity thus added, may be from twice to ten times the bulk of the night soil,—the more within these limits, the better. When the vault is full, the mass should be removed, worked well over, and after a few days' standing will be ready to use to manure corn, tobacco, etc., in the hill, or for any purpose to which guano or poudrette is applied. If it cannot be shortly used, it should be made into a compact heap, and covered with a thick stratum of peat. When signs of heating appear, it should be watched closely, and if the process attains too much violence additional peat should be worked into it. Drenching with water is one of the readiest means of checking too much heating, but acts only temporarily. Dilution with peat to a proper point, which experience alone can teach, is the surest way of preventing loss. It should not be forgotten to put a thick layer of peat at the bottom of the vault to begin with."

In many European cities attempts have been made to manufacture merchantable manure from night soil by mixing it with such absorbent materials as charcoal, peat, tan-bark, street cleanings, land plaster, etc., but the products thus obtained must necessarily have varied greatly in composition, and judging from the results of analysis, have had very little value as manures. In years past great quantities of night soil were made into *poudrette*.

Poudrette, commercially considered, had little value as a manure, but it was in excellent mechanical condition at a time when no other manure shared this important quality.

Poudrette.

Its good effects were probably due to the presence in great abundance of the nitric bacteria, which, acting on the humus of the soil, excited nitrification. From a chemical point of view the poudrette manufactured at Paris had very little manurial value.

It would seem that the most practical way of disposing of the night soil of the farm would be some modification of Fusselmann's or Müller's processes of admixing excrement with lime. Fusselmann's process consists in slaking quicklime with an equal bulk (or half its weight) of fresh urine, and the dry product thus obtained is mixed with the fresh solid excrement in the proportions of two and one-half parts of slaked lime to two parts of excrement. The product is at once ready for use, and contains all the original constituents of the urine and solid excrement, except a minute amount of ammonia and the water evaporated by the heat disengaged in the slaking of the lime.

How to Dispose of Night Soil.

The process is only applicable to night soil, when the solid excrement and urine are fresh. If the lime be added to old or fermenting night soil, large quantities of ammonia are expelled and lost.

Alexander Müller, of Stockholm, was studying the action of lime upon night soil about the same time that Fusselmann published the results of his researches in France.

Müller arrived at the same results; he urges, however, that the proportion of lime should be kept as small as possible and that it will usually be best to resort to the air and the heat of the sun to complete the drying. Müller also says that the process can be applied to fermented night soil, provided that some acid substance such as peat wet with sulphuric acid or superphosphate of lime be employed to fix the ammonia.

The "*earth-closet*" system invented by Mr. John Wright, of Stamford, Eng., is in use in many small towns, and is at least an excellent means of getting rid of the odor of night soil, but the product obtained by this device has little value as a fertilizer. In the earth-closet the excrement is instantly covered with fine, dry earth,—sifted loam mixed with fine coal ashes is considered best. When night soil is thus covered its odor instantly ceases, and the excrement is so completely deodorized that the same earth may be used over and over again without offence. In practice the earth-closet has proved a very imperfect device for saving manure. It is now pretty clearly understood that the oxidizing power of loose, dry earth defeats the object of the system in so far as it may be regarded as a means of preserving manure. The tendency of microdermes present in the earth is to "burn up" and destroy the manure. The same earth, after having been used over and over again, will contain little or no more nitrogenous compounds than rich garden soil.

A simple and effectual way of disposing of the night soil on a farm is to so construct the closet that the urine will at once drain to a lower level, and there be mixed with an equal quantity of quicklime. The solid excrement should be covered daily with a small quantity of quicklime mixed with a little fine charcoal or peat. Such a receptacle can be made by any farmer at comparatively little cost, and will more than compensate for the care it entails by doing away with ill-smelling odors and the disagreeable and often dangerous task of cleaning vaults, besides furnishing a very rich manurial product for admixture with farm-yard manure or compost. Such receptacle should be made in the form of a shallow drawer or box with an inclined bottom, and should rest upon stout runners like a stone boat or drag, so that, at frequent intervals, it can be drawn by a horse to the manure pile or compost heap.

On the bottom of the drawer should be kept a thin layer of quicklime mixed with peat, wood-pile dirt, or loam.

COARSE COMPOSTING. (*From photograph taken at Fordhook Farm.*)

CHAPTER X.

NATURAL MANURES.

COMPOSTS.

Composts are made up of a great variety of waste products mixed together and brought quickly into a state of decomposition by the admixture of animal and chemical manures, fish, flesh, etc., which induce a more rapid fermentation, and, therefore, a quicker disintegration of organic matters than follows under natural conditions of decay.

Straw, leaves, weeds, peat, tan-bark, sawdust, turf, farm-yard manure, lime, and wood-ashes are some of the leading ingredients that enter into the composition of composts.

As a matter of actual experience there can be no doubt but that a larger proportion of the fertilizing constituents of the solid excrement and the urine of farm animals can be saved by mixing with peat, muck, marsh-mud, etc., before fermentation has begun, than by allowing the manure to ferment by itself.

The use of such absorbent material as bedding, or its admixture with freshly made manure, is a sort of composting, for the trouble of which the farmer is more than repaid by the comfort of his animals and in the increased value and quantity of manure. The peat or muck completely absorbs the urine and other moisture of the manure, and the ammonia and other gases evolved in the fermentation.

Composting Peat or Muck with Farm-yard Manure.

"The best plan for composting," says Prof. S. W. Johnson, in "Peat and Its Uses," "is to have a water-tight trench, four inches deep and twenty inches wide, constructed in the stable floor, immediately behind the cattle, and every morning put a bushel-basketful of muck behind each animal." * * * "When the dung and muck are removed from the stable they should be well intermixed, and as fast as the compost is prepared it should be put into a compact heap and covered with a layer of muck several inches thick."

The more usual way of making peat composts, however, is in beds or heaps. A layer of peat from eight to ten feet wide and from one to two feet in thickness is made, and over this a somewhat thinner layer of night soil or farm-yard manure is spread, followed by another layer of peat.

Alternate layers of peat and manure are laid on until the bed is four or five feet in height.

Various proportions of peat and manure are used, according to the quality of the peat and the richness of the manure. The practical rule, as laid down by the best agricultural writers, is to "**use no more peat than can be thoroughly fermented by the manure.**"

Professor Storer says: "Possibly a better rule would be not to use enough peat or other admixture wholly to prevent the dung from fermenting. In case the dung were free from long litter it is possible, though not probable, that it might be still better to mix as much peat with the dung as will just prevent it from fermenting. But, in our ignorance of what the so-called process of fermentation is, it would be hard to determine which of the three rules is theoretically the best. If we could only be sure, when peat enough is used to prevent the dung from fermenting in the usual way, that the heap would not proceed to ferment in some other unusual and hurtful way, and so destroy itself, the subject would be a great deal clearer than it is now. Probably there are many cases where it would be well to keep dung and urine in the barn-yard fresh and raw, if that could be done without too much labor, even if the peat should remain unfermented. The probabilities are that it would not be very easy to do it unless the mixture were put in a silo. Hence, the second rule suggested, not to use enough peat wholly to prevent the dung from fermenting, may possibly be the best of the three."

As we have already said in treating of farm-yard manure, little is known as to the chemical reactions which occur when manures or composts ferment. About the most that can be said with certainty is that the original constituents of the fermenting materials undergo changes of form, which are due to the presence of "vegetative ferments," "micro-organisms," "bacteria," or "microdermes," and that these fermentations are induced somewhat in the same manner as alcoholic fermentation in the wort of beer, or in aqueous solutions of sugar, or as in the leavening of bread.

M. Pasteur has shown that two distinct classes of micro-organisms are concerned in fermentations. One of these classes manifests activity only in the presence of air or free oxygen gas; the other class requires neither air nor free oxygen for its support, but can appropriate this particular kind of food from organic matters that contain oxygen as an essential constituent.

The micro-organisms that require air or free oxygen are called **aerobic**, and those which perform their life functions in the absence of air are designated, **anaerobic.**

The anaërobic ferments, or those which do not require air for the fulfillment of their vital functions, "break up" the existing organic compounds into new and simpler forms, and when their life work has been accomplished all activity necessarily ceases; but with the **aerobic ferments**, if the fermentable body be exposed to air, decomposition will go on indefinitely and the *aërobic ferments* will continue to thrive even in the disorganized materials which have been exhausted by **anaerobic ferments.** So in the fermentation of manure, when the conditions are such that the external air cannot gain access to the heap, the anaërobic fermentations of the constituents of the manure may speedily be completed. Carbon dioxide (carbonic acid) and other gaseous products of decomposition disengaged during the **anaerobic** fermentations, by permeating every part of the heap must help to exclude the atmosphere and so tend to retard **aerobic** fermentations. "It may be laid down as a rule," says Prof. Storer, "that the fermentations of manure will vary materially according as more or less air has access to the heaps, and as more or less water is contained in them; or, in other words, according as circumstances favor the growth of one or another kind of microdermes. It is with manures somewhat as with soils, only that the fermentations of manures are more evident and pronounced.

Anaerobic Ferments.

In dry, porous heaps of manure there may be rapid wasting of the carbonaceous matters by processes of oxidation. On the other hand, when fresh urine comes in contact with putrid urine, the urea contained in the former will quickly be changed to carbonate of ammonia by the action of a peculiar organism with which putrid urine has become charged. And when air is excluded from manure, there may occur either such fermentations as produce marsh gas or those which generate butyric acid and other kinds of acids, while hydrogen gas is evolved. Sometimes the lactic ferment may occur. Ordinarily, several kinds of fermentations appear to progress simultaneously, or, at least, to succeed one another rapidly."

From what has been said it will be seen that fermentation, whether it be the leavening of bread, the transformation of the wort of beer into alcohol, or the conversion of the inert organic nitrogen of peat into nitric acid, is a particular instance of the manifestation of a special force residing in living organisms or rather in their cellular elements. The forms of life which give rise to fermentations are simple elementary organisms reduced to a single cell ; but a plant or an animal of high order is only the union, under special laws, of different kinds of cells, each acting in a certain determinable manner. The more simple an organism, the fewer special kinds of cells it contains and the simpler are the vital chemical reactions which take place in it—reactions which are manifestations of the chemical phenomena of life, and which are due to the intervention of a force differing from those which we handle in our laboratories.

Preparation of Peat.—Every farmer must determine for himself the most appropriate time for getting out peat or muck. Many prefer to do this work late in the summer or early in the autumn, when the bogs are usually dry and most accessible to teams and workmen. Others find winter to be a more appropriate season. There is then less hurry on the farm, and the hired help can be kept remuneratively employed. And the disintegrating action of air and frost on the peat thrown out—the freezing and thawing—greatly aid in *weathering* or *seasoning*, and in preparing the peat for use. The subjection of fresh, wet peat to frost quickly destroys its coherence and reduces it to a condition that admits of easy pulverization. Exposure also brings the peat into a more active chemical state. By exposure to the atmosphere it appears to acquire the properties of the humus of the soil, or to some extent of farm-yard manure ; it is also more readily oxidized by weathering, and part of its nitrogen is converted into nitric acid.

Peat Composts.

When a peat contains soluble salts of iron to an extent that is hurtful to vegetation, such salts may be converted into innocuous compounds by prolonged exposure to air; but in the case of a peat containing iron salts (iron sulphate or copperas) to an injurious extent, the imperfect exposure of the heap to the action of the atmosphere alone would be insufficient to correct its bad qualities. To render such peat fit for use upon crops it should be composted with an alkali such as lime or potash, or the same result may be obtained by the action of the ammonia evolved by decomposing animal matters.

Guano may be composted very advantageously with peat. In such composts the peat should be moist and quite fine. The peat prevents most effectually any waste of the guano, and the compost is brought into a good state of fermentation in from one to two weeks in warm weather. Composts of peat and guano may be made in the proportion of one part, by measure, of guano, to eight or ten parts of peat. If less than eight parts of peat to one of guano be used, the compost should be spread broadcast, for if placed in the hill it may prove injurious to tender plants.

Guano and Peat Composts.

The droppings of fowls composted with peat forms a rich and quick acting manure, resembling guano compost.

A rich nitrogenized and phosphatic manure is obtained by composting peat or muck with fish or the refuse of the fisheries. The proportion of peat or muck and of fish should be varied according to the crop the compost is to be applied to.

Fish Composts.

Prof. S. W. Johnson ("Peat and Its Uses") recommends for rye from twenty to twenty-five loads per acre of a compost made with one load of menhaden ; for corn, one part of fish to ten or twelve of muck ; as a top dressing for grass or other crops the proportion of fish may be increased.

The caustic alkalies, potash, lime, soda, and ammonia, and their carbonates, also produce fermentations in peat and other like materials. On the other hand, acids and acid salts check or hinder the growth of the micro-organisms that are the cause of fermentations.

Alkali Composts.

Professor Johnson ("Peat and Its Uses") gives the following formula and says :—

"With regard to the proportions to be used no very definite rules can be laid down ; but we can safely follow those who have had experience in the matter. Thus, to a cord of muck, which is about one hundred bushels, may be added, of unleached wood-ashes twelve bushels, or of leached wood-ashes twenty bushels, or of peat ashes twenty bushels, or of marl or gas-lime twenty bushels. Ten bushels of quicklime, slaked with water or salt-brine previous to use, is enough for a cord of muck.

"Instead of using the above-mentioned substances singly, any or all of them may be employed together.

"The muck should be as fine and free from lumps as possible, and must be intimately mixed with the other ingredients by shoveling over. The mass is then thrown up into a compact heap, which may be four feet high.

"When the heap is formed it is well to pour on as much water as the mass will absorb (this may be omitted if the muck is already quite moist), and, finally, the whole is covered over with a few inches of pure muck, so as to retain moisture and heat.

"If the heap is put up in the spring it may stand undisturbed for one or two months, when it is well to shovel it over and mix thoroughly. It should then be built up again, covered with fresh muck and allowed to stand as before until thoroughly decomposed.

"In all cases five or six months of summer weather is a sufficient time to fit these composts for application to the soil."

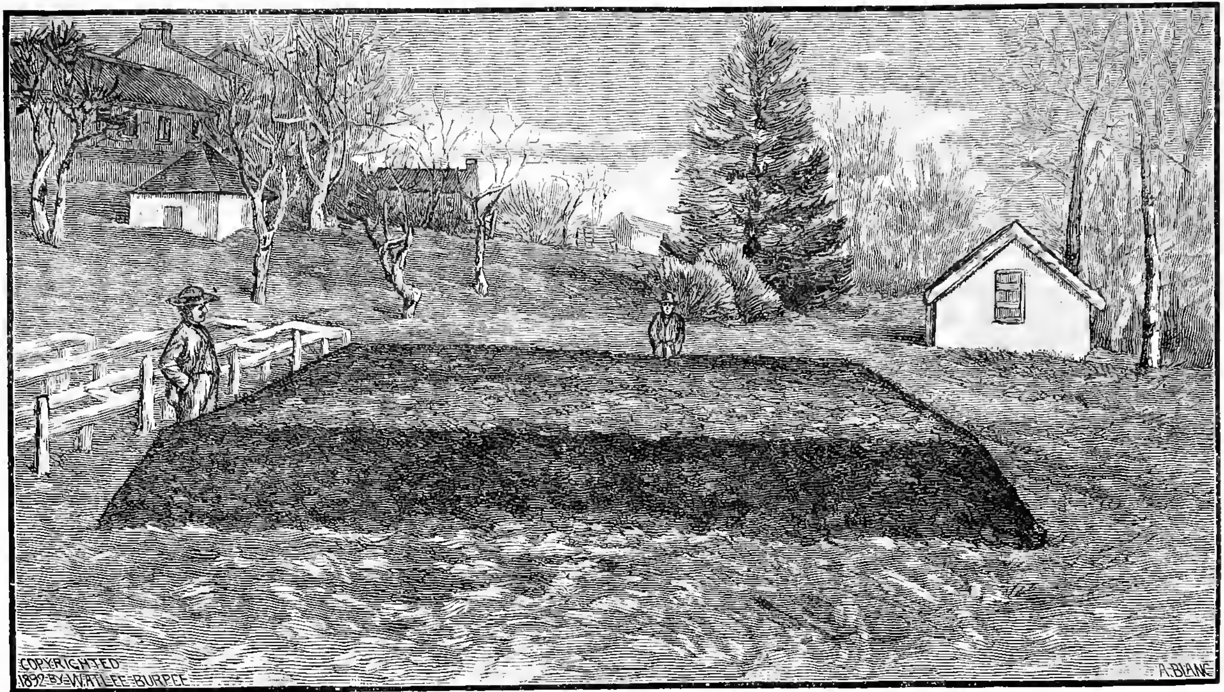
Formula of Mr. Fleming, from Sir C. A. Cameron's "Agricultural, Chemistry and Geology":—

Sawdust, or peat,	40 bushels.
Coal-tar,	20 gallons.
Bone-dust,	7 bushels.
Sodic sulphate (sulphate of soda),	1 cwt.
Magnesium sulphate,	1½ cwt.
Common salt,	1½ cwt.
Quicklime,	20 bushels.

From the days of Sir Humphry Davy until the present much has been written about the use of lime and salt in composts, but now that the true nature of the action of this mixture is pretty clearly understood it is doubtful if lime and salt mixtures will be much used hereafter in composting. The usual method is to slake quicklime to a fine, dry powder with brine made by dissolving common salt in water, using about one bushel of salt to six bushels of lime. The freshly slaked and still warm product is spread in layers upon the moist muck, just as it has been raised from the bog, in the proportions of about two bushels of lime to one cord of muck or peat. The salt is decomposed by the lime, and small quantities of caustic soda and calcium chloride are formed, and, these being soluble in water, are diffused through the compost. The force of capillary attraction here comes into play, and by the now known laws of *unequal diffusion* in liquids the caustic soda diffuses through the porous peat at a much faster rate than the calcium chloride, so that the two soon become separated from each other.

Lime and Salt in Composts.

In the chemical reactions which take place under these conditions, small quantities of carbonates and bi-carbonates of soda and of lime are formed. The soda compounds are more soluble in water and are more strongly alkaline than the lime; and the more active an alkali is, the greater is its decomposing and solvent action on peat. It is



Low Compost. (*From photograph taken at Fordhook Farm.*)

therefore manifest that the success of the operation is dependent in great measure upon the porosity of the compost, and that the best conditions for success are not easily determinable, nor within the range of practical control.

As an alkali, soda has no advantage over potash, and since the decomposing action of the soda is due to its alkalinity, why use the salt at all? Potash not only actively decomposes the peat, but adds an essential constituent of plant-food to the compost, and if used in the form of wood-ashes, the lime carbonate of the ashes neutralizes the acid properties of the peat, and the growth of the nitric ferment is greatly promoted.

Soda is, in rare instances, needful as a plant-food, and in the case of composts is not needed at all; and if soda were needed it would be better economy to use barilla, black ash, or soda ash. In these composts the writer invariably substitutes kainit or other products of the German mines for common salt.

Following is a tried formula for making composts with **lime and salt mixture**:—

Take of peat or muck, ...	50	cords.
Caustic lime, ...	100	bushels.
Common salt, ...	17	"

Make a brine with the salt, and with the brine slake the lime (only as wanted) down to a fine dry powder, using about one bushel of salt for six bushels of lime, spread immediately while warm over the peat, which should be in layers about six inches in thickness. The common practice is to build such composts from four to five feet high and of any convenient width and length.

But there is a great saving of labor by making composts long and of such a height that they can be quickly turned by a road scraper or the sub-soil plow. A compost may be thus turned half a dozen times with less labor than once with the fork, and it is by this frequent aëration of the heap that the most favorable conditions for nitrification are maintained.

The compost, if made late in the summer, will be ready to spread in the following spring, and may be used at the rate of from fifteen to forty cords to the acre.

Sawdust, leaves, cornstalks, tan bark, and all kinds of coarse vegetable materials are more rapidly decomposed by the aid of caustic alkalies than by any other means. Coarse materials, like cornstalks, trimmings from fruit trees, hedges, grape vines, etc., are rich in plant food, and instead of being burned should be composted with potash and lime in separate heaps. More time must be allowed for the decomposition of coarse materials, and they should always be composted in large heaps and kept moist.

The Use of Carbonate of Lime.

Carbonate of lime, though nearly insoluble in water, and much less active in decomposing peat or other inert vegetable matter, is much used in the forms of shell marl, chalk, leached wood-ashes, old mortar, and peat-ashes as disintegrating agents in peat and muck composts.

Lime carbonate, as stated, is slightly soluble in water, but in water saturated with carbon dioxide (carbonic acid) about thirty times as much lime carbonate is dissolved as in pure water. The water of a compost must be considerably impregnated with carbon dioxide and a weak solution of lime carbonate formed; this faintly alkaline solution, acting through a considerable period of time, undoubtedly has some chemical influence in disintegrating organic matter.

In the case of peat containing sulphate of iron, lime carbonate renders the harmful iron salts innocuous, and by its favorable influence in promoting the growth of the nitric bacteria powerfully accelerates nitrification.

Some Formulas for Concentrated Composts.—These composts should be made and kept under cover. In making those containing cotton-seed the barn-yard manure, peat, muck, or other absorbent material should be spread first in a layer about four inches deep, cotton-seed should follow in a layer of about the same depth, and then the several ingredients in layers until all the materials are used. Wet each layer with urine, or, if that cannot be had, use water. Cover the heap with land plaster, dry peat, or loam; in from four to six weeks the cotton seed will be killed, when the heap should be forked over and thoroughly mixed.

I and II are good general composts in concentrated forms, and may be used on winter wheat, rye, corn, and cotton at the rate of from 500 to 800 pounds per acre.

I.

Dissolved bone meal,	500 pounds.
Cotton seed,	800 pounds.
Farm-yard manure,	700 pounds.
	2000 pounds.

II.

Dissolved bone-black, ...	600 pounds.
Castor pomace, ...	700 pounds.
Farm-yard mauure, ...	700 pounds.
	2000 pounds.

III.

Dissolved bone meal, ...	450 pounds.
Marl, ...	500 pounds.
Muriate of potash, ...	200 pounds.
Sulphate of potash (high grade), . .	100 pounds.
Sulphate of ammonia, ...	150 pounds.
Peat, muck, or marsh-mud (dry), . .	600 pounds.
	2000 pounds.

From 400 to 600 pounds per acre for wheat, oats, rye, or corn.

IV.

Sawdust, peat, muck, or marsh-mud (dry), ...	40 bushels.
Ground bone (fine), ...	10 bushels.
Sulphate of soda, ...	120 pounds.
Sulphate of magnesia, ...	120 pounds.
Common salt, ...	120 pounds.
Quicklime, ...	20 hushels.

This is an old formula, much used and highly esteemed in England for general crops.

V.

Dissolved bone-black, ...	200 pounds.
Basic slag phosphate, ...	300 pounds.
Cotton-seed meal, ...	600 pounds.
Muriate of potash, ...	300 pounds.
Peat or muck (dry), ...	600 pounds.

COTTON COMPOSTS.

1.* **Cotton composts,** *per aere, 1600 pounds.* (From South Carolina Experiment Station Reports.)

Acid phosphate, ...	333⅓ pounds.
Kainit, ...	166⅔ pounds.
Cotton-seed, ...	750 pounds.
Stable manure, ...	750 pounds.

* Compost of the late Farish Furman, of Georgia.

2. **Georgia and Alabama compost,** *per acre, 1600 pounds.*

Acid phosphate,	500 pounds.
Cotton seed,	750 pounds.
Stable manure,	750 pounds.

3. **North Carolina compost,** *per acre, 1600 pounds.*

Acid phosphate,	800 pounds.
Kainit,	200 pounds.
Cotton seed,	600 pounds.
Stable manure,	400 pounds.

4. **South Carolina compost,** *per acre, 1600 pounds.*

Acid phosphate,	750 pounds.
Kainit,	350 pounds.
Cotton-seed,	600 pounds.
Stable manure,	300 pounds.

5. **South Carolina compost,** *per acre, 1600 pounds.*

Floats,	750 pounds.
Kainit,	350 pounds.
Cotton-seed,	600 pounds.
Stable manure,	300 pounds.

6. **South Carolina compost,** *per acre, 1600 pounds.*

Acid phosphate,	750 pounds.
Kainit,	350 pounds.
Cotton-seed,	900 pounds.

7. **South Carolina compost,** *per acre, 1600 pounds.*

Floats,	750 pounds.
Kainit,	350 pounds.
Cotton-seed,	900 pounds.

8. **South Carolina compost,** *per acre, 1600 pounds.*

Cotton-seed,	1000 pounds.
Stable manure,	1000 pounds.

In experiments with these composts on the several farms of the South Carolina Experiment Station, No. 5 has, through a series of years, shown uniform superiority.

CHAPTER XI.

NITRE-BEDS OR SALTPETRE PLANTATIONS.

NITRIFICATION.

The nitre-beds or saltpetre plantations formerly employed in Europe for obtaining the nitrate of potash used in the manufacture of gunpowder, were nothing more than extensive composts intermixed with lime, potash, magnesia, etc., and managed systematically for the production of nitre. There are good reasons for believing that a revival of the systematic practices of the "**nitre maker**" or "**saltpetre boiler**," may yet be resorted to by farmers as a source of cheap nitrogen; farmers may, at least, employ those principles so far as may be necessary to obtain a highly charged nitrous earth for spreading upon their fields. The idea has already been suggested in Germany, and for the benefit of those interested in the home production of manure we will describe the methods practiced by the nitre-makers before the introduction into commerce of the Chilian nitrates.

Though gunpowder was probably employed as early as 1337 by Edward III, during the invasion of Scotland, it was not, however, until the reign of Queen Elizabeth that the manufacture of this explosive was established in England. Early in Elizabeth's reign the artificial production of saltpetre, for use in making gunpowder, was introduced into England, but the quantity thus produced was insignificant and the bulk of the supply was imported from the continent and from Barbary. In 1626 the East India Company began the importation of saltpetre from India, where it occurs as a natural efflorescence on the surface or in the upper stratum of the soil.

On the continent, and especially in France and Germany, great attention was at one time given to the artificial production of saltpetre.

The supply of nitre, as found in the fissures of calcareous rocks and caves and as an efflorescence on the surface of certain soils in France, Germany, Hungary, and Russia, was wholly inadequate to the demand, and nitre was not only imported from Egypt and India, but the artificial production of the salt by means of nitre-beds became an industry of great national importance.

In our Revolutionary struggle and in the second war with England the source of a gunpowder supply was, at times, a serious cause of uneasiness to the American Government; and during the reign of Napoleon I the supremacy of England on the seas placed an absolute embargo on the importation of saltpetre by her enemies.

In Sweden the system of the nitre-maker is still in vogue, though not carried on so extensively as formerly. The custom among the Swedes is to mix leached wood-ashes and lime with heaps of manure, loam, marl, and decaying animal and vegetable matter, and to work the beds over once a week in summer and once a month during winter for a period of three years. Gutters extend around the heaps, and into these excavations the fluid manures of the barn-yard are collected and frequently sprinkled over the fermenting beds.

Twigs, straw, and litter of all kinds are introduced into the beds to keep them more porous, and thus to facilitate the admission and circulation of air through the interior of the mass. In Sweden the time usually allowed for the ripening of a nitre-bed is three years; additions are made yearly to the fermenting heaps, so that one-third of a bed is ready for use every year. But in most parts of this country with our almost tropical summers such beds could be brought to a highly nitrified condition in much shorter time. It is at high summer temperatures that nitrification takes place most rapidly in the soil, and by judicious management composts conducted on the principles of the nitre-bed might be brought into a highly nitrous condition in one year.

In Germany the artificial manufacture of nitre was carried on somewhat differently. Beds were made of animal and vegetable remains, together with ashes and calcareous earth, which were mixed up with a portion of loose soil, and placed under sheds to shelter the fermenting mixture from the rain, while the sides were left open to permit the free ingress of air.

The mixture was disposed in little heaps which were frequently turned over with a spade and sprinkled with urine. When the contents of the beds contained about four ounces of the salt for every cubic foot of the materials they were deemed fit for lixiviation. This occurred at the end of two or three years.

The process employed in France was essentially the same as that in use among the Germans. Another French method for obtaining nitre from old plaster rubbish consisted in reducing the materials to powder and lixiviating with hot water.

The process of nitrification in the nitre-bed, the compost heap, or in the soil is precisely the same. The formation of nitrates is due to the continuous life and development of a **micro-organism** known as the **nitric ferment** or **nitric bacteria**, which lives upon the nitrogenous organic matters, ammonium compounds, and other things present in the soil. The nitric ferment is a microscopic plant somewhat like the yeast used for leavening bread, and for fermenting malt liquors ; and under favorable conditions of temperature and moisture, and in the presence of oxygen is propagated with marvelous rapidity in the soil. One of the results of the life of this minute plant is the formation of nitrates and nitrites.

Nitrification.

Nitrification is extremely feeble in winter and at temperatures below 40° F. almost entirely ceases. It is most active at about 98° F. to 99° F., and is more rapid in the dark than in bright sunlight. At temperatures above 100° F. the formation of nitrates rapidly decreases and at 131° F. entirely ceases. As we have just stated, it has been noticed that the nitric ferment thrives best in the dark, and, hence, one good reason for making compost beds under sheds or in sheltered situations. When so made the conditions for nitrification are more favorable and the beds are protected from the leaching action of storms.

To ensure rapid nitrification all the food elements required by the nitric ferment must be present in the compost. The ash ingredients of plants, phosphates, ammonia, carbonaceous matter, and an excess of oxygen must be present.

Peat containing much copperas, coal-tar, gas-lime containing sulphites and sulphides, kill the ferment. The nitric ferment is developed during the slow decay of organic matter in all soils ; during rapid oxidation and in the presence of a large excess of oxygen nitrates are not formed.

When saltpetre plantations were still cultivated in Europe the presence of lime was reputed necessary to the formation of saltpetre, and the carbonate of lime, and especially chalk was considered the most favorable form for use in nitre-beds.

Composts should be slightly alkaline. Weak solutions of the carbonates of lime, potash, ammonia, magnesia, and soda are known to promote the formation of nitrates to a much greater degree than quicklime. Nor is it alone for the nitrates and nitrites formed in the nitre-bed and in the compost heap that this method of obtaining cheap nitrogen is to be wholly commended. In addition to the soluble and quickly acting nitrates and other manurial products thus obtained, the whole fermenting mass of composted materials is full of the living micro-organisms which feed upon the humus-like materials of soils, inducing nitrification and converting the inert soil nitrogen into forms that can be assimilated by crops. A well ripened nitre-bed or compost-heap is not only a valuable store of soluble nitrogenous compounds, but when spread upon the field it may also be regarded as a kind of **yeast for leavening the land.** By the continued life, development, and reproduction of the ferment, the conditions of the nitre-bed are to a certain degree transferred to the field, and just as the little leaven of yeast leavens the whole loaf, so does the living nitric ferment propagate itself with marvelous rapidity in the soil; and the frequent stirring of the soil with the cultivator insures ample aëration and greatly promotes the activity of the ferment.

Humus is the dead organic matter of successive generations of plants and animals which have lived and died upon the land. The fallen leaves of forests, the stems, roots, and seeds of vegetation, by their slow decay accumulate on the surface and in the upper soil of fields, forests, pastures, and marshes, forming a brown or black mould-like mass, generically termed humus. So, also, the plowing under of green crops, the decay of sods and stubble, and of composts or manure applied to the land all aid in the formation of humus in the soil.

When plants die and are exposed to the action of air and moisture at ordinary temperatures, a series of physical and chemical changes takes place with the formation of new organic compounds which are mostly due to the oxidation of carbon and hydrogen. If the decaying vegetable matter is supplied with an excess of air, and is kept moist and warm, the oxidation proceeds uninterruptedly until the organic matter is completely oxidized to carbonic acid, water, free nitrogen, ammonia, and nitrates, and little or nothing remains but the mineral constituent or ash. But in temperate climates these conditions rarely prevail, at least, on a scale of any great magnitude. In the lower layers of fallen forest leaves, in the sods of pastures and meadows, and more particularly in bogs and swamps, where the access of air is limited, the oxidation is rapid at first, and the more tender portions of vegetable matter are oxidized to carbonic acid and water, but the process of decay is checked by the formation of compounds which resist further oxidation, and a large residuum of organic materials remain. So long as such humus like materials continue in a cool, wet condition, and are not freely exposed to the action of the atmosphere, they continue to accumulate in vast quantities, as leaf-mould, swamp muck, and peat.

Little is known as to the precise chemical composition of humus. When subjected to the action of alkalies, humus yields well-defined chemical substances having acid properties, known as **humic** and **ulmic** (geic) acids. By the further oxidation of humus, **crenic** and **aprocrenic** acids, which are faintly acid in their properties, are also obtained. The value of humus is chiefly due to the fact that it contains the stored-up nitrogen of successive generations of vegetation, and by its slow decay much of this nitrogen is made available for the use of growing crops.

Acids Obtained from Humus.

Humus also absorbs and holds ammonia and ammonium salts, and other substances used as plant-food, and by its slow decay supplies carbon dioxide (carbonic acid), the solvent action of which upon the mineral constituents of soils has already been considered. It is also probable that the organic acids of humus aid in the disintegration of rocks and soils. The soluble salts of humic and ulmic acids unite energetically with other bases, such as lime, oxide of iron, etc., and these salts attack the minerals of the soil and hasten their solution.*

Humus absorbs water and watery vapor, and by its lightness and porosity improves the mechanical texture of many soils. This power of retaining capillary water renders the presence of humus a matter of great importance in sandy soils. These soils have little attractive force for watery vapor, but by admixture with humus, as is done in dressing them with composts, or by green manuring, such soils are greatly ameliorated.

Humus binds together loose sandy soils, and, on the other hand, lightens and mellows heavy clays, but on soils that are naturally cold and wet humus does positive injury.

* Professor Johnson, "How Crops Grow."

CHAPTER XII.

GREEN MANURING.

By green manuring is meant the plowing in of green crops grown specially for that purpose, the turning under of sod-land, or of green vegetable waste materials, sea-weed, etc.

It has long been known that leguminous crops, such as peas, clover, lucerne lupines, etc., collect nitrogen and accumulate it in soils, and on these plants do farmers usually depend for green manures in any system of crop rotation. A most striking characteristic of leguminous plants is the large amount of nitrogen which they contain, the quantity often being twice as great as that found in cereals. The nutrition of leguminous crops is not, at present, very clearly understood. Boussingault, one of the keenest investigators of his time, says: "If there is in physiology a fact perfectly demonstrated it is the non assimilability of free nitrogen by plants, even those of an inferior order, such as mycoderms and fungi." De Saussure and other observers maintained that under some conditions a part of the nitrates formed when vegetable substances decay come from the nitrogen of the air. Notwithstanding the high authority of Boussingault, the distinguished French chemist, Berthelot, believes that atmospheric nitrogen, under the influence of living organisms, which are found on the roots of some plants, enters into organic forms assimilable by plants. Dr. Paul Wagner, of Darmstadt, Germany, concludes from his own carefully conducted researches that leguminous plants have the power to fix atmospheric nitrogen, and he divides plants into two classes, viz.:—

First, Nitrogen Collectors, or those which have the power of fixing the free nitrogen of the air.

Second, Nitrogen Consumers, or those which have no such power, bnt take from the soil all the nitrogen contained in the crop. As has been intimated, it is with the nitrogen collectors that we have mostly to deal in any system of culture in which green manuring is resorted to.

Notwithstanding the opposing opinions of philosophers as to the source of nitrogen in these plants, it is an ascertained fact that deep-rooted leguminous crops, like lupines and red clover, collect nitrogen compounds from the sub-soil and bring them to the surface ; if a crop be removed, as hay, a large quantity of nitrogen is taken with it, but the surface soil will be left actually richer in nitrogen than it was before, from the stubble and roots remaining in the soil.

Following are the principal plants used in green manuring :—

Plants Used in Green Manuring. *Pea, bean, clover, white mustard, rye, buckwheat, lupine, turnip, Indian corn, millet, rape, borage, spurry*, and *sea-weed* or *sea wure.*

Plants like peas and clover have the power of gathering in food from the surrounding air, and by sending their roots deep into the sub-soil bring to the surface valuable stores of food beyond the reach of other crops.

In some parts of Europe, after the clover has been cut, the stubble is given a top dressing of farm-yard manure or other fertilizer, which induces a heavy growth of aftermath for plowing under. According to Dr. Harlan ("Farming with Green Manures," page 71), a ton of green clover contains twelve pounds of nitrogen, two and one-half pounds of phosphoric acid, and nine pounds of potash.

We give the following results of experiments conducted by the Alabama Agricultural Experiment Station, and published in Bulletin, No. 14, new series, April, 1890 :—

"With a view of encouraging the growth of these valuable plants (that is, pea-vine and clover), especially of peas, and of answering some important questions, an investigation was undertaken a few months ago to determine the real value of pea-vines as a fertilizer, and the relative value of vines and roots.

"With the aid of Dr. J. T. Anderson, assistant chemist in the State Laboratory, some interesting results have been obtained.

"Several chemists have investigated the composition and value of roots, among whom may be mentioned Dr. Walker, in England, Dr. Weiske, in Germany, and Dr. Atwater, in this country ; but I have found no presentation of the comparative value of the vines and roots as fertilizers. To determine this question four samples were taken October, 1889, from a crop raised on the experiment farm, as follows : Sample A was taken from a space one yard square. The vines were carefully cut, leaving the usual amount of stubble with the roots. A trench was dug around this square yard to a depth of several feet, and the earth washed away by a stream of water from a suitable hose. The roots were collected as completely as possible.

"Samples B, C, and D were from a cubic foot each, selected at random in the patch, the earth was removed entirely, dried, and then carefully sifted from the roots. Care was taken to secure, as far as possible, all fibres, however small. It was found that in this soil, a sandy loam with sandy sub-soil, the roots were virtually all included in the first foot in depth. Vines and roots with stubble attached were air-dried and weighed with the following results :—

WEIGHTS EXPRESSED IN GRAMS.

	A.	B.	C.	D.
Weight of vines, ...	210	137	58	69
Weight of stubble and roots, .	67	20	11	9

Calculated for one acre, these give in pounds :—

	A.	B.	C.	D.
Weight of vines, ...	2,236	13,128	5,558	6,612
Weight of roots, ...	713	1,916	1,054	862

"Thus we have in A a little more than three times as much vines as roots ; in B nearly seven times as much ; in C five and one-half times as much ; and in D a little more than seven and one-half times as much ; the average being six of vines to one of roots.

The vines and roots yielded as follows :—

	A.		B.		C.		D.	
	PER CENT.		PER CENT.		PER CENT.		PER CENT.	
	Vines	Roots.	Vines	Roots.	Vines	Roots.	Vines	Roots.
Phosphoric acid, ...	1.03	1.09	0.56	0.56	0.55	0.62	0.44	0.30
Potash, ...	1.24	1.17	1.25	1.11	1.33	1.24	1.35	1.14
Nitrogen, ...	2 62	1.09	1.73	0.75	1.46	0.54	1.45	0.36
Moisture, ...	11.79	10.95	10 49	11.10	11.48	9.05	11.04	9.53
Crude ash, ...	14.37	20.65	8 87	23.54	7.81	18.18	7.31	17.53

"The amounts of phosphoric acid, nitrogen, and potash, calculated for one acre, are given in the following table in pounds :—

	A.		B.		C.		D.	
	Pounds.		Pounds.		Pounds.		Pounds.	
	Vines	Roots.	Vines	Roots.	Vines	Roots.	Vines	Roots.
Phosphoric acid, ...	23.03	7.77	73.51	10.72	30.56	6.53	29.09	2 58
Potash, ...	27.72	8.34	164.10	21.26	74.10	13.06	89.26	9 82
Nitrogen, ...	58.58	7.77	227.11	14.37	80.59	5.69	95.87	3.10

"Table expressing averages in pounds on one acre with commercial values, taking the yield of the four samples analyzed :—

	Pounds.		Value in Dollars and Cents.	
	Vines.	Roots.	Vines.	Roots.
Phosphoric acid, ...	39.05	6.90	$2.93	$ .52
Potash, ...	88.79	13.12	.89	.13
Nitrogen, ...	115.54	7.70	22.53	2.50
			$26.35	$3.15

"To determine the loss of nitrogen caused by allowing the vines to lie upon the ground during the fall and winter, samples of dry vines were collected during the last weeks of December and January, and the percentage of nitrogen determined. The following table gives these results, and, for comparison, the percentage of nitrogen in green vines is also given as previously obtained :—

	Percentage of Nitrogen.			
	(1)	(2)	(3)	(4)
Green vines collected in October, . .	2.62	1.73	1.45	1.45
Dry vines collected in December, . .	0.81	0.88	. .	. .
Dry vines collected in January, . . .	0.66	0.72	0.66	0.70

"The leaves had mostly disappeared from the dry vines, and such changes had taken place by atmospheric agencies that it was impossible to institute, with any degree of exactness, a comparison between the weight of green vines on a given area, air-dried in the laboratory, and the weight of the same when dried in the field and gathered in December and January. The shrinkage from loss of moisture and decomposition by atmospheric agencies would, however, greatly increase the relative loss of nitrogen as exhibited in the table. It is evident that much of the nitrogen collected by pea-vines is lost when the crop is left exposed in the soil where it grew.

"No experiments have been made to test the views of those who hold that more or less of this nitrogen becomes oxidized and passes into the soil as nitrate. The gaseous condition of nitrogen, ammonia, and other compounds of this element which result from the decomposition of organic substances, renders it, however, more than probable that the nitrogen escapes into the air. Many of our best agriculturists, however, condemn the practice of turning under the pea-vines while green, in our climate, unless some other crop is to follow immediately, believing that the saving of nitrogen contained in the vines will not compensate for the loss produced by the exposure of the plowed land to atmospheric agencies during the fall and winter.

"An excellent plan would be to use the vines as a feed stuff, preserve the manure, and return it to the soil just before the time of planting.

"The following conclusions are drawn from these results :—

"First. Pea-vines contain a large percentage of phosphoric acid, potash, and nitrogen, the three valuable constituents of commercial fertilizers, and are specially rich in nitrogen, which they accumulate directly or indirectly from the atmosphere and furnish as a fertilizer to other crops.

"Second. In these experiments the vines weigh about six times as much as the roots, and are about *eight and one-third* times as valuable as a fertilizer, calculating their value on the basis of valuation used in Alabama for commercial fertilizers.

"Third. The vines lose a large percentage of their nitrogen when left on the ground during the fall and winter months."

Buckwheat, rye, and the lupine will thrive on poor, light lands and under very unfavorable conditions. For buckwheat the land is usually plowed in June and the seed immediately harrowed in. The crop is plowed under in August, or when the plants are in full bloom and the land dressed with air-slaked lime at the rate of from twenty-five to thirty bushels per acre. In some sections white turnips, which will continue to grow until late in the autumn, are sown after the buckwheat has been plowed in, or rye is planted on the buckwheat sod, and plowed in the following spring,

Buckwheat, Rye, and Lupine.

and corn planted. According to Dr. Harlan one ton of buckwheat contains eight pounds of nitrogen, three pounds of phosphoric acid, and eleven pounds of potash.

One ton of green rye contains eleven pounds of nitrogen, four and one-half pounds of phosphoric acid, and twelve and one-half pounds of potash. One great advantage in using rye as a green manure, is the fact that it grows at a time when the land could be used for no other crop but wheat. It protects the land from washing and absorbs nitrogen compounds that otherwise would be washed away. It may be plowed in for corn, or if cut in bloom will mulch the land, and a second crop will soon spring up, and the whole may be turned under with ample time for growing a third green crop for turning under for wheat.

Lupines do well except on marly, and low, wet, cold soils.

In Italy lupines have been in use for centuries as green manures. The roots go deep into the sub-soil. Both the white and yellow lupine produce enormously bulky crops, but the hay is not relished by farm animals, and is, to some extent, poisonous to them. Lupines are, therefore, rarely grown except for the purpose of green manuring. On account of the great bulk it is usual to mow the crop before plowing under. The white lupine yields the heaviest crop and is considered the best for plowing in.

White Mustard.—In England, and to a limited extent in this country, white mustard is used in green manuring. It should be sown at the rate of about twenty pounds to the acre. White mustard is a quick-growing plant, being ready to turn under in from seven to eight weeks from sowing. Like buckwheat, white mustard when plowed under is a good crop for destroying the larval forms of insects in the soil.

Turnips.—A good crop of turnips, including the tops, will often amount to twenty or more tons per acre. Griffiths gives the following percentages of nitrogen in turnips :—

Roots,	2.189,
Leaf,	4.280.

On compact, clayey soils the land will be rendered more porous by plowing under a turnip crop, but in calcareous and light sandy soils where sheep are kept it is better to fold the land; in eating off the turnips sheep help to consolidate the loose soil, while it will be greatly enriched by their droppings. When plowed in for wheat, top-dress with farm-yard manure, or lightly with nitrate of soda after the heavy spring rains are over.

Indian Corn.—According to Dr. Harlan a ton of green Indian corn contains six pounds of nitrogen, two and one-half pounds of phosphoric acid, and nine pounds of potash. This author says: "I find by years of experience that it is better to plow in two crops of corn in one year than one great, heavy crop which has grown all the spring and summer." * * * "Two crops in a year, each containing in tops and roots about twenty tons per acre, will manure the land well." * * * Having plowed in the first crop of corn about the middle of July, what shall we do next? I will tell you my plan, and if it does not meet your full approval do not follow it; or, if doubtful of its value, try it on a small plot and you will lose but little if it fails.

"About the middle of August, having the land in good condition, put in the corn in furrows six or seven feet apart and seven or eight grains to the foot. Keep the ground mellow and free from weeds with the cultivator while the corn is growing. This you ought to do if there was no crop to work, in preparing the land for wheat. Now, when the time comes to sow wheat you will find the sown corn from three to four feet high, according to the quality of the soil and the warmth and wetness of the season. Then sow the seed between the rows and fluke it in. Now mark the results.

"No blasting winds in winter nor in the early spring can injure the wheat. The drifting snows will be retained and help to shelter it. The soil, powdered by freezing and drying into fine dust, will not be blown away. No droughts will check its growth. The ground will always be found moist and mellow beneath the shelter. * * * * And when it decays in the warm days of spring, the rains will leach out its soluble elements and saturate the soil with them, and do more good to the ripening wheat than the same amount of green fodder fed to cattle, and the residue returned to the field."

Hungarian Millet.—One ton of Hungarian millet, according to the same writer, when in bloom, contains twenty pounds of nitrogen, two and one-half pounds of phosphoric acid, and seventeen pounds of potash. Two crops are readily obtained, together amounting to from twenty to twenty-five tons per acre. Sow about one bushel per acre, and when in bloom sow one-half bushel per acre on the growing crop and then mow. A second crop will spring up, and when in bloom, plow under.

Vetches, spurry, borage, and **rape** have been long used in Germany and other countries of continental Europe. With the exception of rape all do well and produce abundant crops in poor, sandy soils. Rape requires a rich soil and is used most advantageously on stiff clays.

Sea-weed or **Sea-ware.**—The use of sea-weed or rather sea-plants for manure is necessarily confined to within short distances of our coasts. Sea-plants contain between seventy and eighty per cent. of water, and though a great mass of bulky material may be spread upon the land, the amount of manure actually received is not large. They decompose rapidly, yielding mostly ammonia and potash to crops. Of the twenty to twenty-five per cent. of organic matter in sea-plants from three to four per cent. is ash.*

Sea-plants furnish to crops nitrogen, phosphoric acid, potash, lime, and magnesia, but because of the large percentage of potash which they contain, are regarded as potassic manures. On the coasts of Scotland and Ireland sea-plants are used almost exclusively as manure for potatoes. The sea manure is spread green at the rate of from twenty to thirty tons per acre, or is composted with farm-yard manure.

Ribbon kelp, broad kelp (devil's apron), carragheen, and **rock weed** contain considerable nitrogen and potash, and decay rapidly when spread upon the land as a top-dressing, or plowed under as a green manure. They may also be used to induce rapid fermentation in peat and other composts.

Eel-grass has generally been condemned as a worthless sea-manure because of the slowness with which it decomposes in the soil, or when composted with animal manures. According to Prof. Storer, eel-grass contains one and one-third per cent. of phosphoric acid, 0.25 per cent. of nitrogen, and one per cent. of potash, and its ashes contain one and one half per cent. of phosphoric acid and seven per cent. of potash. When eel-grass can be had within easy hauling distance of the farm it should not be disregarded as a source of cheap manure.

Composted with lime the tough, fibrous materials may be quickly reduced to manageable form, and if then mixed with bone meal a very complete and quick-acting manure is obtained.

One great advantage about the use of manures made from sea-plants is their freedom from the seeds of weeds, the eggs of insects, and the spores of fungi.

A system of successful farming in practice for over fifteen years in

---

*Some sea-plants used in Great Britain for manures are stated by Griffith to contain three per cent. of nitrogen and eighteen to thirty-two per cent. of ash.

the vicinity of Cranbury, N. J., consists of a five years' rotation in which green manuring and the use of chemical manures are the recognized factors of success.

"Four crops," says Mr. H. W. Collingwood in his excellent little work "Chemicals and Clover," "are grown—potatoes, wheat, grass two years, and corn. The potatoes are planted in drills with over 1500 pounds of high-grade fertilizer to the acre, or 1000 pounds broadcast before planting and 500 or more in the drills. The potato ground is plowed and seeded to wheat in the fall with timothy, with clover added in the spring. After two years of grass what stable manure is made is hauled out in summer and spread on the sod—the aftermath being permitted to grow and decay on the ground. This is all plowed in in the spring and the ground is planted to corn, to be followed the next spring by potatoes, and so on through the rotation. The theory of this system of fertilization is that the heavy dressing of potato fertilizer will not only produce a profitable crop of potatoes, but will leave enough fertility in the soil to maintain the wheat and grass."

For a complete description of this unique system of farming, see "Chemicals and Clover," by H. W. Collingwood, Managing Editor of the *Rural New Yorker*.

CHAPTER XIII.

ARTIFICIAL OR CHEMICAL FERTILIZERS.

COMMERCIAL AND AGRICULTURAL VALUATIONS OF FERTILIZERS.

A commercial valuation is an approximate estimate of the value or cash cost in unmixed raw materials of the nitrogen, phosphoric acid, and potash in one ton of fertilizer.

The following elements of cost and expense enter into the *total* cost to the farmer of a commercial fertilizer; (*a*) retail cash cost of unmixed raw material; (*b*) the cost of mixing; (*c*) cost of transportation; (*d*) storage, insurance, commission, long credit, bad debts, etc.

A commercial valuation, it will be seen, excludes all elements of cost but the retail cash cost of unmixed raw materials.

The agricultural value of a fertilizer is based upon its power to produce crops.

A commercial valuation does not necessarily bear any relation to crop producing value. The agricultural value is determined by the soil and the crop to be raised, while the commercial value depends upon the money cost of the essential fertilizing constituents contained therein.

A particular fertilizer may have a high commercial valuation and also a high agricultural value for a particular soil and crop, and yet for another soil and another crop, while its commercial value remains the same, the agricultural value may be comparatively low; and conversely, a fertilizer having a low commercial value, may have a high or a low agricultural value according to the soil and crop to which it is applied; or to summarize—

(*a*) *The commercial value is determined by the cost of raw materials.*

(*b*) *The agricultural value depends upon crop-producing power.*

As an example the complete fertilizer, formula I, page 154 contains nitrogen as nitric acid in nitrate of soda, as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood, dried fish, and dissolved bone meal. It is a fertilizer of high commercial value, but its agricultural value on a light soil planted to clover or other leguminous crop would be less than that of the mixture in formula III, page 154. The latter has a much lower commercial value, but its agricultural value on a leguminous crop would be higher than the more costly manure.

On a loam or clay soil, or, in fact, on any soil containing sufficient natural stores of potash, or for a crop consuming nitrogen and phosphoric acid in abundance and potash moderately, the former fertilizer would have a very high agricultural value. The latter has a comparatively low commercial value, but its agricultural value on a soil in need of potash and on a crop of clover would be much higher than the former. On a **nitrogen-gathering crop** its value would be high, on a **nitrogen-consuming crop** its value would be low.

It is by the intelligent application of the simple principle underlying what is here said that agricultural problems are to be solved, in so far as they relate to soil fertilization and crop feeding. Plants, like animals, must have their natural food, and whether that food is supplied by direct or indirect fertilization our practice and our theory are coincident.

How to Make Commercial Valuations.

First, of unmixed chemicals.

Nitrate of Soda.—Multiply the guaranteed per cent. of nitrate of soda by 16.47, which gives the per cent. of nitrogen; multiply the per cent. of nitrogen thus obtained by the trade value of nitrogen in the form of nitrates (for 1892 this is 15 cents per pound, see page 84); then multiply the last result by 20, which gives the value per ton.

Example.—A nitrate of soda is guaranteed to be 95 per cent. pure; that is, the total impurities in it amount to 5 per cent.: $95 \times 16.47 =$ 15.64 per cent. of nitrogen; 15.64×15 (trade value for 1892) $= 234$ cents, or \$2.34, value of nitrogen in 100 pounds; $\$2.34 \times 20 = \$46.80$, value per ton.

Sulphate of Ammonia.—Multiply the per cent. of ammonia by .8235, and then multiply the result by the trade value of nitrogen in ammonia salts ($17\frac{1}{2}$ cents for 1892); multiply the result by 20, which gives the value per ton.

Example.—A manufacturer guarantees his sulphate of ammonia to contain 22 per cent. of ammonia: $22 \times .8235 = 18.12$ per cent. of nitrogen; $18.12 \times 17\frac{1}{2} = 317$ cents, or \$3.17 the value of nitrogen in 100 pounds of sulphate of ammonia; $\$3.17 \times 20 = \$63.40$, value per ton.

Sulphate of Potash.—Multiply the guaranteed per cent. of sulphate of potash by .54 ; multiply the result by the trade value for potash in high-grade sulphate ($5\frac{1}{2}$ cents for 1892), and multiply the last result by 20.

Example.—A high-grade sulphate of potash is guaranteed by the manufacturer to contain 45 per cent. of sulphate of potash : $45 \times .54 = 24.30$ per cent. of actual potash ; $24.30 \times 5\frac{1}{2} = 134$ cents, or $1.34 the value of actual potash in 100 pounds of sulphate ; $\$1.34 \times 20 = \$26.80$, value per ton.

Muriate of Potash (Chloride).—Multiply the guaranteed per cent. of muriate (chloride) by .63 ; then multiply the result by the trade value for potash in the form of muriate ($4\frac{1}{2}$ cents per pound for 1892), and multiply the last result by 20.

Example.—A muriate of potash is guaranteed to contain 80 per cent. of muriate (chloride): $80 \times .63 = 50.40$ per cent. of actual potash ; $50.40 \times 4\frac{1}{2}$ cents = 227 cents, or $2.27 the value of actual potash in 100 pounds of sulphate ; $\$2.27 \times 20 = \$45.40$, value per ton.

Second. How to make a commercial valuation of a fertilizer from a guarantee-analysis as given by manufacturers.

The statements of guarantee-analysis as used by manufacturers differ considerably in form, and the amount of each constituent is usually stated as being between two more or less widely varying limits. Thus, we are offered a fertilizer which in the guaranteed analysis is stated to contain : Ammonia, from 2 to 3 per cent.; available phosphoric acid, 8 to 10 per cent.; insoluble phosphoric acid, 2 to 3 per cent.; and potash, *equal* to 3 to 5 per cent. In estimating the valuation from such form of statement of analysis the *lower numbers* should be always used, for the manufacturer is held legally only to the lower figures given in the guarantee. The per cent. of nitrogen in the guarantee-analysis is most usually given in the form of ammonia, and the per cent. of potash may be given in the form of sulphate or muriate (chloride) of potash. When the per cent. of organic nitrogen is given multiply the per cent. of nitrogen by the trade value adopted for organic nitrogen in mixed fertilizers. But if the nitrogen is stated in the form of ammonia, multiply the guaranteed per cent. of ammonia by .8235, which will give the per cent. of actual nitrogen ; then multiply the result by the trade value for organic nitrogen in mixed fertilizers, which will give the value of the nitrogen in 100 pounds of fertilizer. Thus, in the fertilizer given above the per cent. of ammonia in the guaranteed analysis is from 2 to 3 per cent. As directed, we take the lower number, 2 per cent.: $2 \times .8235 = 1.65$ per cent. of nitrogen ; $1.65 \times 15\frac{1}{2}$ cents = 25.58 cents.

The per cent. of available phosphoric acid is guaranteed to be from 8 to 10 per cent.: $8 \times 7\frac{1}{2}$ cents = 60 cents. Insoluble phosphoric acid: 2×2 cents = 4 cents.

The guaranteed per cent. of potash is 3 to 5 per cent. But the statement of analysis does not tell the form in which the potash is present. All we know is that there is from 3 to 5 per cent. of actual potash contained in the fertilizer, so we will give ourselves the benefit of the doubt and assume the potash to be in the form of muriate (chloride): $3 \times 4\frac{1}{2}$ cents = $13\frac{1}{2}$ cents.

We now have the value in cents of the nitrogen, available and insoluble phosphoric acid, and potash. Add these together and the sum is the value in cents of the total fertilizing constituents in 100 pounds of fertilizer. This sum multiplied by 20 gives the value in cents of one ton.

Example:—

Nitrogen, ...	$1.65 \times 15\frac{1}{2}$	= 25.5	cents.
Available phosphoric acid,	$8 \times 7\frac{1}{2}$	= 60.0	"
Insoluble phosphoric acid,	2×2	= 4.0	"
Potash, ...	$3 \times 4\frac{1}{2}$	= 13.5	"
Total value of 100 pounds, ...		103.0	"

$103 \times 20 = 2060$ cents, or $20.60 value per ton.

If the potash is given in the form of sulphate we find the equivalent of actual potash by multiplying the per cent. of sulphate by .54 and the result by the trade value ($5\frac{1}{2}$ cents for 1892). If the potash is given in the form of muriate (chloride), multiply the per cent. of muriate (chloride) by .63 and the result by the trade value ($4\frac{1}{2}$ cents for 1892).

Example 1.—A manufacturer's guarantee analysis is 8 to 10 per cent. of potash as sulphate: $8 \times .54 = 4.32$ per cent. of actual potash; $4.32 \times 5\frac{1}{2}$ cents = 23.7 cents, the trade value of actual potash as sulphate in 100 pounds of fertilizer.

Example 2.—A manufacturer's guarantee-analysis is 6 to 8 per cent of potash as muriate (chloride); $6 \times .63 = 3.78$ per cent. of actual potash; $3.78 \times 4\frac{1}{2} = 17.0$ cents, trade value of actual potash as muriate in 100 pounds of fertilizer.

Summary of the methods heretofore used in converting one chemical compound into an equivalent of another chemical compound.

(*a*) To change nitrogen into an equivalent amount of ammonia, multiply the given amount of nitrogen by 1.214.

(*b*) To convert ammonia into an equivalent amount of nitrogen, multiply the given amount of ammonia by .8235.

(*c*) To convert a guaranteed per cent. of nitrate of soda to an equivalent of nitrogen multiply the per cent. of nitrate of soda by 16.47.

(*d*) To convert a guaranteed per cent. of sulphate of potash to an equivalent of actnal potash multiply the per cent. of sulphate by .54.

(*e*) To convert muriate (chloride) of potash to an equivalent amount of actual potash, multiply the per cent. of muriate (chloride) by .63.

(*f*) To convert actual potash to an equivalent per cent. of sulphate of potash, multiply the per cent. of actual potash by 1.85.

(*g*) To convert potash to an equivalent per cent. of mnriate (chloride) of potash, multiply the per cent. of actnal potash by 1.585.

We now have the data for estimating the commercial valnes of fertilizers from the guarantee-analyses as usually published by mannfacturers. We may in a few moments calculate the comparative commercial values of different trade-brands, and be governed in buying by their actual commercial values and by the requirements of our soil and the crops to be grown. Or, if we have an eye to saving from twenty to thirty per cent. by mixing our own fertilizers dnring the idle winter months, when we can usually buy agricultural chemicals cheaper than at any other season of the year, we can now proceed intelligently and prepare chemical manures containing just such percentages of nitrogen, phosphoric acid, and potash, as soil and crop requirements demand.

We ascertain the cheapest source of raw materials, estimate our wants and buy for cash on guaranteed analyses. Or, better still, by coöperating with several other farmers we purchase, at wholesale, sufficient raw materials for our combined use. With a few hoes and shovels, a good-sized ash-sieve, and an even barn floor we are ready for work.

Mixing Raw Materials.—We proceed to spread the weighed raw materials in thin layers on the barn floor, building them layer upon layer to a height convenient for easy manipnlation; then intimately mix with hoes by working the piles over from the outward edge inward, pass the mixed materials through the sieve, and having secured an even admixture, store the finished materials away in bags or barrels nntil needed for use.

Examples.—We want a complete high-grade fertilizer for general use, and decide it shall contain from 4 to 5 per cent. of nitrogen, 8 to 9 per cent. of phosphoric acid, and from 6 to 7 per cent. of potash. In making an approximate estimate of our wants we will take the higher numbers given. Then for one ton we want—nitrogen 5 per cent. (or 5 pounds in each 100 pounds of fertilizer) × 20 = 100 pounds, phosphoric acid (available) 9 per cent. × 20 = 180 pounds, and potash 7 per cent. × 20 = 140 pounds.

The tables of analyses in the appendix have been carefully consulted before purchasing and our raw materials have been bought upon guaranteed analyses, are of good merchantable quality and are up to the standard of guarantee. We conclude to get our three essential components from a variety of materials and proceed thus :—

Material. Pounds.		Nitrogen. Pounds.	Phosphoric Acid. Pounds.			Potash. Pounds.
			Available.	Insoluble.	Total.	
200	Nitrate of soda..........	31.50	....	....	....	....
250	Sulphate of ammonia.....	51.25	....	....	....	....
100	Dried blood.............	10.52	....	1.91	1.91	....
350	Dissolved bone meal......	9.10	47.35	14.24	61.59	....
800	Dissolved bone-black......	......	133.60	2.40	136.00	....
200	Muriate of potash (chloride)	......	....	....	....	104.92
100	Sulphate of potash (high grade)...............	......	....	....	....	38.60
2000	Total quantities in one ton	102.37	180.95	18.55	199.50	143.52
	Per cent. in one ton......	5.11	9.04	.92	9.97	7.17

Now let us suppose that out of these same materials we wish to make a fertilizer containing from 1 to 2 per cent. of nitrogen, 6 to 8 per cent. of phosphoric acid, and from 2 to 3 per cent. of potash. We have four ingredients that supply nitrogen, namely, nitrate of soda, sulphate of ammonia, dried blood, and dissolved bone meal, and they supply it in the three forms of nitric acid, ammonia, and organic nitrogen. We want from 20 to 40 pounds of nitrogen, 120 to 160 pounds of phosphoric acid, and from 40 to 60 pounds of potash. In compounding our formula we will take the higher number for nitrogen (40 pounds), and will take the nitrogen in about equal proportions; that is, 10 pounds of nitrogen from each of the four nitrogenous constituents. We begin with nitrate of soda, containing 15.75 pounds of nitrogen in each 100 pounds of the nitrate. Now, how many pounds of nitrate of soda must we have to get 10 pounds of nitrogen? It is a very simple calculation; since in 100 pounds there are 15.75 pounds of nitrogen there must be in 1 pound of nitrate of soda the one-hundredth part of 15.75 pounds, or .1575 pounds of nitrogen. Hence, we must have about 63½ pounds of nitrate of soda.*

We make a similar calculation for sulphate of ammonia, as follows: 100 pounds of sulphate of ammonia contains 20.50 per cent. of nitrogen. Therefore, 1 pound of sulphate of ammonia contains the one-hundredth part of 20.50, or .2050, and we have .2050 ÷ 10.0000 = 48.7 pounds, or we simply take 50 pounds of sulphate of ammonia, which contains 10.25 pounds of nitrogen. Like calculations for all the raw materials are made, and, after estimating the required quantities for all the constituents, we have—

Material. Pounds.		Nitrogen. Pounds.	Phosphoric Acid. Pounds.			Potash. Pounds
			Available.	Insoluble.	Total.	
63½	Nitrate of soda..........	10.00	....	....	....	....
50	Sulphate of ammonia.....	10.25	....	....	....	....
100	Dried blood.............	10.52	....	....	1.91	....
400	Dissolved bone meal......	10.40	54.12	16.28	70.40	....
515	Dissolved bone-black......	....	86.00	1.54	87.54	....
100	Sulphate of potash (high grade)...............	....	....	....	....	38.60
45	Muriate (chloride)........	....	....	....	....	23.60
1273½	Total quantities in one ton.	41.17	140.12	17.82	159.85	62.20
	Per cent. in one ton......	2.05	7.00	0.89	7.99	3.11

We have the required percentages of nitrogen, available phosphoric acid, and potash, but instead of 1 ton of 2000 pounds we have only 1273½ pounds of materials. We may add 721½ pounds of land plaster, peat, coal ashes, or loam to make up the ton.

This formula illustrates the question often raised by farmers: "Why does the sum of the fertilizing constituents in the analysis of a fertilizer amount to so much less than the total weight of the fertilizer, and what is used by the manufacturer to make up the difference?" We find that when the percentages of nitrogen, total phosphoric acid, and potash are added together, the sum of

* .1575 ÷ 10.0000 = 63½ pounds.

their weights range between 16 and 30 per cent. of the total weight, and that in each ton of fertilizer there is from 70 to 84 per cent. of something else. This great difference is not due to dishonesty on the part of manufacturers or dealers in agricultural chemicals. The essential elements are always combined with other substances which often are of no use whatever to growing crops. Thus, in 100 pounds of nitrate of soda we have only 15.75 pounds of nitrogen and 84.25 pounds of sodium, oxygen, and moisture, and so it is with all other constituents of fertilizers—the greater part of the weight is made up of moisture, dirt, etc. In many States of the Union there is much greater protection against fraud in buying commercial fertilizers than in the purchase of food or clothing.

But commercial fertilizers or raw materials, for mixing, should never be bought except upon guaranteed analyses, and with strict regard to soil requirements and the character of the crop to be fed.

In the above formula we might slightly change the percentages of fertilizing constituents, and probably get a better crop effect by the change. We might drop out the muriate of potash and reduce the sulphate of potash to 50 pounds, and then substitute 821½ pounds of unleached wood-ashes for the sulphate and muriate of potash left out. In the wood-ashes there will be 45.21 pounds of potash and 15.20 pounds of phosphoric acid. Our formula would then stand :—

Material Pounds.		Nitrogen. Pounds.	Phosphoric Acid. Pounds.			Potash. Pounds.
			Available.	Insoluble.	Total.	
63½	Nitrate of soda..........	10.00	......	......	......	......
50	Sulphate of ammonia.....	10.25	......	......	......	......
100	Dried blood.............	10.52	......	......	1.91	......
400	Dissolved bone meal......	10.40	54.12	16.28	68.40	......
515	Dissolved bone-black......	......	86.00	1.54	87.54	......
50	Sulphate of potash (high grade)...............	......	......	......	......	19.30
821½	Wood-ashes (unleached)..	......	......	......	15.20	45.21
2000	Total quantities in one ton.	41.17	140.12	17.82	173.05	64.51
	Per cent. in one ton......	2.05	7.00	0.89	8.65	3.22

THE UNIT SYSTEM.

In the wholesale fertilizer trade some raw materials are bought and sold on the "**unit system.**" The unit is 1 per cent., or 20 pounds per ton.

Thus, a lot of dried blood, containing 10.50 per cent. of nitrogen, equivalent to 12.75 per cent. of ammonia, is said to contain 12¾ units of ammonia, and, if quoted at $2.50 per unit, a ton will cost: 12¾ × $2.50 = $31.87½.

A quotation of $1.50 per unit of available phosphoric acid means $1.50 for each *20 pounds* contained in the material quoted.

Illustration.—A manufacturer offers dissolved bone black, guaranteed to contain 16½ units of available phosphoric acid, at $1.50 per unit: 16½ × $1.50 = $24.75 per ton.

TRADE VALUES OF FERTILIZING INGREDIENTS IN CHEMICALS AND RAW MATERIALS.

	CENTS PER POUND.		
	1890	1891	1892
Nitrogen in ammonia salts	17	18½	17½
" " nitrates	14½	14½	15
Organic nitrogen in dry and fine ground fish, meat, and blood	17	15½	16
Organic nitrogen in cotton-seed meal and castor pomace	15	15	15
" " " fine ground bone and tankage	16½	15	15
" " " " medium bone and tankage	13	12	12
Organic nitrogen in medium bone and tankage	10½	9½	9½
" " " coarse bone and tankage	8½	7½	7½
" " " hair, horn shavings, and coarse fish scrap	8	7	7
Phosphoric acid, soluble in water	8	8	7½
" " " " ammonium citrate	7½	7½	7
" " in dry, ground fish, fine bone, and tankage	7	7	7
Phosphoric acid in fine medium bone and tankage	6	5½	5½
" " " medium bone and tankage	5	4½	4½
" " " coarse bone and tankage	4	3	3
Potash as high-grade sulphate and in forms free from muriate (chlorides), in ashes, etc	6	5½	5½
Potash in kainit	4½	4½	4½
" " muriate	4½	4½	4½
Organic nitrogen in mixed fertilizers	17	15½	16
Insoluble phosphoric acid in mixed fertilizers	2	2	2

The trade values in the table on page 94 represent the average prices at which, in the six months preceding March first, the respective ingredients, in the form of unmixed raw materials, could be bought at retail, for cash, in such trade centres as New York, Boston, Philadelphia, Baltimore, and Chicago.

CHAPTER XIV.

MATERIALS USED IN MAKING COMMERCIAL OR CHEMICAL MANURES.

THOSE CONTAINING NITROGEN.

Nitric Acid.—Pure nitric acid is formed by the chemical union of two parts or equivalents of nitrogen with five equivalents of oxygen gas. This is the chemical compound referred to by chemists in analyses. The common nitric acid or *aqua fortis* is a combination of pure nitric acid with water.

Nitric Acid.

Nitrates are salts formed by replacing the hydrogen of nitric acid with some base like soda, lime, potash, magnesia, etc.

The union of nitric acid with these bases forms nitrates of soda, potash, lime, magnesia, etc.

Nitrate of soda or Chili saltpetre occurs in vast deposits in the rainless districts on the west coast of South America, chiefly in Peru, Chili, and Bolivia, from whence it is imported to this country for use in chemical manufacture and in agriculture. As imported into the United States, nitrate of soda usually contains from fifteen to sixteen per cent. of nitrogen. Nitrate of soda resembles common salt, with which and sodium sulphate it is often adulterated. This salt is at once available as a *direct fertilizer*, and being very soluble in water is therefore liable to be washed from soils. Whenever practicable it should be applied as a top dressing to growing crops, and if possible the dressings should be given in two or three successive rations.

Nitrate of Soda or Chili Saltpetre.

Nitrate of soda is usually applied at the rate of from 100 to 200 pounds per acre on land previously dressed with farm-yard manure. To secure an even distribution, the nitrate should be previously well mixed with from three to five parts of fine loam or sand.

Much has been said and written about nitrate of soda exhausting the soil. This is all a mistake and is the outcome of incorrect reason-ing. Nitrate of soda does not exhaust soils. It does promote the development of the leafy parts of plants, and its effects are at once noticeable in the deep, rich green, and vigorous growth of crops. The growth of plants is greatly stimulated by its use for the nitrate in supplying an abundance of nitrogenous food to plants, imparts to them a thrift and vigor which enables their roots to gather in the shortest time the largest amount of other needed foods from a greater surface of surrounding soil. Nitrate of soda adds nothing of value to the soil but nitric acid. The thirty-seveu to forty per cent. of soda which it contains is practically of no use to agricultural plants. In the increased crop obtained by its use there must necessarily be more potash and phosphoric acid than would have been contained in a smaller crop on which the nitrate of soda had not been used. The increased consumption of phosphoric acid and potash is due to the increase in the weight of the crop. The office of the nitrate is to convert the raw materials of the soil into a crop; or we obtain by its use, as Dr. Griffiths has tersely said, "the fullest crop with the greatest amount of profit, with the least damage to the land."

How Used.—On cereals nitrate of soda should be used alone or mixed with dry superphosphate and applied as a top dressing.

On grass lands it may be applied as a top dressing at the rate of 150 to 200 pounds per acre.

Some of our most successful onion growers use nitrate of soda at the rate of from 500 to 700 pounds per acre, applying the nitrate in three successive top dressings, the last ration being given when the crop is about half grown.

Griffiths, in his "Treatise on Manures," gives the following formula containing nitrate of soda for use upon lands that are clover-sick :—

Nitrate of soda,	2½	hundredweight	equals	280	pounds.	
Wood ashes, . .	16	"	"	1792	"	
Gypsum, . . .	4	"	"	448	"	
	22½	"	"	2520	"	per acre.

For Potatoes (Griffiths' "Treatise on Manures") :—

Nitrate of soda,	1	hundredweight	equals	112	pounds.	
Sulphate of soda,	1	"	"	112	"	
	2			224	"	per acre.

From what is known of the fertilizing action of nitrate of soda, the following conclusions may be safely drawn, viz.:—

First. The nitrate of soda is, in most cases, a reliable manure for cereals, roots, and grasses, increasing the yield over other nitrogenous manures.

Second. Many crops grown with nitrate of soda mature from one to two weeks earlier than when grown with other nitrogenized manures.

Third. The best results are obtained by applying the nitrate to crops in fractional top dressings during the active stages of growth.

Fourth. Crops grown with nitrate of soda generally have a higher feeding value than those grown with other forms of nitrogen.

Fifth. Crops grown with nitrate of soda seem to resist the attacks of parasitic organisms better than those grown without its aid.

Sixth. Nitrate of soda does not exhaust the land.

Nitrate of Potash, known in chemistry as **potassium nitrate**, and commonly called saltpetre, is a valuable fertilizer both for the nitrogen and the potash which it contains. It occurs as an efflorescence on the soils of several hot countries, notably India, Egypt, Chili, and Peru. This substance was once used to some extent as a fertilizer, but the supply is now limited and the price so high, owing to its great demand in the manufacture of gunpowder, that it can no longer be used with profit in compounding manures.

Ammonia.

Ammonia is a compound formed by the chemical union of nitrogen and hydrogen. It is a very unstable, dark-blue liquid possessing a metallic lustre; its compounds closely resemble those of the alkali metals, potassium and sodium. The chief source of ammonia compounds used in agriculture is the ammonia obtained by the distillation of coal in making illuminating gas; it is also a bye product in coke-making.

Doctor Priestley first separated ammonia in the gaseous state in 1774. Scheele, in 1777, discovered that it contained nitrogen, and Bertholet ascertained its true composition in 1785.

Atmospheric Ammonia.—Ammonia occurs in minute proportions in the atmosphere in the forms of carbonate and nitrate, and in these forms is readily washed down in the rains, and fixed in the soil for the use of plants. Atmospheric ammonia is also absorbed by the leaves of plants, but the amount in the air is always very small, and the power of the leaves to appropriate the ammonia of the atmosphere is not believed to greatly influence the growth of vegetation. Florists and market gardeners take advantage of this power of the leaves of plants to absorb ammonia; by placing small lumps of carbonate of ammonia upon the steam pipes of greenhouses and conservatories the ammonia is volatilized and a vigorous growth promoted.

Chloride of Ammonia or *Sal Ammoniac* was first obtained from the vicinity of the temple of the Egyptian deity, Jupiter Ammon, in Libya, from which the name ammonia is supposed to have been derived. Chloride of ammonia is produced in Egypt and the East, from the soot formed in the burning of camels' dung. Egypt is believed to have been the country in which sal ammoniac was first manufactured, and from whence it was introduced into European commerce by the Venetians.

Sulphate of Ammonia is one of the most concentrated forms in which ammonia can be applied to crops. This salt is prepared in large quantities from the ammoniacal liquors of gas-works. Sulphate of ammonia, like nitrate of soda, is a most active and directly available plant-food, stimulating both a vigorous growth of foliage and root development, and enabling plants to collect in the shortest time other essential food elements from the soil.

On cereals, tobacco, potatoes, turnips, and root crops generally, it is used with great success. Its effects are most noticeable on loamy and clayey soils ; on limestone soils sulphate of ammonia should not be used.

The action of the lime of the soil is to liberate gaseous ammonia, much of which escapes into the atmosphere and is lost. On limestone soils nitrate of soda should be used as a source of nitrogen.

M. Ville, in his formulas, recommends the use of from 260 pounds to 354 pounds of sulphate of ammonia per acre, on grains ; and for the valuable agricultural grasses about 175 pounds per acre, applied as a top dressing after the early spring growth has fairly begun.

Both the chloride and the sulphate of ammonia have been recommended for steeping the seeds of cereals before planting, to hasten germination and to insure a better early and aftergrowth.

Ammoniacal or gas-liquor is an impure solution of carbonate and acetate of ammonia, together with minute quantities of ammonia in combination with sulphur and cyanogen. The amount of ammonia in gas-liquor is variable, but it is always a safe rule to dilute it with about five times its bulk of water before sprinkling upon growing crops, which is best done by means of a water-cart. It is a valuable manure for cereals, grasses, potatoes, and turnips. Ammoniacal liquor may be mixed with absorbent materials, like fine charcoal, saw-dust, peat, muck, etc , and then, if dissolved bone meal or superphosphate is added, an excellent complete manure is obtained, which may be spread broadcast or used in the drill. At those seasons when ammoniacal liquor should not be applied to the soil a very rich compost can be made by saturating about three thousand pounds of straw with one thousand gallons of the liquor and covering the mass with peat or loam. A violent oxidation takes place in which the temperature rises above 212° F., with the evolution of much carbonic acid and watery vapor. At the end of thirty days the mass should be carefully forked over and covered with fresh peat or loam.

When the fermentation is well managed a rich compost is obtained. (See illustration opposite.)

With a view to storing the nitrogen of ammoniacal liquor from the manufacture of gas, experiments by De Vogüè at Cosne (*Compt. Rend., 115, 1892, No. 1*) are of great practical interest from the fact that they indicate a convenient means of utilizing ammoniacal liquors in the vicinities of small cities. In these experiments straw and the ammoniacal liquor were used in about the proportions we have suggested, and the experiments were conducted in an apparatus which permitted the temperature to be observed and the evolved gases to be analyzed. At the beginning a violent oxidation took place, the temperature rising above 212° F., with the evolution of carbonic acid and copious amounts of watery vapor. The intensity of reaction reached the culminating point on the thirteenth day, but the evolution of carbonic acid continued with decreasing activity to the end of the operation, which was complete in about four and one-half months. The mass had decreased in weight a little more than one-third. It presented the appearance of half-rotted black manure. (See Experiment Station *Record,* Vol. IV, No. 3, 1892.)

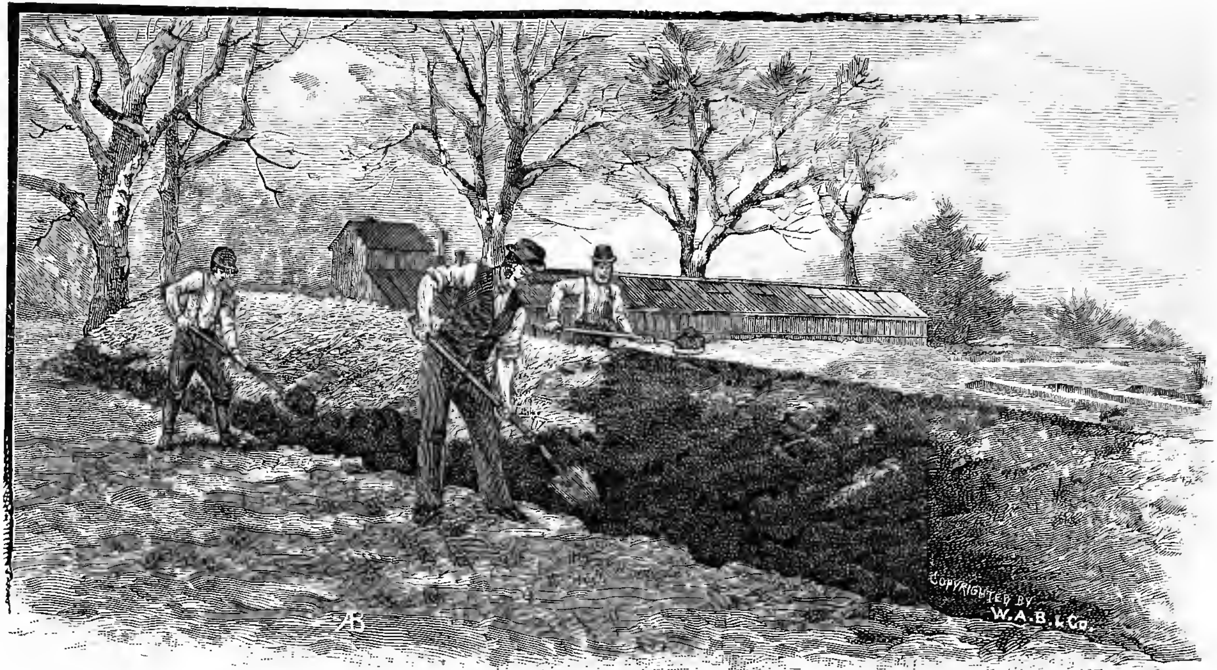
Guano.

Guano consists of the consolidated excrement of marine birds; it has accumulated through long periods of time, and has undergone slow decomposition by which a very complex chemical composition has been produced. The best guanos have been fonnd in rainless regions, and on barren granitic islands in tropical or sub-tropical seas. In the old Peruvian language guano signified dung. The modern term is from *huano,* a name given to guano by the Spanish conquerors of Peru.

The ancient Peruvians used guano in the cultnre of their arid soils for centuries before its uses were known to Europeans, and protected, by severe penal laws, the sea-fowl which deposited it on the granitic islands of their coasts; under the government of the Incas the destruction of these birds was punishable by death.

Alexander von Humboldt first observed the vast deposits of guano in Peru in 1804, and its importance in agriculture was soon afterward made known to the world by him.

Guano was first imported into the United States at Baltimore, in 1832, and in that and succeeding years was used by the planters of



High Straw Compost. (*From photograph taken at Fordhook Farm.*)

Maryland and of other Southern States. It was introduced into England by the Earl of Derby in 1841; in the next few years the general introduction of guano into the markets of the world gave a most powerful impetus to agriculture.

The Chincha Islands guano was the best introduced into commerce. It came from a group of islands of granitic formation in the rainless region on the coast of Peru, where it had accumulated for ages until the deposits varied in thickness from 75 to 200 feet. The percentage of nitrogen in the best Chincha Island guano ranged from fifteen to seventeen per cent. Nearly twenty-five per cent. of the entire weight of this guano was phosphate of lime, equivalent to about twelve per cent. of phosphoric acid. It was a **complete** fertilizer, rich in nitrogen, phosphoric acid, and potash. The supply of Chincha Island guano is now practically exhausted. Peruvian guano is still imported from other groups of islands on the Peruvian coast, but it lacks the high excellence of that brought from the Chincha Islands a quarter of a century ago.

The guano, as now imported into New York, averages from seven to eight per cent. of nitrogen, twelve to fifteen per cent. of phosphoric acid, and from two to three per cent. of potash.

Bolivia, Chili, Patagonia, Curacoa, Cuba, the Ichaboe Islands, and many islands of tropical and sub-tropical seas, export guano; but while all these manures have the same general origin, they are greatly inferior to the old Peruvian guano.

Two kinds of guanos are found in commerce:—

(1) *Nitrogenous guanos*, of which that from the Chincha Islands was the best type.

(2) *Phosphatic guanos*, or those which have lost all or nearly all of their nitrogen and potash by exposure to storms.

Nitrogenous guano is a very complex manure. It contains phosphate, carbonate, urate, and oxalate of ammonia, free uric acid, guanin, and various nitrogenized organic matters in small quantity. It is, indeed, the most complicated of all known fertilizers and is the most like animal manures in its action upon crops. Nitrogenous guano is an excellent manure for cereals, potatoes, and all root crops. It should be used at the rate of from 250 to 350 pounds per acre, with half the usual quantity of farm-yard manure. On winter grains about 125 pounds should be applied when the seed is sown, and the remainder in the spring.

The guano from the **Ichaboe Islands**, on the southwest coast of Africa, is one of the best nitrogenous guanos now obtainable. It consists of the fresh excreta of sea-fowl, collected by the inhabitants and stored in vats to prevent loss of nitrogen. Ichaboe Island guano contains from nine to twelve per cent. of nitrogen, and from twenty to twenty-two per cent. of phosphate of lime.

Nitrogenous guano is not a reliable fertilizer on dry, arid soils; it should be used on lands well supplied with moisture during the period of growth, and is, therefore, more certain in its fertilizing action on clays and moist loams. In dry seasons and on dry, sandy soils guano is liable to fail. The nitrogenous guano now sold does not equal that of twenty-five or thirty years ago. It is probably a sophisticated article, and may consist of varying grades of real guano mixed with sulphate of ammonia and other materials.

One of the very best ways of using nitrogenous guano is in the form of concentrated compost. The guano should be in a fine, powdery condition before admixture with peat, muck, or farm-yard manure.

Concentrated Guano Composts.

I.

Nitrogenous guano, ...	500 pounds.
Dry muck or peat (weathered and free from lumps), ...	1000 "

Compost in thin layers, and moisten each layer with liquid manure or water. Over the completed compost sprinkle a good coat of fine muck, peat, or land-plaster. Sow broadcast in the spring at the rate of from 1200 to 1600 pounds per acre.

II.

Nitrogenous guano, ...	600 pounds.
Farm-yard manure, ...	600 "
Peat, muck, or loam (dry and fine), ...	800 "
	2000 "

Compost and use as in I. Guano composts should be made under sheds and carefully protected from exposure to storms.

These formulas furnish complete manures in forms that give excellent results on a great variety of soils. The quantities here given per acre are those usually applied by intelligent farmers. Much larger quantities may be used with profit; in fact, in high farming it is no uncommon practice to use these concentrated composts at the rate of from one to one and a half tons per acre. They are the best forms in which to apply guano to sandy soils.

Rectified Guano.—Guano as now sold is usually treated with sulphuric acid before reaching the farmer, and is advertised by importers and manufacturers as "*Dissolved*" or "*Rectified*" guano.

The idea originated in treating with acid guano which had been damaged by contact with sea-water, with a view to selling the product as super-phosphate of lime. The fertilizer thus obtained proved of such excellent quality that the practice of rectifying guano, or rather of treating it with acid, has become common among importers. The manurial action of rectified guano is quicker than with that which has not been treated with acid. The calcium phosphate and guanin are rendered soluble and the ammonia is converted into sulphate of ammonia, a compound that is still soluble and not liable to waste by keeping.

Bat guano is the accumulated excreta of vast numbers of bats, and is usually found in caves and caverns. According to Dr. Voelcker bat guano contains nitrogen in three separate forms, viz., first, as organic matter; second, as ammonia salts; and third, in the form of nitrates. It also contains over six per cent. of phosphoric acid and twelve per cent. of lime. Considerable *bat guano* is sent into commerce from Texas.

SUBSTITUTES FOR GUANO.

The late Prof. J. F. W. Johnson, F. R. S., recommended the following substitute for guano:—

Bone dust,	7	bushels	per	acre.
Ammonia sulphate,	100	pounds	"	"
Common salt,	100	"	"	"
Sodium sulphate,	11	"	"	"
Wood ashes (unleached),	20	"	"	"

The following is given by Dr. Griffiths, ("Treatise on Manures"):—

Bone dust,	315	pounds	per	acre.
Pearl ash 20 pounds or wood ashes,	80	"	"	"
Common salt,	80	"	"	"
Sulphate of ammonia,	100	"	"	"
Sulphate of soda,	20	"	"	"
Nitrate of soda,	25	"	"	"
Sulphate of magnesia (crude),	50	"	"	"

Phosphatic Guano (see next chapter).

Blood.

Blood in its natural state is a quick-acting manure containing about eighty per cent. of water, two and a half to four per cent. of nitrogen and fractional parts of one per cent. of phosphoric acid and alkali salts. When diluted with from ten to twelve times its bulk of water, fresh blood is a valuable fertilizer for young fruit trees, and is also highly esteemed in horticulture.

The blood of animals slaughtered upon the farm, or that to be had from neighboring butchers, may be readily preserved by the use of lime, as follows:—

In a trough or shallow box thoroughly mix the blood with about five per cent. of its weight of dry, freshly slaked lime, and cover the mixture with a thin layer of lime. This mixture, when dry, can be kept for a long time without appreciable change. It may be applied directly to the land, or used in the compost heap.

In England farmers compost blood with peat-ashes and charcoal powder for use on the wheat and turnip crops, using about eight bushels of peat-ashes and charcoal powder to fifty gallons of blood.

M. Paul Marguerite-Delacharlonny, by means of acid ferric sulphate (acid sulphate of iron), has transformed blood into a solid and inodorous manure.

Dried blood is a highly concentrated nitrogenous manure which yields ammonia and nitric acid by gradual decomposition in the soil. It is a good manure for all nitrogen-consuming crops, and is effective on all soils, but is especially so on lands that are light, poor, and sandy. Practically, the dried blood of commerce is a mixture with other animal remains reduced to powder. When of good quality it contains about twelve to thirteen per cent. of moisture, ten to eleven per cent. of nitrogen, one to one and one-half per cent. of phosphoric acid, and about three-fourths of one per cent. each of potash and lime.

The ash of dried blood contains (Griffiths) :—

Sodium phosphate,	16.77
Calcium and magnesium phosphates,	4.19
Iron oxide, / " phosphate,	8.28
Sodium chloride (common salt),	59.34
Potassium "	6.12
Calcium "	3.85
Gypsum and loss,	1.45
	100.00

Cotton Seed. **Cotton Seed.**—The whole seed, as separated from the fibre, contains on an average, per ton, about one thousand pounds of hulls and the same quantity of kernels. From the latter about three hundred pounds of oil and seven hundred pounds of the pressed meal may be obtained.

The pressed cake is dried and ground after the oil has been removed, and, when used with judgment, is a highly valuable food for farm animals. When fed to cattle, nearly all the fertilizing value is retained in the manure. Cotton seed meal in a damaged condition is sometimes offered in the market at prices much below its manurial value. It is a complete fertilizer, decomposing rapidly in the soil, and is in excellent form for plant-food. When it can be purchased for $20 per ton or less, it is a cheap manure. Cotton seed meal contains from thirteen to fourteen per cent. of nitrogen, six per cent. of phosphoric acid, and about four per cent. of potash.

Castor Bean Pomace.

Castor bean pomace is a waste product in the manufacture of oil from the castor bean. It contains from five to five and one-half per cent. of nitrogen, one and one half to two per cent. of phosphoric acid, and one to one and one-half per cent. of potash. By many planters, castor pomace is believed to have a particularly favorable effect on the quality of the tobacco leaf.

FERTILIZERS FROM REFUSE ANIMAL MATTER.

Azotin and **Ammonite** (*cracklings*) are names given to preparations made from refuse animal matter, and are, practically, the same thing, being the meat and membrane from which the fat has been extracted at pork-packing and rendering establishments. They contain from ten to eleven per cent. of nitrogen and from three to three and one-half per cent. of phosphoric acid.

Tankage.

Tankage is the dried and ground meat, entrails, and other refuse of the slaughter-houses. These materials are steamed in tanks to remove the fat, and the residue is dried and ground into a kind of flesh-meal. Tankage when in good merchantable condition contains from ten to twelve per cent. of water, about seven per cent. of nitrogen and ten per cent. of phosphoric acid.

Fish Guano, Fish Scrap, Fish-meal, Fish-chum.—A highly nitrogenous manure, under these various names, is now largely used by the manufacturers of artificial fertilizers for mixing with superphosphates.

Prof. Storer says of this material: "There can be no question that farmers should buy this cheap material directly from the fishermen, and use it as such, *i. e.*, under its own name, instead of paying a comparatively high price for it, as is now often done after it has been admixed with superphosphates. I have myself found fish scrap to serve extremely well, as a substitute for barnyard manure, when used in conjunction with wood ashes or other potassic fertilizers."

The article usually sold in the European markets is made chiefly from the refuse of the large curing factories, and consists of the bones, heads, and offal that accumulate at the Norwegian cod fisheries.

The American fish scrap or fish guano is a by-product in the manufacture of oil from menhaden. These fish are taken in vast quantities along our coast for the oil which they contain, and after the extraction of the oil the *chum* is reduced to a fine, dry meal, and is sold as fish guano, or is used by the manufacturers of artificial manures for mixing with superphosphates.

Norwegian fish scrap, according to Arendt, contains :—

	Per cent.
Moisture,	17
Nitrogen,	$10\frac{1}{2}$
Phosphoric acid,	4
Organic matter,	12
Ashes,	11

The European manufacturers prepare a complete fertilizer by mixing the German potash salts with the Norwegian fish guano.

Griffiths recommends a manure of this composition, containing 5.5 per cent. of nitrogen (equal to ammonia), eleven per cent. of phosphates, and eight per cent. of potash, per acre, on cereals, roots, and leguminous crops, to be applied at the rate of 560 pounds per acre, sown broadcast and harrowed into the soil before sowing the seed in autumn or the early spring; and on pasture or grass land from 280 to 480 pounds per acre, to be sown broadcast during showery weather.

For potatoes, celery, cabbage, mustard, asparagus, radishes, lettuce, and tobacco the same author recommends the use of from 560 to 780 pounds per acre.

The waste materials of woolen and cloth mills contain varying percentages of nitrogen, sometimes ranging from five to nine per cent. When treated with sulphuric acid these waste materials form soluble manures.

Shoddy and Woolen Waste.

A considerable part of their nitrogen is also rendered soluble by superheated steam (Dr. Petermann). After evaporating the resulting liquid to dryness, a brown residue is obtained that is almost entirely soluble in water, and that has been found to be an excellent manure for beets, hops, and wheat. Perhaps the easiest way to convert woolen waste into manageable form for manure would be to digest the materials in sulphuric acid for two or three months and to compost the product with finely ground phosphate rock.

Hoof and horn-meal, hair, leather-waste, and feathers are all rich in nitrogeu. Hair, feathers, horn shavings, and leather-waste are of less value than most animal matters, owing to their nitrogeu being in forms that are not easily made available for crops.

CHAPTER XV.

MATERIALS USED IN MAKING ARTIFICIAL OR CHEMICAL MANURES.

THOSE CONTAINING PHOSPHATES.

Bones. The bones of animals are composed of two distinct and very unlike substances. One of these forms the hard, earthy framework of the skeleton and consists mostly of calcium phosphate; the other, a soft, jelly-like substance, called *ossein*, is composed of nitrogenous matter, which completely interpenetrates the solid, animal frame.

If a bone is soaked in dilute hydrochloric acid the earthy part will, in time, be dissolved, and there will be left a tough, elastic mass of animal matter containing much nitrogen. On the other hand, if the bone is burned until all the organic matter has been converted into gaseous products, and these have passed off into the air, a white, earthy residue, known as *bone-ash* or *phosphate of lime*, will remain.

Bone-ash. Bone-ash is but little used as a manure. The nitrogen of bones is lost in combustion, and the chief constituent of the ash is an insoluble phosphate of lime (insoluble calcium phosphate) equivalent to from thirty to thirty-five per cent. of phosphoric acid.

When applied to the land bone-ash is probably dissolved by the carbonic acid water of the soil, and, after having entered into combination with other mineral constituents, is finally taken up by the roots of plants.

Bones are used to some extent as fuel on the treeless plains of South America, whence the ash is imported into the United States and England. On most soils the fertilizing action of bone-ash is inferior to that of **ground bone**; the former is little used in this country except in making superphosphates.

Ground bone is a highly nitrogenized manure. It contains not only the earthy or mineral constituents of bones, but also the *ossein*, which speedily decomposes in soils containing an abundance of potash, yielding ammonia and other nitrogenous compounds at once available for crops. The products of this decay, carbonic acid, ammonia, etc., also act as solvents of the mineral parts of bones and of other plant foods present in the soil. Gronnd bone is known by various names, as *bone dust*, *bone flour*, and *bone meal*, according to the degree of fineness to which it is ground.

Ground Bone.

Ground bone should contain from 3 to 4 per cent. of nitrogen and from 20 to 25 per cent of phosphoric acid. It is liable to be adulterated with ground rock phosphate, ground oyster shells, coal ashes, gypsum, etc.

Before grinding bones are usually boiled or submitted to the action of steam to remove objectionable fatty substances which make grinding difficult and retard decomposition in the soil. Bone meal often fails on dry soils and on stiff, wet clays. It is most serviceable mixed with potash manures on soils "neither too light and dry, nor too close and wet" (Storer). Bone meal is much used for tobacco, turnips, potatoes, and all root crops. For these crops it may be used at the rate of from 600 to 1000 pounds per acre, intimately mixed with from 25 to 40 bushels of unleached wood-ashes.

Raw bone meal contains the natural fat or oil of bones. This fat is of no use to plants and hinders the decomposition of bone meal in the soil.

Dissolved Bone.—When bone or ground bone is treated with sulphuric acid a product is obtained known as *dissolved bone*, *acid phosphate*, or *superphosphate*.

By the action of the acid the insoluble phosphate of lime is converted mostly into soluble form which is immediately available for growing crops. Dissolved bone also contains some insoluble phosphates, and some of the phosphate rendered soluble by the acid in time reverts to a less soluble form. (Reverted phosphate of lime.)

Bone-black, also known as *bone-charcoal* and *bone coal*. We have already seen that when bones are burned in the open air a white insoluble residue, called bone-ash, is obtained. But when broken bones are submitted to destructive distillation, that is, are raised to a high heat in iron cylinders or retorts, from which the air is excluded, gas, water, oily and tarry matters, ammoniacal and other products are driven off from the bones, while bone-black remains in the retort. This consists of insoluble phosphate of lime intimately admixed with car-

Bone-black.

bon or charcoal. Fresh bone-black is a very porous substance and has the remarkable power of decolorizing liquids. It is used in enormous quantities for removing the coloring matter from raw or brown sugars, and for purifying chemicals. After a time bone-black ceases to be effective in clarifying liquids, and the spent black is then sold to the fertilizer manufacturers.

By treating the spent bone-black with sulphuric acid *dissolved bone-black* is obtained, which is a highly valuable phosphatic fertilizer, containing from 15 to 25 per cent., and in some instances 30 per cent., of phosphoric acid.

The Reduction of Bones on the Farm.

Many methods for decomposing bones by means of acid, potash salts, wood ashes, and lime have been published from time to time, but every process is troublesome and none can be commended as without fault; unless the decomposition is carefully conducted there is a very considerable loss of nitrogen. From the experience of those who have given the subject much practical study, it appears that the reduction of bone on the farm is accomplished with greater certainty and economy by the aid of the caustic alkalies, potash and lime, than by the use of sulphuric acid.

Prof. S. W. Johnson's method for the reduction of whole bone is as follows: "Arrange a circular layer of bones, closely laid, on a bed of loam a foot thick, under shelter; wet them from a watering-pot, and sprinkle them over with wood-ashes, enough to fill all the chinks; then give a coat of gypsum; put upon that a few inches of muck or loam, adding all along as much water as will moisten the earth and ashes, but not more than the mass can readily absorb; then place another layer of bones, with ashes, gypsum, loam, or muck, and water as before, until the heap is built up several feet; finally cover with loam, and keep moist by adding water from time to time, but not enough to run away from the bed. When the bones are sufficiently softened, mix well together with the loam used on the bed, and cover with loam."

The following method given by Prof. Storer ("Agriculture," Vol. I, page 256) is said to have originated in Russia: "In a trench three or four feet deep wood ashes and whole bones are piled in alternate layers, each about six inches thick. The lowest and uppermost layers are of ashes, and each layer of ashes is saturated with water as soon as it has been laid. Upright stakes are set in the trench at intervals of about three feet at the beginning, and they are withdrawn after eight or ten days' time. Into the holes which the stakes have left enough water is poured to saturate anew the ashes. At the end of two months, when the bones have become considerably softened, the heap should be thrown over, moistened, and allowed to ferment anew; and this process should be repeated at intervals, as often as may be needed. Five months in all, and perhaps three forkings over, will be sufficient to reduce the bones so completely that only some fragments will remain of the largest head and thigh bones. These will naturally be laid aside to be thrown into the next heap that is made."

Fermenting Whole Bones with Horse Manure.—A German method is as follows: "Soak the bones in water for several days, then pack them in a dung-pit layer by layer with horse manure, taking care to moisten each layer with the water in which the bones have been soaked, and with other water as well.

Fermenting Whole Bones with Horse Manure.

"Each layer of bones should be about three inches thick, and the layers of horse manure twelve inches thick. The heap is topped with loam.

"At the end of ten months the bones will be reduced and the mixture fit for use." (Storer's "Agriculture," Vol. I, page 253.) The following modification of this receipt has been found effectual on a small scale. Soak the whole bones for ten days in a strong solution of caustic potash, or a lye made from wood-ashes. Then interstratify the bones with horse manure as directed above. Moisten each layer with the solution or lye used for soaking the bones, and with water or liquid manure. Cover the top layer with a foot of loam, peat, or muck, and spread over this a layer of damp gypsum. This method is a good one where small quantities of bone are obtainable, as upon farms and in village communities.

Walderdorff recommends the following method for disintegrating whole bones by means of quicklime: "Ordinary bones which have been neither boiled nor broken are spread out in a layer six inches deep, and covered first with a layer of quicklime of equal depth, and then with a layer of loam. Other similar layers are piled above the first series until the heap has been built up to a convenient size, when it is covered with a thick layer of earth. Holes are then pierced in the heap and water poured in to slake the lime. As much lime is taken as will amount to about twice the bulk of the bones. A heap of this sort, which contained some eight thousand pounds of

Reducing Bone with Lime.

all sorts of bones, remained very hot for eight weeks, and in active fermentation ; the heat coming not only from the action of the water upon the lime, but from the action of the lime upon the bones. When the fermentation ceases the bones are said to be found in a brittle, friable condition, and the heap is finally shoveled over in order to mix the materials." (Storer's "Agriculture," Vol. I, pages 257–259.)

Reduction of Bone with Acid.

When bones are treated with sulphuric acid the insoluble calcium phosphate, as previously explained, is converted into soluble form, so that growing crops may make use of the phosphoric acid at once. The bones are ground to a powder and then treated with sulphuric acid (oil of vitriol) of the specific gravity of 1.66.

We do not advocate the reduction of bones by the use of acid on the farm. The process offers no advantages over the use of the caustic alkalies,—lime, and potash, and the risks of accidents are immeasurably greater. We give the following simple directions for the use of those who prefer home-made superphosphate :—

Construct a stout wooden trough ; six feet wide, two to 2½ feet deep, and of any desired length, coat the inside with pitch, or line with sheet lead (the latter is preferable).

On the bottom of this trough place a layer of bones broken into small pieces, and over them pour one-third of their weight of pump or spring water. To these add, *very cautiously*, sulphuric acid equal to one-half the weight of the bones. The contents of the trough are then thoroughly mixed with a long-handled wooden spade, and the mass is allowed to stand for three or four hours. The contents of the trough may then be removed to a manure pit or other sheltered receptacle, and covered with finely ground South Carolina rock or Thomas phosphate. At the expiration of six to eight weeks, if the mass is not sufficiently dry for handling, add enough finely ground mineral phosphate to make the product manageable and apply to the land.

Bone Meal and Wood-Ashes.—"Take one ton of bone meal and five barrels of hard wood-ashes, mix thoroughly in a water-tight tank and fill with water, all that will soak in. Let this mixture stand at least *two weeks*, and keep wet.

"*Do Not Let It Dry.*—At the end of two weeks mix the above with twice its bulk of muck and loam in equal parts Mix very thoroughly by machinery and pile in a heap to dry. *Do not let it dry enough to heat*, and keep it from the air as much as possible."

This formula is taken from the "Annual Report of the Maine State College Agriculture Experiment Station for 1889." The same report places the station valuation of this mixture at $8.24 per ton; but as the station valuation is usually about twenty per cent. less than the actual selling price of reliable factory-made superphosphates, it is conceded that the price of the article in question should be about $10 per ton. This fertilizer is sold by the manufacturer at his factory for $20 per ton cash.

The analysis as made by the Maine Experiment Station is :—

Moisture,	20.97
Nitrogen,	.81
Phosphoric acid, soluble,	..
" " insoluble,	2.94
" " reverted,	2.04
Potash,	.38

A fair estimate of price is made by the Maine Station, thus :—

Bone-meal,	2000 pounds, costing	$35 00
Ashes (5 barrels or 15 bushels, about 600 pounds),	600 " "	3 75
Muck, loam, and water,	6500 " "	...
	9100 " "	38 75
Selling price of 9000 pounds (4½ tons), at $20 per ton,		90 00
Difference between cost of bone-meal and ashes and selling price of fertilizer,		$51 25

Can the farmer afford to pay a difference of over $50 for having these materials treated and mixed when he can do the work just as well himself?

Phosphatic Guano.—Although in the phosphatic guanos the nitrogen compounds and the potash which they originally contained have been washed out by the rains, much of the phosphoric acid is in a form that can be more readily dissolved by the roots of plants and by the carbonic acid water of the soil than is the case with many of the finely-ground rock-derived phosphates. Phosphatic guanos, when finely powdered, do excellently for moist grass lands and in soils rich in humus, and are also excellent materials for working into composts or manure heaps. But the phosphatic guanos, of which the Jarves, Baker, and Howland Islands are types, are rarely applied directly to the soil. They are chiefly valuable for the phosphate of lime which they contain, and are used almost altogether in the manufacture of superphosphates

Phosphatic Guano.

Phosphatic rock and **South Carolina rock** are names by which mineral phosphates are most commonly known in the United States. Vast natural deposits of mineral phosphates occur in North and South Carolina, Georgia, and Florida. Two varieties abound in these States; the first is known as *river rock* phosphate, from the fact that it is found in the beds of rivers and under the mud accumulations of swamps. It is of a shining gray or bluish-black color, and very hard, but is easily ground, and then makes a good quality of phosphatic manure.

Mineral Phosphates.

The second variety, called *land rock* or *land phosphate*, is formed in perforated nodular masses of a light fawn or grayish-yellow color.

The river rock contains from twenty-five to twenty-eight per cent. of phosphoric acid and from thirty-five to forty-five per cent. of lime, and small quantities of iron, magnesia, soda, silica, alumina, etc.

The land rock contains from twenty-two to twenty-six per cent. of phosphoric acid, thirty-five to thirty-seven per cent. of lime, and small quantities of the other minerals found in the river rock.

These phosphatic rocks are always found in nodular (egg or kidney-shaped) form, and the nodules vary in size from several feet to the fractional part of an inch in diameter. In these deposits are contained the accumulated fossil remains of land and marine animals, which have undergone a long series of geological changes involving great transformations even in the mineral constituents themselves.

The nodular masses break easily and are ground to a fine powder before being subjected to the action of acid in making commercial fertilizers. When ground to an extremely fine powder mineral phosphates are called floats, and in that condition are sometimes used on the land without being treated with acid.

Basic Slag Phosphate or Thomas Slag.—This new source of phosphoric acid is a waste, or bye-product, incidental to the manufacture of pure Bessemer steel by what is known in metallurgical science as the *basic process*.

Basic Slag Phosphate, or Thomas Slag.

In the basic process the phosphorus of certain ores of iron is eliminated by the use of lime, and a phosphate of lime (tetra-calcium phosphate) is formed, which, when ground to an impalpable powder, possesses a high degree of solubility, and is an effective fertilizer.

Basic phosphate, or basic slag, is known in commerce under a number of names, as *Thomas phosphate*, *odorless phosphate*, *Thomas slag meal*, *basic iron slag*, *German phosphate slag*.

This material gets its more common name from the late Sidney Gilchrist Thomas, the discoverer of the basic process in England.

After many years of litigation, Jacob Reese, of Pennsylvania, was adjudged prior inventor of the process, and under the name of *odorless phosphate* basic slag phosphate is now manufactured at Pottstown, Pa., under the Reese patents. Following is the published analysis of the Pottstown product:—

Phosphoric acid,	21.37
Silica,	5.10
Magnesia,	5.90
Alumina,	4.01
Manganese oxide,	5.56
Iron,	12.00
Soda and potash,	.80
Lime,	45.26
	100.00

The phosphoric acid of basic slag phosphate, when finely powdered, is largely soluble in weak acids, and hence can be readily absorbed by the acid secretions of the roots of plants.

This manure is specially recommended by Dr. Griffiths for peat, clay, and sandy soils, also for moorlands and wet meadows.

Märcker recommends for spring sowing a mixture of one part superphosphate and two parts Thomas phosphate, as a most profitable manure for barley, oats, and beet-root.

Basic slag phosphate has proven particularly successful when used in connection with the potash products of the Stassfurt mines.

It can be mixed with nitrate of soda or the German potash salts, but such mixtures should only be made just before spreading on the land; this phosphate must not be mixed with sulphate of ammonia, as a part of the ammonia will be liberated and lost. English authorities recommend that basic slag phosphate, when used alone, be applied from six to eight weeks earlier than superphosphate, because of the greater solubility of the superphosphate; and that the basic phosphate be used in preference to superphosphate on wet, peaty, and marshy soils on account of its containing an excess of free lime, which neutralizes the organic acids of the soil. Dr. Paul Wagner recommends four- and one-half hundredweight (five hundred and four pounds) of basic slag phosphate per acre for general crops.

Dr. Griffiths, in his "Treatise on Manures," gives the following mixture containing basic slag phosphate as an excellent manure for potatoes upon clayey soils of medium quality :—

Superphosphate, ...	1	hundredweight or,	112	pounds.
Thomas slag (basic phosphate,) .	1	" "	112	"
Kainit, ...	½	" "	56	"
Nitrate of soda, ...	1	" "	112	"
			392	"

While basic slag phosphate probably ranks in availability with the superphosphates, farmers in purchasing this new source of phosphoric acid should insist on its being in the form of an inpalpable powder.

Apatite, caprolites, and phosphorites are other forms of mineral phosphates found in various parts of this country, and, in fact, throughout the world.

Apatite is a very hard mineral, found in New York and other States, and also in Canada and Norway. The Norwegian apatite is a better material for manure making than any of the American varieties, and is much used, for that purpose, in Europe.

Caprolites or coprolites resemble the Carolina phosphatic rocks, being nodular in form, but much smaller in size. They are found in France and England, and are used in those countries for making commercial fertilizers. Caprolites contain animal remains, such as scales, fish-bones, and teeth. They are believed to be the fossilized excrement of extinct animals. Contain from twenty-five to thirty-five per cent. of phosphoric acid.

Phosphorites are found in Spain, France, and Germany. The phosphorites of Spain, which were the first mineral phosphates ever used in agriculture, contain from thirty-five to thirty-nine per cent. of phosphoric acid.

CHAPTER XVI.

MATERIALS USED IN MAKING ARTIFICIAL OR CHEMICAL MANURES.

THOSE CONTAINING POTASH.

Wood-ashes.

Wood-ashes are not exclusively a potassium manure. In addition to the carbonate of potash they contain carbonate and phosphate of lime and magnesia, all of which are essential plant foods. The potash in wood-ashes varies from four to eight per cent., and the phosphoric acid from one to two per cent. If exposed to the weather, or leached, they rarely contain more than one to two per cent. of potash and about one per cent. of phosphoric acid.

Wood-ashes are signally effective on clover and other leguminous plants. As a top dressing on grass lands and pastures they encourage the growth of clover and the valuable agricultural grasses, and thus tend to crowd out weeds, moss, and worthless vegetation.

In England unleached wood-ashes are used largely on the turnip crop. The practice in England is to take of—

Wood-ashes, ...	850	pounds.
Bone meal, ...	650	"
	1500	"

The wood-ashes and bone meal are thoroughly mixed and drilled in at the rate of fifteen hundred pounds per acre. On clover wood-ashes should be used as a top dressing mixed with one-fourth to one-fifth their weight of land plaster.

The value of wood-ashes varies according to the sources from which they are obtained and the care with which they are stored. They are richer or poorer in fertilizing ingredients according to the kinds and parts of plants from which they have been derived, and the character of the soil upon which the plants grew. There is, however, but slight variation in the composition of wood-ashes from house fires.

The potash manufacturers of this country and Canada consider the average yield of potash from a bushel of forty-eight pounds of house-ashes should be a little over four pounds. Professor Storer has investigated this question, and, as a result of a number of analyses of samples of house-ashes, has given the following results (see "Agriculture," Vol. II, page 113) :—

Potash, per bushel of ashes, ...	$8\frac{1}{2}$ per cent.,	or $4\frac{1}{4}$	pounds.
Phosphoric acid, per bushel of ashes, .	2 "	" 1	"
		$5\frac{1}{4}$	"

worth from twenty to twenty-five cents. Professor Storer considers that from ten to fifteen cents addition may be allowed for the "*alkali*" power of the ashes. There is a prevailing opinion among farmers, and scientific men, too, that soft wood-ashes are worthless or nearly so. This is a mistake. The ashes from pine, poplar, and other soft woods are light and the yield of ash from these woods is extremely small; but weight for weight the ashes from soft woods are about as good for agricultural purposes as those from hard woods. Wood-ashes exert a decided influence upon the capillary powers of soils. Solutions of the alkaline carbonates, or the caustic alkalies, make dry soils more plastic and adhesive than pure water does. It is because of this peculiarity of the alkalies that it is often impracticable to till soils when large proportions of the alkalies are contained in them. Unless the alkalies be removed or decomposed, such soils cannot be brought into good condition. And the reverse is the case with open porous soils. Professor Storer cites a case in which a plot of light porous land was dressed during several years with large quantities of wood-ashes. The soil became firmly bound, and during all the years of the experiments the land was better supplied with water from below than adjacent plots that were not so treated. ("Agriculture," Vol. II, page 115.)

Prof. S. W. Johnson suggests that an imitation of leached wood-ashes be made by mixing together—

Fresh burned shell lime, ...	30	pounds.
Bone meal, ...	10	"
Kainit, ...	8	"

Equal to about one hundred pounds of leached wood-ashes. In many localities this mixture would be cheaper than leached ashes, and the mixture has this decided advantage, it will not contain the seeds of troublesome weeds.

Manuring with Wood-ashes.

Proportions recommended by J. J. H. Gregory, of Marblehead, Mass., in his excellent "Treatise on Fertilizers:"

Manuring with Wood-ashes.

For Cabbage and Cauliflower.—Per acre, from 125 to 200 bushels harrowed in early in the spring.

For Corn.—From 40 to 80 bushels per acre, harrowed in before planting, and, after covering the seed, from 15 to 28 bushels per acre spread on top of the hills.

For Cucumbers and Melons.—Harrow in 88 bushels per acre, and scatter a pint over each hill.

For Lawns, Meadows, or Pastures.—From 25 to 125 bushels per acre, in the fall or early spring, or soon after haying. If the latter number of bushels are used none will be required for several years.

In Laying Down to Grass.—From 45 to 225 bushels, in the summer or fall. The next year plant to potatoes, top dressing with from 12 to 18 bushels per acre. In the following year sow to wheat or rye, and lay down to grass. "No more fertilizer needed for eight or ten years when the largest quantity is used."

For Wheat, Rye, or Oats.—From 85 to 170 bushels spread broadcast in November and plowed just under the surface. In the spring plow deeper, throwing the ashes up to the surface; "or for the immediate crop 20 bushels may be harrowed in in the spring; but in the long run the larger use will be the more profitable."

For Onions.—From 45 to 250 bushels spread broadcast in the fall and plowed in just beneath the surface. Replow to the surface in the spring. If 250 bushels are used, 40 bushels will be sufficient for the second year, 60 bushels for the third, and 85 bushels for the fourth year.

For Strawberries.—Apply during the summer or early fall at the rate of from 40 to 125 bushels per acre, and spade in a little coarse bone meal (from 100 to 200 pounds per acre) before the plants begin to grow in the spring.

Caution in the Purchase of Wood-ashes.—Recent analyses show widely varying chemical composition and fertilizing value in Canada and other wood-ashes. The difference in value is so great without any change in appearance that it is no longer safe to purchase wood-ashes without chemical examination and a guaranty from the seller of the actual contents of potash and phosphoric acid.

Lime-kiln and Brick-kiln ashes have very little value as manures. They are largely mixed with lime dust, clay, or brick dust.

Coal ashes contain a trace of potash and some lime. They have no fertilizing action, but from their mechanical effect may be of slight service on stiff clay soils, on reclaimed bogs, or on soils rich in humus.

Cotton-seed Hull Ashes.—These are a comparatively new source of potash. They come from the cotton-producing States of the South, being a product incidental to the manufacture of cotton-seed oil. At the factories the hulls, after being removed from the seed, are used as fuel, and the ashes thereby obtained are a valuable fertilizer, containing from five to ten per cent. of phosphoric acid, from eighteen to thirty per cent. of potash, and about ten per cent. of lime. Cotton-seed hull ashes are much used as manures by tobacco growers, and also by the makers of commercial fertilizers.

Cotton-seed Hull Ashes.

Tobacco stems are valuable both for the potash and the nitrogen which they contain. They are finely ground, and are used to some extent in the manufacture of commercial fertilizers. Tobacco stems contain from one to two-and-one-half per cent. of nitrogen, from three to seven per cent. of potash, and a little phosphoric acid.

Kainit is the most common of a class of mineral salts containing potash which are found in vast deposits near the Prussian town of Stassfurt, in Northern Germany. Kainit is comparatively a low grade mixture of the chlorides and sulphates of potassium, sodium, and magnesium, with some impurities.

Kainit.

A good commercial kainit contains from twelve to fourteen per cent. of potash. This salt is most effective on light, sandy, and peaty soils ; on heavy soils the more concentrated potash salts are preferable. Kainit is valuable for cereals, cabbage, beans, peas, clover, potatoes, and root crops generally. It should not be used on tobacco, as the chlorides which it contains impair the combustibility of the tobacco-leaf.

Kainit is used at the rate of from 300 to 700 or 800 pounds per acre, and the best time to apply it to the land is in the fall in conjunction with nitrogenous and phosphatic manures.

Chloride or muriate of potash is the principal potash fertilizer imported into this country from Germany. This salt is also a product of the Stassfurt mines, and is most commonly known under the name of *muriate of potash.* As imported into this country it is somewhat variable in composition, but contains, approximately, fifty per cent. of actual potash. Its chief use is as a source of potash in commercial fertilizers. It is the richest and

Chloride or Muriate of Potash.

most soluble of all the German potash salts, and may be used with decided profit on all crops but tobacco. Apply in the fall at the rate of from 200 to 350 pounds per acre.

Carnallite, kieserite, krugite, and sylvanite are names given to other German potash salts, all of which, in chemical composition, bear more or less similarity to kainit.

Sulphate of potash, also known as potassium sulphate and potassic sulphate. The chief source of supply is the Stassfurt mines. Pure sulphate of potash contains about fifty pounds of potash in every one hundred pounds of the salt, but the best "*high-grade*" sulphate imported into this country for agricultural purposes contains only from twenty-eight to thirty five per cent. of potash. Sulphate of potash has been found to be beneficial to leguminous and some root crops on which the muriate cannot be used without injury. It is the best adapted of all the German potash products for tobacco, sugar beets, sugar-cane, and potatoes. Apply in the fall at the rate of from 150 to 300 pounds per acre.

Sulphate of Potash.

There is an American product incident to the manufacture of muriatic acid against which the farmer needs to be warned. This is an acid sulphate (sesquisulphate), from which the excess of sulphuric acid has not been expelled by roasting. It is a corrosive salt, unfit to be applied directly to the land, but is an excellent thing for composting with weeds.

Sulphate of potash is the best form of potash salts for applying to heavy soils.

Sulphate of potash and magnesia, more commonly known as *double manure salt*, is similar to the sulphate in its effects upon soils and crops. It is a valuable preserver of manures, with which when mixed it forms an excellent fertilizer for tobacco. It may be used on all crops requiring potash fertilization at the rate of from 200 to 500 pounds per acre. Apply to the land in the fall.

CHAPTER XVII.

ECONOMY IN THE PURCHASE OF FERTILIZERS.

HOME MIXTURES.

Economy in the purchase of fertilizing materials or of agricultural chemicals depends not only on the price paid per pound or per ton, but also on the relation existing between the price paid and the amounts and forms of the nitrogen, phosphoric acid, and potash furnished. To illustrate, we will assume that two fertilizers, both made from the best class of materials, are offered by a manufacturer at thirty dollars and thirty-five dollars per ton. The first is guaranteed to contain three per cent. of nitrogen, seven per cent. of available phosphoric acid, and three per cent. of potash. The second is guaranteed to contain five per cent. of nitrogen, ten per cent. of available phosphoric acid, and seven per cent. of potash.

We have but to calculate the commercial values of these fertilizers, as directed in Chapter XIII, to ascertain their true relation to the prices asked by the manufacturer. By simply multiplying the actual content of nitrogen, phosphoric acid, and potash by the trade values for these constituents in mixed fertilizers, we find that there is an actual difference of nearly $14 in their commercial values, whereas the difference in price made by the manufacturer is only $5.

No. 1 has a commercial value of less than $24, while No. 2 has a commercial value of nearly $37 per ton; or in No. 1 we are asked $1.50 per 100 pounds for a fertilizer worth about $1.16, and in No. 2 we are asked $1.75 per 100 pounds for a fertilizer worth $1.85.

The fertilizing materials in the higher priced fertilizer are about thirty-three per cent. cheaper than those in the lower priced article.

As a general rule *the more concentrated the form of fertilizing materials in commercial fertilizers, or the higher the grade of unmixed raw materials purchased by the farmer for home-mixing, the greater will be the saving in actual cost.*

The higher the grade of materials the less will be the expense for freight, mixing, and spreading upon the land.

There are these decided advantages about the mixing of materials at home, viz., each raw material can be separately examined, and if there is any cause for suspecting inferior forms of nitrogen, phosphoric acid, or potash, samples may be sent to the State Experiment Station for analysis. The detection of error or fraud is more certain and much easier in unmixed raw materials than in mixed fertilizers. Another important advantage of home-mixing is the opportunity afforded the intelligent farmer to adapt the composition of a fertilizer to the special soil requirements of his land and to the wants of the crop to be grown. And, lastly, home-mixtnres have, as a rule, proved to be much cheaper than ready-made fertilizers. However, the economy of home-mixing should in every instance be determined by actual calculation.

Nitrogen, phosphoric acid, and potash, as we have already seen, are necessary for the complete development of farm crops, and are the constituents most likely to be deficient in cultivated soils; different crops have different capacities for consuming these plant foods, so that when no increase in crop production follows a rational application of one, two, or all three of these coustituents the soil evidently contains them in sufficient stores to develop crops to limitations fixed by season and existing climatic conditions. By a careful study of the capacities of different crops for using nitrogen, phosphoric acid, and potash, we may, within reasonable limits, approximate the quantities, which, under average conditions of crop, soil, and season, should be restored to the land to balance the consumption of growing crops.

Tables exhibiting the average amounts of nitrogen, phosphoric acid, and potash found profitable for different crops are given in Chapter XIX.

In using complete fertilizers, or in special crop feeding, it should be borne in mind that lands in a high state of cultivation generally respond to heavy fertilization with much greater immediate profit than those of ordinary fertility.

Home-Mixing.

The following formulas, together with the analyses and valuations, are taken from the Twelfth Annual Report of the New Jersey State Agricultural Experiment Station for 1891.

They prove most conclusively that farmers can make even mixtures of raw materials which in mechanical condition compare favorably with the best manufactured brands of complete fertilizers, and that the cost of mixing by the manufacturers may be saved without increasing the cost of farm labor.

The results also show that in this particular instance there was a total difference of thirty-one per cent. in cost in favor of home-made mixtures.

"In making these mixtures two important points were taken into consideration. First, that the *value* of a complete fertilizer depends upon the kind and quality of the essential ingredients, nitrogen, phosphoric acid, and potash contained in it; and, second, that the higher the grade of the materials used in making the mixture the less will be the expenses of freight and handling per pound of essential ingredients.

"High-grade materials were used in the preparation of all of these mixtures, and the different combinations were, as a rule, adopted after a careful stndy of the plant-food requirements of the soil for different crops.

Chemical analyses were made of all the materials used in the mixtures.

FORMULAS.

For General Crops :—

Nitrate of soda, ...	200	pounds.
Sulphate of ammonia, ...	200	"
Peter Cooper's bone, ...	400	"
Bone black superphosphate, ...	400	"
South Carolina rock, ...	600	"
Muriate of potash, ...	200	"
	2000	"

For Potatoes :— I.

Nitrate of soda, ...	100	pounds.
Sulphate of ammonia, ...	200	"
Ground fish, ...	200	"
Ground bone, ...	400	"
Bone black superphosphate, ...	400	"
South Carolina rock, ...	400	"
Muriate of potash, ...	200	"
High-grade sulphate of potash, ...	100	"
	2000	"

II.

Nitrate of soda, ...	250	pounds.
Sulphate of ammonia, ...	200	"
Dried blood, ...	200	"
Bone-black superphosphate, ...	900	"
High-grade sulphate of potash, ...	450	"
	2000	"

III.

Nitrate of soda,	250	pounds.
Tankage,	500	"
Bone-black superphosphate,	800	"
High-grade sulphate of potash,	450	"
	2000	"

IV.

Nitrate of soda,	250	pounds.
Sulphate of ammonia,	400	"
Bone-black superphosphate,	800	"
Double sulphate of potash and magnesia,	675	"
Land plaster,	500	"
	2625	"

For Peach Trees :—

Nitrate of soda,	300	pounds.
Dissolved bone,	400	"
South Carolina rock superphosphate,	700	"
Muriate of potash,	600	"
	2000	"

"The mechanical condition of the mixtures was all that could be desired; they were fine, dry, and in every respect equal to *the best brands of mixed fertilizers on the market in the State.*"

WHAT WAS SHOWN BY THE ANALYSES.

"The main objects of the analyses were to determine, first, whether farmers using the ordinary tools and labor of the farm could make even mixtures of the materials used, and, second, whether in the cost of actual plant food home-mixing presented any advantages over the usual method of buying manufactured fertilizers.

"In the following table the actual composition of the different mixtures is compared with the calculated composition of a perfect mixture in each case, the analyses of the raw materials and the weights used in the formulas serving as a basis for the calculation. The estimated commercial value of the mixture is also compared with the estimated value of an even mixture of the materials used.

TABLE OF ANALYSES AND GUARANTEES.

Station Number.	Total Nitrogen.			Total Phosphoric Acid.			Potash.			Valuation at Station's Price.	
	Guaranteed.	Found.	Difference.	Guaranteed.	Found.	Difference.	Guaranteed.	Found.	Difference.	Mixture.	Materials Used.
3960	4.01	4.01	. . .	13 34	13.69	+0.35	6.43	5.40	—0.03	$35.70	$36.34
4002	4.43	4.21	—0.22	10.69	11.45	+0.76	7.65	6.96	—0.69	33.92	37.10
3986	5.12	4.92	—0.20	7.00	7.20	+0 20	11.16	11.29	+0.13	40.03	40.16
3978	3.55	3.87	+0.32	9.50	9.57	+0.07	11.25	11.79	+0.54	39.19	36.18
4246	4.59	4.52	—0.07	4.73	5.04	+0.31	6.86	7.22	+0.36	32.49	30 92

"The plus, +, and minus, —, signs in the difference column. indicate the percentage more or less found by analyses than was guaranteed.

"There is a very close agreement between the calculated and actual composition of these mixtures; the widest variation is 0.32 per cent. for nitrogen, 0.76 per cent. for phosphoric acid, and 0.69 per cent. for potash. In home-made mixtures the value of exactness in composition depends very largely upon the value of the relative proportions of the plant food applied to the soil for the different crops. A pound per acre, more or less, of either nitrogen, phosphoric acid, or potash would probably not be observed in the results secured from their use. Taking the widest variation in the above mixture it would require 313 pounds to make a difference of one pound in the nitrogen, 133 pounds in the phosphoric acid, and 145 pounds in the potash. The mixtures do contain practically the amount and proportion of plant food that they were intended to furnish, and, *therefore, show that farmers are able to make even mixtures of such raw materials as the market affords.*

"A comparison of the commercial value per ton of the materials used with that of an actual mixture also confirms the results of analyses, the average difference between the two values being but thirteen cents per ton. This is a severe test, since in three cases out of the five the three forms of the expensive element nitrogen were used, each of which has a different commercial value, and also because in three mixtures ground bone or tankage was used, materials which in themselves are valued in a different manner than when they are used in a mixed fertilizer.

Valuation.

"In Nos. 3960 and 4002 the cost of raw materials included freight charges to point of consumption; in the others the average cost of freight was $1.00 per ton. The cost of mixing was variously estimated, ranging from 50 cents to $1.50 per ton. In the table showing cost and value of the mixtures $1.00 per ton has been assnmed as the average cost of mixing.

Station Number.	3960	4002	3986	3978	4246	4207
Cost per ton..............	$29.06	$30.60	$36.76	$33.00	$27.74	$30.10
Freight and mixing......	1.00	1.00	2.00	2.00	2.00	2.00
Total cost per ton........	30.06	31.60	38.76	35.00	29.74	32.10
Station's value...........	35.70	33.92	40.03	39.19	32.49	33.45
Value exceeds cost........	5.64	2.32	1.27	4.19	2.75	1.35

"The average value per ton of these mixtnres is $2.92, or 8.9 per cent. greater thau their cost at point of consumption. This sum, while worthy of careful consideration by the farmers, by no means represents the actual saving in the cost of plant food that this method of buying offers over the usnal hap-hazard method of buying on credit from small dealers and without regard to the source of materials used or reliability of the manufacturer. The following results shown by stndy of the analyses of complete fertilizers, made in 1890, clearly illustrate this point, viz., that the value per ton of the average of over 200 brands of complete fertilizers was $28.37 and the average selling price $34.64, a difference of $6.27 per ton, or a cost of 22.1 per cent. greater than the value; this added to the 8.9 per cent. would make a total difference in favor of home mixtures of 31 per cent.; in other words, *an amount of plant food in a mixture that would cost on the average $100 when bought in the form of raw materials and mixed at home would, on the average, cost $131 when bought in the usual manner in the form of manufactured brands.*

Formulas for Mixtures.

From the Eleventh Annual Report of the New Jersey State Agricultural Experiment Station, 1890, pages 39 and 40.

No. 1. Wheat, Oats, Rye, Corn. (*To make 1000 pounds.*)

Nitrate of soda................100 lbs.	Containing lbs. of nitrogen...... 40		Application per acre 400 lbs.
Sulphate of ammonia.......... 50 lbs.			
Dried blood, high-grade.......100 lbs.			
Bone-black Superphosphate....600 lbs.	Phosphoric acid, 96		
Mnriate of potash............150 lbs.	Potash.......... 75		

No. 2. Potatoes and Roots. (*To make 1000 pounds.*)

Nitrate of soda	125 lbs.	Containing lbs. of nitrogen...... 51	Application per acre, 400 lbs.
Sulphate of ammonia	100 lbs.		
Dried blood, high-grade	75 lbs.		
Bone-black superphosphate	400 lbs.	Phosphoric acid, 64	
High-grade sulphate of potash,	100 lbs.	Potash..........102	
Double sulphate of potash	200 lbs.		

No. 3. Garden Produce. (*To make 1000 pounds.*)

Nitrate of soda	100 lbs.	Containing lbs. of nitrogen...... 54	Application per acre, 600 lbs.
Sulphate of ammonia	125 lbs.		
Ammonite, high-grade	100 lbs.		
Bone-black superphosphate	400 lbs.	Phosphoric acid, 64	
Muriate of potash	110 lbs.	Potash.......... 98	
Double sulphate of potash	165 lbs.		

No. 4. Fruit Trees. (*To make 1000 pounds.*)

Nitrate of soda	250 lbs.	Containing lbs. of nitrogen...... 47	Application per acre, 500 lbs.
Ground bones	200 lbs.	Phosphoric acid, 80	
Bone-black superphosphate	250 lbs.		
Muriate of potash	300 lbs.	Potash..........150	

"The following formula may be substituted for No. 4, with the additional application in the spring of 100 pounds per acre of nitrate of soda :—

(*To make 1000 pounds.*)

Ground bone	300 lbs.	Containing lbs. of nitrogen...... 11	Application per acre, 350 lbs.
Bone-black superphosphate	300 lbs.	Phosphoric acid, 108	
Muriate of potash	400 lbs.	Potash..........200	

No. 5. Clover, Beans, Peas, etc. (*To make 1000 pounds.*)

Bone-black superphosphate	500 lbs.	Containing lbs. of phosphoric acid, 80	Application per acre, 500 lbs.
Muriate of potash	150 lbs.	Potash..........120	
Kainit	350 lbs.		

"The best forms of fertilizing materials were used in the preparation of these formulas, as they will probably be found to be the cheapest in the majority of cases. These are, as a rule, in good mechanical condition, and can be bought direct from the leading dealers or manufacturers, and should in all cases be accompanied by a guaranteed composition. It is important that the materials should be evenly mixed. This can be easily done by forming, on the barn floor or other dry and level place, a series of layers of the different materials, and working the heap over from the edge outward, breaking all the lumps in the process ; a few turnings will suffice to answer the purpose. Screening is also advisable if suitable apparatus is at hand. It is not claimed that the buying of raw materials and mixing at home is the best and cheapest method of getting fertilizers under all conditions ; however, the important points in favor of the system will bear repeating, viz.:—

"1st. That a definite knowledge of the quality of the materials is secured ; and

"2d. That where farmers know what they want, and unite in purchasing car lots, there is a decided saving in the cost of plaut food."

The elaborate investigations of the New Jersey Experiment Station plainly indicate that there is a decided saving in the cost of plant food by buying the unmixed raw materials and mixing them at home.

Farmers and farmers' clubs should give the method a practical trial. They will have the ready co-operation of their State experiment stations in so far as it may be necessary to test by analyses the materials to be used.

A matter of paramount importance in purchasing raw materials for home mixture is to take advantage of market fluctuations in laying in a season's supply. Marked variations in cost occur, and a saving of from ten to twenty per cent. is often the result of buying early in the year before the spring work has fully begun, and there is no better time for mixing than during the idle winter months.

Some Good Home Mixtures.

1. Mixture for General Use. (Connecticut Experiment Station.)

Dissolved bone-black,	834	pounds.
Tankage,	666	"
Sulphate of ammonia,	208	"
Muriate of potash,	292	"
	2000	"

2. Mixture for Corn. (Connecticut Experiment Station.)

Ground bone,	700	pounds.
Tankage,	500	"
Dissolved bone-black,	1000	"
Sulphate of ammonia,	300	"
Muriate of potash,	250	"
Double sulphate of potash and magnesia,	200	"
	2950	"

3. For Corn. (Connecticut Experiment Station, 1890.)

Ground bone,	500 pounds.
Muriate of potash,	200 "
Sulphate of potash,	100 "
Dissolved bone-black,	500 "
Tankage,	350 "
Nitrate of soda,	500 "
	2150 "

4. For Potatoes. (Connecticut Experiment Station, 1890.)

Muriate of potash,	200 pounds.
Sulphate of potash,	300 "
Tankage,	750 "
Nitrate of soda,	350 "
Dissolved bone-black,	500 "
	2100 "

5. For Corn. (Connecticut Experiment Station, 1890.)

Dissolved bone-black,	1668 pounds.
Tankage,	1334 "
Muriate of potash,	334 "
Sulphate of potash,	668 "
Sulphate of ammonia,	333 "
Fine ground bone,	500 "
	4837 "

6. For Potatoes. (Connecticut Experiment Station.)

Dissolved bone-black,	1668 pounds.
Tankage,	1534 "
Muriate of potash,	334 "
Sulphate of potash,	668 "
Sulphate of ammonia,	333 "
	4537 "

7. Mixture for Turnips and Grass. (Connecticut Experiment Station.)

Dissolved bone-black,	800 pounds.
Tankage,	400 "
Sulphate of potash,	600 "
Sulphate of ammonia,	150 "
Nitrate of soda,	300 "
Fine ground bone,	250 "
	2500 "

8. For Potatoes. (Connecticut Experiment Station.)

Blood, bone, and meat,	800	pounds.
Bone,	400	"
Dissolved bone-black,	550	"
Sulphate of ammonia,	50	"
Nitrate of soda,	50	"
Sulphate of potash,	100	"
Muriate of potash,	50	"
	2000	"

9. Mixture for General Use. (Connecticut Experiment Station.)

Tankage,	450	pounds.
Sulphate of ammonia,	170	"
Dissolved bone-black,	1000	"
Muriate of potash,	280	"
Bone (meal),	100	"
	2000	"

The foregoing formulas from the annual reports of the Connecticut Agricultural Experiment Station for the years 1889 and 1890 are all **Home-made mixtures,** prepared by farmers themselves. Commenting on these and other home mixtures analyzed at the Connecticut Experiment Station, the report for 1889 says :—

"The mechanical condition of these mixtures is excellent, and their chemical composition corresponds with that of the ready-mixed "**special fertilizers**" and ammoniated superphosphates of the highest grade.

"The *actual* cost in many, if not all, of these cases has been very considerably reduced by special rates which are given where a number of farmers give a cash order for a car lot or more.

"The average cost of materials in these home-mixed fertilizers has been thirty four dollars and twenty-three cents per ton delivered at the purchaser's freight station. Two dollars will fully cover the cost of screening and mixing. (From a dollar to a dollar and a half is the estimate of those who have done the work.) The average valuation has been thirty-four dollars and eighty five cents per ton. On the basis of these figures the average difference between cost and valuation has been less than six per cent. In factory-mixed goods it has averaged in round numbers eighteen per cent.

"There is no longer any question as to the expediency of home-mixing in many cases. From such raw materials as are in our markets, without the aid of milling machinery, mixtures can be and are annually made on the farm which are uniform in quality, fine, and dry, and equal in all respects to the best ready-made fertilizers."

CHAPTER XVIII.

FORMULAS FOR FERTILIZERS.

GENERAL FARM CROPS.

The best farmers have abandoned the idea that they can get along with farm-yard manure. The history of agriculture in all old countries proves the utter falsity of the notion. Farm-yard manure costs too much ; we can produce better manures with less labor much more cheaply. We must have chemical manures, and use them liberally.

Under the best systems of culture there is some periodic waste from all cultivated lands, and the way to repair that waste is not by spasmodic applications of chemical manures, not by doling out an occasional scanty ration to the hungry soil, but by systematic replacement of the natural loss. The food materials of soils are washed into streams and rivers, crops are sold from the land, and millions of tons of fertilizing materials taken from our fields are emptied into the sewers of great cities, and from the sewers are washed into the sea. The ocean is a great natural reservoir into which we are continuously pouring the fertility of our lands, and from the ocean we should draw no inconsiderable part of the supplies required for the maintenance of soil fertility.

The scavenger fish of the sea feed upon the vast deposits of sewage and on the infusorial life which it supports, and to these fish, which annually migrate to our shores, we should look for cheaper nitrogen and phosphoric acid. Apropos of the now threatened extinction of the menhaden fisheries, Mr William H. Bowker, in an address before the Massachusetts Agricultural Society (*New England Homestead*, December 8, 1892), gave the following interesting statistics, which convey some significance of the importance of this industry to farmers :—

"QUANTITY OF FISH SCRAP HARVESTED.

Year.	*Tons.*	*Year.*	*Tons.*
1874,	50,976	1883,	45,166
1875,	53,625	1884,	68,863
1876,	51,245	1885,	41,135
1877,	61,144	1886,	18,395
1878,	103,096	1887,	22,630
1879,	96,622	1888,	28,044
1880,	70,795	1889,	50,218
1881,	32,619	1890,	41,512
1882,	27,581	1891,	27,677

Summary.	*Menhaden.*	*Waste Fish.*	*Total.*
Total product, tons, ...	891,343	150,000	1,041,343
Containing plant food (nitrogen and phosphoric acid), tons, . .	106,829	27,500	134,329
Value of this plant food, ...	$25,856,762	$500,000	$30,356,762

"This quantity of plant food is too enormous to be comprehended readily. The 134,329 tons would supply all the nitrogen and more than enough phosphoric acid for 700,000,000 bushels of potatoes—four times the average crop of the United States. Or it would be sufficient (potash excepted) for 160,000,000 bushels of corn, or 108,000,000 bushels of wheat, or 5,000,000 tons of hay."

This great industry is now threatened ostensibly for the purpose of protecting food-fishes and preventing the extinction of the menhaden, but those whose capital is invested, and whose interests would suffer most heavily financially by the ruin of the fisheries, are not the men who are asking legal protection for the fish, nor have they any fears that the menhaden will become extinct so long as the present methods of fishing are continued. There is a grave suspicion that the sportsmen and the bluefish will be the chief beneficiaries under the proposed new laws, and until the farmer can see some tangible prospects of cheaper bluefish for his table, or is at least convinced that the blue fish are worth more for food than the menhaden are for fertilizers, he might safely frown down any proposed State or national legislation which means to increase the cost of every pound of nitrogen and phosphoric acid which he spreads upon his fields. If all the nitrogenous and phosphatic fertilizers used in the world were manufactured from fish, it is doubtful if the consumption would keep pace with the supply, and were it possible for us to use all the predatory fish for manures we certainly could never catch them. There is about as much danger of the methods of fishing as practiced in our coast waters to-day exhausting the predatory and scavenger fish of the sea as there is likelihood of our clover patches exhausting the free nitrogen of the air. Farmers can no longer depend on farm yard manure alone for plant-food, and the sea is a cheap and inexhaustible source of supply.

"One of the most serious points at issue between science and agricultural practice at present," says Professor Wrightson, "appears to be the comparative values of farm-yard manure and artificial fertilizers. So far as absolute experiment goes, the evidence seems to be in favor of the application of the latter, while, on the other hand, the preponderating opinion among farmers is on the side of farm-yard manure."

The author's own experience and observation, in so far as it applies to general farming, leads him to favor a rational use of chemical and farm-yard manures, together with systematic composting and green manuring as the best means for maintaining a high state of soil fertility.

There is some well-founded cause for the prejudice among farmers against commercial manures.

The use of artificial fertilizers has been accompanied by an amount of empiricism which seems incredible in this practical, matter-of-fact age; and it is, perhaps, due to this fact, as much as to chronic aversion to innovation, that farmers, as a class, are prejudiced against the use of chemical manures.

Were it possible in every case, or in any case, to determine, under the varying conditions of soil, crop, and season, just what were the most economical forms and quantities of nitrogen, phosphoric acid, or potash, or of other plant foods that would produce the most profitable crop, the prejudice against artificial fertilizers would speedily die, but unfortunately to this question an accurate or definite answer is impossible.

If this be true, and it most certainly is true, farmers may with just propriety ask: "How, then, are we to learn the crop-producing capacity of soils or the economic value of any given mixture of raw materials?"

There is but one solution to this problem, and for that solution both the farmer and the chemist must appeal to the soil.

It is by rationally conducted experiment that the food requirements of soils and crops are ascertained; the most carefully constructed formulas simply indicate the best forms of raw materials for particular crops and soils, and are based not on theoretical estimations alone, but on the known specific effect which certain forms of plant food have upon certain plants and soils under average conditions of season and culture. Thus we use sulphate of potash for potatoes, tobacco, and sugar-beets, because this salt produces larger and better crops of these products than the muriate (chloride) of potash. For the same reason we use the nitrogen of nitrate of soda for wheat, rye, barley, oats, tomatoes, and asparagus ; or the sulphate of ammonia for spinach ; the chlorides of the Stassfurt minerals for peach trees and small fruits, and basic slag phosphate for grasses on meadows and wet pastures.

The most the chemist can do is to ascertain, by comparative research, under varying conditions of soil, season, climate, and culture, the best forms and proportions of plant food for particular crops. The farmer must interpret and apply these researches intelligently to his own conditions ; he must abandon the hap-hazard practice of using costly manures because they contain all the required elements of plant nutrition, or because they have produced good crops for a neighbor, or have been recommended by an agent or a friend, or because the formulas in this volume and others contain nitrogen for nitrogen-consuming crops, and phosphates and potash for those requiring large rations of phosphoric acid or potash. Farming must be regarded not as a game of chance, but as a business, and the soil as a laboratory in which raw materials are to be worked up into finished marketable products. We can no longer afford to fertilize on the advice of our neighbor or depend on his success in the use of chemical manures ; his advice and the results of his experience should not be despised, for we may find them serviceable in more ways than one, but if we wish to bring our lands to a high state of productiveness, we must, like the chemist, find the key to success in the soil. We must observe closely and experiment intelligently.

The formulas which follow will be found helpful to the farmer in his effort to increase the productive powers of his soil. He should not follow blindly in the path we have marked out for him, nor hesitate to alter the constituents of a formula to meet local field wants as revealed by soil tests or by experience.

Agriculture is an experimental science not limited by strict rule, and our best formulas are largely empirical. Those which follow are drawn from the ablest sources and represent careful field studies on a great variety of crops and soils, conducted by earnest, patient workers, laboring for the advancement of agricultural science.

Asparagus, *per acre.*—

Dissolved bone meal, ...	100 pounds.
Basic slag phosphate, ...	200 "
Kainit, ...	300 "

Nitrate of soda, ...	180 pounds.
Dissolved bone meal, ...	120 "
Dried blood, ...	40 "
Dissolved bone-black, ...	140 "
Muriate of potash, ...	100 "
Kainit, ...	220 "

Barley, *per acre.* (Purdue University Agricultural Experiment Station.)

Sulphate of ammonia, ...	235 pounds.
Dissolved bone-black, ...	140 "
Muriate of potash, ...	62½ "

Beans, *per acre.*—

Sulphate of ammonia, ...	50 pounds.
Dried blood, ...	100 "
Dissolved bone-black, ...	500 "
Muriate of potash, ...	250 "

Lima Beans, *per acre.*—

Nitrate of soda, ...	50 pounds.
Dried fish (ground), ...	300 "
Dissolved bone meal, ...	100 "
Dissolved bone-black, ...	200 "
Dissolved South Carolina rock, ...	50 "
Muriate of potash, ...	200 "

1. **Beets,** *per acre.*—

Nitrate of soda, ...	400 pounds.
Superphosphate, ...	400 "
Muriate of potash, ...	100 "

Adapted to market gardening, generally insuring increased size of roots, and quick maturing crops.

2. **Beets,** *per acre.*—

Nitrate of soda, ...	100 pounds.
Sulphate of ammonia, ...	100 "
Dissolved South Carolina rock, ...	100 "
Dissolved bone-black, ...	100 "
Muriate of potash, ...	80 "

Buckwheat, *per acre.*—

Nitrate of soda,	160 pounds.
Dissolved South Carolina rock,	160 "
Muriate of potash,	100 "

Buckwheat, *per acre, when land is to be seeded down.*—

Nitrate of soda,	160 pounds.
Dissolved South Carolina rock,	160 "
Basic slag phosphate,	140 "
Muriate of potash,	100 "

Cabbage, *per acre.* (B. Dyer.)

Nitrate of soda,	224 pounds.
Bone meal (fine),	112 "
Superphosphate,	448 "
* Common salt,	336 "

Top dress with the nitrate of soda.

Cabbage and Cauliflower, *per acre.*—

Nitrate of soda,	200 pounds.
Sulphate of ammonia,	125 "
Dissolved bone meal,	200 "
Dissolved bone-black,	200 "
Muriate of potash,	125 "
Wood-ashes, unleached,	150 "

Farm-yard manure,	10 tons.
Nitrate of soda,	100 pounds.
Sulphate of ammonia,	100 "
Dissolved bone meal,	200 "
Dissolved bone-black,	150 "
Dissolved South Carolina rock,	100 "
Muriate of potash,	100 "
Wood-ashes,	35 bushels.

Cantaloupes, *per acre.* (Georgia Experiment Station.)

Cotton-seed meal,	400 pounds
Superphosphate,	800 "
Muriate of potash,	100 "

Cotton-seed meal,	400 pounds.
Dissolved bone meal,	400 "
Dissolved bone-black,	400 "
Muriate of potash,	100 "

---

* Kainit at the rate of 700 pounds per acre would furnish 240 pounds of common salt and 100 pounds of potash.

Cantaloupes, *per acre.* (*Continued.*)

Nitrate of soda,	100 pounds.
Tankage,	300 "
Dissolved South Carolina rock,	400 "
Dissolved basic slag phosphate,	300 "
Muriate of potash,	100 "

Carrots, *per acre.*—

Nitrate of soda,	300 pounds.
Superphosphate,	400 "
Muriate of potash,	100 "

Nitrate of soda,	160 pounds.
Sulphate of ammonia,	100 "
Dissolved bone meal,	140 "
Dissolved South Carolina rock,	100 "
Muriate of potash,	80 "

Celery, *per acre.*—

Nitrate of soda,	100 pounds.
Sulphate of ammonia,	300 "
Dissolved bone meal,	300 "
Dissolved bone-black,	320 "
Muriate of potash,	100 "

Sulphate of ammonia,	200 pounds.
Dissolved bone meal,	100 "
Dried blood,	100 "
Dissolved bone-black,	200 "
Muriate of potash,	100 "

Clover and all Leguminous Crops, *per acre.*

Nitrate of soda,	100 pounds.
Dissolved bone-black,	300 "
Kainit,	400 "

Apply the nitrate of soda in the spring after heavy rains are over; dissolved bone-black and kainit at planting.

Cow Peas, *per acre.* (Georgia Experiment Station.)

Nitrate of soda,	80 pounds.
Superphosphate,	160 "
Muriate of potash,	80 "

Nitrate of soda,	75 pounds.
Superphosphate,	175 "
Kainit,	175 "

Peas, *per acre.*—

Sulphate of ammonia, ...	50 ponuds.
Dissolved bone meal, ...	500 "
Dried blood, ...	100 "
Muriate of potash, ...	250 "

Corn, *per acre.* (Maine Experiment Station.)

Sulphate of ammonia, ...	150 pounds.
Dissolved South Carolina rock, ...	500 "
Muriate of potash, ...	100 "

Soils, heavy loams in pasture from six to nine years.

Cotton seed meal, ...	500 pounds.
Cotton-seed hull ashes, ...	500 "

Corn.

The following advice to farmers taken from the Report of the Hatch Experiment Station, Massachusetts Agricultural College, will apply to many of the New England and Middle States, or wherever farmers have devoted a large share of their lands to the growth of pasture grasses and forage crops :

"*a.* In breaking up sod land for corn, particularly that which is in fair condition, but which has been under ordinary farm management, if fertilizers only are to be used, apply those which are rich in potash. Use materials which will supply 80 to 100 pounds of actual potash, from 25 to 30 pounds of phosphoric acid, and from 15 to 20 pounds of nitrogen per acre.

"*b.* If a special corn fertilizer is to be used, apply only a moderate quantity, say 400 to 500 pounds per acre, and use with it about 125 pounds of muriate of potash. It is believed this combination will produce as good a crop as 800 to 1000 pounds of 'corn fertilizer ;' and it will cost considerably less.

"*c.* With ordinary barn yard or stable manure for corn use potash. I would recommend using about four cords of manure and 100 pounds of muriate of potash per acre.

"*d.* For fodder or ensilage corn use either in fertilizers or with manures abont one-fourth more potash than above recommended.

"*e.* In our experiments all fertilizers and manures have been applied broadcast and harrowed in, and I believe this is the best method.

"*f.* Although I recognize the danger of giving empirical directions of a general nature, the resnlts of our work lead me to recommend with considerable confidence any one of the following mixtures per acre for corn :—

I.

Muriate of potash,	175 pounds.
Dissolved bone-black,	175 "
Nitrate of soda,	100 "

II.

Muriate of potash,	175 pounds.
Plain superphosphate,	150 "
Bone meal,	100 "
Dried blood,	175 "

III.

Wood-ashes,	1500 pounds.
Bone meal,	100 "
Nitrate of soda,	100 "

IV.

Wood-ashes,	1500 pounds.
Dry ground fish,	400 "

V.

Muriate of potash,	175 pounds.
Dry ground fish,	400 "

"The ashes, bone meal, or fish should be applied very early in spring or late in winter. Apply all these fertilizers broadcast and harrow in. Do not mix a long time before use, especially important in case of Nos. III and IV." (William P. Brooks, Agriculturist, Hatch Experiment Station, *Bulletin*, No. 14, May, 1891.)

Cotton, *per acre.* (South Carolina Experiment Station.)

Nitrate of soda,	330 pounds.
Acid phosphate,	160 "
Muriate of potash,	100 "

Cotton-seed meal,	100 pounds.
Dissolved South Carolina rock,	200 "
Kainit,	300 "

Cotton-seed meal,	150 pounds.
Basic slag phosphate,	300 "
Kainit,	100 "

Nitrate of soda,	250 pounds.
Acid phosphate,	150 "
Muriate of potash,	75 "

Cotton, *per acre.* (Georgia Experiment Station.)

Nitrate of soda, ...	130 pounds.
Dissolved South Carolina rock, ...	468 "
Muriate of potash, ...	78 "

In a series of valuable experiments conducted by the Georgia Experiment Station, season of 1891, the foregoing formula gave the most profitable returns. The crop was planted on land previously in pea-vines. Apropos of results we quote from *Bulletin*, No. 16, Georgia Experiment Station, February, 1892 :—

"Pea-vines furnish the most reliable and by far the cheapest means of restoring our worn soils and of advancing them to a much higher productiveness than they possessed when in the virgin condition. But pea-vines will not grow luxuriantly on a poor, unfertilized soil. Therefore the true policy of our Southern farmers should be to plant peas and other leguminous crops, such as clover, peanuts, burr clover, vetches, etc., fertilizing with phosphates and potash ; convert the product of these into pork, beef, butter and milk, mutton ; return the manure to the land. Then plant in cotton or corn or small grain, using the stable manure obtained as above, supplemented by a judicious application of commercial fertilizers.

"The higher the condition into which a soil may be brought by renovating crops, and stable manure, the more certainly and profitably will it respond to large doses of fertilizers."

Cotton, *per acre.*—

Cotton-seed meal, ...	275 pounds.
Kainit, ...	75 "
Superphosphate of lime, ...	200 "

Cotton, *per acre.* (South Carolina Experiment Station.)

Nitrate of soda, ...	330 pounds.
Acid phosphate, ...	160 "
Muriate of soda, ...	100 "

Cucumbers, *per acre.*—

Nitrate of soda, ...	200 pounds.
Sulphate of ammonia, ...	120 "
Dissolved bone meal, ...	200 "
Dissolved bone black, ...	200 "
Muriate of potash, ...	120 "
Wood-ashes (unleached), ...	360 "

Cucumbers, *per acre.* (*Continued.*)

Farm-yard manure,	10 tons.
Nitrate of soda,	100 pounds.
Sulphate of ammonia,	100 "
Dissolved bone meal,	200 "
Dissolved bone-black,	150 "
Dissolved South Carolina rock,	100 "
Muriate of potash,	100 "
Wood-ashes,	350 "

Grass, *per acre.*—

Sulphate of ammonia,	100 pounds.
Dried blood,	150 "
Superphosphate,	400 "
Muriate of potash,	150 "

For Clover-Sick Land, *per acre, as a top dressing.* (Dr. Griffiths.)

Nitrate of soda,	336 pounds.
Sulphate of lime,	560 "
Unleached wood-ashes,	2240 "

Pasture Land, *per acre.*—

Raw ground bone,	200 pounds.
Basic slag phosphate,	300 "
Uuleached wood-ashes, from 30 to	100 bushels.

Laying Down Land to Grass, *per acre.*—

Coarse ground bone (steamed),	300 pounds.
Basic slag phosphate,	300 "
Uuleached wood-ashes, from 150 to	250 bushels.

Meadows, *per acre.*—

Thomas slag,	300 pounds.
Kainit,	600 "

Hungarian Millet, *per acre.* (J. J. H. Gregory.)

Sulphate of ammonia,	50 pounds.
Dissolved bone,	400 "
Muriate of potash,	150 "

Sulphate of ammonia,	75 pounds.
Dissolved bone-black,	325 "
Muriate of potash,	100 "

Hemp, *per acre.*—

Nitrate of soda,	160 pounds.
Dissolved bone-black,	280 "
Kainit,	400 "

Hemp, *per acre.* (Kentucky Experiment Station.)

Nitrate of soda,	160 pounds.
Acid phosphate,	320 "
Muriate of potash,	160 "

Sulphate of ammonia,	120 pounds.
Acid phosphate,	320 "
Muriate of potash,	160 "

Lettuce, *per acre.*—

Nitrate of soda,	100 pounds.
Sulphate of ammonia,	300 "
Dissolved bone meal,	300 "
Dissolved bone-black,	320 "
Muriate of potash,	100 "

Sulphate of ammonia,	200 pounds.
Dissolved bone meal,	100 "
Dried blood,	100 "
Dissolved bone-black,	200 "
Muriate of potash,	100 "

Mangels, *per acre.*—

Nitrate of soda,	240 pounds.
Dissolved South Carolina rock,	280 "
Sulphate of potash (high grade),	200 "

Nitrate of soda,	300 pounds.
Dissolved bone-black,	250 "
Sulphate of potash (high-grade),	200 "

(Dr. Griffiths.)

Nitrate of soda,	112 pounds.
Superphosphate,	448 "
Kainit,	112 "
Common salt,	224 "
Iron sulphate,	56 "

Melons, *per acre.*

Nitrate of soda,	200 pounds.
Dissolved South Carolina rock,	800 "
Muriate of potash,	100 "

Adapted to market gardening at the South.

Oats, *per acre.* (Georgia Experiment Station.)

Cotton-seed meal,	320 pounds.
Superphosphate,	280 "
Muriate of potash,	160 "

Oats, *per acre.* (*Continued.*)

Nitrate of soda,	120 pounds.
Basic slag phosphate,	120 "
Dissolved South Carolina rock,	120 "
Muriate of potash,	160 "

Onions, *per acre.* *High fertilization.*

Nitrate of soda,	500 pounds.
Dissolved bone-black,	200 "
Basic slag phosphate,	200 "
Unleached wood-ashes,	200 bushels.

Sow the wood-ashes broadcast in the fall and plow lightly into the upper soil. Replow the ashes to the surface in the spring and give a light dressing of very short farm-yard manure, or, better still, of poultry manure or rich old compost. Mix the dissolved bone-black and basic slag phosphate just before use and sow broadcast. Harrow in the manure or compost and mixed phosphates, and when the young plants begin to grow give them a top dressing of nitrate of soda (applied broadcast) at the rate of 100 pounds per acre, and continue these applications of the nitrate about once every three weeks.

Potatoes, *per acre.* (New Jersey Experiment Station.)

1.	Dried blood,	280 pounds.
	Bone-black,	320 "
	Sulphate of potash,	160 "
2.	Dried blood,	280 pounds.
	Bone-black,	320 "
	Muriate of potash,	160 "
3.	Farm-yard manure,	10 tons.
	Nitrate of soda,	100 pounds.
	Bone black,	160 "
	Sulphate of potash,	80 "

The three foregoing formulas from the Twelfth Annual Report of the New Jersey Experiment Station, 1891, gave the largest returns in bushels in comparative trials with chemical and farm-yard manures. The results in the order of the best financial returns were: First, with chemical manures alone (formula No. 1); second, chemical and farm-yard manures (formula No. 3); and, third, with farm-yard manures alone at the rate of twenty tons per acre.

Nitrogen in these experiments was more effective in the form of dried blood than in the form of nitrate of soda. Kainit was less effective than either sulphate or muriate of potash, nor did the sulphate produce larger yields than the muriate. Sulphate of potash, however, gives a rich, nutty flavor to potatoes that is not developed by the other German potash salts.

Dr. Griffiths ("Treatise on Manures") has obtained far better results with potatoes on clayey soils of medium quality by using equal parts of superphosphate and finely ground basic slag phosphate (Thomas' phosphate) than by using twice the quantity of superphosphate and no basic phosphate.

Potatoes, *per acre.* (Maine Experiment Station.)

Sulphate of ammonia,	150 pounds.
Dissolved South Carolina rock,	150 "
Muriate of potash,	100 "

On dry, slaty loam; good potato land.

Sulphate of ammonia,	75 pounds.
Dissolved bone-black,	325 "
Muriate of potash,	100 "

Potatoes Following a Manured Crop, *per acre.*—

Dissolved bone-black,	340 pounds.
Muriate of potash,	160 "

Potatoes, *per acre.*—

Cotton-seed meal,	350 pounds.
Superphosphate,	320 "
Muriate of potash,	300 "

Pumpkins and Squashes, *per acre.*—

Nitrate of soda,	100 pounds.
Sulphate of ammonia,	250 "
Dissolved South Carolina rock,	500 "
Muriate of potash,	150 "

Farm-yard manure,	10 tons.
Nitrate of soda,	100 pounds.
Sulphate of ammonia,	100 "
Dissolved bone-black,	400 "
Muriate of potash,	150 "
Wood-ashes, unleached,	250 "

Rye, *per acre.*—

Cotton-seed meal,	320 pounds.
Dissolved South Carolina rock,	280 "
Muriate of potash,	160 "

Rye, *per acre.* (*Continued.*)

Nitrate of soda,	120 pounds.
Basic slag phosphate,	120 "
Dissolved South Carolina rock,	120 "
Muriate of potash,	160 "

Sugar Cane, *per acre.* (Louisiana Experiment Station.)

1.	Cotton-seed meal,	500 pounds.
	Acid phosphate,	500 "
	Kainit,	100 "

On pea-vine crop turned under.

2.	Cotton seed meal,	500 pounds.
	Acid phosphate,	250 "

On pea-vine crop turned under.

3.	Cotton-seed meal,	500 pounds.
	Acid phosphate,	250 "
	Kainit,	100 "

On pea-vine crop turned under.

Sweet Potatoes, *per acre.* (New Jersey Experiment Station.)

1.	Farm yard manure,	10 tons.
	Nitrate of soda,	100 pounds.
	Bone black,	160 "
	Sulphate of potash,	80 "
2.	Dried blood,	280 pounds.
	Bone-black,	320 "
	Muriate of potash,	160 "

Experiments with sweet potatoes by the New Jersey Experiment Station, season of 1891, point to the following general conclusions :—

"1. That the yield of sweet potatoes may be very profitably increased by the use of chemical manures alone.

' 2. That a combination of chemical and barn-yard manures is especially useful.

"3. That nitrogen is a valuable ingredient in the fertilizers for this crop.

"4. That organic forms of nitrogen, as dried blood, are more desirable than nitrate of soda.

"5. That muriate of potash is more useful than the other commercial forms."

We suggest the following modification of the first formula for sweet potatoes, *per acre*:—

Farm-yard manure, ...	10 tons.
Dried blood, ...	140 pounds.
Bone-black, ...	160 "
Muriate of potash, ...	75 "

Sweet Potatoes, *per acre*. (Georgia Experiment Station.)

1.	Cotton-seed meal, ...	360 pounds.
	Superphosphate, ...	320 "
	Muriate of potash, ...	120 "
2.	Cotton-seed meal, ...	360 pounds.
	Superphosphate, ...	320 "
	Kainit, ...	640 "
3.	Nitrate of soda, ...	400 pounds.
	Superphosphate, ...	400 "
	Muriate of potash, ...	100 "
4.	Dissolved bone meal, ...	250 pounds.
	Dissolved bone black, ...	100 "
	Cotton-seed hull ashes, ...	50 "

Tobacco, *per acre*.—

Nitrate of soda, ...	140 pounds.
Dissolved South Carolina rock, ...	260 "
Sulphate of potash (high grade), ...	180 "

Tobacco, *per acre*. (Kentucky Experiment Station.)

Nitrate of soda, ...	160 pounds.
Superphosphate, ...	320 "
Sulphate of potash, ...	160 "

See Appendix, page 1.

Tomatoes, *per acre*.—

Nitrate of soda, ...	200 pounds.
Dried blood, ...	100 "
Cotton-seed meal, ...	300 "
Dissolved bone-black, ...	400 "
Dissolved South Carolina rock, ...	400 "
Muriate of potash, ...	100 "

Tomatoes, *per acre*. (Georgia Experiment Station.)

Nitrate of soda, ...	400 pounds.
Superphosphate, ...	800 "
Muriate of potash, ...	200 "

Tomatoes, *per acre.* (New Jersey Experiment Station.)

1.	Nitrate of soda,	160 ponnds.
	Dissolved bone-black,	320 "
	Muriate of potash,	160 "
2.	Nitrate of soda,	160 pounds.

No. 2 gave the best results on land in a good state of cultivation and that had previously received liberal fertilization. The resnlts of three years' experiments by the New Jersey Experiment Station lead to the following general conclusions :—

"1. That maximum yields of tomatoes depend upon a full supply of immediately available nitrogen.

"2. That the nitrogen in itself is not a complete fertilizer ; and,

"3. That to economically use commercial manures the farmer must know the average capacity of his soil for the crop."

Tomatoes, *per acre.* (Georgia Experiment Station.)

Cotton-seed meal,	400 ponnds.
Superphosphate,	800 "
Muriate of potash,	100 "

Turnips, *per acre.*—

Sulphate of ammonia,	225 pounds.
Superphosphate,	450 "
Cotton-seed hull ashes,	225 "

Turnips, Swede, or Ruta Baga, *per acre.*—

Nitrate of soda,	180 pounds.
Dissolved bone-black,	360 "
Muriate of potash,	140 "

Nitrate of soda,	200 pounds.
Dissolved bone meal,	150 "
Dissolved bone-black,	150 "
Muriate of potash,	100 "

Wheat, *per acre.*—

Dissolved bone meal,	130 pounds.
Snlphate of ammonia,	80 "
Muriate of potash,	50 "

Apply dissolved bone and muriate of potash in the fall, and one-half the sulphate of ammonia when the grain is sown and remainder in the spring.

Wheat, *per acre.* (Georgia Experiment Station.)

Cotton-seed meal, ...	300 pounds.
Acid phosphate, ...	100 "
Muriate of potash, ...	25 "

Nitrate of soda, ...	180 pounds.
Dissolved bone-black, ...	180 "
Muriate of potash, ...	80 "

One-third the nitrate of soda in the fall.

CHAPTER XIX.

FORMULAS FOR FERTILIZERS.

ORCHARDS, GARDEN FRUITS, AND VEGETABLES.

Phosphoric acid and potash are the fertilizing constituents most likely to be deficient in the soils of orchards and of lands devoted to small fruit culture. In the fertilization of such soils mixtures containing two per cent. of nitrogen, eight to ten per cent. of phosphoric acid, and from ten to twelve per cent. of potash will generally be found most efficient. Dissolved bone meal or dissolved bone-black acts quickly, but coarse steamed bone is more generally used, and its fertilizing action, though less quick, is extended through a period of several years.

Basic slag phosphate, used in connection with dissolved bone meal,* has, in recent experiments, proven to be a very effective fertilizer for fruits, especially so for small fruits and peach trees affected by *yellows*.

General Formulas for All Fruit Trees.

Per acre.—

I.

Sulphate of ammonia,	50 pounds.
Sulphate of maguesia,	25 "
Muriate of potash,	100 "
Dissolved bone-black,	425 "

II.

Nitrate of soda,	100 pounds.
Unleached wood-ashes (about 575 pounds),	12 bushels.
Sulphate of magnesia,	25 pounds.
Sulphate of lime (land plaster),	50 "
Basic slag phosphate,	200 "

Peach Trees, *per acre.* (New Jersey Experiment Station.)

1.	Nitrate of soda,	150 pounds.
	Superphosphate,	350 "
2.	Muriate of potash,	150 pounds.

* The basic slag phosphate should be applied alone late in the fall and the dissolved bone meal early in the following spring. These materials should not be mixed before spreading upon the land, owing to the presence of free lime in the basic slag phosphate.

Peach Trees, *per acre.* (*Continued.*)

3.	Nitrate of soda,	150 pounds.
	Superphosphate,	350 "
	Muriate of potash,	150 "

Strawberries and Small Fruits, *per acre.*—

Dissolved bone meal,	200 pounds.
Unleached wood-ashes,	130 "

Apply the wood-ashes late in the summer or early in the fall, and harrow in the bone meal early in the spring.

Small Fruits, *per acre.* (*Mr. J. H. Hale, of Connecticut, Report of U. S. Dept. Agr., 1891.*)

Wood or cotton-seed hull ashes,	200 bushels.
Fine ground bone,	3000 pounds.

A method of fertilizing fruit trees, in vogue in Holstein, Germany, is suggestive and not unworthy of trial. The trees receive no cultivation and the fruit is said to be large, sound, and produced in abundance.

Every two years a few holes are dug in the ground about four or five feet from the trunk of the tree, and about one foot deep.

"These holes are filled with liquid manure about four times during the winter months. For small trees the liquid is diluted with an equal quantity of water, and, of course, the holes are dug closer to the trees. Small fruits of all kinds, as well as vegetables, are likewise fertilized with diluted liquid manure, using an old street sprinkling wagon for this purpose. If there is more liquid manure than is required for these purposes, it is carted on the meadows, which show the effect in a very short time." (*American Agriculturist,* February, 1892.)

Strawberries, *per acre.* (New Jersey Experiment Station.)

Nitrate of soda,	200 pounds.
Precipitated phosphate,	500 "
Kainit,	1000 "

Kainit and phosphate applied in the fall; nitrate of soda sown broadcast in the following spring after the plants were well started, but before any bloom had appeared. Care should be taken to apply the nitrate when the leaves are dry.

Strawberries, *per acre.* (Georgia Experiment Station.)

Cotton-seed meal,	500 pounds.
Acid phosphate,	1000 "
Muriate of potash,	250 "

Apply late in the summer or early in the fall. One hundred pounds of nitrate of soda may be used in connection with this mixture, sown in the spring.

FOR GENERAL GARDEN PRODUCE.

I.

Nitrate of soda,	200	pounds.
Sulphate of ammonia,	200	"
Dried blood,	100	"
Dried fish,	100	"
Dissolved bone meal,	800	"
Dissolved bone-black,	200	"
Muriate of potash,	400	"
	2000	"

Contains $5\frac{1}{2}$ per cent. of nitrogen, 9 per cent. of phosphoric acid, and 10 per cent. of potash. May be used at the rate of from 300 to 1200 pounds per acre.

II.

Nitrate of soda,	200	pounds.
Dried blood,	200	"
Dried fish,	200	"
Dissolved bone black,	800	"
Muriate of potash,	200	"
Wood-ashes (unleached),	400	"
	2000	"

Contains $3\frac{1}{3}$ per cent. of nitrogen, $7\frac{1}{2}$ per cent. of phosphoric acid, and $6\frac{1}{3}$ per cent. of potash. Use as in I.

III.

Nitrate of soda,	150	pounds.
Dissolved bone meal,	600	"
Dissolved bone-black,	350	"
Muriate of potash,	300	"
Kainit,	400	"
Wood-ashes (unleached),	200	"
	2000	"

Contains nearly 2 (1.9) per cent. of nitrogen, 8 per cent. of phosphoric acid, and 11 per cent. of potash. Well adapted for use on gooseberries, currants, and all fruit-bearing vines; also for garden vegetables in connection with composts and farm-yard manure. Use on fruits at the rate of from 400 to 700 pounds per acre; on garden crops from 300 to 1000 pounds per acre in addition to moderate dressings of compost or farm-yard manure.

Proportions of Nitrogen, Phosphoric Acid, and Potash, and Quantities of Fertilizer Per Acre Recommended for Crops.

Unleached wood-ashes and high-grade sulphate of potash are always intended, when used in these tables.

Crop.	Per Cent. of				Best Form for Crop.		
	Nitrogen.	Available Phosphoric Acid.	Potash.	Pounds Per Acre.	Nitrogen in	Phosphoric Acid in	Potash in
Asparagus..................	4 to 5	6 to 7	7 to 9	400 to 800	Nitrate of soda. Dried blood. Dissolved bone meal.	Dissolved bone-black. Basic slag phosphate.	Wood-ashes and kainit.
Barley......................	5 to 6	7 to 8	3 to 5	250 to 600	Nitrate of soda. Sulph. ammonia.	Dissolved bone-black.	Wood-ashes and muriate.
Beans......................	1 to 2	6 to 8	7 to 9	400 to 800	Sulph. ammonia. Nitrate of soda. Dried blood.	do.	do.
Beets, Mangels...............	5 to 6	5 to 6	7 to 9	400 to 800	Nitrate of soda.	Dissolved bone-black. Dissolved S. C. rock.	Sulphate.

PROPORTIONS OF NITROGEN, PHOSPHORIC ACID, AND POTASH, AND QUANTITIES OF FERTILIZER PER ACRE RECOMMENDED FOR CROPS.—*Continued.*

CROP.	PER CENT. OF				BEST FORM FOR CROP.		
	Nitrogen.	Available Phosphoric Acid.	Potash.	Pounds Per Acre.	Nitrogen in	Phosphoric Acid in	Potash in
Blackberries	2 to 3	5 to 6	7 to 9	500 to 800	Nitrate of soda. Raw bone meal.	Dissolved bone-black. Raw bone meal.	Wood-ashes and kainit.
Buckwheat	4 to 4½	7 to 8	9 to 10	400 to 600	Nitrate of soda.	Dissolved S. C. rock. Basic slag phosphate.	Muriate.
Cabbage	5 to 6	5 to 6	7 to 9	800 to 2000	In the three forms of nitric acid, ammonia, and organic nitrogen.	Dissolved bone-black. Dissolved S. C. rock.	Wood-ashes and muriate.
Cauliflower	4 to 5	5 to 7	7 to 9	900 to 1800	do.	do.	do.

Carrots........................	5 to 6	5 to 6	8 to 10	600 to 900	Nitrate of soda. Sulph. ammonia.	do.	do.
Celery........................	5 to 6	5 to 6	8 to 10	1000 to 1500	In the three forms of nitric acid, ammonia, and organic nitrogen.	do.	do.
Clover and Legumens	1 to 2	6 to 8	8 to 10	400 to 800	Sulph. ammonia. Dried blood.	do.	do.
Corn........................	2 to 2½	7 to 8	6 to 7	500 to 1000	Nitrate of soda and organic nitrogen.	do.	do.
Cotton........................	2 to 2½	7 to 9	4 to 5	300 to 400	Nitrate of soda. Cotton-seed meal.	do.	Cotton-seed hull ashes. Wood-ashes. Kainit.
Cucumber....................	4½ to 5	5 to 6	6 to 8	1000 to 1500	In the three forms of nitric acid, ammonia, and organic nitrogen.	Dissolved bone-black.	Wood-ashes and muriate.
Fruit Trees..................	1½ to 2	7 to 9	10 to 12	400 to 700	Nitrate of soda. Raw bone meal.	Dissolved bone-black. Dissolved bone meal.	Wood-ashes, muriate, and kainit.

PROPORTIONS OF NITROGEN, PHOSPHORIC ACID, AND POTASH, AND QUANTITIES OF FERTILIZER PER ACRE RECOMMENDED FOR CROPS.—*Continued.*

Crop.	Per Cent. of				Best Form for Crop.		
	Nitrogen.	Available Phosphoric Acid.	Potash.	Pounds Per Acre.	Nitrogen in	Phosphoric Acid in	Potash in
Grape Vines..................	$1\frac{1}{2}$ to 2	7 to 9	10 to 12	500 to 700	Nitrate of soda. Raw bone meal.	Dissolved bone-black. Dissolved bone meal.	Wood-ashes, muriate, and kainit.
Grass........................	5 to 6	5 to 6	7 to 8	400 to 800	Nitrate of soda. Dried blood. Raw bone meal.	Raw bone meal. Basic slag phospbate.	Wood-ashes and kainit.
Hops.........................	$2\frac{1}{2}$ to $3\frac{1}{2}$	5 to 6	12 to 14	800 to 1200	Nitrate of soda and organio nitrogen.	Dissolved bone-black. Dissolved bone meal.	Wood-asbes and muriate.
Lettuce......................	5 to 6	5 to 6	8 to 10	900 to 1500	In the three forms of nitric acid, ammonia, and organic nitrogen.	Dissolved bone meal. Dissolved bone-black.	do.

Melons	5 to 6	5 to 6	7 to 9	500 to 1500	Nitrate of soda. Dissolved bone meal.	do.	do.
Oats	4 to 5	5 to 6	8 to 10	300 to 600	do.	Dissolved S. C. rock. Basic slag phosphate.	do.
Onions	5 to 6	5 to 6	8 to 10	900 to 1800	Nitrate of soda.	Dissolved bone-black.	do.
Peas	1½ to 2	7 to 9	7 to 9	400 to 800	Nitrate of soda. Sulph. ammonia.	Dissolved bone-black. Dissolved S. C. rock.	Muriate and kainit.
Potatoes	4 to 6	5 to 7	7 to 9	500 to 1500	Nitrate of soda. Dried blood.	Dissolved bone-black.	Sulphate.
Pumpkin	5 to 6	5 to 6	8 to 9	600 to 1000	Nitrate of soda.	do.	Wood-ashes and muriate.
Raspberries	2½ to 3	5 to 7	8 to 10	500 to 1000	Raw bone meal. Nitrate of soda.	Dissolved bone meal. Dissolved bone-black.	Wood-ashes and kainit.
Rye	4 to 5	5 to 7	8 to 10	300 to 600	Nitrate of soda.	Dissolved S. C. rock. Basic slag phosphate.	Wood-ashes and muriate.

Proportions of Nitrogen, Phosphoric acid, and Potash, and Quantities of Fertilizer Per Acre Recommended for Crops.—*Continued.*

Crop.	Per Cent. of				Best Form for Crop.		
	Nitrogen.	Available Phosphoric Acid.	Potash.	Pounds Per Acre.	Nitrogen in	Phosphoric Acid in	Potash in
Squash......................	5 to 6	5 to 6	7 to 9	500 to 1500	Nitrate of soda.	Dissolved bone-black. Dissolved S. C. rock.	Wood-ashes and muriate.
Strawberries.................	$2\frac{1}{2}$ to 3	5 to 7	7 to 9	500 to 1500	Nitrate of soda. Raw bone meal.	Dissolved bone-black. Raw bone meal.	Wood-ashes and kainit.
Sugar Cane..................	$1\frac{1}{2}$ to 2	7 to 9	7 to 9	600 to 900	Nitrate of soda. Cotton-seed meal.	Dissolved bone-black. Dissolved S. C. rock.	Muriate and kainit.
Tobacco......................	5 to 7	5 to 6	8 to 11	1000 to 2000	Nitrate of soda. Dried blood.	Dissolved bone-black.	Cotton-seed hull ashes, wood ashes, and sulphate.

Tomatoes	4 to 6	5 to 6	6 to 8	500 to 1000	Nitrate of soda. Dried blood.	Dissolved bone-black. Dissolved S. C. rock.	Wood-ashes and muriate.
Turnips, Ruta Bagas	4 to 5	6 to 7	7 to 9	300 to 800	Nitrate of soda. Dissolved bone meal.	Dissolved bone-black. Dissolved bone meal.	Wood-ashes and muriate.
Wheat	4 to 5	6 to 8	3 to 4	300 to 600	Nitrate of soda. Sulph. ammonia. Dried blood.	Dissolved bone-black. Basic slag phosphate.	Muriate.

In the preceding tables are given the proportions of nitrogen, phosphoric acid, and potash found profitable for the crops specified. The tables also show the quantities of mixed chemical manures for use per acre, and the best forms of materials for particular crops, so far as they are now known. The writer's experience leads him to favor the use of various forms of nitrogenous, phosphatic, and potassic materials in mixing fertilizers for general use. This will be found a safe rule, especially so in mixing high-grade chemical manures. If we want one hundred and twenty pounds of nitrogen for a mixture to contain six per cent. of nitrogen it is a good plan to take the nitrogen in about equal proportions in the three forms of nitric acid, ammonia, and organic nitrogen. We may take the nitric acid from the nitrate of soda, ammonia from sulphate of ammonia, and organic nitrogen from dried blood, meat or fish scrap, or dissolved bone meal. From dis solved bone black, dissolved bone meal, and dissolved South Carolina rock we may select the phosphoric acid, and use whatever form of potash is best for the crop, always giving preference to unleached wood ashes if obtainable at reasonable cost. Where crops show no particular preference, use whichever ingredient furnishes the required amount of potash at the least cost.

CHAPTER XX.

SOIL TESTS WITH FERTILIZERS.

Soil tests with fertilizers are designed to enable the farmer to study the needs of his soil and the specific action of fertilizers. By the aid of such experimental tests the fertilizing ingredients present in soils and those which are wanting are significantly indicated, and we also learn, where all other factors are favorable, the most appropriate forms of plant food for use in manuring.

The utility of such knowledge is obvious. It enables us to use manures with true economy, that is, in the most appropriate forms where actually needed.

The practice with most farmers is to use fertilizers without regard to the needs of crop or soil, a practice which is not only wholly empirical, but illogical and impracticable. Not that we are to feed out fertilizers to meet the bare requirements of plants. We should store phosphoric acid and potash in the soil until there is present a surplus beyond the demands of the most exhausting crops. The soil will hold fast these fertilizing ingredients committed to its care, and respond in succeeding seasons with more bountiful crops. But we have no such inducement to store nitrogen. Its most valuable compounds are soluble in water and are readily washed away. Therefore we should use only the necessary quantities required for the production of the largest crops the land is capable of yielding.

"Different ingredients are deficient in different soils. The way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant-food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.

"It is good farming to make the most of the natural resources of the soil and of the manures produced on the farm, and to depend upon artificial fertilizers only to furnish what more is needed. It is not good economy to pay high prices for materials which the soil may itself yield, but it is good economy to supply the lacking ones in the cheapest way. The rule in the purchase of costly commercial fertilizers should be to select those that supply, in the best forms and at the lowest cost, the plant-food which the crop needs and the soil fails to furnish." (Circular No. 8, U. S. Department Agriculture, March, 1889.)

In any series of soil tests with fertilizers we cannot too strongly urge upon farmers the importance of conducting such soil studies under the direction of the State experiment stations. The work will then be properly inaugurated, farmers will have the benefit of much timely advice from the station officials, and the liability to error will be reduced to the lowest minimum.

If, however, soil tests cannot be conducted under the guidance and with the co-operation of the stations, then in experimenting with the following test formulas farmers will do well to adhere closely to these preliminary directions :—

Select some staple crop regularly grown upon the farm, such as corn, wheat, or potatoes, and make the trials on alternate plots of land of one-twentieth of an acre each, or separate the plots by paths about three feet wide. Through the intervening plots or paths run a deep furrow to act as a drain that surface water may not run from one trial-plot to another. If possible select level land, with soil of uniform quality in fields worn by long cropping without manure, and let all the experiments be subject to the same culture and to the same conditions of sunlight and weather. The fertilizers can be sown broadcast or drilled in. Nitrate of soda may be applied at planting, provided the experiments are not on a winter crop like wheat or rye ; or the nitrate may be sown as a top dressing when the young plants are just above ground, or applied in fractional rations through the active stages of growth. On a winter crop, such as wheat or rye, sow a one-third ration of the nitrate in the fall and the remainder after the heavy rains of early spring are past. It is important to have each trial mixture in fine, even, mechanical condition, and to get it evenly and thoroughly distributed through the soil. This applies not only in the preparation of the land for soil tests, but also in all farming where either chemical or natural manures are used. In manuring with commercial fertilizers, as practiced by American farmers to-day, the probable average application does not exceed 400 pounds per acre. There are about 7000 grains in a pound and nearly 6,275,000 square inches in an acre ;* at

* An acre contains 6,272,640 square inches.

this rate there is less than one-half grain of fertilizer for each square inch of soil.

The following general directions for *soil tests* with fertilizers are taken from Circular No. 8, United States Department of Agriculture :—

"**Everything in Order Before Starting.**—(1) Have your plans complete and clearly in mind, and everything ready before you start. Proper plans at the outset; uniform soil for all the experiments; 'worn-out' soils for the soil tests; plots of proper size, shape, and accurately laid out; right application of the fertilizers; good seed; careful measurement of crops; full notes of details; and careful observation of the effects of the fertilizers on succeeding crops, are essential to the best results.

"**Conveniences.**—(2) It will be well to have at hand, in planting, a small spring balance and a light bucket or coal-hod. With these it is easy to weigh out the fertilizers from the bags, divide the contents of each bag into portions for one or more square rods each, and carry these portions of the fertilizers to corresponding portions of the plot, on which they can be spread. This will greatly help in uniform spreading.*

"At harvest you will need a scale, and, for such crops as potatoes a basket holding at least two or three pecks, to determine the quantity of the crop. The produce on each plot can be divided by square rods, and thus weighed and measured in small portions.

"A small note-book will be needed to take into the field during the

---

* On small plots, say the twentieth of an acre, the writer favors the following method, in which there is little liability to error in preparing fertilizers for soil tests.

Measure and stake off the plots, and from each take a quantity of fine soil (five or ten times the bulk of the fertilizer to be used), which put into a bag plainly marked with the number of the plot from which taken. Do all the weighing and mixing on the barn floor or in other suitable place; and as the fertilizer for each plot is weighed out thoroughly incorporate it with the dry soil from the plot on which the test is to be made, return the mixed soil and fertilizer to the numbered bag, and so proceed until all the mixtures are made. There is little danger of error in weighing and numbering in this manner, and if each fertilizer is thoroughly mixed with several times its bulk of fine, dry soil, a much more even distribution can be made over the surface of the plot.

Care must be taken, however, that the bags of soil are correctly numbered, and that each is used for the fertilizer to be spread upon the plot from which the soil was taken.

season and put down observations as made. From this you can copy all you wish to preserve in a more substantial book at your leisure.

"**Uniform Soil.**—(3) The soil should be as nearly uniform in quality as possible. There will be more or less variation in different parts of the same field at best. The less there is of this the more reliable will be the experiment. Level land should be chosen if practicable, but if it is sloping, let the plots run up and down the ascent, so that wash by rains will not transfer the materials from one plot to another. Of course, the portion chosen for experiment should be a fair sample of the whole field.

"**Kind of Soils for Tests.**—(4) The action of the different fertilizers will be most clearly shown on soils that are more or less worn down by culture. To learn what the soil itself can do by its own natural strength, rather than what it will do with the aid of a store of plant food which has been accumulated by natural processes or left over from previous manuring and will obscure the action of the fertilizers, it is important to select wornout soils. On soils in high condition the results of such tests are apt to be unsatisfactory. At the same time, land which has been generously treated with certain kinds of manures or artificial fertilizers may still be unsuited to certain crops, and tests of soils of this class may give very valuable results.

"**Lay out Plots Accurately.**—(5) Lay out the whole experimental area and the individual plots as accurately as you can. Measure with chain or tape, if you have it; otherwise with pole marked in feet and inches. Drive good, strong stakes firmly into the ground at the boundaries, so that you may be able to tell in this and coming seasons where the divisions are. There should be four stakes for each plot, one at each corner. These will show the boundaries of the plots and of the unmanured space between them. The stake for each plot can be marked with the number of the plot. The marks can be cut in the stakes with a knife. The tag on the bag can be tied to one of the stakes of the plot to which it belongs.

"**Size and Shape of Experimental Field and of Plots.**—(6) If the seed is to be planted in rows the length of the plots can be adapted to the distance of the rows apart. The 'Condensed Directions' give figures which will help in calculating the dimensions of the plots and field. If the soil is even, small, short plots will do. But generally it will not be even, and long plots are therefore safer.

"An unmanured strip at least three feet wide should be left between each two plots, so as to prevent the plants of one from being affected by the manure of another.

"**Arrangement of Plots.**—(7) The diagram herewith shows a convenient arrangement of plots. It provides for farm manures and lime in addition to the fertilizers of the experimental set. Of course, these and other extra materials can be used at discretion. It is very important that several unmanured plots should be left for comparison. Experience justifies the number in this schedule. An even better test of the uniformity of the soil, however, is the duplication of fertilized plots where that is practicable.

PLAN OF EXPERIMENTAL FIELD.—*For One-twentieth of an Acre.*

(Adapted from Circular No. 8, U. S. Department Agriculture.)

1.	Nothing.	
2.	Nitrate of soda	8 lbs.
3.	Dissolved bone-black	16 lbs.
4.	Nothing.	
5.	Muriate of potash	8 lbs.
6.	Nitrate of soda Dissolved bone-black	8 lbs. 16 "
7.	Nitrate of soda Muriate of potash	8 lbs. 16 "
8.	Nothing.	
9.	Dissolved bone-black Muriate of potash	16 lbs. 8 "
10.	Nitrate of soda Dissolved bone-black Muriate of potash	8 lbs. 16 " 8 "
11.	Land plaster	8 lbs.
12.	Nothing.	
13.	Farm-yard manure	2000 lbs.
14.	Lime (air-slacked)	16 lbs.
15.	Nothing.	

"*Field.*—Length, 213 feet 4 inches; width, 204 feet; area, 43,520 square feet. (One acre is 43,560 square feet.)

"*Plots.*—Length, 204 feet; width, 10 feet 8 inches; area, 2176 square feet. (One-twentieth of an acre is 2178 square feet.)

"*Strips between and outside the experimental plots.*—Length, 204 feet; width, 3 feet 4 inches.

"The fifteen plots here provided for (ten manured and five unmanured), with the sixteen strips outside and between the plots, make together 40 square feet less than an acre. If one of the outside strips be made 3 feet 6 inches, instead of 3 feet 4 inches, the whole will be 43,554 square feet, or 8 square feet less than an acre.

"The width of the plots, 10 feet 8 inches, has been found in practice convenient for use of machinery for planting corn and potatoes, sowing wheat, and harvesting wheat and grass."

"**Application of Fertilizers.**—(8) The fertilizers should be—

"First. Applied evenly over the plots where they belong, and not allowed to get outside.

"Second. Well distributed through the soil.

"Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost, through wrong application. Farmers are apt to think the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just-germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want not only to give the crop a good start, but to help it out on the home-stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this, remember how well barn manure acts when applied as a top-dressing long before the seed is put in.

"But if we concentrate the fertilizers in one place, fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true; still, we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizers gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant food available.

"Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, nitrate of soda, dried blood, or high-grade superphosphates may kill them. Since in these experiments it is particularly important that the effect of each fertilizer be fairly tested, it will be well to *mix them with three or four times their bulk of mellow earth before applying*, but this earth should be taken from the plot to which the fertilizer is applied. Moist sawdust, when obtainable, is apt to be more convenient. Do this by all means if applied in the hill or drill. When the plots are accurately staked out and the fertilizers carefully applied and worked in, the plow or harrow may be run across the plots without fear of transporting the fertilizers from one to another, provided the surface is free from stubble, litter, and clods.

"**See that all is Done Rightly.**—Attend to the work yourself. Don't trust it to the hired man, unless you are sure he will do it better than you can.

"**Plans for Continuing the Experiments in Coming Years.**—To give the experiments their proper value they should be continued through a series of years with the same fertilizers on the same plots, and with either a rotation of crops or with the same crop year after year. It is hoped that a considerable number of the experiments may be thus repeated. For this the stakes bounding the plots must be kept in place.

"**This Programme is not as Difficult as it Seems.**—This may seem a pretty heavy programme for ordinary farmers. Of course, the circumstances in which you work will require changes which your own good judgment will regulate.

"Good things are not to be had without cost, and to those who have the spirit of the investigator—and there are very many who have that spirit—the task is pleasant and not burdensome. Some of the most accurate, thorough, and valuable field experiments ever made in this country have been carried out by farmers.

"The following 'condensed directions' are for use in the field :—

"**Condensed Directions.**—(1) Have your plans all made and everything ready before you start. Remember that worn-out soil for the soil tests, uniform soil for all, plots long and narrow and accurately measured and staked out, and right application of the fertilizers are essential to the best success. Don't forget the tape or pole for measuring the plots, the scales for weighing, the pail for carrying the fertilizers, and the stakes (four for each plot).

"(2) Select a fair average portion of the field to be tested and lay it out as accurately as you can. Leave an unmanured strip at least three feet wide between each two plots, to prevent the roots of the plants from feeding on their neighbors' fertilizers.

"(3) Designate each plot by a number, as suggested in the diagrams, and corresponding to the number of the fertilizer. Put a strong stake firmly into the ground at each corner of each plot, and mark it with the number of the plot. If the plots are not staked and marked before the fertilizers are applied, you will risk making mistakes. When the fertilizer is applied to a plot, take the tag from the bag and fasten it to one of the stakes for a label.

"(4) Distribute each fertilizer evenly over its plot, and do not let it get outside. Lay your plans for doing this in advance, otherwise you may find the fertilizer all used up before you get to the end, or have some left over. Remember what was said about mixing well with the soil, especially when it is put near the seed. If you do not, you may kill some of the seed and injure the growth of the rest.

"(5) Be as systematic and accurate as you ean, not only iu starting the experiments, but in carrying them out, harvesting and measuring the produce, and noting the results.

"The following figures will be of service in calculating the dimensions of the experimental plots and field. To calculate the size of plot of one-twentieth of an acre, find in the left-hand column, 'Width,' the figure for the width decided upon; the opposite figure in the right-hand column will represent the length. Or, given the length in the right-hand column, the opposite figure in the left-hand column will be width. For one tenth acre plots, of course take double the given length for same width, or double the given width for same length.

ONE-TWENTIETH-ACRE PLOT, WIDTH AND LENGTH.

ASSUMED WIDTH.	REQUIRED LENGTH.	ASSUMED WIDTH.	REQUIRED LENGTH.
Rods :—	*Feet. Rods. Ft.*	Rods :—	*Feet. Rods. Ft.*
One-third,	396 = 24 00	Two-thirds,	198 = 12 00
Two-fifths,	330 = 20 00	Three-fourths,	176 = 10 11
One-half,	264 = 16 00	Four-fifths,	165 = 10 00
Three-fifths,	220 = 13 5¼	One,	132 = 8 00
Feet :—		Feet :—	
6	363 = 22 00	11½	189 = 11 8
6½	335 = 20 5	12	182 = 11 00
7	312 = 18 14	12½	174 = 10 9
7½	291 = 17 10	13	168 = 10 3
8	273 = 16 8	13½	161 = 9 13
8½	257 = 15 9	14	155 = 9 7
9	242 = 14 10	14½	150 = 9 2
9½	230 = 15 15	15	145 = 8 13
10	218 = 13 4	15½	141 = 8 8
10½	208 = 12 9	16	136 = 8 4
11	198 = 12 00	16½	132 = 8 00

In the most careful system of plot experimentation it is almost impossible to guard against error; slight differences in fertility, in exposure, in mechanical condition, or in preparing the land, irregularity in seeding or harvesting the crop, mistakes in measuring and weighing, and injuries by storms, birds, insects or fungoid diseases, all affect the ultimate results. And, therefore, duplicate trials should be made to get results that are approximately trustworthy. The difference between the yield of duplicate plots and their average may be regarded as the probable error, and in indicating this the plus (+) and minus (—) signs should be prefixed to this difference. Thus, one trial plot gives a yield of thirty bushels of wheat per acre, and the other gives a yield of thirty-four bushels, then the average yield of the two is thirty-two bushels, and ± two bushels, the difference between the average yield of the two plots, represents the probable error.

SPECIAL NITROGEN EXPERIMENTS.

The object of these experiments is to ascertain how plants respond to the use of nitrogen in different forms and amounts when added to a *basal mixture* of phosphoric acid and potash.

By a *basal mixture* we mean a specified amount of fertilizer (in this case it being the mixed minerals, phosphoric acid and potash) used as a basis for comparison in studying the effect of some other fertilizing constituent or constituents (in this case nitrogen) in different forms and amounts upon crop production.

In this case we compare the produce from the basal mixture with that obtained when nitrogenous compounds are added to it, the increased yield being regarded as due to the action of nitrogen.

Phosphoric acid and potash are supplied in about the proportions that occur in a corn crop of from fifty to sixty bushels, and nitrogen is supplied in one-third, two-thirds and full rations. The nitrogen is applied at the rate of twenty-six pounds per acre in one-third rations, fifty-one pounds per acre in two-third rations, and seventy-seven pounds per acre in full rations. Nitrogen is used as nitric acid in nitrate of soda, as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood.*

Twenty plots are provided for in the field plan, eighteen of which receive the experimental manures, and two receive none.

Three plots, Nos. 10, 14, and 18, are duplications of No. 6, which contains the basal mixture. This duplication of the plots receiving the basal mixture serves a threefold purpose, viz., 1st, in testing the uniformity of the soil, 2d, in replacing unmanured plots, and 3d, in showing with greater accuracy the effects of nitrogen.

---

* The quantities of fertilizers in these and all subsequent test-mixtures, are made to conform to those in use by the U. S. Dept. of Agriculture.

SPECIAL NITROGEN EXPERIMENTS.—*For one-twentieth of an acre.*

Field Plan I.

Group	Plot	Fertilizers	Quantity	Note
	0.	No manure.		
GROUP I.	1.	Nitrate of soda	8 lbs.	Each ingredient by itself.
	2.	Dissolved bone-black	16 lbs.	
	3.	Muriate of potash	8 lbs.	
GROUP II.	4.	Nitrate of soda Dissolved bone-black	8 lbs. 16 "	Two-by-two.
	5.	Nitrate of soda Muriate of potash	8 lbs. 8 "	
	6.	Dissolved bone-black Muriate of potash	16 lbs. 8 "	
GROUP III.	7.	Nitrate of soda Dissolved bone-black Muriate of potash	8 lbs. 16 " 8 "	Nitrogen as nitric acid in nitrate of soda.
	8.	Nitrate of soda Dissolved bone-black Muriate of potash	16 lbs. 16 " 8 "	
	9.	Nitrate of soda Dissolved bone-black Muriate of potash	24 lbs. 16 " 8 "	

SPECIAL NITROGEN EXPERIMENTS.—*For one-twentieth of an acre.*

Field Plan I.—*Concluded.*

Group	Plot	Manuring	Amount	Nitrogen
	10.	Duplicate No. 6.		
GROUP IV.	11.	Sulphate of ammonia Dissolved bone-black Muriate of potash	6.1 lbs. 16 " 8 "	Nitrogen as ammonia in sulphate of ammonia.
GROUP IV.	12.	Sulphate of ammonia Dissolved bone-black Muriate of potash	12.2 lbs. 16 " 8 "	Nitrogen as ammonia in sulphate of ammonia.
GROUP IV.	13.	Sulphate of ammonia Dissolved bone-black Muriate of potash	18.3 lbs. 16 " 8 "	Nitrogen as ammonia in sulphate of ammonia.
	14.	Duplicate No. 6.		
GROUP V.	15.	Dried blood Dissolved bone-black Muriate of potash	11.6 lbs. 16 " 8 "	Nitrogen as organic nitrogen in dried blood.
GROUP V.	16.	Dried blood Dissolved bone-black Muriate of potash	23.2 lbs. 16 " 8 "	Nitrogen as organic nitrogen in dried blood.
GROUP V.	17.	Dried blood Dissolved bone-black Muriate of potash	34.9 lbs. 16 " 8 "	Nitrogen as organic nitrogen in dried blood.
	18.	Duplicate No. 6.		
	0.	No manure.		

Special Phosphoric Acid and Potash Experiments.

Special phosphoric acid and potash experiments may be arranged on the plan of the foregoing special nitrogen experiments, starting, as in the case with nitrogen, from the soil test experiments as a basis. In the following plan for special phosphoric acid experiments we have used as a basal mixture 160 pounds each of nitrate of soda and muriate of potash. Soluble phosphoric acid is supplied in the form of dissolved bone-black at the rate of 160, 320, and 480 pounds per acre, which amounts are regarded, respectively, as one-third, two-thirds, and full rations. In any series of experiments where the acid phosphate is objectionable the precipitated phosphate may be prepared and used by taking a high-grade acid phosphate containing thirty-two per cent. of soluble phosphoric acid (Keystone concentrated phosphate, for instance), and adding an equal weight of lime. Insoluble phosphoric acid in the form of finely ground bone or South Carolina rock (floats) may also be used in quantities furnishing the same amounts of phosphoric acid as are contained in the rations of soluble and precipitated phosphates.

SPECIAL PHOSPHORIC ACID EXPERIMENTS.—*For one-twentieth of an acre.*

Field Plan II.

0.	No manure.	
1.	Dissolved bone-black	8 lbs.
2.	Nitrate of soda	8 lbs.
3.	Muriate of potash	8 lbs.
4.	Dissolved bone-black Nitrate of soda	8 lbs. 8 "
5.	Dissolved bone-black Muriate of potash	8 lbs. 8 "
6.	Nitrate of soda Muriate of potash	8 lbs. 8 "
7.	Dissolved bone-black Nitrate of soda Muriate of potash	8 lbs. 8 " 8 "
8.	Dissolved bone-black Nitrate of soda Muriate of potash	16 lbs. 8 " 8 "
9.	Dissolved bone-black Nitrate of soda Muriate of potash	24 lbs. 8 " 8 "
10.	Nitrate of soda Muriate of potash	8 lbs. 8 "
0.	No manure.	

SPECIAL POTASH EXPERIMENTS.

In the special potash experiments, we have used 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black for a basal mixture, and to these have added muriate of potash at the rate of 80, 160, and 320 pounds per acre, which are regarded as one-third, two-thirds, and full rations. Other materials may be used in quantities furnishing the same proportions of potash.

SPECIAL POTASH EXPERIMENTS.—*For one-twentieth of an acre.*

Field Plan III.

0.	No msnure.	
1.	Muriate of potash	4 lbs.
2.	Nitrate of soda	8 lbs.
3.	Dissolved bone-black	16 lbs.
4.	Muriate of potash Nitrate of soda	4 lbs. 8 "
5.	Muriate of potash Dissolved bone-black	4 lbs. 16 "
6.	Nitrate of soda Dissolved bone-black	8 lbs. 16 "
7.	Muriate of potash Nitrate of soda Dissolved bone-black	4 lbs. 8 " 16 "
8.	Muriate of potash Nitrate of soda Dissolved bone-black	8 lbs. 8 " 16 "
9.	Muriate of potash Nitrate of soda Dissolved bone-black	16 lbs. 8 " 16 "
10.	Nitrate of soda Dissolved bone-black	8 lbs. 16 "
0.	No manure.	

Field plans (II and III), for special phosphoric acid and potash experiments correspond to groups I, II, and III in the special nitrogen experiments. Plots 1, 2, and 3, in field plans II and III, show the effects of partial fertilization where each ingredient is used separately, numbers 4, 5, and 6 show the effects of partial fertilization where the same ingredients are used two-by-two, and 7, 8, and 9 show the effects of complete fertilization in which phosphoric acid and potash are used in one-third, two-thirds, and full rations.

It will be observed that the plan of field I provides for twenty plots, of which eighteen receive the experimental manures and two receive none: 6, 10, 14, and 18 are used for the basal mixtures, for the purpose of comparing the crops produced from the use of this mixture with those obtained from it on other plots with the addition of nitrogenous materials. There are four plots containing the basal mixture, one on each side of the groups III, IV, and V, the plots on which the effects of nitrogen are tested.

With field plan I as a guide, farmers can increase the number of plots in the special phosphoric acid and potash experiments to test the effects of different phosphatic and potassic fertilizers. In extending plans II and III the same general arrangement of I should be adhered to.

In the following field plan for soil tests, we start with a basal mixture containing over 8 per cent. of available phosphoric acid and over 13 per cent. of potash, to which nitrogen is added in the three forms of nitric acid, ammonia, and organic nitrogen. We begin by adding nitrogen in each form, at the rate of between 3 and 4 per cent. By referring to the tables on pages 155–161, it will be observed that these test mixtures may be used in experimenting on a large number of farm crops. In fact, by substituting for dissolved bone-black or muriate of potash, other forms of phosphatic or potassic manures known to be more favorable to particular plants, we may use this field plan for many crops requiring over 3 per cent. of nitrogen for maximum production.

In substituting other ingredients in these or other test mixtures, the same proportional amount of phosphoric acid or potash should be used. The excess of phosphoric acid and potash above the requirements of crops will not be lost, but safely held by the soil for the use of future vegetation.

SOIL TESTS.*—*For one-twentieth of an acre.*

Field Plan IV.

1.	Farm-yard manure .... 2000 lbs.
2.	No manure.
3.	Nitrate of soda .... 8 lbs.
4.	Dissolved bone-black .... 16 lbs.
5.	Muriate of potash .... 8 lbs.
6.	Nitrate of Soda .... 8 lbs. Dissolved bone-black .... 16 "
7.	Nitrate of soda .... 8 lbs. Muriate of potash .... 8 "
8.	Dissolved bone-black .... 16 lbs. Muriate of potash .... 8 "
9.	Nitrate of soda .... 8 lbs. Dissolved bone-black .... 16 " Muriate of potash .... 8 "
10.	Nitrate of soda .... 16 lbs. Dissolved bone-black .... 16 " Muriate of potash .... 8 "
11.	Nitrate of soda .... 24 lbs. Dissolved bone-black .... 16 " Muriate of potash .... 8 "
12.	Duplicate No. 6.

*It is suggested that a series of tests be made with wheat, oats or rye, using just one-half the quantities of nitrogenous and potassic ingredients given in Field Plan IV.

SOIL TESTS.—*For one-twentieth of an acre.*

Field Plan IV.—*Concluded.*

13.	Sulphate of ammonia Dissolved bone-black Muriate of potash	6.1 lbs. 16 " 8 "
14.	Sulphate of ammonia Dissolved bone-black Muriate of potash	12.2 lbs. 16 " 8 "
15.	Sulphate of ammonia Dissolved bone-black Muriate of potash	18.3 lbs. 16 " 8 "
16.	Duplicate No. 6.	
17.	Dried blood Dissolved bone-black Muriate of potash	11.6 lbs. 16 " 8 "
18.	Dried blood Dissolved bone-black Muriate of potash	23.2 lbs. 16 " 8 "
19.	Dried blood Dissolved bone-black Muriate of potash	34.9 lbs. 16 " 8 "
20.	Duplicate No. 6.	
21.	No manure.	
22.	Farm-yard manure	2000 lbs.
23.	Farm-yard manure Nitrate of soda Dissolved bone Muriate of potash	1000 lbs. 4 " 8 " 4 "
24.	Farm-yard manure Nitrate of soda Dissolved bone-black Muriate of potash	1000 lbs. 8 " 16 " 8 "

The preceding plan (IV) for soil tests contains all the groups of field plan I and, in addition, plots for studying the effects of farm-yard manure alone, along with farm-yard mauure to which varying rations of complete chemical fertilizers have been added.

The object of the experiment is to ascertain the effects of nitrogen in different forms and amounts upon crops and inferentially to learn if the soil is deficient in any or all of the fertilizing constituents contained in the test mixtures: also to test comparatively the effects of chemical and farm-yard manures alone and together invarying rations.

What the Tests Will Show.—If nitrogen only is needed for maximum crop production, plot 3 will show its deficiency; if phosphoric acid or potash is insufficient, in the crops of 4 or 5 the needs of the soil will be made manifest; if any two of the constituents are needed, plots 6, 7, and 8 will give us decisive indications of the needed combination, and if all the constituents are deficient we will have, in plots 9, 10, and 11, not only an unequivocal answer to our test, but the results will also show how the crop responds to different rations of nitrogen, as nitric acid in the form of nitrate of soda.

Plots 13, 14, and 15 will show the effects of different quantities of nitrogen in the form of ammonia salts, and plots 17, 18, and 19 will indicate the effects of similar fertilization with organic nitrogen in the form of dried blood. In additiou to these groups we also have for comparative study tests with farm-yard manure alone and with farm-yard manure to which complete chemical fertilizers are added.

From the data given in the foregoing plans for soil tests with fertilizers, farmers may devise many others for studying the needs of crops and soils.

The writer would impress on all tillers of the soil the urgent need of such investigation and the importance of its being carried on by professional farmers.

There is nothing practicable about feeding to crops manures which they do not need, and yet that is often the practice with many so called practical men. We need to know the wants of plants and soils and then to fertilize understandingly. And this knowledge we obtain by carefully conducted soil tests.

The farming of the future must be so conducted. It will be a business founded on comprehensive experimental knowledge. As our science broadens and we learn more about the use of chemical manures and the needs of crops and soils, the true significance of nitrogen-gathering plants in their relations to systemic crop rotation will become apparent.

We will then learn to appreciate in some degree the inscrutable wisdom and far-reaching beneficence of the Divine Author of nature in providing us with a class of plants whose office it is to restore the lost fertility of our fields. Not by creating something out of nothing, as much of our past farm literature might seem to imply, but by helping us to help ourselves,—by gathering into the tissues of plants the free nitrogen of the air, by converting into organic forms the crude food materials of our mines, and by rendering available for crop absorption the treasures of potential * plant food locked up in the surface and lower soils. We will then learn that it is just as possible to enrich lands by growing crops on them as it is to make them poor.

"The entire art of manuring," says Dr. Wagner, "is dependent upon a rational and exact application of nitrogen."

Herein lies the secret of successful farming. We have in mineral deposits and in soils inexhaustible treasures of phosphoric acid and potash ; nor have we reason to anticipate increased cost with the increased consumption of these materials. With improvements in manufacturing and mining, and with the discovery and development of new sources of supply, the cost of phosphoric acid and potash will, in all probability, slowly decline, but nitrogen in its best forms now costs us from $300 to $350 per ton with no reasonable probability of lower cost, unless drawn from atmospheric sources. We cannot get along without nitrogen ; how, then, are we to get it at less expense?

No manure costs the farmer so little as that elaborated by legumens, and these plants are gatherers of nitrogen. True, we must feed them with phosphoric acid and potash, and they respond gratefully to lime and sulphuric acid ; nor should we grudge them a morsel of nitrogen in soils sapped of this element. We will but make them hungry for more nitrogen, which they have the power of gathering from the atmosphere.

Let us see what Dr. Wagner, the foremost agriculturist of Germany, has to say on the most profitable use of commercial manures : "I at once present this question : Under what conditions is it possible to essentially increase the return from the soil by the application of arti-

---

* Potential plant food consists of the insoluble organic and inorganic food materials present in soils. Potential plant food is also food *held in reserve.* By the decomposition of green crops in the soil and the solvent action of carbonic acid and the acids of the humus group, aided by alkalies and thorough culture, potential plant food is released from insoluble combinations and made available for root absorption.

ficial fertilizers? The answer is: Wherever hungry plants grow, wherever the earth produces plants which hunger for nitrogen, phosphoric acid, or potash, there the application of commercial manures should be made.

"The cause for small returns is not always a lack of plant food. Often the plant suffers from thirst; from insufficient porosity of the soil, whereby the root development is checked; from caking of the soil, which works harmfully; from impenetrability of the soil, by which stagnant water with all its attendant evils is entailed; from deficiency of lime, of humus, etc.; in short, there are very many physical and chemical relations of soil or unfavorable conditions of weather, which prevent the plant from a healthy development, and which diminish the crop.

"In such cases, generally, the plant has no need of a large addition of food; it does not hunger. The small quantities of nutriment present in the soil suffice to produce the crops possible under so unfavorable circumstances. Here the establishment of better conditions must be made by irrigation or draining, deep culture, better plowing, harrowing, hoeing, marling, mucking, etc. The plants will then attain a development requiring, for the production of the harvest then possible, a greater food supply than the unenriched soil can yield.

"Deep, well-tilled, humus loam, under good atmospheric conditions, offers, therefore, relatively the best pledge for a sure effect from commercial manures; and every means which improves the quality of soil, advances the success of the same. Luxuriant plant growth and intensive soil culture are synonymous with intensive conversion of plant food into crops. The demand for, and consumption of, plant food must therefore always be greatest where the greatest yield is produced or producible. In a given case, the more favorable the conditions, aside from those relative to nitrogen, phosphoric acid and potash, the faster will be the consumption of, and the quicker the hunger for, those substances, and just so much earlier can an addition of plant food, beyond that barely necessary to appease hunger, be made to the crops; that is, the crops can be, as it were, fattened.

"In intensive cattle feeding, something more is sought to be accomplished than the satisfying of the mere needs of the animals. Were it simply a question of appeasing hunger, food could often be saved. But a further end is sought; namely, an intensive conversion of fodder constituents into animal matter within the animal organism; namely, a production of milk, muscle, fat, which shall be considerably greater than that actually demanded by the animals, and which can only be accomplished by increasing the appetite, by the use of specially palatable and easily digestible food.

"But the same order holds in crop production. When feasible, plants should be cultivated which possess prominent productive powers, as it were, great fattening capacity; and these plants should be stimulated to more intensive assimilation and work of transmutation than correspond to their normal necessities, by being supplied with easily soluble manures. As already stated, the best possible results are to be reached only on better grades of soil and under relatively favorable conditions. Still, it would be a grave mistake to assume that artificial manures can be used advantageously only on better grades of soil. This would be absolutely incorrect; for large, and under favorable circumstances larger results are secured from the application of artificial manures on poor and even neglected and exhausted soils. In such cases the application of fertilizing material must be made with greater precaution and intelligence; for it demands far greater attention to special conditions, and entails greater risk than with better soils." *

We are indeed slow to learn that the land must produce food for crops in order to provide the greatest abundance for ourselves. A few progressive farmers have learned this secret of *growing manures*. By intensive culture, by a discrete and liberal employment of artificial fertilizers, together with the use of renovating crops, these farmers prosper and the land grows fertile. And what is the lesson to be learned from their success? Is it not the necessity among farmers of a broader knowledge of plant and soil wants, of careful experimentation and close observation, and of that spirit of liberal inqniry which is satisfied only with the highest attainable truth? We are slowly learning the true value of chemical manures and the importance of using them, not in paroxysmal or irregular applications, but continuously; the utility of green manures and the true significance of deep, thorough, and constant culture slowly but surely becomes more and more apparent. By the conjoint action of these agencies—chemical and green manures, and perfect culture—we have learned that the productive powers of soils not absolutely barren may be greatly increased; and hence in all the older States where lands have been

* Translated by Prof. Charles Wellington, Ph. D.—From special bulletin, Mass. Agricultural College.

worn down by exhaustive culture the manure problem presents to farmers questions of vital economic importance.

In the soil conditions of the Atlantic seaboard and trans-Appalachian regions there is a lesson that it is to be hoped will not be lost on the farmers of this country,—a lesson not for those in the older States alone, but for farmers cultivating the virgin soils of the west. To the former the all important question is the restoration of lost fertility, to the latter the condition of the east is an object lesson and warning that appeals for thoughtful, rational culture which shall aim to retain, unimpaired, the natural wealth of rich prairie soils. Other great problems are pressing to the front, problems which farmers must meet and deal with thoughtfully and not with skepticism or intolerance.

In the farming of the future men who disregard the teachings of agricultural science will be left behind in the race. They will be to the rest of the world mere hewers of wood and drawers of water. Chemical manures will be used much more liberally than now, but the relative cost of manuring will probably decrease. Our fields will be kept growing crops continuously, and much of the indispensable nitrogen which is so elusive and costly now, will be harvested from the exhaustless stores of the atmosphere. The precise significance of atmospheric nitrogen to future systemic soil management and to the regular transmutation of dead matter into living forms is beyond even the realm of rational conjecture, but as the horizon of our knowledge broadens we shall find underlying the practical teachings of our science the evidences of supremely beneficent law.

Surely nature has a method full of thrift and bounty for restoring the lost fertility to the land. Let us study her ways faithfully and thoughtfully, and endeavor to make her method our own.

APPENDIX.

ORGANIC NITROGEN ON TOBACCO.

In 1890 Major R. L. Ragland, of Halifax County, Va., the well-known authority on tobacco, conducted for the Virginia Agricultural Experiment Station a number of experiments with fertilizers on tobacco. This valuable series of trials was carried out in accordance with a plan furnished by Col. W. B. Preston, who was then in charge, as director, of the Station.

The results of these interesting and suggestive experiments are important to tobacco growers, and are in full accord with the experience of many planters who have compared the effects of organic nitrogen in such forms as flesh, dried blood, or fish scrap, with nitrates or ammonia salts on tobacco.

We condense the following from the report of the results published in *Bulletin*, No. 12, January, 1892, Virginia Agricultural and Mechanical College, Agricultural Experiment Station :—

"The tests were intended to ascertain the effects of nitrogen, phosphoric acid, and potash on the yield and quality of tobacco, and the form or forms in which nitrogen can best be applied to this crop.

"Every application contained the same amounts of potash and phosphoric acid, and practically the same amount of nitrogen, but in different forms, thus giving at the same time all the fertilizing constituents required and full effect to the nitrogen employed.

"The tests occupied six plots of one acre each, contiguous to one another, and as nearly alike as possible in exposure, situation, physical condition, and fertility. The field selected was typical yellow tobacco land, only one year from the forest, on which tobacco had been cultivated the preceding year. A sample of this soil, analyzed by Prof. Walker Bowman, formerly chemist to the Station, gave as follows :—

Soil.

AIR-DRIED SOIL.

Moisture,	.577	Magnesia,	.039
Organic matter,	2.982	Potash,	.019
Phosphoric acid, P_2O_5,	.019	Soda,	.038
Lime,	.076	Nitrogen,	.090
Ferric oxide and alumina,	1.550		

Commenting upon this analysis Professor Bowman remarks : "The soil is remarkable for the small amount of mineral matters which it gives up to acids. Judging from the foregoing figures it would undoubtedly, for ordinary farm crops, such as wheat, corn, oats, etc., be called poor. It is a matter of interest, however, to determine to what extent its favorable physical properties and climatic surroundings, together with the application of suitable fertilizers, will render it a good soil for the growth of tobacco. It appears to be of easy tilth and drainage, and of fair, but not very great, water holding power."

The plots were carefully surveyed and staked off by an assistant of the Virginia Agricultural Experiment Station. The land was well prepared by several plowings and harrowings during the winter and spring.

The fertilizers were applied by sowing half the quantity allowed each plot broadcast, and by drilling in the remainder. The tobacco, Long Leaf Gooch, was planted three and one third feet by three feet, on May 28. Thorough cultivation was given throughout the season. It is scarcely necessary to add that all the plots received exactly the same treatment, except in the matter of fertilization. An almost perfect stand was secured. The first tobacco was cut September 5, the last September 20.

At each cutting one hundred selected sticks were taken from each of the fertilized plots and placed in one room of a barn containing five rooms, so as to keep the product of each plot separate, in order to give all the same treatment in the barning and curing. The tobacco on the unfertilized plot, No. 6, ripened from ten days to two weeks later than that grown on the manured plots, showing that fertilizers hastened the maturity of the tobacco to that extent.

The year 1890 was favorable to tobacco. Somewhat too much rain fell during the growing season, but the rains ceased in a measure after July, and the weather during August and September proved exceptionally favorable to the barning and curing of the crops. A full crop, over the average in quality, was in consequence obtained.

The details of the experiments are given in Tables I and II. Table No. I shows the kinds and amounts of fertilizers applied on each plot and the weight and value of the various grades of tobacco taken from it.

TABLE I.—EFFECTS OF DIFFERENT FERTILIZERS ON TOBACCO.

No. of Plot.	Kinds and Amounts of Fertilizer per Acre.	Yield of Various Grades per Acre in Pounds.											
		Best Leaf.	Value.	Second Leaf.	Value.	Third Leaf.	Value.	Best Lugs.	Value.	Second Lugs.	Value.	Total Produce.	Aggregate Value.
	Lbs.	*Lbs.*	$	*Lbs.*	$	*Lbs.*	$	*Lbs.*	$	*Lbs.*	$	*Lbs.*	$
1	Sulphate of ammonia..... 50 Dried blood.............. 80 Sulphate of potash.......120 Acid phosphate..........114	105	29.40	367	35.05	130	13.00	135	12.15	298	21.60	1035	131.20
2	Nitrate of soda.......... 72 Dried blood.............. 80 Sulphate of potash.......120 Acid phosphate..........114	105	29.49	253	40.48	186	22.32	115	10.92	354	24.73	1013	127.90
3	Dried blood..............160 Sulphate of potash.......120 Acid phosphate..........114	170	42.50	363	58.08	112	12.32	121	12.70	280	21.00	1046	146.60
4	Nitrate of soda..........143 Sulphate of potash.......120 Acid phosphate..........114	127	33.65	278	48.96	123	13.53	140	14.00	250	20.00	946	130.14
5	Sulphate of ammonia.....100 Sulphate of potash.......120 Acid phosphate..........114	100	27.00	269	40.35	160	14.40	94	9.40	267	18.48	887	109.63
6	Unfertilized..................	44	9.68	240	33.60	66	7.26	132	15.84	280	19.60	762	83.98

Table I gives in detail the financial results of the several tests.

TABLE II.—FINANCIAL RESULTS OF TESTS.

No. of Plot.		Cost of Fertilizer Per Acre.	Value of Tobacco Per Acre.	Value of Increased Yield Per Acre.	Profit Per Acre.
		$	$	$	$
1	Sulphate of ammonia..... Dried blood.............. Sulphate of potash........ Acid phosphate...........	8.25	131.20	45.22	36.97
2	Nitrate of soda........... Dried blood.............. Sulphate of potash....... Acid phosphate...........	8.25	127.90	41.92	33.67
3	Dried blood.............. Sulphate of potash........ Acid phosphate...........	8.25	146.60	60.62	52.37
4	Nitrate of soda........... Sulphate of potash........ Acid phosphate...........	8.25	130.14	44.16	35.91
5	Sulphate of ammonia...... Sulphate of potash........ Acid phosphate...........	8.25	109.63	23.65	15.40
6	No fertilizer...	....	85.98	....	....

It was observed on July 14 that the manured plots were beginning to grain, and that the color of No. 3 was decidedly the yellowest—a difference which was maintained throughout. The product of this plot also showed up brighter when cured.

In comparison with Nos. 1, 2, 3, 4, and 5, it appears that the unmanured plot gave the poorest returns.

Of the nitrogenous fertilizers used the dried blood gave the largest yield and also the largest financial returns.

The yield and value of the crops of plots Nos. 1 and 2 were nearly alike, and, while the yield of No. 4 was less than that of either of the others, its value was slightly greater than that of No. 2, and but little under that of No. 1.

In weight and value the crop of No. 5 was the lowest of any of the fertilized plots. The tobacco on this plot suffered more from field-fire than on any of the others. This injured the yield and reduced its value. There was some field-fire on plot No. 1, on which less sulphate of ammonia was used.

Dried blood gave good results on the three plots on which it was used, and where combined with nitrate of soda, in plot No. 2, the results were also good. This plot, unlike Nos. 5 and 2, showed no field-fire.

Where dried blood and nitrate of soda were used in combination or separately there was scarcely any field-fire—much less than where no fertilizers were applied.

There was also more stalk-rot (called by some planters "hollow stalk") on the unmanured plot than on all the fertilized plots put together. This is suggestive. If verified by future tests it will point planters to the remedy.

The results of the tests, to sum up, appear to indicate that nitrogen was most effective in the form of dried blood, and that the nitrogen of nitrate of soda was more available than that of sulphate of ammonia. Also that fertilizers can be made to pay, and to pay well, if compounded of materials suited to the tobacco crop and adapted to the thin silicious soils of Middle Virginia.

IRON SULPHATE AS A MANURE.

Sulphate of iron or copperas has been used with some success as a manure in France, England, and Germany. Griffiths, in his "Treatise on Manures," gives some highly interesting results from experiments conducted by himself during the years 1883, 1884, and 1886. He says of experiments upon bean crops: "Many of the experiments were performed in the vicinity of Bromsgrove, Worcestershire, where the soil consists chiefly of clay and loam derived from the lias or the upper members of the new red sandstone formations, and may be looked upon as a good soil for the growth of leguminous crops, especially beans.

"The analysis of the soils used in these experimental investigations gave the following composition :—

	I.	II.
Silica and insoluble matter	80.75	80.74
Organic matter	4.92	4.90
Ferric oxide	3.93	3.96
Alumina	2.92	2.89
Magnesia	0.50	0.49
Lime carbonate	3.25	3.28
" sulphate	0.26	0.27
Potash.. } Soda..... }	0.36	0.35
Phosphoric acid	0.38	0.42
Moisture	2.73	2.70
	100.00	100.00

"In 1883 two plots of land of the same size (an acre each) were used for the growth of beans. One plot was treated with the crystallized iron sulphate of commerce (the quantity applied being one-half hundredweight [fifty-six pounds] per acre), and the other was left in its normal condition. Both plots of land were exposed to the same amount of sunshine and rain fall. On each plot was planted (on the same day) the same number of bean seeds; that is, the plants grew under like conditions as far as composition of soil, climatic conditions, etc., were concerned. At the harvest the following results were obtained :—

(*a*) Bean Crop of 1883. (*Vicia faba.*)

	Plot of Land Manured with Sulphate of Iron.		Plot of Land Normal (Not Manured).	
	Weight when Gathered.	Weight when Dry.	Weight when Gathered.	Weight when Dry.
Total weight of crops—grain and straw	6,783 lbs.	5,882 lbs.	5,210 lbs.	4,487 lbs.

"The crop grown by the aid of the iron manure yielded fifty-six bushels of grain (dry), while the crop grown without the iron manure yielded only thirty-five bushels of grain, a marked difference in the weights of the produce of the two pieces of land.

"The bean crop of 1884 was grown under similar conditions to those of 1883. The crop grown with iron sulphate yielded forty four bnshels of dry grain, while the crop grown without the iron sulphate yielded only twenty-eight bushels.

"During the season of 1886 bean crops were once more grown upon two plots of land of the same size (an acre each). There was a point of difference here from the crops of 1883 and 1884, for both plots of land were treated with the same weight of farm-yard manure, whereas the plots in the previous experiments received no farm-yard manure.

"Upon each plot (1886 crops) was sown the same number of bean seeds, and after the plants were about six inches above ground one plot was treated with one-half hundredweight of commercial iron sul phate to the acre, and the other did not receive any top dressing. The results obtained at the harvest were as follows :—

	Grown with Iron Sulphate.		Grown without Iron Sulphate.	
	Weight when Gathered.	Weight when Dry.	Weight when Gathered.	Weight when Dry.
Total weight of crops—grain and straw, per acre......	7,016 lbs.	5,929 lbs.	5,192 lbs.	4,726 lbs.

"The crop of beans grown with a top dressing of iron sulphate yielded fifty bushels, whilst the crop grown without the iron manure gave only thirty bushels of grain."

To make sure that these excellent results were produced by the agency of the iron sulphate, Griffiths submitted a number of the plants grown on each plot to chemical analysis. As a result of these analyses he drew the following conclusions :—

"(*a*) That in the ashes of the entire bean plants it is found that the plants grown with an iron manure contain a much larger percentage of iron oxide in their ashes than the plants grown withont iron snlphate ; (*b*) and that the phosphoric acid in the ashes increases as the iron oxide increases. Thus it is seen that the composition of the ash of the bean plant is greatly influenced by the manure applied to the soil."

With the crops grown with iron sulphate there was also a marked increase in the albuminoids and soluble carbohydrates which means an increased feeding value for the crop. The three years experiments showed that a small dressing, in this case a half a hundredweight per acre, of iron sulphate is a beneficial manure for beans.

Similar experiments were made with turnips, meadow hay, mangel wurzel, potatoes, and wheat. We give a brief summary of these trials with the results obtained.

Iron Sulphate on Turnips.

In the trials on the turnip crop plots of one acre each were planted. The land was of about the same chemical composition and in like mechanical condition. Both plots had the same culture and were subject to the same atmospheric conditions. On one plot one-half hundredweight of iron sulphate was used.

The yield of turnip roots was as follows :—

With iron sulphate, ...	$16\frac{1}{2}$ tons.
Without iron sulphate, ...	13 "

Analyses showed in the crop grown with the iron manure an increase of nearly four times the amount of ferric oxide in the roots, and of nearly three times the percentage in the leaves, as compared with the crop from the unmanured plot.

Meadow Hay.

Both plots were first manured with equal quantities of farm-yard manure. Upon each plot sixteen pounds of grass seed were used. After the grass had made its appearance one-half hundredweight of iron sulphate was spread on one plot as a top dressing; the other plot received none. The grass manured with the iron sulphate grew much more rapidly and was of a beautiful green color. The yield of hay was :—

Acre manured with iron sulphate and farm-yard manure, ...	3 tons 2 hundredweight.
Acre manured with farm-yard manure alone, ...	$1\frac{1}{2}$ tons.

As in the case with beans and turnips the percentages of albuminoids and soluble carbohydrates were highest in the hay grown upon the plot that had received the iron manure, thus giving a higher feeding value to the hay.

The ashes of the hay from the two plots showed an increase of ferric oxide and phosphoric acid in the crop that had received the dressing of iron sulphate.

A number of experiments, both in England and France, prove the value of iron sulphate on mossy pastures.

13

Experiments with Mangel-wurzel.

In the trials with mangel-wurzel, plots of one acre each of well-drained land, subject to the same atmospheric conditions, were planted with the Orange Globe variety of mangel.

During the previous winter each plot was manured with ten tons of farm-yard manure.

"In the spring," says Dr. Griffiths, "the following mixture was applied broadcast to each plot:—

Kainit, ...	1	hundredweight.
Nitrate of soda, ...	1	"
Superphosphate of lime, ...	4	"
Common salt, ...	2	"

"On each plot five pounds of seed was planted, and when the young plants were ready they were 'singled,' the distance between plant and plant being about twelve inches. A month after 'singling' a top dressing of one hundredweight of nitrate of soda and one-half hundredweight of iron sulphate were applied to plot A, whilst one hundredweight of nitrate of soda only was used on plot B. At the end of the harvest (October) the following results were obtained:—

(*a*) MANGEL-WURZEL CROPS OF 1886.

	PLOT A. GROWN WITH IRON SULPHATE.	PLOT B. GROWN WITHOUT IRON SULPHATE.
Weight when gathered (root and leaf)..	97,682 pounds.	78,369 pounds.

"The crop grown with iron sulphate yielded thirty-two tons of roots, while the crop grown without iron sulphate yielded only twenty-six tons of roots.

"An analysis of the roots showed that in those crops grown with an iron manure the albuminoids and soluble carbohydrates are increased, thereby giving a higher value to the roots as 'feeding stuff.' The following table (*b*) gives the composition of these crops :—

(*b*) MANGEL-WURZELS.

	PLOT A. GROWN WITH IRON SULPHATE.	PLOT B. GROWN WITHOUT IRON SULPHATE.
Albuminoids	2.89	1.90
Soluble carbohydrates	11.21	9.32
Woody fibre	1.98	2.05
Fat	0.25	0.21
Ash	1.52	1.00
Water	82.15	85.51
	100.00	99.99

"The ashes of the roots and leaves of the crops showed, on analysis, an increase of ferric oxide and phosphoric acid in the crops grown with iron sulphate."

Iron Sulphate on Potatoes.

In trials on the potato crop three plots of one acre each were chosen. The land was of good quality, and of about the same chemical composition, and was exposed to the same climatic conditions. The first plot (A) received no manure. The second plot (B) was manured with—

Kainit,	1 hundredweight.
Nitrate of soda,	1 "
Iron sulphate,	½ "
Superphosphate of lime,	2 "

The third plot was manured with the above manure less the one-half hundredweight of iron sulphate.

On each plot seven hundredweight of good potatoes were planted. The following results were obtained :—

Plot A. No manure,	3 tons.
Plot B. Manure containing iron sulphate,	8½ "
Plot C. Manure without iron sulphate,	6½ "

The percentages of ferric oxide and of phosphoric acid were highest in the ashes of the crop grown on plot B containing iron sulphate.

During the next year (1886) two plots of land (each one acre) were manured with fifteen tons each of farm yard manure applied in the previous autumn. Upon each plot six hundredweight of tubers were planted. When the young plants were fairly above ground one plot (A) received a top dressing of one-half hundredweight of iron sulphate, and the other (B) two hundredweight of kainit (containing sixteen per cent. of potash). The harvest was as follows :—

	Tubers.
Plot A. Grown with ½ hundredweight iron sulphate,	9 tons.
Plot B. Grown with 2 hundredweight kainit,	6 "

In this experiment Dr. Griffiths does not attribute the great increase in the crop of tubers solely to the direct manurial value of the iron sulphate, for it is known that this salt of iron retains ammonia and phosphoric acid in the soil, and hence it may be that some of the properties of the farm-yard manure were retained to a greater extent in the soil treated with iron sulphate than in the soil on which kainit was spread.

From the experiments of Griffiths and others iron sulphate cannot be considered of high manurial value upon cereals, but there is one well-ascertained advantage in using this salt of iron on the wheat crop. The plants dressed with one-half hundredweight of iron sulphate when six to eight inches high are always healthier, and completely resist the attacks of the wheat mildew, rust, and smut.

In addition to the crops previously named iron sulphate has been used with success on barley, onions, cabbage, and tobacco. Griffiths gives the following formula for tobacco manure used with excellent results on English soils :—

Sulphate of potash,	4 parts.
Sulphate of iron,	1 "
Sulphate of ammonia,	1 "

Iron sulphate should be applied to the soil as a top dressing after rain. *It must never be used upon dry, parched land.* The soil must always be wet, and, in spreading, the powdered iron salt should be mixed with from five to ten times its weight of soil or sand, in order to secure a more uniform distribution. If an overdose of iron sulphate should be applied to the land, a light dressing of lime will correct the evil.

It should not be forgotten that iron sulphate is an antiseptic and germicide ; that is, it has properties which destroy certain microscopic organisms known as mildews, fungi, bacteria, etc., and the spores of these micro-organisms are always present in the air, water, and soil.

The manure pile is a prolific source of fungoid diseases. The spores of these organisms are introduced into the manure heap with the straw and litter of previous crops, and, after hibernating through the winter under the most favorable conditions for their future development, with the opening of spring are spread broadcast over the farm. To kill the spores of parasitic diseases, Dr. Griffiths has used with success a solution made by dissolving a half pound of iron sulphate in one gallon of water and sprinkling the solution over the manure before plowing into the land. Iron sulphate not only kills the spores of micro organisms destructive to farm crops, but also prevents the evaporation of ammonia from soils and manure heaps. Crew, in his work on "Manures," recommends that farm-yard manure be sprinkled with a solution of iron sulphate made in the proportions of one pound of the salt to one gallon of water.

From what has been said in the preceding pages it will be seen that soluble iron salts, in small quantities, are decidedly beneficial to crops developing a large amount of leaf-green or chlorophyl. On beans, peas, cabbage, mangels, grass, potatoes, and tobacco the value of iron sulphate is established beyond all controversy. It increases the soluble carbohydrates and albuminoids (the flesh and fat forming constituents of crops), and, therefore, enhances their feeding value. Iron sulphate furnishes iron and sulphur to plants and holds ammonia and phosphoric acid in the soil. As an antiseptic, iron sulphate destroys the germs or spores of parasitic vegetable diseases, kills mosses on pasture lands and promotes the growth of useful agricultural grasses.

Farmers must not, however, lose sight of the fact that iron sulphate, if used in excess, is an energetic plant poison. If, by accident, an excess has been spread upon the land, a dressing of lime will correct the evil. In the use of this comparatively new artificial manure care should be taken not to overdose the land or to apply it to crops under any conditions but those in which practical experiment has proven its usefulness. Not more than from one-half hundredweight to one hundredweight per acre should be used, and, if spread as a top dressing, the iron sulphate should be thoroughly mixed with five to ten times its bulk of soil or sand, and should be spread after rain or when the soil is wet. The French experimenters recommend that this salt be used in solution with water as a top dressing to crops. Iron sulphate is not a stimulant, but furnishes food both directly and indirectly to a great variety of farm crops.

AMOUNTS OF MANURE PRODUCED BY FARM ANIMALS.

From Bulletin 27, Cornell University Agricultural Experiment Station.

Cows.—In the experiment with cows eighteen Jersey and Holstein grades in milk were kept in their places during the whole twenty-four hours, and the manure carefully collected as it was excreted, and a sufficient quantity of bedding and absorbents of known composition and weight were used to make the collection complete.

The cows consumed 114 pounds of hay, 893 pounds of ensilage, 186 pounds of beets, and 154 pounds of a mixture of 12 parts wheat bran, 9 parts cotton-seed meal, 3 parts corn meal, and 1 part malt sprouts. The other details of the experiment are shown in the table.

	Eighteen Cows for One Day.	Average Per Cow Per Day.
Weight of cows, pounds	20,380	1132
Food consumed, pounds	1,347	75
Water drunk, pounds	876	49
Total excretion, pounds	1,452.5	81
Nitrogen, pounds	7.35	.41
Phosphoric acid, pounds	5.01	.28
Potash, pounds	7.40	.41
Value of nitrogen	$1.10	$ .06
Value of phosphoric acid	.35	.02
Value of potash	.33	.02
Total value	1.78	.10

Composition of the mixed excrement :—

Nitrogen,	.51 per cent.
Phosphoric acid,	.35 "
Potash,	.51 "
Value per ton,	$2.46

A few days later a second trial was made with four of the same cows and the solid and liquid excrement carefully collected and analyzed separately. The conditions of food, water, etc., were almost identical.

	First Trial.	*Second Trial.*
Average weight,	1132	1178
Average food eaten,	75	76
Average water drunk,	49	40
Average total excrement voided,	81	82

The four animals yielded in twenty-four hours 255 pounds of solid and 72.25 pounds of liquid excrement, which had the following composition :—

	Solid. *Per cent.*	*Liquid.* *Per cent.*	*Mixed.* *Per cent.*
Nitrogen,	.26	1.32	.49
Phosphoric acid,	.28	. .	.22
Potash,	.20	1.00	.38
Value per ton,	$2.08		

The average of the two trials shows that well-fed cows, yielding milk heavily, may be counted upon to return nearly ten cents' worth of valuable fertilizing materials per day, and the last trial shows that the liquid excrement is of equal value with the solid.

Horses.—The determination of the amount of excrement was made by carefully collecting the manure made by the ten horses in the University barn during the time they were in the stable, for a period of eleven days including one Sunday. During this time the bedding used was also weighed and separately analyzed. The horses were mostly grade draft horses of about 1400 pounds weight, doing heavy work and liberally fed on oats and hay. During the eleven days of the experiment 3461 pounds of clear excrement of the following percentage composition was voided :—

	Per cent.
Nitrogen,	.47
Phosphoric acid,	.39
Potash,	.94
Value per ton,	$2.79

The amount and value of the fertilizing materials would, therefore, be :—

	10 Horses for 11 days.	*Average per horse per day.*
Nitrogen, pounds,	16.27	.15
Phosphoric acid, pounds,	13.50	.12
Potash, pounds,	32.53	.30
Nitrogen, value,	$2.44	$ .02
Phosphoric acid, value,	.81	.01
Potash, value,	1.46	.01
Total,	$4.71	.043

The horses, therefore, returned in the manure during the time that they were in the stable rather more than four cents each per day, in about thirty-two pounds of excrement.

Sheep.—For this trial tight galvanized iron pans, covering the whole surface of the pen, were used : the sheep were kept continuously upon them, and enough weighed straw bedding of known composition was used to keep them dry and clean. The sheep were grade Shropshires, of medium size, and were fed on grain, beets, and hay. The experiment lasted for thirty-three and two-thirds days with three sheep, during which time 723 pounds of clear excrement of the following percentage composition were obtained :—

	Per cent.
Nitrogen,	1.00
Phosphoric acid,	.08
Potash,	1.21
Value per ton,	$4.19

The other details of the experiment were as follows :—

	3 Sheep for 33⅔ days.	*Average per sheep per day.*
Weight of sheep,	426	142
Food consumed,	536	5.3
Water drunk,	765	7.5
Total excrement,	723	7.2
Nitrogen, pounds,	7.21	.071
Phosphoric acid, pounds,	.60	.005
Potash, pounds,	8.74	.086
Nitrogen, value,	$1.08	$ .01
Phosphoric acid, value,	.04	.0004
Potash,	.39	.004
Total value,	$1.51	.015

The most striking thing in regard to the sheep manure is the extremely low percentage of phosphoric acid. It will be noted that we obtained, in valuable fertilizing materials, about one and one-half cents' worth per sheep per day.

Swine.—The determinations of the amount of manure produced by swine were made in the same general way as the sheep, *i. e.*, by keeping the swine continuously upon tight galvanized iron pans and weighing and analyzing the bedding separately. Two determinations were made with two lots of swine fed on different rations ; one lot, known as the carbonaceous lot, was fed nothing but corn meal ; the other lot, known as the nitrogenous lot, was fed a ration of two parts corn meal and one part flesh meal. It will be noted that the excrement differed very materially both in amount and quality, as is shown by the following analysis :—

	Nitrogenous. Per cent.	*Carbonaceous. Per cent.*	*Average. Per cent.*
Nitrogen,	.92	.74	.83
Phosphoric acid,	.06	.01	.04
Potash,	.64	.58	.61
Value per ton,	$3.41	$2.94	$3.18

Other details of the experiment :—

	Nitrogenous.	Carbonaceous.	Average.	
	Four Pigs in Seven Days.	Four Pigs in Seven Days	Four Pigs in Seven Days.	Per Pig Per Day.
Weight of swine	600.	426	513.	128.
Food consumed	122.	78.	100.	3.6
Total excrement	146.	48.	97.	3.5
Nitrogen	1.34	.36	.85	.03
Phosphoric acid, pounds	.09	.007	.05	.002
Potash, pounds	.93	.28	.61	.02
Nitrogen, value	$ .20	$ .05	$ .13	$ .005
Phosphoric acid, value	.006	.005	.005	....
Potash, value	.04	.01	.03	.001
Total value	.25	.07	.16	.006

Summary :—

	Value Per Ton.	Value Per Animal Per Day.	Value Per Thousand Pounds Live Weight Per Day.	Value Per Thousand Pounds Live Weight Per Year.
Horse *	$2.79	$ .044	$ .031	$11.47
Horse †	....	.073	.052	19.12
Cows	2.27	.093	.082	29.82
Sheep	4.19	.015	.106	38.55
Swine	3.18	.006	.047	17.11

* Manure voided while at work not included.

† Total excrement calculated on the basis that three-fifths was collected in the stable.

ANALYSES OF COMMERCIAL FERTILIZING MATERIALS.

Name of Substance.	Moisture.	Nitrogen.	Potash.	Phosphoric Acid. Available.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Total.
I. Phosphatic Manures.						
Apatite	..	..	..	..	..	36.08
Bone ash	7.00	..	..	..	..	35.89
Bone-black	4.60	..	..	..	..	28.28
Bone-black (dissolved)	..	..	..	16.70	0.30	17.00
Bone meal	7.47	4.12	..	8.28	15.22	23.50
Bone meal (free from fat)	..	6,20	..	..	..	20.10
Bone meal (from glue factory)	..	1.70	..	..	..	29.90
Bone meal (dissolved)	..	2.60	..	13.53	4.07	17.60
Caribbean guano	..	..	..	..	..	18.90
Cuba guano	24.27	1.67	..	..	..	13.35
Mona Island guano	12.52	0.76	..	7.55	14.33	21.88
Navassa phosphate	7.60	..	..	..	..	34.27
Orchilla guano	7.31	..	..	..	..	26.77
Peruvian guano	14.81	7.85	2.61	8.36	6.90	15.26
S. Carolina rock (ground)	1.50	..	..	0.60	27.43	28.03
S. Carolina rock (floats)	..	..	..	..	..	27.20
S. C. rock (dissolved)	..	..	..	11.60	3.60	15.20
Thomas slag (American)	..	..	..	..	..	21.37
Thomas slag (English)	..	..	..	6.09	13.31	19.40
Thomas slag (German)	..	..	..	..	..	30.51
II. Potash Manures.						
Carnallite	..	..	13.68	..	..	..
Cotton-seed hull ashes	7.33	..	23.80	..	..	8.50
Kainit	3.20	..	13.54	..	..	..
Krugite	4.82	..	8.42	..	..	..
Muriate of potash	2.00	..	52.46	..	..	..
Nitrate of potash	1.93	13.09	45.19	..	..	..
Spent tan-bark ashes	6.31	..	2.04	..	..	1.61
Sulph. potash (high grade)	1.25	..	38.60	..	..	..
Sulph. potash and magnesia	4.75	..	23.50	..	..	..
Sylvinite	7.25	..	16.65	..	..	..
Waste from gunpowder works	2.75	2.43	18.00	..	..	..
Wood-ashes (unleached)	12.00	..	5.50	..	..	1.85
Wood-ashes (leached)	..	..	1.10	..	..	1.40
III. Nitrogenous Manures.						
Ammonite	5.88	11.33	..	..	..	3.43
Castor pomace	9.98	5.56	1.12	..	..	2.16
Cotton-seed meal	6.80	6.66	1.62	..	..	1.45
Dried blood	12.50	10.52	..	..	..	1.91
Dried fish	12.75	7.25	0.45	3.05	5.20	8.25
Horn and hoof waste	10.17	13.25	..	..	..	1.83
Lobster shells	7.27	4.50	..	..	..	3.52
Meat scrap	12.09	10.44	..	..	..	2.07

ANALYSES OF COMMERCIAL FERTILIZING MATERIALS.—*Continued.*

NAME OF SUBSTANCE.	Moisture.	Nitrogen.	Potash.	PHOSPHORIC ACID.		
				Available.	Insoluble.	Total.
III. Nitrogenous Manures.—Continued.						
Malt sprouts	7.40	4.04	2.20	..	..	1.70
Nitrate of soda	1.25	15.75	..	..	..	..
Nitre-cake	6.00	2.30	0.40	..	..	..
Oleomargarine refuse	8.54	12.12	..	..	..	0.88
Sulphate of ammenia	1.00	20.50	..	..	..	..
Tankage	13.20	6.82	..	5.02	6.23	11.25
Tobacco stems	10.61	2.29	6.44	..	..	0.60
Wool waste	9.27	5.64	1.30	..	..	0.29
IV. Miscellaneous Materials.						
Ashes (anthracite coal)	..	..	0.10	..	..	0.10
Ashes (bituminous coal)	..	..	0.40	..	..	0.40
Ashes (corn-cob)	..	..	23.20	..	..	..
Ashes (lime-kiln)	15.45	..	0.86	..	..	1.18
Ashes (peat and bog)	5.20	..	0.70	..	..	0.50
Gas lime	4.40	0.30	..	..	..	..
Marls (Maryland)	1.73	..	1.25	..	..	0.38
Marls (Massachusetts)	18.18	..	..	..	..	1.05
Marls (North Carolina)	1.50	..	0.04	..	..	0.56
Marls (Virginia)	15.98	..	0.49	..	..	0.09
Muck (fresh)	76.20	0.30	..	..	..	..
Muck (air-dry)	21.40	1.30	..	..	..	..
Mud (fresh water)	40.37	1.37	0.22	..	..	0.26
Mud (from sea-meadows)	53.50	0.20	0.20	..	..	0.10
Peat	61.50	0.75	..	..	..	..
Pine straw (dead leaves or pine needles)	7.80	0.30	0.10	..	..	0.20
Shells (mollusks)	..	0.10	0.04	..	..	0.03
Shells (crustacea)	..	6.20	0.20	..	..	2.30
Shell lime (oyster-shell)	19.50	..	0.04	..	..	0.20
Soot	5.54	..	1.83	..	..	..
Spent tan	14.00	0.20	0.10	..	..	0.04
Spent sumach	30.80	1.00	0.30	..	..	0.10
Sugar-house scum	50.20	2.10	..	..	..	..
Turf	19.29	1.94	..	..	..	..

Analyses of Farm Manures.

Taken chiefly from reports of the New York, Massachusetts, and Connecticut Experiment Stations.

Name of Substance.	Moisture.	Nitrogen.	Potash.	Phosphoric Acid.
I.				
Cattle (solid fresh excrement),	.	0.29	0.10	0.17
Cattle (fresh urine),	. .	0.58	0.49	. .
Hen manure (fresh),	.	1.63	0.85	1.54
Horse (solid fresh excrement),	. .	0.44	0 35	0.17
Horse (fresh urine),	. .	1.55	1.50	. .
Human excrement (solid),	77.20	1.00	0.25	1.09
Human urine,	95.90	0.60	0.20	0 17
Poudrette (night soil),	.	0.80	0.30	1.40
Sheep (solid fresh excrement),	. .	0.55	0.15	0.31
Sheep (fresh urine),	. .	1.95	2.26	0.01
Stable manure (mixed),	73.27	0.50	0.60	0.30
Swine (solid fresh excrement),		0.60	0.13	0 41
Swine (fresh urine),		0.43	0.83	0.07

Analyses of Fertilizing Materials in Farm Products.

Analyses of Hay and Dry Coarse Fodders.

Name of Substance.	Moisture.	Nitrogen.	Potash.	Phosphoric Acid.
II. Hay and Dry Coarse Fodders.				
Blue melilot,	8.22	1.92	2.80	0 54
Buttercups,	. .	1.02	0.81	0 41
Carrot tops (dry),	9.76	3.13	4.88	0.61
Clover (alsike),	9 93	2.33	2.01	0.70
Clover (Bokhara),	6 36	1.77	1.67	0.44
Clover (mammoth red),	11.41	2.23	1.22	0.55
Clover (medium red),	10.72	2.09	2.20	0.44
Clover (white),		2.75	1.81	0.52
Corn fodder,	. .	1 80	0.76	0 51
Corn stover,	28 24	1.12	1.32	0.30
Cow-pea vines,	9 00	1.64	0 91	0.53
Daisy (white),	9.65	0.28	1 25	0 44
Daisy (ox-eye),	. .	0.80	2 23	0.27
Hungarian grass,	7 15	1.16	1 28	0.35
Italian rye-grass,	8.29	1.15	0.99	0.55
June grass,	. .	1.05	1.46	0 37
Lucerne (alfalfa),	6.26	2.07	1.46	0.53
Meadow fescue,	9.79	0.94	2 01	0.34
Meadow foxtail,	. .	1.54	2.19	0.44
Mixed grasses,	11.26	1.37	1.54	0.35
Orchard grass,	8 84	1.31	1 88	0 41
Perennial rye-grass,	9.13	1.23	1.55	0 56
Red-top,	7.71	1.15	1.02	0.36
Rowen,	12.48	1.75	1.97	0.46
Salt hay,	5.36	1.18	0 72	0.25
Serradella,	7.39	2.70	0.65	0.78
Soja bean,	6.30	2.32	1.08	0.67

ANALYSES OF FERTILIZING MATERIALS IN FARM PRODUCTS.—*Continued.*

NAME OF SUBSTANCE.	MOISTURE.	NITROGEN.	POTASH.	PHOSPHORIC ACID.
II. Hay and Dry Coarse Fodders.—Continued.				
Tall meadow oat,	. .	1.16	1.72	0 32
Timothy hay,	7.52	1.26	1.53	0.46
Vetch and oats,	11.98	1.37	0.90	0.53
Yellow trefoil,	.	2.14	0.98	0.43
III. Green Fodders.				
Buckwheat,	82.60	0.51	0.43	0.11
Clover (red),	80.00	0 53	0.46	0.13
Clover (white),	81.00	0.56	0.24	0.20
Corn fodder,	72.64	0 56	0.62	0.28
Corn fodder (ensilage),	71.60	0.36	0 33	0.14
Cow-pea vines,	78.81	0.27	0 31	0.98
Horse bean,	74.71	0.68	1 37	0.33
Lucerne (alfalfa),	75.30	0.72	0.45	0.15
Meadow grass (in flower),	70.00	0 44	0 60	0.15
Millet,	62.58	0.61	0.41	0 19
Oats (green),	83.36	0.49	0.38	0.13
Peas,	81.50	0.50	0.56	0.18
Prickly comfrey,	. .	0.42	0.75	0.11
Rye grass,	70.00	0.57	0.53	0.17
Serradella,	82.59	0.41	0.42	0.14
Sorghum,	. .	0.40	0.32	0.08
Spanish moss,	60.80	0.28	0.26	0.30
Vetch and oats,	86.11	0.24	0.79	0.09
White lupine,	85.35	0.44	1.73	0.35
Young grass,	80 00	0.50	1.16	0.22
IV. Straw, Chaff, Leaves, etc.				
Barley chaff,	13.08	1.01	0.99	0.27
Barley straw,	13.25	0.72	1.16	0.15
Bean shells,	18 50	1.48	1.38	0.55
Beech leaves (autumn),	15.00	0.80	0.30	0.24
Buckwheat straw,	16.00	1 30	2 41	0.61
Cabbage leaves (air-dried),	14 60	0.24	1.71	0.75
Cabbage stalks (air-dried),	16.80	0.18	3.49	1.06
Carrots (stalks and leaves),	80.80	0.51	0.37	0.21
Corn cobs,	12.09	0.50	0.60	0.06
Corn hulls,	11.50	0.23	0.24	0.02
Hops,	11.07	2.53	1 99	1.75
Oak leaves,	15.00	0 80	0.15	0.34
Oat chaff,	14.30	0.64	1.04	0.20
Oat straw,	28 70	0.29	0.88	0.11
Pea shells,	16.65	1.36	1.38	0.55
Pea straw (cut in bloom),	.	2.29	2.32	0.68
Pea straw (ripe),	. .	1.04	1.01	0.35
Potato stalks and leaves,	77.00	0.49	0.07	0.06
Rye straw,	15 40	0.24	0 76	0.19
Sugar-beet stalks and leaves,	92.65	0.35	0.16	0.07
Turnip stalks and leaves,	89.80	0.30	0.24	0.13
Wheat chaff (spring),	14.80	0.91	0.42	0.25
Wheat chaff (winter),	10 56	1.01	0.14	0.19
Wheat straw (spring),	15.00	0.54	0.44	0.18
Wheat straw (winter),	10.36	0.82	0.32	0 11
V. Roots, Tubers, etc.				
Beets (red),	87.73	0.24	0.44	0.09

ANALYSES OF FERTILIZING MATERIALS IN FARM PRODUCTS.—*Continued.*

NAME OF SUBSTANCE.	MOISTURE.	NITROGEN.	POTASH.	PHOSPHORIC ACID.
V. Roots, Tubers, etc.—Continued.				
Beets (sugar),	84.65	0.25	0.29	0.08
Beets (yellow fodder),	90.60	0.19	0.46	0.09
Carrots,	90.02	0.14	0.54	0.10
Mangolds,	87.29	0.19	0.38	0.09
Potatoes,	79.75	0.21	0.29	0.07
Ruta bagas,	87.82	0.21	0.50	0.13
Turnips,	87.20	0.22	0.41	0.12
VI. Grains and Seeds.				
Barley,	15.42	2.06	0.73	0.95
Beans,	. .	4.10	1.20	1.16
Buckwheat,	14.10	1.44	0.21	0.44
Corn kernels,	10.88	1.82	0.40	0.70
Corn kernels and cobs (cob meal)	10.00	1.46	0.44	0.60
Hemp seed,	12.20	2 62	0.97	1.75
Linseed,	11.80	3.20	1.04	1.30
Lupines,	13 80	5 52	1.14	0.87
Millet,	13.00	2.40	0 47	0 91
Oats,	20.80	1.75	0.41	0.48
Peas,	19 10	4.26	1.23	1.26
Rye,	14.90	1.76	0.54	0.82
Soja beans,	18.83	5.30	1.99	1.87
Sorghum,	14.00	1.48	0.42	0.81
Wheat (spring),	14.75	2.36	0.61	0.89
Wheat (winter),	15.40	2.83	0.50	0.68
VII. Flour and Meal.				
Corn meal,	13.52	2 05	0.44	0.71
Ground barley,	13.43	1.55	0 34	0.66
Hominy feed,	8 93	1.63	0.49	0.98
Pea meal,	8.85	3.08	0.99	0.82
Rye flour,	14.20	1.68	0.65	0.85
Wheat flour,	9.83	2.21	0.54	0.57
VIII. By-products and Refuse.				
Apple pomace,	80.50	0.23	0.13	0.02
Cotton hulls,	10.63	0.75	1.08	0.18
Cotton-seed meal,	. .	6.52	1.89	2.78
Glucose refuse,	8.10	2.62	0.15	0.29
Gluten meal,	8.53	5.43	0.05	0.43
Hop refuse,	8.98	0 98	0.11	0 20
Linseed cake (new process),	6.12	5.40	1.16	1 42
Linseed cake (old process),	7.79	6.02	1.16	1.65
Malt sprouts,	10.28	3 67	1.60	1.40
Oat bran,	8.19	2.25	0.66	1 11
Rye middlings,	12.54	1.84	0.81	1.26
Spent brewer's grains (dry),	6.98	3.05	1.55	1.26
Spent brewer's grains (wet),	75.01	0.89	0.05	0 31
Wheat bran,	11.01	2.88	1.62	2 87
Wheat middlings,	9.18	2.63	0.63	0.95
IX. Dairy Products.				
Milk,	87.20	0.58	0.17	0.30
Cream,	68 80	0.58	0 09	0.15
Skim-milk,	90.20	0.58	0.19	0.34
Butter,	13 60	0.12	. .	. .

ANALYSES OF FERTILIZING MATERIALS IN FARM PRODUCTS.—*Continued.*

NAME OF SUBSTANCE.	MOISTURE.	NITROGEN.	POTASH.	PHOSPHORIC ACID.
IX. Dairy Products.—Continued.				
Butter-milk,	90.10	0.64	0.09	0.15
Cheese (from unskimmed milk)	38 00	4.05	0.29	0.80
Cheese (from half-skimmed milk),	39 80	4.75	0.29	0.80
Cheese (from skimmed milk),	46.00	5.45	0.20	0.80
X. Flesh of Farm Animals.				
Beef,	77.00	3.60	0.52	0.43
Calf (whole animal),	66.20	2.50	0.24	1.38
Ox,	59.70	2.66	0.17	1.86
Pig,	52.80	2.00	0.90	0.44
Sheep,	59.10	2.24	0.15	1.23
XI. Garden Products.				
Asparagus,	. .	0.32	0.12	0.09
Cabbage,	. .	0.30	0 43	0.11
Cucumbers,	.	0.16	0.24	0.12
Lettuce,		0.20	0.25	0.11
Onions,		0.27	0.25	0.13

TABLE SHOWING THE NUMBER OF POUNDS OF NITROGEN, PHOSPHORIC ACID, AND POTASH WITHDRAWN PER ACRE BY AN AVERAGE CROP.

(From New York, New Jersey, and Connecticut Experiment Stations' Reports.)

NAME OF CROP.	NITROGEN.	PHOSPHORIC ACID.	POTASH.
Barley,	78	35	62
Buckwheat,	63	40	17
Cabbage (white),	213	125	514
Cauliflower,	202	76	265
Cattle turnips,	187	74	426
Carrots,	166	65	190
Clover, green (trifolium pratense),	171	46	154
Clover (trifolium pratense),	37	18	29
Clover, scarlet (trifolium incarnatum),	95	17	57
Clover (trifolium repens),	89	29	58
Cow pea,	254	64	169
Corn,	146	69	174
Corn fodder (green),	122	66	236
Cotton,	110	32	35
Cucumbers,	142	94	193
Esparsette,	239	36	103
Hops,	200	54	127
Hemp,	. .	34	54
Lettuce,	41	17	72
Lucerne,	289	65	181
Lupine, green (for fodder),	219	46	63
Lupine, yellow (lupinus luteus),	80	37	155
Meadow hay,	166	53	201

TABLE SHOWING THE NUMBER OF POUNDS OF NITROGEN, PHOSPHORIC ACID, AND POTASH WITHDRAWN PER ACRE BY AN AVERAGE CROP.—*Continued.*

NAME OF CROP.	NITROGEN.	PHOSPHORIC ACID.	POTASH.
Oats,	89	35	96
Onions,	96	49	96
Peas (pisuni sativum),	153	39	69
Poppy,	87	30	87
Potatoes,	119	55	192
Rape,	154	79	124
Rice,	39	24	45
Rye,	87	44	76
Seradella,	128	57	196
Soja bean,	297	62	87
Sugar cane,	518	37	107
Sorghum (sorghum saccharatum),	446	90	561
Sugar beet (beet-root),	95	44	200
Tobacco,	127	32	148
Vetch (visia sativa),	149	35	113
Wheat,	111	45	58

ANALYSES OF HAY.

(*From Bulletin 15, 1889, Vermont Experiment Station.*)

STATION NO.	KIND OF FODDER.	FERTILIZING INGREDIENTS.		
		Nitrogen.	Phosphoric Acid.	Potash.
	Timothy hay,	1.26	0.500	1.58
	Hay with much clover,	1.54	0.580	1.89
1086	Hay, early cut,	1.68	0.312	2.38
1087	Hay, late cut,	1.28	0.179	1.28
1088	Hay,	1.00	0.302	2.07
1089	Hay,	1.16	0.207	1.60
1090	Rowen,	2.02	0.353	1.76
1091	Hay, early cut,	1.26	0.291	1.81
1092	Hay,	0.97	0.255	1.10
1093	Upland hay,	1.63	0.329	2.04
1094	Low meadow hay,	1.56	0.223	1.74
1098	Hay,	1.44	0.355	1.40
1100	Hay,	1.25	0.253	1.77
1103	Hay,	1.40	0.345	1.53
1108	Early cut hay,	1.88	0.512	1.20
1109	Late cut hay,	0.97	0.359	0.85
1117	Hay,	1.23	0.329	1.92
1131	Hay from new seeding,	1.89	0.347	1.96
1132	Hay from old stocking,	1.58	0.336	1.96
	Average,	1.42	0.311	1.671

Fertilizer Experiments on Meadow Land.

(Kentucky Agricultural Experiment Station Bulletin, No. 23, February, 1890.)

On low and decidedly wet land.

English Blue Grass.

Fertilizers Used Per Acre.	Amount Per Acre in Pounds.	Yield of Hay in Pounds Per Acre.
Sulphate of potash,	160	3000
Muriate of potash,	160	2950
Nitrate of soda,	160	3100
Sulphate of ammonia,	130	3600
No fertilizer,	. .	2850
Stable manure,	20 loads.	2970
Tobacco stems,	4000	4700

Timothy.

Kind of Fertilizer Used.	Amount Per Acre in Pounds.	Yield of Hay in Pounds Per Acre.
Sulphate of potash,	160	1900
Muriate of potash,	160	2320
Nitrate of soda,	160	2670
Sulphate of ammonia,	130	2520
No fertilizer,	. .	1620
Stable manure,	20 loads.	2200
Tobacco stems,	4000	3350

Time Required for the Complete Exhaustion of Fertilizing Materials and the Amounts of Each Remaining in the Soil During a Period of Seven Years.

(From Scottish estimates.)

"ON UNCULTIVATED CLAY LOAM.

Kind of Fertilizer,	*Exhausted (in years).*	*Per cent. remaining in the soil unexhausted at the end of each year.*						
		1	*2*	*3*	*4*	*5*	*6*	*7*
Lime,	12	80	65	55	45	35	25	20
Bone meal,	5	60	30	20	10	00	00	00
Phosphatic guanos,	5	50	30	20	10	00	00	00
Dissolved bones and plain superphosphates,	4	20	10	5	00	00	00	00
High grade ammoniated fertilizers, guano, etc.,	3	30	20	00	00	00	00	00
Cotton-seed meal,	5	40	30	20	10	00	00	00
Barn-yard manure,	5	60	30	20	10	00	00	00

ON UNCULTIVATED LIGHT OR MEDIUM SOILS.

Kind of Fertilizer.	*Exhausted (in years).*	*Per cent. remaining in the soil unex hausted at the end of each year.*						
Lime,	10	75	60	40	30	20	15	
Boue meal,	4	60	30	10	00	00	00	
Phosphatic guanos,	4	50	20	10	00	00	00	
Dissolved bones and plain superphosphates,	3	20	10	5	00	00	00	00
High grade ammoniates, guanos,	3	30	20	00	00	00	00	00
Cotton-seed meal,	4	40	30	20	10	00	00	00
Barn-yard manure,	4	60	30	10	00	00	00	00

ON UNCULTIVATED PASTURE LAND.

Lime,	15	80	70	60	50	45	40	35
Bone meal,	7	60	50	40	30	20	10	00
Phosphatic guano,	6	50	40	30	20	10	00	80
Dissolved bone, etc.,	4	30	20	10	00	00	00	00
High grade ammoniated guanos,	4	30	20	10	00	00	00	00
Cotton-seed meal,	5	40	30	20	10	00	00	00
Barn-yard manure,	7	60	50	40	30	20	10	00

"Sulphate of ammonia, nitrate of soda, sulphate, nitrate and muriate of potash are generally held to be entirely exhausted by the crops grown the season of their application.

"The figures given above are always used in fixing the price for new tenants. In this country no such careful estimates have been made, but the proportions probably vary but little from those in other countries.

Amounts of Nitrogen, Phosphoric Acid, and Potash Found Profitable for Different Crops Under Average Conditions Per Acre.

(*Taken chiefly from New Jersey Experiment Station's Reports.*)

	Nitrogen. Pounds.	*Phosphoric Acid. Pounds.*	*Potash. Pounds.*
Wheat, rye, oats, corn,	16	40	30
Potatoes and root crops,	20	25	40
Clover, beans, peas, and other leguminous crops,	.	40	60
Fruit trees and small fruits,	25	40	75
General garden produce,	30	40	60

THE VARIOUS POTASH SALTS AND THEIR COMPOSITION.

(*From Potash and Paying Crops.*)

A. NATURAL PRODUCTS OF THE MINES.	Sulphate Potash.	Chloride Potash.	Sulphate Magnesia.	Chloride Magnesia.	Chloride Sodium (Common Salt).	Sulphate Lime (Gypsum).	Insoluble in Water.	Water.	Potash.	Salts Neutralizing Ammonia.
Kainit,	21.3	2.0	14.5	12.4	34.6	1.7	0.8	12.7	12.8	28.6
Carnallite,	. .	15.5	12.1	21.5	22.4	1.9	0.5	26.1	9.8	35.5
Kieserite,	. .	11.8	21.5	17.2	26.7	0.8	1.3	20.7	7.5	39.5
Sylvinite, *a*,	7.1	24.7	5.8	4.0	46.2	1.9	1.9	8.4	19.4	11.7
Sylvinite, *b*,	17.2	11.1	11.8	8.1	38.2	3.6	0.3	9.7	16.3	23.5
Sylvinite, *c*,	16.3	14.0	11.8	9.3	34.9	3.6	1.8	8.3	17.6	24.7
B. CONCENTRATED PRODUCTS.										
a. Sulphates of Potash.										
1. Sulphate of potash, high-graded, 96%,	97.2	0.3	0.7	0.4	0.2	0.3	0.2	0.7	52.7	
2. Sulphate of potash, high-graded, 90%,	90.6	1.6	2.7	1.0	1.2	0.4	0.3	2.2	49.9	
3. Double sulphate of potash and sulphate of magnesia (double manure salt),	50.4	. .	34.0	. .	2 5	0.9	0.6	11.6	27.2	34.9
4. Calcined kieserite,	. .	. .	65.8	. .	0.9	6.5	15.7	11.1	. .	72.3
b. Muriates of Potash.										
Muriate of potash, 90–95%,	. .	91.7	0.2	0.2	7.1	. .	0.2	0.6	57.9	
Muriate of potash, 80–85%,	. .	83.5	0.4	0.3	14.5	. .	0.2	1.1	52.7	
Muriate of potash, 70–75%,	1.7	72.5	0.8	0.6	21.0	0.2	0.5	2.5	46.7	
Calcined manure salt, high grade,	. .	44.5	22.5	4.6	12.4	2.9	5.3	7.8	28.1	30.0
Calcined manure salt, low grade,	. .	25.6	31.1	6.3	10.3	3.5	10.6	12.6	16.2	40.6

ROTATION OF CROPS.

In the changed conditions of agriculture elaborate systems of crop rotation are no longer necessary. With the help of chemical manures and the judicious use of renovating crops farmers are no longer subject to rigid rule, but may adapt rotations to the varying demands of local market conditions.

SOME AMERICAN ROTATIONS.

1. Potatoes.
2. Wheat.
3. Clover.
4. Clover.
5. Wheat, oats, or rye.

1. Potatoes.
2. Wheat.
3. Grass, timothy, and clover.
4. Grass, timothy, and clover.
5. Corn.

1. Roots.
2. Wheat.
3. Clover.
4. Clover.
5. Corn, oats, or rye.

1. Roots.
2. Wheat.
3. Clover.
4. Clover.
5. Wheat.
6. Oats.

The following English rotations are given by Dr. Griffiths in his "Treatise on Manures":—

East Lothian System.

1. Oats.
2. Beans.
3. Wheat.
4. Roots.
5. Wheat or barley.
6. Seeds.

Ayrshire System.

1. Oats.
2. Turnips.
3. Wheat.
4. Beans.
5. Wheat.
6. Seeds.

Dundee System.

1. Wheat.
2. Turnips.
3. Oats.
4. Potatoes.
5. Wheat.
6. Seeds.
7. Oats.
8. Potatoes.

Derby Eight-Years' System.

1. Oats.
2. Wheat.
3. Beans or green crop.
4. Wheat.
5. Roots.
6. Barley.
7. Clover.
8. Clover.

Bedfordshire System.

1. Wheat.
2. Roots.
3. Wheat.
4. Barley.
5. Clover.

South Lancashire System.

1. Potatoes.
2. Wheat.
3. Barley.
4. Clover or grass.
5. Clover or grass.

Norfolk System.

1. Wheat.
2. Turnips or roots.
3. Barley.
4. Clover.

Modified Norfolk System.

1. Turnips or roots.
2. Barley.
3. Clover.
4. Clover.
5. Wheat.

Cumberland System.

1. Oats.
2. Roots.
3. Wheat, barley, or oats.
4. Clover.
5. Grass.

Yorkshire Wolds' System.

1. Wheat.
2. Roots.
3. Barley.
4. Peas.
5. Roots.
6. Oats.
7. Seeds.

Wiltshire System.

(a) On Strong Land.

1. Wheat.
2. Beans.
3. Wheat.
4. Vetches and mangels.
5. Wheat.
6. Clover (twice cut).
7. Clover (once cut, then fed).

(b)

1. Wheat.
2. Swedes and turnips.
3. Barley.
4. Beans or peas.
5. Wheat and oats.
6. Clover (twice cut).
7. Clover (once cut, then fed).

INDEX.

I.

K.

L.

M.

N.

O.

P.

R.

S.

T.

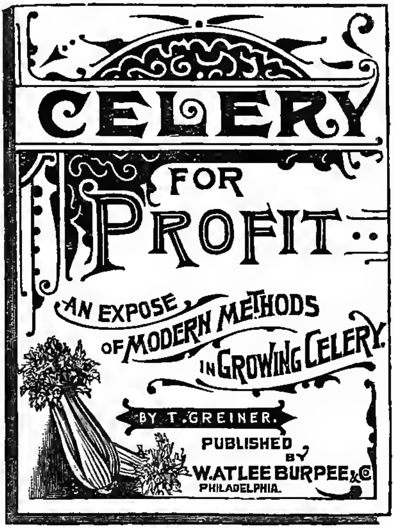
U.

V.

W.

CELERY FOR PROFIT.

All agree that Celery offers greater chances for making money than any other garden crop. The difficulties encountered by the old methods of growing, however, made success uncertain, and sure only with comparatively few expert growers. Modern methods make all this uncertainty a thing of the past. From the same area which would give $100.00 in any other vegetable, you may take $400.00 or even $500.00 in Celery, if you **know how.** This new book, just published, is written by T. GREINER, author of ONIONS FOR PROFIT, and other books on gardening. It tells how to dispense with nine-tenths of the labor generally thought necessary in Celery growing, and how to make the business pay really big profits. Under the right culture and conditions several thousand dollars' worth of Celery can be raised on a single acre. The book is thoroughly complete in every detail, and is embellished with many helpful and original illustrations. Here is a glimpse of the table of contents :—



Generalities—An Introduction—The Early Celery—The New Celery Culture—The Irrigation Problem—The Fall and Winter Crop—Winter Storage—Marketing Problems—Varieties, etc., etc.

Price, Postpaid, 30 Cents,

or can be selected FREE as a premium with any order amounting to THREE DOLLARS or more.

PUBLISHED BY

W. ATLEE BURPEE & CO., PHILADELPHIA, PA.