

Fertility

and

Fertilizer Hints

By

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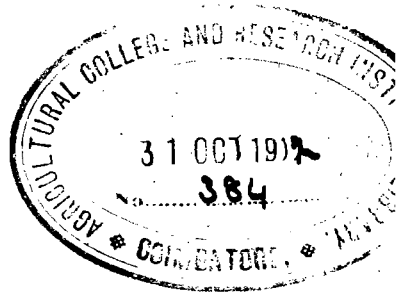
THE CHEMICAL PUBLISHING CO.

1911

LONDON, ENGLAND:

WILLIAMS & NORGATE

14 HENRIETTA STREET, COVENT GARDEN, W. C.



FERTILITY AND FERTILIZER HINTS

Published by

The Chemical Publishing Co.

Easton, Penna.

Publishers of Scientific Books

Engineering Chemistry

Portland Cement

Agricultural Chemistry

Qualitative Analysis

Household Chemistry

Chemists' Pocket Manual

Metallurgy, Etc.

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PREFACE.

The little book is an abridged edition of the author's, Soil Fertility and Fertilizers. The symbol* has been used throughout the text to refer to notes, in the back of the book, that state the topics of subject matter that have necessarily been omitted in this work.

This book has been written to be within the reach of the farmer, student, or any other person interested in the subject, "Fertilizers," and should more complete data be desired the unabridged edition, Soil Fertility and Fertilizers should be consulted.

The writer is indebted to the Louisiana Experiment Station, for illustrations.

J. E. HALLIGAN.

Baton Rouge, La.

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CHAPTER I.

CHEMICAL ELEMENTS NEEDED BY PLANTS AND THE COMPOSITION OF PLANTS.

In order to thoroughly understand the subject "fertilizers," we must become familiar with the chemical elements needed by plants.

There are about 81 chemical elements known to us, but only 15 of these are required for plant life so far as we know.

The Fifteen Elements.—Hydrogen, oxygen, nitrogen, carbon, potassium, phosphorus, calcium, sulphur, silicon, iron, chlorine, magnesium, sodium, aluminum and manganese are the elements used by plants. Hydrogen, oxygen, nitrogen and chlorine, in the pure state, generally occur as gases, while the other elements are solids.

The Symbols.—The chemist uses the following symbols for these elements.

Hydrogen (H)	Oxygen (O)	Nitrogen (N)
Carbon (C)	Potassium (K)	Phosphorus (P)
Calcium (Ca)	Sulphur (S)	Silicon (Si)
Iron (Fe)	Chlorine (Cl)	Magnesium (Mg)
Sodium (Na)	Aluminum (Al)	Manganese (Mn)

Small amounts of oxygen are sometimes used by plants in the elementary state. Certain plants also use nitrogen in the free state. All other elements, and generally oxygen and nitrogen must be combined with other of these elements to be favorable for the support of plant life.

Hydrogen.—This is a colorless invisible gas, having no smell or taste. It is generally found in combination with other elements as water, hydrochloric acid, marsh gas, sulphuretted hydrogen, all acids and most organic (animal and vegetable) compounds. It is most commonly found as water (H_2O), which is the most necessary food of the plant. In the free state hydrogen occurs only in small quantities upon the earth in the gases of petroleum wells, around volcanic eruptions, and it is evolved by the fermentation and decomposition of some organic substances.

Oxygen.—In the free gaseous state, about one-fourth, by volume, of the atmosphere is made up of this element, mechanically mixed with nitrogen. It is found in enormous quantities in combination with other elements. It constitutes about eight-ninths by weight of water and nearly one-half of the earth's crust. All combustion and decay require oxygen. The plant stores up oxygen in combination with other elements and without oxygen plants would die. The plant takes in oxygen, from the atmosphere, in combination with carbon, as carbonic acid gas, through the openings on the under sides of the leaves; the carbon is absorbed and the excess of oxygen given off. Oxygen combines with most other elements forming oxides. It often combines with other elements in varied amounts forming oxides of different composition which are generally quite stable. The color of soils is often determined by oxides such as iron oxides. The iron oxides influence the moisture condition of soils because of their absorptive qualities and help to oxidize organic substances in the soil. The roots of plants when deprived of air in the soil are able to draw upon iron oxides for oxygen.

Nitrogen.—About four-fifths of the atmosphere, or about 35,000



Fig. 1.—Cowpeas have the power of gathering nitrogen from the air.
For every acre of land is made up of nitrogen in the free

gaseous state. In combination this element is found in many substances such as ammonia, sodium nitrate (Chile saltpeter), potassium nitrate and many organic compounds. Certain plants, namely the legumes, of which the pea, bean, alfalfa, clovers, cowpea, soy bean, etc., are members, have the power of gathering nitrogen from the air, by means of certain growths (tubercles) on their roots.* Although nitrogen is abundant in the free state it cannot be used as such by most plants and it must be combined with other elements to be available as plant food. Nitrogen as sold in fertilizers is in combination with other elements, and is the most fugitive and expensive of the essential elements. This will be described more fully later on.

Carbon.—This element is found in the free state in charcoal, graphite and diamonds. In coal it is also present in an impure state. Muck and peat contain considerable carbon. Humus (the decayed organic matter in soils) is made up partly of carbon. In combination with oxygen we find carbon as carbon dioxide (carbonic acid gas) in the air. It is present in greater quantities in plant life than any other element. Henry¹ says: "10,000 volumes of air contain about 3 volumes of carbonic acid gas; 32 cubic yards of air hold one pound of this gas. An acre of growing wheat will gather during four months, 2,000 pounds of carbonic acid gas, or an amount equal to all the air contains over the same area of land to a height of three miles." All of our farm crops use a great amount of carbon in the form of carbonic acid gas. All carbonates (limestone, chalk, marble, shells, etc.) and all organic substances contain carbon. The carbonates of lime found in the soil exert a great influence upon the conversion of some forms of nitrogen into available plant food and in the general physical condition of the soil.

Potassium in combination is very common. It is mined in large quantities as potassium salts in the Stassfurt mines of Germany. The presence of this element in wood ashes, as potassium carbonate, makes this substance a valuable fertilizer. Potassium is found in most rocks and soils. In plants it is associated with organic acids. It is found in sea water and saltpeter. This

¹ Feeds and Feeding.

element is essential to plant growth and is found in the stems, leaves and fruits of plants.

Phosphorus is found in combination with oxygen and metals, as phosphates. Vast deposits of phosphates are found in Tennessee, South Carolina, Florida and some of the western states. It is present in many rocks and most soils and is an important element for plant food. It exists in combination with organic substances in plants and constitutes an important part of the ash of plants. Bones, which contain about 60-65 per cent. of calcium phosphate, are an important source of phosphorus for plant food.

Calcium is an element which occurs in combination in many substances as lime, marble, shells, coral and gypsum. It makes up about one-sixteenth part of the earth's crust. Plants and animals require this element, sometimes in larger amounts than one would imagine. The bones of animals are made up largely of this element in combination as lime. Lime is a great factor in regulating the physical condition of soils.

Sulphur.—This is a yellow substance which is found in the free state in large deposits in Louisiana, western United States, and Sicily. It is found in combination in gypsum (an important indirect fertilizer), pyrites (a source of sulphuric acid), galena, etc. It is also found in many natural waters. In plants it occupies an important place, occurring in organic compounds as protein, or nitrogenous portions, and also as sulphuric acid. Most of our soils are sufficiently supplied with this element for the nourishment of plants.

Silicon occurs in combination as sand, flint, quartz, etc., and constitutes about one-half the earth's crust. It is present in most rocks and soils and plays an important part in the physical make up of the soil. Plants require this element to support certain parts of their structure. The hulls and straws of plant substances are often comparatively rich in this element.

Iron is a very common element and in combination it is widely distributed. Although used in small amounts by plants it is nevertheless very important, as it is necessary for the production and activity of chlorophyll (the green coloring matter of

plants). The color of soils (red and yellow) are chiefly due to the presence of iron compounds.

Chlorine is most commonly found as chloride (common salt). It also occurs in combination with hydrogen, as hydrochloric acid.

Magnesium.—This element is found in most rocks and soils in sufficient amounts for the needs of the plant. It is used in different parts of the plant but mainly in the formation of seeds.

Sodium.—Chloride is the commonest compound of this element and is present in common salt, sea water, salt lakes, and in many springs and waters. It occurs in sodium carbonate and sodium nitrate; the latter compound is a valuable fertilizer because of its nitrogen content. Sodium is believed to be helpful in plant growth.

Aluminum.—This element is the most widely distributed next to oxygen and silicon of the earth's crust. About one-twelfth of the earth's crust is aluminum. In combination it is found in clay, slate, kaolin, etc. Although it is very abundant it is not used much by plants.

Manganese occurs in combination as manganese blend, manganese spar, manganite, etc. Plants use this element in small amounts although it is not believed to be necessary for plant growth.*

How Plants Feed.¹—Every seed is made up of a germ (embryo plant) surrounded by stored up food. When a seed is dropped into the warm soil it germinates and feeds on this stored up food material until it has put forth a root, stem and leaves. It is now able to gather its food from the air, water and soil. On the roots of plants are minute root hairs, composed of single cells, which absorb food materials from the soil water, by means of osmosis or diffusion. The leaves, on the under sides, have minute openings which permit the breathing of air which contains carbonic acid gas. The carbon is used in building up the plant and the excess of oxygen is given back to the atmosphere. This process requires the presence of light as does chlorophyll (green coloring matter of plants). Plants will grow without

¹ Much of the remaining portion of this chapter has been taken from Halligan's *Elementary Treatise On Stock Feeds and Feeding*.

light as long as the food supply in the seed lasts, but they will be white and will not produce seed. By the aid of sunlight the materials gathered by the root hairs and leaves are manufactured into compounds and retained by the plants.

The Food of the Plant.—The plant keeps growing until it produces seed. It may continue its growth for years as is the case with trees. In this continual growing process we cannot see the plant feeding but we know its nourishment is obtained from the soil, water and air. The food of the plant, then, consists of the mineral substances, water and gases taken from the soil and air.

Composition of Plants.—All plants are made up of water and dry matter. The water is composed of hydrogen and oxygen while the dry matter contains many elements and combinations of elements.

Water.—All plants and parts of plants contain water. The water is present in two forms, namely, physiological and hygroscopic.

1. **Physiological water** is that which is contained in the plant structure. It is obtained from the soil. It is used to keep the leaf tissues and their cell walls moist so that carbonic acid gas may be absorbed, to transfer food materials, and to regulate the temperature of the plant by means of evaporation of water, just as the temperature of the animal body is regulated by the evaporation of perspiration. When green grass is dried in the sun the loss in weight is mostly due to evaporation of physiological water.

2. **Hygroscopic water** is that which is taken up from the air and may vary from day to day according to the humidity of the surrounding air. On rainy days more water would be taken up than on dry days. The writer has often determined the water content of the same samples of corn meal, wheat bran, cotton-seed meal, hays, etc., on different days and found variations often of two per cent. Sometimes there is an increase and at other times a decrease of hygroscopic water, depending upon the humidity of the surrounding air. The hygroscopic moisture also varies with different plant materials.

Amounts of Water Used by Plants.—According to Whitson, the amount of water used by plants varies greatly with the kind of plant and with climatic conditions, but is always large. For instance, in the growth of one pound of dry matter of corn about 250 to 300 pounds of water are used; for potatoes, 350 to 400 pounds; for clover, 500 to 600 pounds.

Amounts of Water Exhaled by Plants.¹

One acre exhales	Pounds of water
Wheat.....	409,832
Clover.....	1,096,234
Sunflowers.....	12,585,994
Cabbage.....	5,049,194
Grape vines.....	730,733
Hops.....	4,445,021

Variation of Water in Plants.—Some species of plants contain much more water than others and the different parts of the same plant show a great variation in water content. We have all no doubt noticed that certain fruits like the apple, pear, lemon, plum, peach, strawberry, etc., and roots and tubers as the turnip, beet, radish, carrot, Irish potato, etc., contain a great deal of water. Perhaps some have not heretofore thought that substances like corn grain, wheat kernel, rice kernel, the several grain straws, etc., have water present. The following table gives us the percentage of water in some familiar plants and parts of plants.

Fruits	Per cent.	Forage plants (green)	Per cent.
Apple	80.0	Alfalfa	71.8
Grape	83.0	Corn	79.3
Peach	88.4	Cowpea	83.6
Pear	83.1	Sorghum	79.4
Strawberry	90.2	Timothy	61.6
Roots and tubers		Cereals and straws	
Beet (mangel)	90.9	Corn (grain)	10.6
Carrot	88.6	Oats (grain)	11.0
Irish potato	78.9	Rice (rough)	10.9
Sweet potato	71.1	Rye straw	7.1
Turnip	90.5	Wheat straw	9.6

¹ Stockbridge, Rock and Soils.

Water in Young and Mature Plants.—The percentage of water in young plants is greater than in mature plants. This is easily accounted for because the young plant uses a great deal of water in transferring food materials required for its growth. The Maine State College conducted an investigation on timothy with the following results:¹

	Water Per cent.		Water Per cent.
Nearly headed out.....	78.7	Out of blossom	65.2
In full blossom.....	71.9	Nearly ripe	63.3

The results on timothy are similar to what would be found with other plants. It follows that the more mature a plant is, the easier it is to field cure.

Active cells in plants contain more water than do the older or less active cells and this may account for the larger percentage of water found in young plants.

Dry Matter of Plants.—As previously stated, the plant is made up of water and dry matter. When water is driven off from plants the dry matter is what remains. Now if we burn this dry matter a large proportion of it passes off in the form of invisible gases. This material which so disappears, in burning, is known as organic matter, that which is left is the ash or mineral matter or inorganic matter. The organic matter is composed of carbon, hydrogen, nitrogen, oxygen, etc. The ash is made up of soda, phosphorus, sulphur, iron, potassium, calcium, silicon, etc.*

We may express the composition of plants as:

$$\text{Plants} \left\{ \begin{array}{l} \text{Water} \\ \text{Dry matter} \end{array} \right. \left\{ \begin{array}{l} \text{Ash} \\ \text{Organic matter} \end{array} \right.$$

Composition of the Dry Matter of Plants.—A German scientist, Knop, estimated; according to Jordan: "That if all the species of the vegetable kingdom, exclusive of the fungi, were fused into one mass, the ultimate composition of the dry matter of this mixture would be the following:"

¹ Jordan, *The Feeding of Animals*.

	Per cent.
Carbon	45.0
Oxygen	42.0
Hydrogen	6.5
Nitrogen	1.5
Mineral compounds (ash)	5.0

From the above analysis it is readily seen that carbon and oxygen make up the largest proportion of plants. Let us examine the composition of some farm products that are familiar to us, and find out if this same predominance of carbon and oxygen exists.¹

	Carbon Per cent.	Oxygen Per cent.	Hydrogen Per cent.	Nitrogen Per cent.	Ash Per cent.
Clover hay	47.4	37.8	5.0	2.1	7.7
Wheat kernel	46.1	43.4	5.8	2.3	2.4
Fodder beets	42.8	43.4	5.8	1.7	6.3
Fodder beet leaves	38.1	30.8	5.1	4.5	21.5
Wheat straw	48.4	38.9	5.3	0.4	7.0

There is some variation in the composition of these farm products but the carbon and oxygen constitute the largest amounts of the elements present.

This predominance of carbon and oxygen is due to the fact that about nineteen-twentieths of the plants' food is obtained from air and water, and the remaining one-twentieth is derived from mineral compounds of the soil and soil water. In other words the farmer only has to supply a small proportion of the elements necessary for producing good crops.*

Acids and Bases.—The mineral elements that make up the ash of plants are not present in the free state but in various combinations, as acids and bases. The acids and bases of the mineral elements of ash are:

¹ Jordan, The Feeding of Animals.

Acids

Sulphuric (hydrogen, sulphur and oxygen) H_2SO_4
 Hydrochloric (hydrogen and chlorine) HCl
 Phosphoric (hydrogen, phosphorus and oxygen) $\text{H}_3\text{P}_2\text{O}_8$
 Carbonic (carbon and oxygen) CO_2
 Silicic (silicon and oxygen) SiO_2

Bases

Lime (calcium and oxygen) CaO
 Soda (sodium and oxygen) Na_2O
 Potash (potassium and oxygen) K_2O
 Magnesia (magnesium and oxygen) MgO
 Iron oxide (iron and oxygen) Fe_2O_3

The mineral elements do not exist as acids and bases in the ash because in the burning of plant substances there is a rearrangement of the mineral elements and salts are formed.

Salts.—The elements exist in the ash of plants as salts. That is the acids and bases are united and form:

Phosphates	}	of	{	Calcium
Sulphates				Magnesium
Chlorides				Sodium
Carbonates				Potassium

We are all familiar with some of these salts. A few of the combinations are:

Chloride of sodium (common salt)	Sulphate of soda (Glauber's salts)
Carbonate of lime (limestone)	Sulphate of magnesia (Epsom salts)
Chloride of potash (muriate of potash)	Sulphate of calcium (gypsum)
Carbonate of soda (baking powder)	Sulphate of potash (common sulphate of potash of commerce)

Variation of Ash.—The content of ash in different plants and parts of plants varies a great deal as the following table shows:

Grains	Ash Per cent.	Straw	Ash Per cent.
Corn	1.5	Oat	5.1
Oats	3.0	Rice	7.8
Rice	5.5	Rye	3.2
Wheat	1.8	Wheat	4.2
Roots and tubers (fresh)		Forage plants (hay)	
Beet (mangel)	1.1	Alfalfa	7.4
Carrot	1.0	Crimson clover	8.6
Irish potato	1.0	Orchard grass	6.0
Sweet potato	1.0	Timothy	4.4

Different parts of the same plant vary in ash content.

	Ash Per cent.		Ash Per cent.
Corn grain.....	1.5	Corn stover (whole plant ex- cept ears)	4.9
Corn leaves.....	9.7	Corn shucks	3.4
Corn (whole plant).....	4.3	Corn cob.....	1.4
Corn germ.....	4.0	Corn bran.....	1.3

There is also a variation in the amounts of compounds in the ash of different parts of the same plant. The percentages of the compounds in this table are figured on 100 per cent. ash of sugar-cane.¹

	Ash of leaves Per cent.	Ash of stalk Per cent.	Ash of roots Per cent.
Potash	31.25	38.23	17.39
Soda	1.17	1.30	0.85
Lime	5.90	5.19	3.45
Magnesia	5.11	5.76	2.61
Iron oxide	1.45	1.13	3.60
Alumina	1.03	0.25	4.70
Silica	30.32	15.70	49.52
Phosphoric acid	7.25	5.27	3.99
Sulphuric acid.....	11.29	18.47	9.15
Carbonic acid	1.10	2.70	0.45
Chlorine	3.08	4.52	0.98
Carbon	0.16	0.54	2.30
Ash.....	2.23	0.64	1.87

From the figures given in the foregoing tables we find that the leaves of plants contain the most ash. The straws contain more ash than the grains.

Let us see the relation of the ash of roots to the leaves of the same plant.

	Roots Per cent. Ash	Leaves Per cent. Ash
Sugar-beet.....	3.83	14.88
Stock turnip.....	8.01	11.64

The per cent. of ash in seeds is generally less than in the plant from which they are derived.*

¹ Bul. 91, Louisiana Experiment Station.

	Ash Per cent.		Ash Per cent.
Sorghum seed	2.1	Sorghum fodder.....	4.6
Cowpea seed.....	3.2	Cowpea hay.....	7.5
Soja bean seed	4.7	Soja bean hay.....	7.2

Occurrence of Mineral Elements in Plants.—According to Forbes;¹ Mineral substances of foodstuffs are present in four mechanical conditions: 1. In solution in the plant juices; 2. as crystals in the tissues; 3. as incrustations in cells and 4. in chemical combination with the living substance.

The mineral content of any species of plant varies considerably as affected (1) by the composition of the soil and the soil water, (2) by the various factors controlling transpiration of water by the plant and (3) by the loss of mineral substance either through shedding of parts or through the leaching effect of dews and rains.

Distribution of Ash in Plants.—Roots and seeds generally contain much less ash than leaves because the mineral elements are carried to the leaves for the elaboration (manufacturing) of food and then the water evaporates and the ash remains. The ash present in roots and seeds is usually needed for supporting germination and early growth of the plant, while some of that in the leaves is in excess of what is really needed.

Phosphorus and potassium are present in the largest amounts in seeds, followed by magnesia. Silicon and potassium predominate in cereal grasses and straws, and the per cent. of calcium is usually larger than phosphorus or magnesium. The leguminous crops (alfalfa, clovers, cowpeas, soy beans, etc.) contain more calcium than phosphorus or potassium. Roots and legumes contain much less silicon than straws.

Ash of Young and Mature Plants.—According to Wolff the per cent. of ash of the dry matter of wheat, oats, rye, and clover, decreases with the growth of the plant. The ash of healthful plants is generally higher in calcium than in sickly plants. The per cent. of calcium and potassium in the ash of grass plants decreases in the growing of the plant and the silicon increases. In the ash of the dry matter of clover, the magnesium and calcium increase while the potassium decreases.

¹ Bul. 201, Ohio Experiment Station.

CHAPTER II.

THE FERTILITY OF THE SOIL.

The fertility of the soil is shown in the crops produced and a soil is said to be fertile when profitable crops are grown under favorable conditions.

Composition of Soils.—In order to understand the conditions which affect fertility let us become familiar with the composition of soils. Soils are made up of disintegrated (ground) rocks and decayed plant and animal life. Some soils, like sandy soils, predominate in rock particles while peaty soils are rich in decayed plant material. Most soils contain both ground rocks and decayed plants.

Inorganic Matter.—That part of the soil composed of ground rocks (sand, silt, clay, etc.) is called inorganic matter and corresponds to some extent to the ash, or non-combustible, or inorganic matter in plants. Of course the particles of inorganic matter in the soil may be different from the original rocks from which they were derived, due to the action of rain, frost, sun, etc., yet we find that a considerable portion of these particles is often of the same composition as the original rocks.

Organic Matter.—The decaying vegetable or animal matter in the soil is called organic matter. It is that part of the soil which is driven off when burned and corresponds to the organic matter in plants. Most of the organic matter in soils comes from decaying vegetation. When this decaying vegetable or animal matter becomes thoroughly decomposed it assumes a black waxy consistency and is called humus. This humus is a very important constituent and influences to a great extent the physical and biological condition of soils.

The amount of organic matter in soil influences its water holding capacity, texture, temperature, color, supply of available plant food and general productiveness.

Factors Influencing Soil Fertility.—There are many factors influencing soil fertility and these may be summed up under the following heads:

1. The available supply of plant food.
2. The physical condition of the soil.
3. The biological condition of the soil.

1. **The Plant Food Supply.**—It may be surprising to know that most farm soils, even those that produce poor crops, are abundantly supplied with plant food.*

Chester of the Delaware Agricultural College, states:¹ An average of the results of 49 analyses of the typical soils of the United States showed per acre for the first eight inches of surface, 2,600 pounds of nitrogen, 4,800 pounds of phosphoric acid and 13,400 pounds of potash. The average yield of wheat in the United States is 14 bushels per acre. Such a crop will

PLANT FOOD REMOVED BY CROPS IN POUNDS PER ACRE.²

Crop	Gross Weight	Nitrogen	Phosphoric acid	Potash	Lime
Wheat, 20 bu.....	1,200	25	12.5	7	1
Straw.....	2,000	10	7.5	28	7
Total.....		35	20	35	8
Barley, 40 bu.....	1,920	28	15	8	1
Straw.....	3,000	12	5	30	8
Total.....		40	20	38	9
Oats, 50 bu.....	1,600	35	12	10	1.5
Straw.....	3,000	15	6	35	9.5
Total.....		50	18	45	11
Corn, 65 bu.....	2,200	40	18	15	1
Stalks.....	6,000	45	14	80	20
Total.....		85	32	95	21
Peas, 30 bu.....	1,800	—	18	22	4
Straw.....	3,500	—	7	38	71
Total.....		—	25	60	75
Flax, 15 bu.....	900	39	15	8	3
Straw.....	1,800	15	3	19	13
Total.....		54	18	27	16
Meadow hay.....	2,000	30	20	45	12
Red clover hay.....	4,000	—	28	66	75
Potatoes, 300 bu.....	18,000	80	40	150	50
Mangels, 10 tons.....	20,000	75	35	150	30

¹ Bowker, Plant Food.

² Bul. 47, Minnesota Experiment Station.

remove 29.7 pounds of nitrogen, 9.5 pounds of phosphoric acid and 13.7 pounds of potash. Now if all the potential nitrogen, phosphoric acid and potash could be rendered available, there is present in such an average soil, in the first eight inches, enough nitrogen to last 90 years, enough phosphoric acid for 500 years and enough potash for 1,000 years.

Let us find out the amounts of nitrogen, phosphoric acid, potash and lime removed per acre by some of our leading farm crops.

From these figures it is evident that all of the above soils have sufficient amounts of plant food to last for many years. Corn yielding 65 bushels per acre, only takes away 85 pounds of nitrogen, 32 pounds of phosphoric acid and 95 pounds of potash. Mangels which are heavy users of potash only show a removal of 150 pounds for a ten ton crop. When we compare the amounts of these constituents removed by crops and the total supply in the average soil we may better realize the amount of stored up plant food in soils.*

Plant Food not Available.—The question naturally arises, what is the use of adding fertilizers or manure to soils when such large amounts of plant food are present? The plant food in the soil is dormant; it is locked up; it is unavailable. Available plant food may be present but the condition of the soil may be such that the plant cannot utilize it. The soil may be acid or sour, or it may contain objectionable substances distasteful to plants.

The plant obtains its nourishment from the salts in solution in the soil water and these soluble salts constitute the available plant food. The chemist can determine the total plant food, or the potential fertility, in the soil, but he cannot tell us how much is available. The available plant food supply may be ascertained, to a certain extent, by carrying on field experiments. The results of such experiments will of course vary with different soils and different crops. The chemist can determine whether a soil is acid, alkaline or neutral and from such data advise whether lime would benefit the soil, the amount to apply and the kind of fertilizers to use. In such cases a chemical analysis is

exceedingly valuable but ordinarily field trials with crops prove the better way of determining productiveness.

The Essential Elements.—In the preceding chapter the elements needed by plants were discussed and the composition of plants given. From the composition of plants aided by field experiments it has been possible to learn that certain elements are necessary for plant growth. From this data it has been ascertained that only three and sometimes four elements are required to be furnished the plant for its complete development, as the other elements are fortunately present in sufficient quantities in the air and the soil so that we do not consider them. Nitrogen, (N) phosphorus (phosphoric acid, P_2O_5) and potassium (potash, K_2O) are the elements usually exhausted most readily from the soil, and occasionally calcium (lime, CaO). Because of the necessity of adding nitrogen, phosphoric acid and potash for the growth of most crops, the name "essential" is applied to these elements, and the remaining elements are termed "unessential." The essential elements, nitrogen, phosphoric acid and potash are usually found in larger amounts in plants and in smaller quantities in soils than the other elements. Nitrogen and phosphoric acid are usually more liable to be deficient than potash, and lime is only occasionally lacking. The term fertilizers is applied to materials containing any or all of these essential elements, in available form, and are supposed to make up for the deficiencies in the soil. Fertilizers may contain other elements as magnesia, sulphuric acid, etc., though needed by the plant are unessential as the soil contains a sufficient amount for crops.

The fifteen elements used by plants may be classified as :

Elements sometimes lacking in the soil	Elements obtained from the air or water	Elements that are present usually in sufficient amounts
Nitrogen	Hydrogen	Calcium (usually)
Phosphorus	Oxygen	Iron
Potassium	Carbon	Sulphur
Calcium (occasionally)	Nitrogen (sometimes)	Magnesium
		Silicon
		Sodium
		Chlorine
		Manganese
		Aluminium

One Element Cannot Replace Another.—It must be understood that no one of these essential elements can take the place of another, as each has its particular functions to perform which are different for each element. Therefore should a soil be deficient in any of these essential elements, the addition of those that are lacking will tend to produce good crops, provided other conditions are favorable. Let us illustrate this by supposing we



Fig. 2.—1, Unfertilized; 2, Potash, phos. acid, nitrogen; 3, phos. acid, nitrogen.
Courtesy German Kali Works.

wish to plant a field of corn. We have perhaps plenty of available phosphoric acid, potash and lime for the needs of the corn and the land is in good condition, but the available supply of nitrogen is deficient in the soil. We cannot grow a profitable crop of corn under such conditions because the phosphoric acid, potash and the lime are unable to take the place of the nitrogen, no matter how abundant they may be. Should nitrogen be supplied in sufficient amount the crop would be satisfied and should prove profitable, other conditions being right.

It has been found that sodium and potassium may replace each other, to a limited extent, in correcting the acidity that may take place in plants, although they cannot replace each other in supplying plant food. There are some elements which have common functions, but each element has its work to perform for the complete development of plants.

2. Physical Condition of the Soil.—There are some soils which contain sufficient amounts of available plant food for the needs of crops but this food cannot be utilized because of other factors which affect the physical condition of soils. Some of these factors will be briefly discussed.

Temperature.—The temperature of the soil depends upon the heat of the air and the nature of the soil. It is a very important consideration in plant growth.* In summer the sunshine causes the upper soil to be warmer than the lower or deeper soil. In winter the deeper soil is warmer than the surface soil. In other words the temperature of the air affects soil warmth.

The germination of seed, the transference of soil water, which contains the available plant food, the movement of the soil air, the development of organisms are all greater when the soil is warm. The coarser soils seem to warm up more readily than the heavy clays. The location of the land influences soil warmth. A soil with a southern exposure is naturally warmer than one with a northern location.*

Mechanical Composition.—Should we examine a few different soils we would find that there is a great difference in the size of the particles or grains that make them up. For example, when lumps of different soils are broken up and passed through sieves of various sizes, or shaken in bottles with water, particles varying in size from gravel to fine dust are apparent. The grains or particles of soil are usually classified into four groups: gravel, sand, silt and clay. Sandy soils predominate in the largest particles, gravel and sand; alluvial or silt soils contain more particles the size of silt, and clay soils have more of the finest particles, clay. It should be understood that all soils contain large and small particles. A loam soil contains all the particles in about equal proportions.*

The percentages of moisture, humus and carbonate of lime are not included in the mechanical analyses of soils.

Surface Area of Soil Grains.—The surface area of soil grains varies with the size of the particles. The smaller the grains the more surface area is exposed to the action of water and soil organisms, and the more quickly is plant food rendered available.*

Diameter of grain.	Square feet of surface in a pound.
Coarse sand 1 mm.	11.05
Fine sand, 0.1 mm.	110.54
Silt, 0.01 mm.	1,105.38
Clay, 0.001 mm.	11,053.81
Fine clay, 0.0001 mm.	1,100,538.16

Lumpy Soils.—The mechanical composition of a soil is important, for the farmer to consider, in order to keep the soil receptive for growing crops. The clustering or lumping of soils is brought about by the adhering of the particles due to the surface tension of the films of water surrounding the grains. As the water dries out the grains are held together with the aid of the salts in solution. Fine soils, like clay, contain many more particles than sandy soils, so it is apparent that clay soils are more apt to form lumps than the coarser soils.

Cracking of Soils.—When soils become dry the films of water around the soil particles become thinner and the soil contracts, breaking in the weakest point, causing cracks.

Puddling of Soils.—If soils are worked when in a very wet condition the soil particles run together and a puddling soil is formed. After such a soil, especially a clay soil, dries out it becomes very hard and most difficult to restore to good condition. A farmer should never work a clay soil when it is too wet.

Freezing and Thawing.—When soils are plowed deeply in the fall and allowed to be acted upon by the frosts a helpful crumb like condition results. The action of frosts is more apparent when northern and southern soils are compared. The northern soils treated as above are usually in better tilth than the southern soils in sections of little or no frost.

Plants are Benefited by Open Soils.—A good tilth of the soil helps the plant a great deal in securing its food, and is therefore an important factor in the production of crops. A soil should

be compact enough to support the plant in an upright position, but if it is too compact the young plant has to overcome a great deal of resistance in securing its food.

Plants Must Have Room.—Only a certain number of plants can be grown successfully on a given space of land. We have only to examine the root development of mature plants to learn the spreading tendency of plants. If plants are too crowded, imperfect development is the result. The roots of plants spread somewhat and the distance apart is regulated to some extent by the available plant food, the nature of the plant and the tillage of the soil. In the foreign countries more plants are usually grown on a given area than in America but the land is perhaps more thoroughly tilled, because land is high in price and labor cheap, while in America land is comparatively cheap and labor high. In well tilled soils roots go deeper and do not spread so much as in soils in poor condition.

Plants Require Oxygen.—A soil that is too compact will not permit of the free circulation of air. When air is excluded from the soil, free oxygen which is absolutely necessary for growth is excluded. It has been shown that when air is not freely supplied to plants they become sickly and growth is retarded. When a soil becomes water-logged, plants will not grow and if the condition continues the plants will die. Some plants will grow in water but the water must be fairly free from soil so as to be able to absorb and diffuse oxygen from the air. It has been found that 40 to 60 per cent. of the water holding capacity of soils is the best amount and 80 per cent. is injurious.

Drainage.—Good crops cannot be grown unless the land is well drained, either naturally or artificially. A certain amount of water is essential for crops, but a water-logged condition must be avoided to secure good results.

Capillary Water.—In the preceding chapter we learned that crops use a great deal of water, the clover crop for example exhales as much as 1,096,234 pounds per acre. Crops usually rely on capillary water for their supply of this constituent. The upward movement of water in the soil is termed capillary moisture, or capillary water, and is caused by the surface ten-

sion of the films of water around the soil particles becoming greater as evaporation from the upper surface of the soil takes place. One of the most important problems in farming is to conserve this soil moisture and prevent its evaporation.

Amounts of Capillary Water Held by Soils.—Sandy soils hold very little capillary water. After a rain it is estimated that 5 to 10 per cent. by weight of the soil will be water. Sandy loams and silt loams retain 15 to 20 per cent. and heavy clay soils 30 to 50 per cent. Heavy clay soils are suitable for grass lands because of this power of holding water, as grasses require considerable water for maximum growth.

How to Prevent Loss of Capillary Water.—As capillary water is so important for the welfare of crops we should learn how to prevent its loss. Water will follow along the path of least resistance. So if we form a soil mulch by cultivating or stirring the soil to the depth of two or three inches we will offer resistance to the upward movement of water. The soil should not be cultivated too deeply because some of the small roots are liable to be injured.

How to Increase the Upward Movement of Capillary Moisture.—When seeds are planted in dry seasons it is often advisable to bring up the water to aid in their germination. This may be accomplished by rolling the soil thus making it firmer. After rolling it is important to form a soil mulch again to prevent the loss of all the water.*

3. The Biological Condition of the Soil.—All cultivated productive soils are full of organisms, both animal and vegetable, which aid in furnishing plant food. There are many different organisms whose functions vary a great deal. Most of these organisms are so small that they cannot be seen without the aid of the microscope, while some, with which we are all familiar, are large.

The rodents, worms and insects all have their place in stirring the soil although the rodents and some of the insects are injurious to crops. Plant roots are beneficial in that they leave organic matter in the soil and openings for the access of water and air.

The organisms we are most interested in are the bacteria (minute plants) because of their beneficial effect in crop production.

The number of bacteria in the soil depends upon its physical condition. Water-logged soils, sandy soils, acid soils, and soils low in organic matter contain very few and sometimes no bacteria. Soils rich in humus, contain sometimes as high as 100,000,000 bacteria per gram,¹ while the average well cultivated soil contains 1,000,000 to 5,000,000 per gram. The cold winters of the north decrease the number of bacteria but these multiply during spring and summer.*

Nitrification.—Certain bacteria have the power of converting the organic nitrogen present in animal and vegetable matter into ammonia. No doubt you are all familiar with the ammonia smell around fermenting manure. This is the result of the action of bacteria. The same action that takes place in the manure heap occurs in the soil when organic matter is present. When the ammonia is formed another kind of bacteria seizes it and changes the ammonia into nitrous acid or nitrites, and this latter compound is in turn attacked by another organism and converted into nitric acid or nitrates. In this latter form it is readily dissolved by the soil water and available as plant food. There is a continual cycle of the forms of nitrogen. The plant uses the nitrogen in the form of nitrates, converts it into organic nitrogen, and when the plant dies it may be returned to the soil to go through the same process again.

Manure or other organic matter helps nitrification.* Keeping the soil well open so that a liberal supply of air may permeate it has a beneficial effect on nitrification. The more porous the soil the deeper nitrification occurs.

Denitrification.—There are some bacteria that set free nitrogen. These bacteria exert a reducing action rather than an oxidizing one. Some reduce nitrates (nitric acid) to nitrites (nitrous oxide) and ammonia. Others reduce nitrates to nitrites and then to free gaseous nitrogen. It has been found that there are more

¹ One ounce = 28.35 grams.

denitrifying organisms than nitrifying bacteria, although the loss of nitrogen from well drained and tilled soils is not large, because the denitrifying bacteria cannot attack the nitrogen in such soils. The nitrogen wasting bacteria work considerable damage in manure heaps.

Organisms that Gather Nitrogen.—Other organisms found in the soil that exert an effect on its fertility are those that live in the tubercles or nodules on the roots of certain plants called the legumes, of which cowpea, bean, pea, clovers, alfalfa, vetch, etc., are examples. These plants through the action of these bacteria have the power of acquiring the free gaseous nitrogen from the air and utilizing it in their growth. The bacteria secure this free nitrogen from the air in the soil and the plant acquires it from the bacteria. When the plant dies the nitrogen left in the roots remains in the soil and thus enriches it. The particular bacterium can only attach itself to the legume it is suitable to. That is, bacteria forming tubercles on the roots of clover will not grow on cowpea roots. When there is a plentiful supply of nitrogen as nitrates in the soil the legumes will not always form tubercles and utilize the free atmospheric nitrogen, but will gather their supply from the soil. Legumes therefore are able to secure nitrogen from the soil and the air. The tubercles seem to form better in alkaline soils containing lime.

Inoculation of the Soil.—The absence of tubercles on the roots of legumes may therefore be due to the absence of the particular bacteria required, to the excess of nitrates, or to the acidity of the soil. Should the soil be deficient in the particular bacteria needed, the soil should be inoculated. This inoculation is accomplished by sowing soil from a neighboring field that has produced a good crop of the kind desired, or if such a soil cannot be obtained, by inoculating the seed before planting with a pure culture which has been obtained from the tubercles of the kind of crop to be raised. These cultures may be obtained from the United States Department of Agriculture and dealers in seeds. In using soil from another field for inoculating, fungus diseases.

insects and objectionable weeds are often introduced which become a serious menace in the production of crops. Care must be taken to secure soil from a disease free field. The pure cultures are not always satisfactory, as they are hard to preserve in transportation, so that the use of soil is perhaps the better method just now.

CHAPTER III.

MAINTAINING SOIL FERTILITY.

As the fertilizer ingredients nitrogen, phosphoric acid and potash are the plant food elements that have to be supplied, let us find out some of the ways they are taken away from the soil and methods of preventing and restoring their loss.

Erosion is the loss of soil by the action of water or wind.

Any one who has ever lived in the South is familiar with the tremendous losses of fertility incurred by erosion. The most serious losses occur on hilly clay soils. Cotton and corn are grown on many of the southern soils year after year and the soil is left bare during the winter. These soils are not plowed very deep and when a heavy rain comes only a small amount of the water can soak into the soil. If the land is hilly the rain forms little rills at first which finally become gullies and much of the good fertile soil is washed to the valleys or bottom lands. In a few seasons a great deal of such hill land becomes unproductive.

There are other sections in America besides the South where erosion is damaging farms. In some of the far western states and other sections where the land is hilly, erosion is a source of loss of fertility.

Erosion by water besides carrying away the most fertile part of the soil puts the land in such a condition that it is difficult to operate. Gullies are objectionable in growing crops.

On light sandy soils the blowing away of the surface soil by wind often results in serious losses of fertility. Mounds or ridges are often formed which interfere with cultivating the soil.

Ways to Check Erosion.—Plowing up and down hill is very bad practice as the furrows become regular waterways during a rain storm. In the South the lands that are subject to erosion are usually the clay soils which will not absorb water readily. Shallow plowing is practiced and deep plowing will cause more water to be absorbed and retained. Most of these soils are lacking in organic matter. By growing green crops in the winter

and turning them under in time for the summer crops, erosion will be stopped considerably during the winter and much organic matter will be supplied which will make clay soils more porous and spongy. Underdrainage prevents erosion by carrying the excess of water away gently.

Many farmers terrace their soil to prevent it from washing away. This custom is not as beneficial as deep plowing, plowing under of green crops, or putting the land in pasture. Many of the most successful farmers keep their rows level so when it rains the water remains in the furrows instead of washing down hill. These furrows will not be straight but answer the purpose of saving fertility.

Drainage.—The loss of fertility by drainage is chiefly concerned in the loss of nitrogen. This element to be favorable for most plants to assimilate must be in the form of nitrates which are readily soluble in water. Phosphoric acid and potash are fixed in the soil so that they are insoluble in water and hence very inappreciable amounts are lost by drainage.*

Experiments have shown that the loss of nitrogen by drainage is greater on soils that are idle than on cultivated soils. At first thought one would suppose that the loss would be greater on the cultivated soils as they are more open and porous, and hence permit of a more free passage of water through the soil.

The excess of nitrates in cultivated soils is carried down in the soil but after a rain the capillary water carries it up again to the plant roots. Again, the plants are continually using up the available supply of nitrogen as fast as it is formed so that there is no appreciable excess to be carried away.

It has been found that about 37 pounds of nitrogen per acre are lost from average idle land during a year. This loss of nitrogen is quite large when we consider that 20 bushels of wheat, not counting the straw, remove 25 pounds of nitrogen; 50 bushels of oats, 35 pounds; and 65 bushels of corn, 40 pounds.*

Fallowing.—In the arid sections of this country where dry farming is followed it is often necessary to let the land remain idle for a season to conserve enough moisture to produce profit-

able crops. The land is usually plowed two or three times, at intervals, or plowed once and harrowed two or three times. This procedure keeps down the weeds and increases the moisture in the soil. According to King, 203 tons more water was found on fallowed land per acre in the spring following the fallow, than on land that was not fallowed, and 179 tons more water was found on the fallowed field after a crop was harvested than on the other field.¹

Fallowing increases the supply of available nitrogen as nitrates and in some sections fallowing is practiced for this reason. The yield of the crop following fallowing is increased but considerable humus is lost by being oxidized, and generally more nitrates are formed than can be used up by the crop following fallowing. Snyder has found by experiments that 590 pounds of nitrogen per acre were lost by two years of summer fallowing, or an amount sufficient for five wheat crops.² At the Rothamstead Experiment Station experiments show that considerable more nitrogen was lost from bare soils than from wheat land.*

On rich soils the losses are greater than on soils deficient in organic matter because the oxidation of humus is more rapid. It is evident, then, that fallowing increases the production of crops at the expense of a reduction of humus.

In sections of plentiful rainfall, fallowing is often injurious and it should only be practiced in the dry sections where there is not enough rainfall to carry away the nitrates and therefore not sufficient moisture for the continuous growing of crops.

Other Ways Nitrogen is lost.—The washing away of nitrogen as nitrates is not the only way this element is lost, but considerable of this valuable constituent escapes in the form of gases. This loss as gas is occasioned by denitrification, which reduces the nitrates to gases, and the liberation of nitrogen from organic matter. The loss on soils rich in organic matter is greater than on poor soils.

Experiments show that in continuous cropping more nitrogen

¹ Roberts, *The Fertility of the Soil*.

² Snyder, *Soils and Fertilizers*.

is usually lost than the crop removes. The following table illustrates this point.¹

LOSS OF NITROGEN BY CONTINUOUS CROPPING PER ACRE PER YEAR.

Name of Crop.	Nitrogen removed by crop. Pounds.	Nitrogen lost by other means. Pounds.	Total nitrogen removed and lost. Pounds.
Wheat	24.5	146.5	171
Corn	56	29	85
Oats	46	150	196
Barley	30	170	200

The loss of nitrogen by continuous cropping of cotton, corn, tobacco and the cereal crops is a very serious one.

Loss of Phosphoric Acid and Potash.—Although phosphoric acid and potash are usually present in the soil as compounds insoluble in water, nevertheless large quantities are lost every year by being carried away with the soil into rivers and other streams. Again, traces of phosphoric acid and potash are carried away in the soluble form by drainage and although this loss is not large per acre it amounts to a great deal in the course of time. The Mississippi River deposits, in the Gulf of Mexico 3,702,758,400 cubic feet of solid material per year. One cubic foot of this solid material weighs about 80 pounds. This material is quite rich in potash often containing as high as 0.50 per cent. of this constituent. The phosphoric acid content is much lower than this figure but is considerable. The rivers that empty into the oceans in the northern part of the United States do not perhaps carry away so much fertility as the rivers of the far south, but the annual loss of the mineral elements carried away in streams is appalling.

One Crop Farming.—The exclusive growing of one crop caused more farms to be abandoned in the United States than any other practice. The continuous cropping of wheat in the West, tobacco in Kentucky, Virginia and North Carolina, cotton in the South, and corn in the North Central States has always resulted in the loss of fertility and depletion of the soil. All of these crops with the exception of corn are sold from the farm

¹ Bul. 53, Minnesota Experiment Station.

without the return of any fertility. On most of these one crop farms no fertility is put on the soil and the farm is abandoned or else artificial (commercial) fertilizers are used. Most of our soils in the United States were formerly fertile but the practice of growing crops without returning organic matter has resulted in decreasing the yields on our older cultivated lands. Under the subject "fallowing" we learned that it was poor procedure to allow the land to lie idle except in dry regions, and the best farmers to-day are those that utilize their land continually and to the fullest extent. When we visit some of the European countries where land has been in cultivation for centuries, we find that these lands are still producing valuable crops, and that the yields are as large, if not larger now, than they were two centuries ago. This condition exists in Europe because fertility has been returned to the soil every year to sustain crops.

Fortunately, land has been comparatively cheap in the United States and when a farm failed to produce paying crops another piece of land was secured, and so on. The time has arrived when the acquiring of new land for one crop farming is hard to obtain at a price within the bounds of such farmers. So it is now necessary and more profitable for the farmer to grow other crops in conjunction with his money crop. This growing of other crops is called diversifying or rotating.

* **Diversification and Rotation of Crops.**—Diversification is the growing of different crops without any regular or definite system. Rotation of crops is spoken of as growing a certain number of crops, in regular order, on the same piece of land. For example, a rotation may consist of four crops, corn, oats, wheat and clover, and will be called a four year rotation because these crops will be grown in order on the same piece of land and take four years to complete. A farmer may have 160 acres in his rotation and each year 40 acres will be allowed for each of the four crops mentioned. Each 40 acres will grow the same crop every fifth year and one of the crops every year. The terms six-year, five-year, four-year, three-year, two-year, etc., are applied to rotations depending upon the time it takes to complete them. Rotations taking 15 years to complete are known

in Europe but the short rotations of three to six years are found to be profitable in the United States.

Make up of a Rotation.—The crops used in rotations are naturally selected according to the location, nature of the soil, available crops, market prices, kind of farming, insect and plant diseases, climate, etc. A stock farm would require different crops than a tobacco farm; a dairy farm in Wisconsin could not probably use the same rotation as a dairy farm in Alabama; two farms in the same state with different soil conditions would perhaps select different crops for a rotation; a farm ten miles from a market would no doubt find it more practical to grow different crops than one 1,000 miles away; and crops would not be chosen that insects or plant diseases ruin.

Reasons for Rotating Crops.—Some of the reasons for rotating crops are:

1. To keep down weeds.
2. To gather nitrogen from the air.
3. To distribute farm labor more evenly.
4. To eradicate insect or other diseases.
5. To furnish feed for live stock.
6. To give the farmer a regular income.
7. To prevent losses of fertility.
8. To utilize plant food more evenly.
9. To include deep and shallow rooted plants.
10. To save fertilizer expenditure.
11. To regulate the humus supply.
12. To conserve moisture in dry sections.

1. **Rotation of Crops Keeps Down Weeds.**—It is well known that the growing of particular crops is accompanied by certain weeds. Those crops that are sown broadcast, as the small grains, are more apt to be weedy than cultivated crops as corn, cotton, tobacco, potatoes, etc. When crops like wheat, hay, etc., are grown continuously the yields or the quality of the crops are often materially reduced by weeds. Intertilled crops as corn, tobacco, cotton, potatoes, etc., when well cultivated, are known as "cleaning crops." So in planning a rotation crops should be

selected that will tend to keep down weeds. Cultivated crops should be included with those that are sown broadcast.

2. Legumes are Profitable.—By including legumes as clovers, Canada field pea, cowpea, velvet bean, soy bean, etc., in a rotation, it is possible to gather considerable nitrogen, which is the most expensive fertilizing element to buy, from the air. A crop of red clover, one year old, is estimated to contain 20 to 30 pounds of nitrogen in the roots, per acre. A crop of cowpeas in Louisiana furnishes 100 pounds of nitrogen per acre. By plowing under leguminous crops enough nitrogen is often furnished so that the following crop does not require any extra supply, and if some nitrogen has to be supplied, that amount is much less than it would be were not nitrogen gathering crops utilized.

The Minnesota Experiment Station¹ found a loss of 2,000 pounds of nitrogen per acre when wheat, barley, corn and oats were grown for twelve consecutive years; two-thirds to three-fourths of this amount was not used by the crops but was lost in other ways. The Ohio Experiment station² found that there was a gain of 300 pounds of nitrogen per acre in excess of what the crop utilized when clover was included in five-year rotations, covering periods of ten years. When timothy and non-legumes were used in place of clover, nitrogen was lost from the soil; the loss of nitrogen from the soil was a little more than that removed by the crop.

3. The Distribution of Farm Labor.—One of the most important points in favor of a rotation of crops is that it allows of a more even distribution of farm labor. When several crops are grown every year the farmer is able to employ help the greater part of the year and thus secure more efficient labor at a less cost for the work performed than should single crop farming be in vogue.

4. The Checking or Eradication of Insects and Plant Diseases.—Many times crops become so badly attacked by insects, or infested with plant diseases, that there are no profits and often large losses in trying to produce them on the same field con-

¹ Bul. 89.

² Bul. 110.

tinually. A rotation of crops often eliminates such troubles because certain insects and plant diseases are only common to one particular crop. A good illustration of this is noticeable in the growing of cotton. There is an insect called the cotton boll weevil, which punctures cotton bolls and destroys the crop. Fields that once produced valuable crops of cotton must now be planted to other crops which are not injured by this insect.

5. **Rotation Furnishes Feed for Live-stock.**—One crop farmers are often forced to buy feed for their live-stock. A farmer who uses a rotation of crops can plan his rotation so that most of the feed will always be produced on the farm. In one crop



Fig. 3.—Oats fit well in rotations and furnish feed for live-stock.

farming the sale of the crop brings only one value. When several crops are grown it is possible to produce feed for live-stock and a double value is received for the crop. This double value is represented in the feeding value and fertilizing value; the crop is fed and the manure spread on the land.

6. **A Regular Income.**—Farmers who raise single crops receive their money but once a year and many of these farmers use

their crops in paying the merchant for the last year's supplies. They often live from year to year on the credit basis and pay much more for their supplies than the farmer who is able to pay for what he gets in cash. In certain sections of this country this credit system of farming has proved disastrous because one or two bad years caused the loss of the farm. The single crop farmer generally has to buy more supplies than the farmer who grows several crops. The farmer who practices rotation has crops to sell at different times in the year and so has a more regular income than the single crop farmer who gets his money but once a year.

7. Preventing Losses of Fertility.—The farmer who rotates his crops may sell the crop that removes the least fertility from the soil and if the money crops remove a great deal of fertility, he may regulate his rotation so as to restore this loss cheaply.

8. A rotation of crops utilizes plant food more evenly than when single crops are continually grown. Corn, wheat and other grain crops use a great deal of nitrogen and phosphoric acid while tobacco and potatoes are heavy potash feeders. By the proper selection of crops forming rotation, the plant food may be drawn on more evenly and losses of fertility prevented through leaching, etc.

9. Deep and Shallow Rooted Plants.—A rotation of crops has an advantage over single crop farming because of the variation in depth of root systems of different crops. Alfalfa and corn have deep tap roots and obtain food from the subsoil, while oats, timothy, blue grass, rye, etc., have shallow roots and feed from the upper soil. By alternating deep and shallow rooted plants the fertility from the subsoil and surface soil is more evenly utilized. Often the surface soil may predominate in nitrogen and phosphoric acid and the subsoil in potash and lime. When the fertility is thus distributed the alternating of shallow and deep rooted plants is important as the fertility of the subsoil is brought to the surface soil by the decay of roots.

Another advantage of growing deep and shallow rooted plants is the improvement of the physical condition of the soil. Deep rooted plants tend to make a soil more porous because the de-

cay of roots leaves passages in the soil which aid in draining and aerating it. Grass crops tend to make a soil compact, while alfalfa, roots, grains and other cultivated crops tend to open up the soil.

A rotation should be selected to keep the soil in good physical condition. Sandy soils are improved by crops that compact them while clay soils should be made more porous.

10. Rotation Saves Fertilizer Expenditure.—On some farms that formerly used 150 to 300 pounds of commercial fertilizer per acre, as high as 1,500 to 2,000 pounds must be used now to give the same yields. A proper rotation of crops will save the employment of such large quantities of commercial fertilizers. Farm manure may be used and commercial fertilizer only applied to those crops that are most in need of nourishment.

11. Rotation of Crops Regulates the Humus Supply.—Some crops furnish humus while others tend to deplete the soil of this material. Single crop farming is very exhaustive on the humus supply of the soil while a rotation of crops should be selected to conserve the humus content of a soil. Grass crops tend to increase the humus supply, while grain, cotton, tobacco, etc., have the opposite effect of consuming humus. The addition of farm manure is helpful in supplying humus.*

12. A Rotation of Crops Conserves Moisture.—In the arid regions the conservation of moisture is an important consideration in planning a rotation. Heavy moisture consuming crops should not be planted in succession in sections of small rainfall, but heavy consuming and light consuming moisture crops should be so grown as to conserve the moisture supply.*

System of Farming.—The loss of fertility sold from the farm depends upon the kinds of crops produced and sold. When live-stock, butter and milk are sold there is less fertility lost than from common farm crops.*

CHAPTER IV.

FARM MANURES.

Farm manure has been used for centuries in restoring fertility to the soil. It is the oldest and one of the most important of our fertilizers. It is formed from vegetable and animal substances and naturally should prove of great value. In some section of this country farm manure is wasted, but the value of this material is generally becoming better understood and is more carefully saved than formerly, especially in the older farming regions.

Kinds of Manure.—When there is a great deal of straw or hay in manure, it is said to be coarse. It is termed stable manure when it is accumulated in stables and contains all the solid and liquid portions. Barnyard manure is a name applied to manure which is subject to exposure of rains and sun and may be composed of pure solid excrement, or excrement and bedding.

✧ **Conditions Affecting the Value of Manure.**—There are many conditions which affect the value of manure.

1. The age of the animal.
2. The use of the animal.
3. The kind and amount of bedding used.
4. The kind of animal.
5. The nature and amount of feed used.
6. The care, preservation and use of the manure.

1. **The age of the animal** influences the value of manure. Manure from young animals is not so rich in the fertilizer constituents, nitrogen, phosphoric acid and potash as that from mature animals, even when the same kind of feed is used. Young animals require and retain nitrogen and phosphoric acid for growth, while mature animals use these constituents for maintaining the functions of the body and for repairing broken down tissues, after which they are cast off in the manure.

2. **The use of the animal** influences the value of manure. Milch cows return less of the fertilizing constituents in the feed than other domestic farm animals. Fattening pigs return less than

fattening sheep and fattening sheep less than fattening oxen. Horses return the same relative amounts from the feed whether at work or at rest.*

3. The Kind and Amount of Bedding Used.—Bedding besides affecting the value of manure renders stables more sanitary. It provides comfort for the animal, makes the manure lighter and easier to handle, absorbs the liquids, lessens fermentation and improves the texture of the manure.

Straw is the most common bedding used and is well suited for this purpose, because it is largely made up of cellulose which is a good absorber on account of its hollow structure.* There is a difference in the composition of straws, but they all contain a high potash content. The nitrogen and phosphoric acid are rather low and when large amounts of straw are employed the fertilizing value of the manure is naturally lowered.

Leaves.—Dried autumn leaves are often gathered and used as bedding. They are not as valuable as straw as they do not ferment very rapidly and are liable to cause acidity in the manure.

Sawdust is often used as bedding and it is much inferior to straw and dried leaves from a fertility standpoint. It decomposes very slowly in the soil. However, this material is a good absorber of the liquid portions and makes a good bedding when it can be obtained cheaply.

Shavings are sometimes used as bedding and possess about the same properties as sawdust.

Peat when dried is a good material to use in stables as it is an excellent absorber. It absorbs not only the liquid portions of the manure but also the nitrogen gases evolved, and renders the stable free from foul odor. It in itself contains considerable organic matter which is beneficial and it is readily fermented in the soil. It is a good material to use in conjunction with straw. The use of peat as bedding increases the nitrogen content of the manure. The nitrogen percentage in peat varies a great deal but it usually approximates 1 to 1.5 per cent.

Absorptive Power of Bedding.—According to Snyder,¹ the absorptive power of different kinds of bedding are:

¹ Soils and Fertilizers.

	Per cent. of water absorbed.
Fine cut straw	30.0
Coarse uncut straw	18.0
Peat	60.0
Sawdust	45.0

Snyder says: "The proportion of absorbents in manure ranges from a fifth to a third of the total weight of the manure."

The following experiment shows the absorptive power of straw and peat in two similar stables carrying the same stock, in one of which straw was used and the other peat.

AMMONIA IN STABLE PER MILLION OF AIR.¹

Litter	1st day	2d day	3d day	4th day	5th day	6th day	7th day
Straw0012	.0028	.0045	.0081	.0153	.0168	—
Peat moss	—	—	—	—	trace	.001	.017

4. **The Kind of Manure.**—Manure from different kinds of animals varies in value.

Horse Manure.—The manure voided by the horse is rich in nitrogen and not so finely divided as the manure from cows, sheep, etc. This is due to the horse only having one compartment in its stomach and therefore the feed, especially coarse feed as hay, etc., is less broken up and digested. Horse manure is generally comparatively dry and hard to incorporate with bedding. On this account, and because of its coarse nature and chemical composition, fermentation readily sets in and considerable nitrogen is lost unless the fermentation is stopped. When fermentation is allowed to continue the value of horse manure is very much decreased. Boussingault found by experiment that when fermentation was allowed to continue, one-half of the nitrogen was lost from the fresh manure.*

The liquid portion of horse manure contains a great deal more nitrogen than the solid. The liquid portion of horse manure contains very little phosphoric acid.

Cow manure is much colder than horse manure and so a fine combination results when it is mixed with horse manure; the

¹ Hall, *Fertilizers and Manures*.

fermentation of the horse manure is stopped and the nitrogen saved, and the mixture is better than cow manure alone. Cow manure contains more water than horse manure due perhaps to the large amount of water drank by this class of animal. Cow manure does not ferment rapidly and when dry decomposes very slowly in the soil. It is estimated that 6 to 10 pounds of straw are necessary to absorb cow manure, depending upon the amount of liquids voided.

The nitrogen content is present in greatest amount in the liquids while there is little phosphoric acid present in this portion of cow manure.

Hog Manure.—The composition of hog manure is quite variable depending upon the feed consumed. When tankage and other highly nitrogenous feeds are employed the manure is rich, but when feeds containing small amounts of fertilizing constituents are used, the manure is not so valuable. Hog manure contains a high percentage of water and is slow to decompose. It is estimated that 4 to 8 pounds of straw are adequate for absorbing pig manure.

The liquid portion of hog manure contains more phosphoric acid and the solids more potash than horse or cow manure. As previously mentioned, the nitrogen content of the liquid portion of hog manure depends upon the nature of the feed. Sometimes the nitrogen will reach 1.5 per cent. in the liquid portion. The liquid portion is higher in water than manure from other farm live-stock.

Sheep Manure.—The manure from sheep is more valuable than that from other farm animals. On account of its being dry and rich in nitrogen it ferments rapidly although not so quickly as horse manure. The slower action is perhaps due to its more compact mechanical condition. Losses of nitrogen in sheep manure are apt to occur unless the manure is well taken care of. Both the solids and liquids of sheep manure run higher in nitrogen than the manure from other farm animals, and the water content is lower. The phosphoric acid content of the solids is also high and that of the liquids appreciable.*

Hen manure contains its nitrogen in a quickly available form and unless carefully preserved, fermentation sets in and drives off considerable of this valuable constituent as ammonia. Lime should not be used where the manure is kept as it hastens the liberation of ammonia. The per cent. of nitrogen in hen manure depends a great deal on the kind of feed consumed. Hens produce, per 1,000 pounds live weight, about 35 pounds of manure per day, and about one bushel of manure is produced by a hen per year. Hen manure approximates sheep manure in composition. It is a valuable manure because it acts quickly.*

ANALYSES OF FARM MANURES.¹

Kind of manure	Water Per cent.	Nitrogen Per cent.	Potash Per cent.	Phosphoric acid Per cent.
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	—
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

How to Calculate the Amount of Manure Produced.—A method used for determining the amount of manure produced by animals is to multiply the amount of dry matter in the feed consumed by 3.8 for a cow, 2.1 for a horse and 1.8 for a sheep. A horse that consumes feed containing 25 pounds of dry matter per day would void $25 \times 2.1 = 52.5$ pounds of manure a day. Add to this the amount of bedding used and you will arrive at the total amount of manure.

5. **The nature and amount of feed used** affects the value of the manure. The richer the feed the higher the fertilizing value of the manure. Coarse feeds like hay, straw, etc., produce less valuable manure than concentrated feeds like linseed meal, gluten meal, cotton-seed meal, etc.*

¹ Fletcher, Soils.

Lasting Effect of Manure.—The lasting effect of manure is shown by the experiments conducted at Rothamstead. A plot of grass land received applications of 14 tons of manure per acre for 8 consecutive years and then the applications were discontinued. During the first year after the discontinuance of manure the yield was twice that of an unmanured plot. Since that time the yield on the manured plot has slowly decreased until at the end of 40 years the excess has been about 15 per cent. greater than the yield of the unmanured plot.

An experiment was conducted with barley. Three plots were employed. One plot received 14 tons of manure per acre since 1852, another received 14 tons of manure per acre for 20 years and then the applications were stopped, and the third has been unmanured since 1852.

The experiment showed that the continuously manured plot had the largest yields but the plot that was manured for 20 years is still producing crops at least 40 per cent. greater than the unmanured plot.

The results in these experiments would not be found to be so apparent in actual farming, as the soils that were used for these experiments were more exhausted than the farmer would use. However, the results are interesting as they show the almost permanent effect of farm manure on soils.*

6. The Care, Preservation and Use of Manure.—From the foregoing pages it is very evident that the composition of manure and the amounts produced by different kinds of animals are exceedingly variable. It is also known that a regular value for this product cannot be estimated from its chemical composition.

Waste of Manure.—In some sections of the United States farm manure is dumped into streams, burned, buried in holes in the ground, or allowed to remain in large piles in some uncultivated place. The soils in many of such sections are fertile enough to produce profitable crops but it seems very wasteful to throw away such valuable fertilizer.

Leaching.—When a manure heap is exposed to the washing of rain and the solutions allowed to wash away, the value of the manure is decreased. The soluble plant food elements are washed

away together with more or less of the manure itself. Leaching is one of the most important subjects to consider in the care and preservation of manure because it is the source of one of the greatest losses in this valuable product. Experiments have been conducted to show the great losses that occur by leaching. Horse



Fig. 4. —The manure from live-stock should be carefully saved.

manure suffers larger losses than mixed horse and cow manure, or cow manure.*

Fermentations.—There are certain bacteria that produce fermentations in manure piles and liberate nitrogen as gas causing large losses in manure. These fermentations are brought about by two classes of organisms; aërobic bacteria and anaërobic bacteria.

1. The aërobic bacteria require oxygen to be active and the anaërobic bacteria are only active in the absence of oxygen. On the outside of manure heaps where air circulates, the aërobic bacteria work while in the interior of the heaps where no air

can penetrate the anaërobic fermentation takes place. The aërobic bacteria convert the nitrogen present in the organic matter of the manure, into ammonia, in which form it passes off into the atmosphere. Because of the great amount of carbon dioxide formed during this action some of the ammonia is converted into carbonate of ammonia which is also volatile.

2. The anaërobic bacteria convert ammonia salts to nitrogen. Some of these bacteria have the power of reducing nitrates to nitrites, and to ammonia. The anaërobic bacteria do not bring about such losses as the aërobic bacteria, so it is important to keep the manure heap well compacted to prevent the action of the aërobic organisms.

Keep the Manure Moist.—Dry manure ferments more readily than wet manure. To prevent active fermentation the manure heap should be kept moist. It is not necessary to add enough water to leach it. Water excludes the air and promote anaërobic action which is beneficial.*

The temperature in fermenting horse, sheep and poultry manure often goes higher than 150° Fahrenheit (65° Centigrade). The highest temperature is usually near the surface as the fermentation is most active there.

Composting manure is helpful in increasing the availability of that plant food. It also kills many weed seeds. There is less loss of plant food when the manure is applied to the soil fresh, than when allowed to rot. It is not generally convenient to haul the manure from the stable to the land as other work is of more importance, so that the manure has to be stored until the regular farm work becomes slack. When manure is composted it should be kept compact and moist and the heap should be shaped to shed water. A layer of earth on the top of the manure compost will tend to absorb some of the gases.

Voelcker¹ gives the following as the composition of fresh and rotted manure.

¹ Lyon and Fippin, Soils.

	Fresh Per cent.	Rotted Per cent.
Water	66.17	75.42
Soluble organic matter.....	2.48	3.71
Soluble organic nitrogen.....	0.15	0.30
Soluble inorganic matter.....	1.54	1.47
Insoluble organic matter.....	25.76	12.82
Insoluble inorganic matter.....	4.05	6.58

It is seen that manure that is composted contains the fertilizer elements in a more available form than in fresh manure.

The organic matter is decreased by allowing manure to rot. Snyder¹ says: "A ton of composted manure is obtained from 2,800 pounds of stable manure." There are of course some losses of nitrogen in composting manure, the extent of these losses depending upon the compactness and dryness of the manure.

The principal benefits derived from composting manure are; the improvement of the physical condition, and decomposition takes place in the manure that ordinarily would have to be performed in the soil.

Sometimes manure is composted with earth, sod, leaves and wastes from the farm.

Store Manure Under Cover.—Whenever manure is left out of doors exposed to the rain losses occur. Many farmers preserve manure in different ways. Some use covered yards where the stock are allowed to exercise and the manure is kept compact by the tramping of the animals. In this practice bedding should be used to absorb all of the liquids and to allow the animals to be comfortable. The site should be well drained and kept dry. The manure from sheep, hogs, young stock, etc., is often preserved in this way. Some farmers keep the manure in cellars under the stable. The fermentation of manure in the cellar of a stable is liable to produce foul odors and is especially objectionable in dairy barns. Another method of storing manure that is used in the older farming sections, especially in dairies, is to build covered cement pits just outside the barn and dump the manure from trucks. The liquid portions are drained

¹ Soils and Fertilizers.

to these pits by pipes. It may not always be possible for a farmer to build a covered cement pit but he can always afford to put a roof over the manure, for the cost of the shed will soon be returned in the increased value of the manure.

The following table, the work of Biernatski, shows the composition of uncovered and covered manure.

	Water Per cent.	Nitrogen Per cent.	Phosphoric acid Per cent.	Potash Per cent.
Uncovered manure	83.78	0.47	0.26	0.43
Covered manure.....	76.54	0.67	0.31	0.76

Preservatives.—In the destruction of the nitrogen present in organic matter in manure, the aerobic bacteria produce ammonia and some of this gas unites with the carbon dioxide evolved and forms ammonium carbonate, a volatile compound. By adding moist gypsum (land plaster) to manure, the ammonium carbonate is converted into ammonium sulphate, a compound that does not pass away in the atmosphere. This latter compound is soluble in water and when manure is exposed to the leaching of rains, it is useless to employ gypsum. Gypsum is perfectly safe to use because it does not injure the feet of animals. Lime is objectionable because it liberates ammonia. Kainit, superphosphate and ground rock phosphate are sometimes used with good success, as they absorb nitrogen. These preservatives may be scattered at the rate of about one pound to an animal. They may also be economically used on covered manure heaps. Hall¹ estimates that it will take about 100 pounds of gypsum per ton of manure to absorb the gases, as some of it is acted upon by the potassium carbonate in the urine.

Physical Effects of Manure.—Manure has a greater value than is represented by its chemical composition. It improves the physical condition of the soil by.

1. Producing a better moisture condition.
2. Producing a better texture.
3. Preventing mechanical losses by winds.
4. Benefiting grass land.

1. **Manure Produces a Better Moisture Condition.**—Manure when added to soils increases the water holding power of those soils because of its humus content. Humus absorbs water readily. A soil that has had manure added to it will resist drought better than one where there is little or no humus. During a heavy rainfall the soil with humus will absorb a great deal more water and give it up more gradually than one without humus.* Manure helps to conserve the moisture supply of soil during dry seasons.

2. **Manure Improves the Texture of the Soil.**—Manure has a very beneficial effect on most soils in improving the texture. The addition of manure to sandy soils makes them more binding and increases their water holding capacity. Clay soils are made more porous by the addition of manure. Some soils may produce good crops during favorable seasons without much organic matter but when the season is bad it is almost impossible to get the soil in good mechanical condition for crops.

NUMBER OF MANGOLD PLANTS TAKING 100 AS THE POSSIBLE.¹

Average of 7 years, 1901-7.

Farm manure, minerals and nitrate of soda	Minerals and nitrate of soda	Minerals and rape cake
69	62	83

The plot receiving rape cake, which was applied at the rate of 2,000 pounds per year, shows the best results, but rape cake like manure supplies a great deal of humus. A better stand was produced with farm manure than with the artificial fertilizer.

3. **Manure Prevents Mechanical Losses by Winds.**—The losses occasioned by heavy winds on certain soils are sometimes more than one would expect. Dry light soils devoid of organic matter are easily blown away by heavy winds. The addition of manure to such soils tends to keep them moist and prevents such loss.

4. **Manure Benefits Grass Land.**—Manure benefits grass land not only by supplying plant food and increasing the moisture holding capacity, but also in protecting this crop from the frosts

¹ Hall, *Fertilizers and Manures*.

of early spring, by the mulch produced. It is noticed that grass that has been manured in the fall has an earlier growth in the spring than such lands unmanured.

Bacteriological Effects of Manure.—Manure when added to the soil aids the growth of bacteria that render plant food available. It also increases the number of these bacteria and supplies food for them, and fermentations are promoted that are very helpful in the production of crops.

Time to Apply Manure.—In order to get all the value from farm manure it is better to apply it while fresh than when rotted. Manure in rotting loses some of its fertility. The Ohio Experiment Station have conducted experiments with fresh manure and exposed yard manure with the following crop returns for ten years.

	Amount applied per acre tons.	Yield per acre.		
		Corn bushels.	Wheat bushels.	Hay pounds.
Exposed yard manure	8	16.03	8 21	698
Fresh manure.....	8	22.24	9 73	1,280

The manure was applied to clover sod which was plowed under and followed by a three year rotation of corn, wheat and clover without the addition of any more manure. The yields favor the fresh manure with an increase of 6.21 bushels of corn, 1.52 bushels of wheat and 582 pounds of hay.

Sometimes it is not practicable to apply manure while fresh as some crops, especially the quick growing market garden crops, require plant food that is available and so prefer rotted manure.

It is common in this country to apply fresh manure to grass land in the fall and turn it under in the spring. This practice is beneficial in that it supplies a great deal of organic matter for the succeeding crop. Corn is a crop that thrives on fresh manure and so it is well to apply manure in this condition to corn and follow this crop with one that prefers rotted manure.

Amount of Manure to Apply.—The amount of manure to apply depends upon the fertility and texture of the soil. Soils

that already have considerable fertility sometimes require a light application of manure to improve their texture. Large applications of manure on such soils would not be profitable. Most farmers use too much on their land at one time. Frequent light applications are more beneficial than large amounts applied at long intervals, as they keep the soil in an even state of fertility and losses by volatilization of nitrogen as gases and leaching of the soluble elements are less. Experiments show that small applications give greater percentage increase than large applications although large applications give larger yields.

Sometimes manure does not furnish sufficient plant food to satisfy the needs of the crop. An addition of some commercial fertilizer which supplies the necessary fertilizer constituents is beneficial in such cases to supplement the manure.

* **How to Apply Manure.**—It is best to spread the manure over the land as it is hauled. Some farmers dump the manure in little piles over the field and leave it in this condition for two or three months. When fermentations take place in these piles nitrogen passes off in the air. This practice is objectionable because the soil under and around the piles gets most of the available plant food that is leached out, and the other soil does not receive its share. The result is that the succeeding crops grow uneven or in patches. There is no objection to dumping manure in small piles over the field if it is spread immediately. The hauling of manure to the field and hand spreading it is perhaps the common method used in this country. It is difficult to spread manure evenly in this way and after the manure is distributed, a brush drag should be used to scatter it more evenly. Manure spreaders distribute manure more evenly than any of the other methods in use. They are labor saving machines and although they usually carry less per unit of draft, they are considered a good investment for those who have much manure to spread. A ton of manure spread uniformly gives better results than a larger amount applied unevenly.

CHAPTER V.

HIGH GRADE NITROGENOUS FERTILIZER MATERIALS.

Nitrogen is the most important element to consider in the study of fertilizers. It is the most expensive and most fugitive of the essential elements. Nitrogen usually costs about three times as much as phosphoric acid or potash. To be in a form available as plant food it must be as nitrates which are readily soluble in water. The air is made up of nitrogen, carbon and oxygen and although plants utilize the carbon and oxygen most of them do not seem to be able to use the nitrogen. There is one class of plants, the legumes (peas, beans, peanuts, alfalfa, clover, etc.) of which we have spoken, that can utilize this elementary nitrogen but most of our other plants do not possess this power. The organic matter, which is made up of animal and vegetable matter, serves as a source of nitrogen, but plants cannot use it in this form. It is understood then that there is plenty of unusable nitrogen in the air and in soils rich in organic matter, but it has no direct plant food value in these forms until it is prepared by electrical means, oxidized and acted upon by certain bacteria.

Forms of Nitrogen.—Nitrogen exists in different forms in the many substances containing it. Not including the nitrogen in the air we may classify these forms into four groups, namely:

1. Organic nitrogen, which is found in vegetable and animal substances, generally as protein.
2. Ammonia nitrogen, which is found in ammonium sulphate.
3. Nitrate nitrogen, which is found in nitrate of soda (Chile salt-peter) and nitrate of potash.
4. Cyanamid nitrogen, which is taken from the air by electrical means and combined with calcium, carbon, etc.

Of these four forms all are soluble in water except organic nitrogen. The organic form is included in many substances, both animal and vegetable, while the remaining forms are found principally in a few products.

The Meaning of the Form of Nitrogen.—The fertilizer materials furnishing nitrogen contain this element in different forms.

We have said that the substances containing nitrate nitrogen, ammonia nitrogen and cyanamid nitrogen are soluble in water and the organic nitrogen is insoluble in water. The nitrogen as nitrates is always the same and of equal value no matter from what substance it is derived. The ammonia nitrogen is also of equal value and equal quantities of it are as good no matter what material it comes from. The soluble nitrogen from ammonium sulphate, however, is not the same as the soluble nitrogen from nitrate of soda and the insoluble nitrogen of organic materials is not the same or of equal value. Therefore the source of soluble and insoluble nitrogen makes a difference in value of the forms of nitrogen. The solubility of nitrogenous substances influences the availability, or the rate with which the nitrogen in a suitable form is supplied so that the plant can assimilate it, to some extent.

The organic form of nitrogen is so called because the nitrogen is combined with other elements as hydrogen, carbon and oxygen in organic matter. Organic nitrogen is different in the various substances. Some animal and vegetable materials are quite rich in nitrogen while others do not contain much and are perhaps not so valuable. Some organic substances may contain considerable amounts of nitrogen but in such a locked-up state that they are undesirable as plant food.

When a substance gives up its nitrogen as nitrates readily we say that the nitrogen is in a form that is active; it is quick acting, quickly available, readily assimilated, etc. When the nitrogen is locked-up we use the terms slow acting, slowly available, etc. There are many degrees of availability of the different forms of nitrogen and they range from the very quick acting of the soluble materials to the organic materials that may take two or three years or even longer before they give up their nitrogen for plants to use as food. There are many organic substances that contain nitrogen, but in such small amounts, or in such a locked-up condition that they cannot be used profitably in the manufacture of fertilizers.

The principal sources of organic nitrogen will now be discussed.

The Vegetable Substances.

Cotton-seed meal is one of the most important sources of vegetable nitrogen. It is usually a bright yellow product with a nutty odor when fresh.*

For the year 1908, 929,287,467 pounds of cotton-seed meal were manufactured in the United States.¹

YIELDS OF PRODUCTS FROM A TON OF COTTON-SEED.²

	Pounds
Linters.....	23
Hulls	943
Crude oil (37.6 gals.)	282
Cake or meal.....	713
Waste	39
Total	2,000

Composition of Cotton-seed Meal.—The composition of cotton-seed meal varies a great deal. When it is not adulterated with hulls the variation in composition may be due to the season, the nature of the soil and the climate. Seed raised on high land is usually richer in nitrogen than seed raised on low land. The Texas meals seem to run high in nitrogen. In the past few years many of the manufacturers have been introducing ground cotton-seed hulls into their meal which of course lowers the value of this product. Cotton-seed meal is in great demand as feed for live-stock and the bright yellow meals are used for this purpose. The darker meals are not so valuable as feed and are usually sold for fertilizer. The dark color may be due to overcooking, to fermentation, or to storing in a wet or damp place. If there is no loss of nitrogen, the product is not injured for fertilizing purposes.*

Value of Cotton-seed Meal.—Large quantities of this product are used in the South where it is especially suitable for the long growing crops as it supplies plant food during the whole season.

An insect, called the boll weevil, is reducing the acreage and yield of this crop. If the entomologists do not find a way of

¹ 1908 Yearbook, U. S. Dept. of Agriculture.

² Lamborn, Cotton-Seed Products.

average about 5.3 per cent. nitrogen, 1.25 per cent. potash and 1.6 per cent. phosphoric acid. Linseed meal is not used extensively as fertilizer because of the high price it commands as feed for live-stock.

Castor pomace is the remaining product from the extraction of oil from the castor bean. It is poisonous to live-stock and therefore is used for fertilizer. It averages about 5.5 per cent. nitrogen, 1.8 per cent. phosphoric acid and 1 per cent. potash. As it decomposes rapidly in the soil it makes an excellent fertilizer.*

The Chief Animal Substances.

Dried blood is obtained from the large packing houses of the United States. There are two kinds on the market, namely, red and black blood. The red blood is obtained by drying blood very carefully with superheated steam and hot air. Should the blood be dried at too high a temperature it chars and turns black. If the blood is injured in any way it is sold as black blood. Red blood averages about 13.5 per cent. nitrogen with traces of phosphoric acid while black blood is a more variable product but usually contains 12 per cent. nitrogen and 1 to 3 per cent. phosphoric acid, depending upon the nature of the impurities. When bone is present the product contains sometimes as high as 4 per cent. phosphoric acid. Red blood is not used for fertilizer because it commands too high a price for other purposes. Both red and black blood are ground and sold in a powdery condition. Black blood is a very valuable nitrogenous fertilizer which is in great demand and is very popular with the manufacturers of fertilizers in satisfying their formulas. It is one of the principal organic fertilizers used by manufacturers in the North. It is not used directly to any extent by farmers as the manufacturers purchase most of it. It is in a fine mechanical condition and is easy to mix with other materials. As plant food it gives excellent results as it decays very rapidly thus furnishing nourishment during the early stages of the growing period. Sometimes salt and slaked lime are put in blood. It is very high in availability being somewhat quicker than cotton-seed meal.

• •

Tankage is composed entirely of animal matter. It is the refuse from slaughter houses and consists of meat, bone, etc. (from which the fat has been extracted) and more or less dried blood. Animals condemned as unsuitable for food are made into tankage.

The phosphoric acid in tankage is slowly available as it is supplied principally by ground bone. The nitrogen is derived principally from meat and blood. When the percentage of bone is large, the phosphoric acid is high, and the nitrogen content is low, and when there is an excess of blood and meat, the nitrogen is high and the phosphoric acid low.

Grades of Tankage.—There are several grades of tankage found on our markets. The most popular nitrogenous grades are those containing 8, 9, and 10 per cent. ammonia which are equivalent to 6.58, 7.41, and 8.23 per cent. nitrogen, and 6.56, 7.64, 10, and 12 per cent. bone phosphate of lime, which are equivalent to 3, 3.5, 4.58, and 5.5 per cent. phosphoric acid. There are many other grades of tankage sold that carry more phosphoric acid and less nitrogen, but these are classed as bone tankages and will be later described under phosphates.

Concentrated tankage is still another grade and the richest of all since it contains more nitrogen and is a more uniform product. It is made by evaporating wastes that contain animal matter in solution, or in other words the tank water. It usually contains 10 to 12 per cent. nitrogen and small amounts of phosphoric acid.

Variation in Tankage.—Because of the great variation in the chemical composition of tankage (no two shipments hardly ever run alike, for the manufacturers cannot seem to control the composition of their output on account of the variation in the by-products), great care must be exercised in purchasing. The product should be bought on its chemical composition and not necessarily on its guarantee, for it may or may not reach its stated composition. Hoof meal and hair are sometimes present in shipments of tankage. For sugar-cane, cotton-seed meal has been found to be more valuable than tankage of the same nitrogen content. Nevertheless, tankage is a valuable fertilizer

and its value depends a great deal on its nitrogen content." It is suitable for crops having a long growing season.

About 1,000,000 tons of tankage and dried blood are produced annually.

Azotin, meat meal, flesh meal, dried meat, animal matter and ammonite are practically the same product, but are by-products from different manufacturing establishments. Most of this product comes from the slaughtering houses and beef extract factories. It is a rich organic fertilizer containing about 13 per cent. nitrogen, but it may run higher or lower than this depending upon its purity. This product is made up generally of the flesh refuse of dead animals from which the fat has been extracted and the remains dried and ground. It is different from tankage because it does not contain bones.

Steamed horn and hoof meal averages about 12 to 15 per cent. nitrogen and is principally marketed by the large packing houses. The choice horns and hoofs are sold for the manufacture of buttons, combs, and novelties, and the imperfect and off-colored horns and hoofs are treated with steam, under high pressure, which renders the nitrogen more available and permits of the product being ground to a fine powder. Horn and hoof meal was not formerly thought much of, but since it has been subjected to superheated steam the product has been much sought after by the manufacturers of fertilizers. It is produced only in limited quantities and is not as valuable as dried blood, but has a fairly high degree of availability, according to recent investigations.*

Dry Ground Fish.—This is also called fish scrap and fish guano and has a yellow color. It is obtained principally from canning factories where the refuse as bones, skin, heads, fins, tails, intestines, etc., of edible fish are saved, dried and ground. Establishments expressing oil and manufacturing glue from inedible fish as Menhaden, furnish a considerable supply. The average annual catch of Menhaden is about 600,000,000 fish, which produce 70,000 tons of fish scrap and 35,000 barrels of oil. Thirty factories with 70 steamers are engaged in this industry and the

largest catch was in 1903 when 1,000,000,000 fish were caught.¹ The whale bone interests, after the bones are removed and the oil extracted from whales, utilize the remainder in the preparation of dry ground fish.

Dried ground fish is variable in composition depending upon the nature of the materials of which it is made. The greater the percentage of bone, the higher is the phosphoric acid content and the lower the nitrogen, and the less bone, the higher the nitrogen and the lower the phosphoric acid. The amount of oil left also influences the composition. It usually ranges from 7.5 to 10.5 per cent. nitrogen, 5.7 to 16 per cent. phosphoric acid, with an average of 8.5 per cent. nitrogen and 9 per cent. phosphoric acid. It is a popular and valuable fertilizer and large quantities are used in the North. Most sections of the South are too far away from where it is manufactured to prevent using it at its market value. Dry ground fish is readily decomposed in the soil and is therefore quick acting. It is not considered as valuable as dried blood.

King crab is obtained on the Atlantic coast and is dried and ground, in which state it is utilized by fertilizer manufacturers. It contains about 10 per cent. nitrogen and is similar to dried ground fish in fertilizer properties.

Guano, or natural guano, is another important source of nitrogen. It was used as early as the 12th century in Peru. On the west coast of South America there are thousands of sea fowl. These birds have roosting and breeding places along the uninhabited portions of the coast and many of them make their home on the smaller islands off the coast of Peru and also on the mainland, because of the abundant supply of fish in that region. The excrement voided by these birds is rich in nitrogen and phosphoric acid because their food, which is fish, is rich in these constituents. During breeding seasons they literally cover these islands and the young birds after they are hatched are fed on fish until they are able to fly. The excreta from the old and the young birds, feathers, and the remains of the young birds that die, all go to make up guano. As this region is practically

¹ American Fertilizer.

rainless and has a dry hot temperature, these remains dry out rapidly and are preserved without much loss of phosphoric acid or nitrogen. There is some loss of nitrogen in these Peruvian guanos due to the formation of ammonium carbonate, a volatile form, and to leaching by occasional rains. However, these deposits have been the best nitrogenous guanos in the world. There are deposits in other parts of South America, West Indies, Africa, Australia, Asia, and the islands of the Pacific, but the Peruvian deposits are the most notable. There is a wide difference in the composition of guanos. In Peru, guano from the same island shows variation in chemical composition, while guano from different islands shows even a greater variation. The oldest deposits usually contain less nitrogen and more phosphoric acid than the more recent. In a wet, damp climate, fermentation, aided by the presence of moisture, destroys all or most of the organic matter driving off the nitrogen as ammonium carbonate. Soluble phosphoric acid is also lost in such regions. Therefore it is easy to understand the wide differences in the composition of these deposits.

Guanos range from rich nitrogenous deposits to phosphatic deposits which only contain traces of nitrogen and considerable amounts of phosphate of lime. There are therefore two classes of guanos, namely, nitrogenous and phosphatic. The phosphatic guanos will be discussed under phosphates.

Formerly guano was used more extensively in the United States but most of the nitrogenous deposits have been exhausted so that the importations are rather decreasing from year to year. There were 16,155 tons imported from Peru in 1905 and 5,500 tons in 1909.¹

The nitrogen in guanos is present in different forms. Some of it is as nitrates, some as ammonia and some as organic nitrogen. The presence of these various forms makes the nitrogenous guanos valuable because they supply plant food during the whole growing season.*

In Mexico there are deposits of bat guano, many of which are good nitrogenous fertilizers, but they are not being worked be-

¹ 1910 American Fertilizer Handbook.

cause of poor transportation facilities. There are also deposits of bat guano in Texas. The bat guanos are not as a rule as valuable as the high grade nitrogenous Peruvian guanos.*

Ammonium sulphate is unlike the organic compounds as it is not a natural product but a manufacturing by-product. When pure it is a white crystalline salt but sometimes foreign substances become mixed with it, in the course of manufacture, which causes it to be grey, yellow, or blue. It is soluble in water and volatile, that is, it will pass off as gas when strongly heated over a flame. It is derived from the distillation of coal in the manufacture of gas; from the distillation of bones in the manufacture of bone-black; and from the manufacture of coke from coal. Coal was formed from vegetable matter and most coals average about 1.8 per cent. nitrogen. When coal is heated, as in the manufacture of gas or coke, about $\frac{1}{5}$ of the nitrogen as ammonia is driven off and this ammonia may be saved by washing it in water in special apparatus. The solution thus formed is then distilled into sulphuric acid, concentrated and the crystals of sulphate of ammonia separate out on standing. Bones contain about 3 to 4.5 per cent. nitrogen and the nitrogen as ammonia is recovered in a similar way as in distilling coal or coke, when they are subjected to dry distillation by heat, as may be practiced in the manufacture of bone-black.*

Composition and Availability.—Sulphate of ammonia when pure contains 21.2 per cent. nitrogen but the commercial article usually runs about 20 per cent. It is in a form very suitable for distribution in the soil and is readily converted into available plant food. It is more available than the organic forms. It is a quick acting fertilizer and suitable therefore for quick returns in crop production, an especial advantage for truckers and market gardeners. It is sometimes substituted for nitrate of soda.

As it is readily soluble in water it should be used sparingly, and frequent small applications are more effective than large amounts applied at long intervals. A continued use of it may cause the soil to become acid because of the sulphates left in the soil after the nitrogen is given up.*

Nitrate of Soda.—This is a white or yellow or pink crystalline salt. The nitrogen in nitrate of soda is in a form that can be used by plants without undergoing any change. Nitrate of soda is the highest in point of availability of any of the nitrogenous fertilizer materials. It induces roots to grow deep. The nitrate diffuses into the subsoil and the plants send down their roots for it. This is indeed of great benefit because it enables the plant to better stand dry spells and it increases the area of plant food supply.

It is found in extensive deposits on the west coast of Chile and is often called Chile saltpeter. The entire deposits are found in layers sometimes 6 feet thick, about 2 to 10 feet below the surface, and are blasted out and treated to rid the product of impurities.*

Composition and Properties.—Nitrate of soda contains 15 to 16 per cent. nitrogen and the average product found on the American market contains 15.3 per cent. nitrogen. It is very soluble in water and therefore it should be supplied in small quantities frequently to prevent losing it by leaching. It should be kept in dry storage as it absorbs water and is liable to liquefy. It is hard to distribute evenly on the soil unless it is mixed with earth or some other material. On account of its caustic action it should be applied around the plants and not on them as it spots green vegetation. It should be kept away from live-stock as it is poisonous. Acid phosphates when damp should not be mixed with nitrate of soda as nitrogen is lost. The acid attacks the nitrate of soda liberating the nitrogen.*

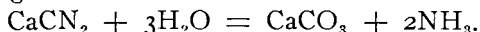
The utilization of nitrogen from the air by artificially uniting and fixing it with other elements to form compounds that could compete with the other nitrogenous fertilizer materials has attracted the attention of chemists and investigators for many years. It seems that at last the problem has been solved and it is now only a matter of a short time when the present modes of manufacturing artificial nitrogen compounds will be so perfected that we will not be forced to worry about the future supply of this important element. There are two of these artificial nitrogenous

compounds being sold to-day, namely, calcium nitrate and calcium cyanamid.

Calcium nitrate sometimes called lime nitrogen is manufactured, with cheap water-power, in Notodden, Norway. It contains about 13 per cent. of nitrogen and can be sold at a profit for \$40 per ton, which is equivalent to nitrate of soda at about \$50 per ton. Recent experiments show it to be as valuable as nitrate of soda in crop producing power.*

Calcium cyanamid is a grey black crystalline powder. It is made from limestone, coke and nitrogen gas with the aid of the electric furnace. When calcium cyanamid was first placed upon the market it contained small quantities of substances injurious to young plants, and the manufacturers now claim to put out a product in which these poisonous materials are absent. It carries 17 to 20 per cent. of nitrogen.*

Properties.—About 80 per cent. of the nitrogen in the improved cyanamid is as cyanamid and the remaining 20 per cent. as nitrate. Calcium cyanamid contains about 20 per cent. of free lime which absorbs water and carbonic acid gas from the air, causing the lime to slake and the product to decompose so that ammonia is formed. This ammonia is not lost to any great extent when the product is kept in bags, but if it is exposed in a loose pile the loss may be appreciable. Calcium cyanamid is soluble in water and when steam is introduced into it ammonia is driven off. In the soil the ammonia is given off by the action of water and soil micro-organisms. The action with water is:



Fertilizing Value.—Experiments show that this product has about the same fertilizing value as ammonium sulphate on most soils. It is therefore highly available. It would no doubt show to good advantage on soils deficient in lime. Care should be exercised in its application. When the product contains injurious substances it is liable to injure seedlings and it is safe practice to apply it sometime before the seed is planted. It is thought to be injurious when used as a top dressing but this point has not been thoroughly proved. Should the "Improved Cyanamid" be free from injurious substances it will prove a much more desirable fertilizer.*

CHAPTER VI.

LOW GRADE NITROGENOUS MATERIALS AND FUNCTIONS OF NITROGEN.

The nitrogenous substances discussed in the previous chapter are all considered high class and valuable standard materials. Some of them as the mineral compounds are immediately or almost immediately available, while the organic materials, both animal and vegetable, vary in their degree of availability, but stay with the crop during the whole or the greater part of the season.

The high prices of these desirable and valuable nitrogenous materials have caused some of the manufacturers of commercial fertilizers to seek and use cheaper sources of nitrogen. Many of these cheaper materials, to be sure, are rich in nitrogen but really of little value as the nitrogen is present in such forms as to be inert or else too slow acting to stimulate plant growth. Many of these low grade nitrogenous waste products are imported from foreign countries yet we produce our share of them in this country. They are made up of wastes from the manufacture of silk, wool, feathers, combs, hair, skins, sugar and some few are derived from vegetable sources. The materials most commonly used will be discussed.

Raw Leather Meal.—This product contains about 8 per cent. nitrogen which is in a form that is very slowly utilized by plants; it may remain in the soil for two or three years before decaying. It takes such a long time for it to decompose that it has not much value for fertilizing purposes. One of the objects in the treatment of leather is to prevent its decay and for this reason raw leather may remain in the soil for a very long time before undergoing any change. This material is sold varying in the degree of fineness from a dust to coarse particles. If it is ever used it should be powdered. At best it is a tough material.

Dissolved leather, sometimes called *treated leather* or *extracted leather*, is made in Belgium. The raw leather is roasted and very finely ground and treated with superheated steam which removes

most of the tannic acid. It is then acidulated with sulphuric acid to fix the nitrogen and render it more available. This material is being used by the manufacturers in the United States to quite a considerable extent because it is cheaper than the more desirable nitrogenous materials per unit of nitrogen. This product contains about 8 per cent. nitrogen and is more valuable than raw leather.

Feather waste and various skin wastes are also saved for fertilizing purposes.

Hair and fur waste is rich in nitrogen. It is unsuitable as fertilizer because it is so slowly decayed. When properly treated with sulphuric acid and rendered assimilative for plants it is more valuable. Hair to a limited extent is often found in tankage.

Mora meal is a vegetable product, brown in color, which is imported from Europe. The mora seed, which are grown in India and probably other tropical countries, are sent to Europe where they are subjected to pressure and the oil extracted. The remaining pomace is ground and sold as mora meal. This product has been used for the past nine years in the United States and the consumption has increased every year.

It carries about 2.5 per cent. of nitrogen which is of low availability. It is not sold with any guarantee of nitrogen, phosphoric acid and potash, but on a flat basis. It is used by manufacturers of commercial fertilizers principally as a dryer and filler. It is good for both of these purposes because it is an excellent absorbent and bulky.

Beet Refuse.—This compound is a grey black powdery substance. It contains from 5 to 7 per cent. nitrogen and about 0.5 to 1 per cent. potash. One manufacturer used this compound in some of his mixtures because he believed it would kill insects in the soil. He believed this because of the presence of sulpho-cyanic acid in this compound.

Scutch.—This is a by-product or waste product in the manufacture of glue and the dressing of skins. It is manufactured in England and contains about 7 per cent nitrogen.

Horn and hoof meal, horn shavings, etc., are products obtained from slaughtering houses or by-products in the manufacture of

combs and similar articles. In the raw state they are extremely hard to grind and are not valuable in this form because they decay too slowly to supply plant food with any degree of rapidity.



Fig. 6.—A stock yards scene where tankage, blood, horn and hoof meal and similar fertilizer products are saved.

When steamed and pulverized they become high grade products as mentioned in the previous chapter.

Wool waste, shoddies, etc., taken collectively is the term applied to any waste from silk or wool manufacturing which is no longer profitable for making cloth. It is slow to decay and is rather undesirable as fertilizer. It is often coarse and bulky and hard to mix in a manufactured fertilizer or to distribute evenly when applied to the soil.*

It is sometimes treated with superheated steam, the liquid evaporated to dryness and the product ground, or else it may be acidulated with sulphuric acid for a long time (2 months) to

render the nitrogen available. When treated by either of the above methods, it is known as dissolved wool, shoddy, etc., and is of course more valuable than the raw products from which it is made.

Garbage Tankage.—Many of the large cities have plants where the garbage is accumulated. It is dried, or charred, or steamed, or extracted and the treated product is sold as garbage tankage. This material contains about 2 per cent. of nitrogen which is in a form that is slowly assimilated by plants. It is not a valuable fertilizer.*

Dried peat, sometimes called dried muck, is used principally by the manufacturers because of its excellent drying properties. The use of it enables the manufacturer to put out a fertilizer in a fine mechanical condition which may be distributed evenly on the soil. This material varies in composition, depending on the amount of vegetable and mineral matter present, but may be considered as averaging 1.5 to 2 per cent. of nitrogen.

Availability of Nitrogenous Fertilizer Materials.—The only correct way to determine the value of any nitrogenous substance is by running experiments with growing plants. The high grade products as nitrate of soda, sulphate of ammonia, dried blood, cotton-seed meal, linseed meal, castor pomace, dry ground fish, tankage, ground bone, steamed horn and hoof meal, etc., have been tested by field experiments to determine their crop producing power. Laboratory methods have been introduced to correspond as near as possible with the field results.

The availability of nitrate of soda is always taken as 100 and the availability of the other materials is based on the results secured when compared to nitrate of soda. Should nitrate of soda give an increased yield of 500 pounds per acre for a crop, the yield of a nitrogenous fertilizer of 75 per cent. availability would give an increase of 375 pounds, etc.

Not Always Possible to Run Field Experiments.—To conduct field experiments is often impossible, because of the great expense, the long time required, the difference in soils, the variation in seasons, the ability of the various crops for securing plant food, the association with other fertilizing materials containing phos-

phoric acid, potash, lime, etc., so that much of our information on the low grade products has been worked out in the laboratory by chemical methods. These methods are not entirely satisfactory but indicate to a great extent the relative values of nitrogenous fertilizers, as to whether they are high grade, medium grade or low grade.*

Value of Low Grade Materials.—Raw leather, wool waste, shoddy, hair, etc., may be rendered fairly available as plant food by special treatment, but such treatment usually is expensive and the market value does not always permit it. The standard high grade materials are always to be preferred and these low grade wastes cannot be sold unless they are much cheaper. Hence these low grade substances are usually only partially treated or not at all, so that they have very little value as fertilizer and the use of them is liable to cause disappointment and poor yields. They are not always sold alone but are sometimes mixed together. The writer has examined a product imported from Belgium and sold as Foreign Imported Tankage which was made up of shoddy, wool waste, hair, and leather and was only partially treated. Most of the material was in the raw state and in poor mechanical condition; chemical methods showed it to be poor plant food. This material contained about 7 per cent. nitrogen with traces of phosphoric acid. Should any of these low grade substances be used, the purchaser should demand that they be powdered, or ground very fine, in order to give the soil organisms a better chance to decompose them. The purchaser should not expect to get quick results with many of these wastes as some of them, particularly the raw leather, may remain in the ground for two or three years without any apparent change.

The Use of Low Grade Materials is Increasing.—The use of these low grade materials seems to be increasing and many manufacturers are using them in their low grade cheap fertilizers which carry low percentages of nitrogen, to a greater or less extent. The writer believes that some of these materials have no doubt been misrepresented to the manufacturers or else they would not use them. In order to insure future business they endeavor to put out fertilizers that will give good crop returns, and by satisfy-

ing their formulas with much of this class of material the poor crop returns will surely hurt them in repeating orders.

Some of these materials are said to be used as dryers by the manufacturers (peat and mora meal for example) but analyses of fertilizers containing them often show that the manufacturers counted the nitrogen content in making the fertilizers. Peat to be sure is a valuable filler for fertilizers as in addition to its drying qualities it contains about 30 per cent. of humus, but its nitrogen is not readily available and fertilizers containing it should have their guarantees satisfied by the use of more available substances.

The Nitrogenous Materials to Use.—We have learned that most plants assimilate nitrogen from the soil as nitrate and occasionally as ammonia. We also know that certain organisms in the soil convert the nitrogen from organic sources into ammonia and from ammonia into nitrates. Therefore it is reasonable to suppose that substances containing nitrogen as nitrates are to be preferred for immediate results in plant growth. As ammonia is converted to nitrates in the soil, materials containing nitrogen as ammonia, as ammonium sulphate for example, are less active than nitrate of soda. Again, nitrogen from organic sources is less active than from substances containing nitrogen as nitrates or ammonia, as organic nitrogen must be changed to ammonia and nitrates before being usable, and we would use materials furnishing this form of nitrogen for slower and more lasting results. We have seen that the nitrogen from organic products varies a great deal in the power of giving up or holding nitrogen. Dried blood and cotton-seed meal, for example, give up nitrogen quicker than tankage and dry ground fish, and these latter substances do not hold nitrogen as long as leather preparations and wool waste. Therefore in selecting the proper nitrogenous material or materials to use we must consider the condition of the soil, climate, locality, kind of crop, etc.

For Immediate Results.—Should immediate results be desired, applications of nitrate of soda, sulphate of ammonia, lime nitrate, or calcium cyanamid should serve the purpose. The locality may prevent the use of organic substances as a certain amount of heat (37° F.) is required for the soil organisms to convert organic

nitrogen into nitrates. A wet season checks nitrification and hence nitrate of soda and sulphate of ammonia should give better results than the organic materials.

For Soils Well Supplied and Long Growing Crops.—Should the soil have a sufficient natural supply of organic nitrogen as from some leguminous crop plowed under, etc., perhaps no organic nitrogenous material should be applied and a small application of some one of the mineral salts may suffice to give the crop a start. If the crop is a long growing one, an organic product may prove best, as it gives up its nitrogen in smaller amounts and more slowly than the chemicals and will thus stay with the crop the whole season. Mixtures of minerals and organic materials may sometimes be best so as to enable the plant to get a quick start by supplying immediate food and when this supply is exhausted, to furnish nourishment from the organic sources for the remainder of the season. The fertilizer manufacturers often use two or three different nitrogenous substances of different forms, as nitrate of soda, sulphate of ammonia and cotton-seed meal, in their fertilizers to allow the plant a continual supply of available nitrogen. Mixtures of organic materials of different availabilities may make excellent combinations for certain crops.

For Large Crops and Building up the Soil.—Should a large crop be desired the chemicals and the active organic substances would perhaps be preferable, but should the building up of the soil for some future crop be wished, the less active organic materials would prove more valuable than nitrate of soda, ammonium sulphate, lime nitrate, calcium cyanamid, dried blood, cotton-seed meal, etc., as these materials are all changed to the nitrate form, except nitrate of soda which is already in this form, either immediately or during the season and would in all probability be lost because nitrates do not become fixed in the soil and are readily washed away by heavy rains. The nitrogen in organic materials is not soluble in water to any great extent as is the case with nitrate of soda, sulphate of ammonia, lime nitrate and calcium cyanamid so that the losses by leaching of the former substances are not considerable as compared to those of the latter.

It is evident then that the farmer should select those sub-

stances that will give the best results for his conditions and not purchase nitrogenous fertilizer that some neighbor recommends



Fig. 7.—A good crop of hay, the result of judicious soil management.

who secured good crops with an entirely different crop and soil etc.*

Functions of Nitrogen.—Nitrogen increases growth and defers maturity. In a certain parish in Louisiana where the people were ignorant along fertilizing lines, cotton-seed meal was the only fertilizer known to them. So year after year they applied this fertilizer to their cotton. For the last three years that they practiced this, they produced excellent large cotton plants but the crop did not mature well or produce scarcely any cotton. The people could not understand it. They did not know that cotton-seed meal was a nitrogenous fertilizer nor did they know that nitrogen produced growth. The Experiment Station was called upon to investigate the trouble and as the soil was naturally rich in potash, applications of acid phosphate corrected the condition. The above example shows the results of an excess of nitrogen in producing growth and deferring maturity.

When excessive nitrogen is applied to potatoes it produces a vigorous growth of vines but very few tubers are formed. Should an excess of nitrogen be supplied the small grain crops it would cause them to lodge and produce grain of inferior quality and the excess of the weight of the crop to the weight of the grain would be high. Excessive nitrogen retards the formation of fruit. It produces growth of wood and leaves when the fruit should be forming.

When nitrogen is lacking in the soil the plants do not grow so high as when the supply is sufficient. With crops grown on such soils the proportion of grain or seed to the weight of the crop is high. No matter how much phosphoric acid and potash there may be in the soil the crops can only use quantities in proportion to the growth of the plants, and the growth of plants will be in proportion to the nitrogen supply.

Generally speaking an application of a nitrogenous fertilizer will produce increased yields without the application of potash and with an occasional supply of phosphoric acid. The nitrogen produces a better leaf development, a better growth, the color of crops become a darker green, and the crop matures later. Often the supplying of nitrogen alone will increase yields to such an extent that farmers may overrate the value of this constituent. On soils that are deficient in organic matter, that have been continually cropped, the need of nitrogen is generally greater than phosphoric acid and potash.*

Market gardeners often take advantage of the power of nitrogen in the growing of lettuce and similar vegetables. Vegetables grown on soils more than amply supplied with nitrogen produce more delicate and tender vegetables, especially lettuce and cabbage, but they do not stand shipping so well; although better for immediate consumption than vegetables grown on average soils they wilt and spoil quickly and are not popular with the commission houses. The cell walls and tissues are not so strong with crops grown on excessive nitrogen as when not.

Excessive Nitrogen Invites Diseases.—Crops grown on soils that have excessive nitrogen are more susceptible to plant diseases than on average soils. This may be noticed to a limited extent

with oats and wheat. When the season is especially favorable to the production of nitrates in the soil during the growing period or when oats and wheat are grown on rich nitrogenous soils rust is more prevalent than usual. Plant diseases due to excessive nitrogen are perhaps more noticeable with crops grown under glass than outside. Most of the soils that are used in hothouses are very rich in nitrogen and the high temperatures kept renders nitrification very rapid. The color of the leaves of hothouse crops becomes a darker green when excessive nitrogen is present; the leaves become tender and thin and seem to be easily attacked by certain fungi unless extra precautions are taken. Cucumbers are especially susceptible to disease in the presence of excessive nitrogen.

CHAPTER VII.

PHOSPHATES.

Phosphates are those materials that contain phosphoric acid. The phosphates occur as phosphate of lime, iron and alumina, in which compounds the phosphoric acid is united with lime, iron and alumina respectively. Since the phosphoric acid in fertilizers is derived mainly from phosphate of lime we will limit our treatment of the subject to the important materials composing this group.

The phosphates of lime occur as organic, organic and mineral, and mineral compounds.

Bones.—The chief source of phosphoric acid from the organic phosphates of lime are bones. The composition of bones is variable. The bones from old mature animals are richer in phosphate of lime than bones from young animals. Different bones from the same animal also show a variable composition, as the harder more compact bones are richer in phosphate of lime than the softer, porous ones.

Raw Bone-Meal.—This is the finely ground product derived from raw bones and it contains all the constituents of them. It carries considerable organic matter much of which is in the form of fats, which makes it hard to grind and to handle on the market. The presence of organic matter makes it objectionable. The fatty matter, which slowly decomposes, tends to make this fertilizer very slowly available for plant food and so it is called a slow acting fertilizer. Raw bone-meal usually contains about 19 to 25 per cent. of phosphoric acid and 2 to 4 per cent. of nitrogen, with an average of 22 per cent. of phosphoric acid and 3.5 per cent. of nitrogen.*

The phosphates are sold to the trade on the basis of tricalcium phosphate present. To convert tricalcium phosphate to phosphoric acid, multiply by the factor 0.4576 and to get the equivalent of tricalcium phosphate from a given percentage of phosphoric acid multiply, by 2.185.

Steamed Bone-Meal.—Most of the bone sold for fertilizing

purposes has been boiled or steamed in the rendering factories to extract the fats and nitrogenous compounds which are used in making soap, glue, and gelatine. The bones are then ground or pulverized and sold as steamed bone-meal, bone-meal and bone-dust. This product is variable in composition, ranging from 17.5 to 29 per cent. of phosphoric acid and 1.5 to 4.5 per cent. of nitrogen. Good clean bone-meal should contain at least 2.5 per cent. of nitrogen and 25 per cent. of phosphoric acid. The treatment of the raw bones affects the final composition of the product (steamed bone-meal); the boiling or steaming reduces the nitrogen content and increases the phosphoric acid.

Steamed bone-meal is a more quickly available fertilizer than raw bone-meal and is therefore better for most crops.

There is a great difference in the steamed bone-meals put upon the market not only in the composition but in the hardness of the product. Steamed bone-meal from some factories is more porous and softer than from others. Some factories put out a product that crumbles easily while others sell meal that is extremely hard.*

Degree of Fineness.—The bones when sold for fertilizing purposes are ground fine and are known as fine ground bone, bone-meal, bone-dust and bone-flour. The mechanical condition of fineness does not affect the composition but increases the availability of the product for plant food. Hence the finer the bones are ground the more valuable they are as quicker acting fertilizers. These products are generally valued according to their degree of fineness and chemical composition. It must be remembered that all bone-meals give up their plant food slowly and are not desirable for immediate results in the production of crops.*

Bone-Black.—In the manufacture of bone-black, the choicest bones are selected, cleaned and dried. They are then put in air-tight vessels, heated and distilled until all the organic or volatile matter has passed off. The product is then ground to a coarse consistency and sold to the sugar refineries for clarifying or decolorizing syrups in the manufacture of white table sugar. After it has served its usefulness in the sugar refineries it is sold for

fertilizer. It contains usually about 30 per cent. of phosphoric acid in the form of phosphate of lime. It is a slow acting fertilizer and is not used extensively in this condition.*

Bone-Ash.—When bones are burned the remaining product is called bone-ash. It is not manufactured a great deal in this country because of the greater value of bone-black. It is an excellent fertilizer and the only shipments received to-day come from South America where the bones are burned to save freight. In burning bones the nitrogen is driven off, so that bone-ash is valuable only for the phosphoric acid it contains. It varies in phosphoric acid content from 30 to 39 per cent. It is used in some countries in the manufacture of fertilizers.*

Bone Tankage.—This product is composed entirely of animal matter. It is the refuse from slaughter houses and rendering factories and consists of meat, bone, etc. (from which the fat has been extracted), and sometimes a little dried blood. There are many grades of tankage put upon the market. Those tankages coming under the head of bone tankage contain considerable bone and small amounts of meat and sometimes dried blood. The amount of phosphoric acid in tankage varies with the bone content. The more bone present the higher is the percentage of phosphoric acid. The bone tankages range from $11\frac{1}{2}$ per cent. to 20 per cent. of phosphoric acid. Those tankages falling below $11\frac{1}{2}$ per cent. of phosphoric acid are discussed under the chapter on nitrogenous fertilizer materials. The phosphoric acid in bone tankages has about the same value as in steamed bone, since both of these products are steamed or boiled to extract the fats, etc. The bone tankages are very popular among farmers in certain sections of this country.

Dry Ground Fish.—This is also an organic source of phosphoric acid from phosphate of lime. The phosphoric acid content depends upon the amount of bones present. This product was described with the fertilizer materials containing nitrogen. Suffice it to say that dry ground fish carries from 6 to 16 per cent. of phosphoric acid.

AVERAGE COMPOSITION OF ORGANIC PHOSPHATES OF LIME.

	Phosphoric acid Per cent.	Nitrogen Per cent.
Raw bone-meal.....	22	3.5
Steamed bone-meal.....	25	2.5
Bone-black.....	30	—
Bone-ash.....	36	—
Bone tankage.....	11.5-20	4-6
Dry ground fish.....	9	8.5

The phosphoric acid present in raw bone-meal, steamed bone-meal, bone tankage, bone-black, bone-ash and dry ground fish is insoluble in water and slowly available as plant food.

Mineral Phosphates.—These occur in natural beds in different parts of the world. According to Van Horn in the American Fertilizer, the known phosphate deposits of the United States are distributed principally among four localities: (1) along the west coast of Florida, running back 20 to 25 miles inland; (2) along the coast of South Carolina, extending 6 to 20 miles inland; (3) in central Tennessee; and (4) in an area comprising southeastern Idaho, southwestern Wyoming, and northeastern Utah. In addition to these areas, some deposits occur in north-central Arkansas, along the Georgia-Florida State line, and in North Carolina, Alabama, Mississippi, and Nevada, but these are mainly of low grade and not utilized at the present time. The three important deposits first mentioned have been worked from ten to thirty years; the fourth is a new field which has as yet had but a small output.*

The most important deposits in this country are in Florida, South Carolina, and Tennessee and the production in the United States amounts to over two million long tons (2,240 pounds) a year while that of the remaining countries approximates one million tons.

South Carolina phosphates were first put upon the market in 1868. There are two kinds of phosphates found in South Carolina, namely, the land and river phosphates. The land phosphate is mined from the land and is known as land rock, while the river phosphate is obtained by dredging rivers and is called river

rock. These phosphates occur in the form of nodules varying in weight from a fraction of an ounce to more than a ton.

Whether the rocks are mined or dredged, they are washed free from the clay and other adhering matter and dried, when they are ready for shipment. When phosphate rock is ground or pulverized it is known as floats and is used in this form in the middle western states quite extensively. The land rock is light fawn colored; the river rock is black; both are very hard. The South Carolina land rock averages about 50 per cent. tricalcium phosphate, which is equivalent to about 23 per cent. of phosphoric acid, and the river rock runs about 50 to 60 per cent. tricalcium phosphate, which is equivalent to 23 to 27.5 per cent. of phosphoric acid.

Including the year 1908, South Carolina's total production of phosphates was 12,138,454 long tons of rock, of which about one-third was shipped to Europe. The discovery of the Florida phosphates decreased the exportation of those from South Carolina, to about 30,000 tons annually, because the Florida phosphates that are exported contain more phosphoric acid and less impurities.*

Florida phosphates occur as soft phosphate, pebble phosphate and boulder or hard rock phosphates. The soft phosphate resembles a whitish clay and generally contains 50 to 60 per cent. of tricalcium phosphate, which is equivalent to 23 to 27.5 per cent. of phosphoric acid. The hard rock ranges from 60 to 75 per cent. of tricalcium phosphate, which is equivalent to 27.5 to 34.3 per cent. of phosphoric acid, although many samples show even a higher content of phosphoric acid. Most all of the high grade phosphates of Florida are exported to Europe where they find a ready market. Florida has put out 14,087,833 tons of phosphate rock from 1888 to 1908.*

Tennessee Phosphates.—These are perhaps the most extensive deposits in the United States that are being worked. Their commercial importance was made known in 1893. The Tennessee phosphates are known as brown rock, blue rock and white rock. About one-fourth of the high grade Tennessee phosphate is ship-

ped to Europe the remainder being used in this country. The output of Tennessee phosphate has amounted to 5,315,422 tons from 1893 to 1908. The Tennessee rock phosphates are not in favor in Europe because of their high content of iron and alumina oxides, which run from 2 to 4.5 per cent.

The brown rock has been sold more than the blue or white rock.*

Canadian Apatite.—This is rock where the phosphate has become crystalline and is known as apatite and is found principally in the provinces of Ontario and Quebec. It is not mined very extensively, only 748 tons being produced for 1907. It is a variable product and contains impurities. The Canadian apatite carries from 75 to 90 per cent. of tricalcium phosphate, which is equivalent to 34 to 41 per cent. of phosphoric acid. Preparing Canadian apatite for the market is a more expensive operation than mining the American phosphates. Apatite is usually considered one of the purest forms of tricalcium phosphate for manufacturing fertilizers.*

Rodunda Phosphate.—This phosphate is found on the Rodunda Island. It is not a phosphate of lime but a phosphate of iron and alumina. Although the per cent. of phosphoric acid is high, (20-38 per cent.) this material cannot be used to manufacture into acid phosphate because of the absence of lime. The gypsum (sulphate of lime) formed in the manufacture of acid phosphate from phosphate of lime acts as a drier. Rodunda phosphate may be used for crops provided it is well pulverized but it must be considered as slow acting. This product is sometimes called iron and alumina phosphate rock.

Basic Slag.—This is known by several names as iron phosphate, Thomas phosphate powder, odorless phosphate, and phosphate slag. When phosphatic iron ores are used for the manufacture of steel by the basic process, an excess of lime is used which unites with the phosphoric acid and iron and forms a product known as basic slag. There is not much of this product manufactured in this country but the production is large in England, France and Germany. According to Wiley: The quantity of basic slag

manufactured in Germany in 1893 was 750,000 tons; in England 160,000; in France 115,000, making the total production of central Europe about 1,000,000, a quantity sufficient to fertilize nearly 5,000,000 acres. During the year 1907, it is estimated that German agriculture made use of from 1,500,000 to 1,600,000 tons of basic phosphate slags. The total output of basic slag is undoubtedly not far from 2,000,000 tons. The total production of basic slag is therefore approximately one-half of that of crude phosphates.¹

This product is sold in the form of an inpalpable powder which is black in color. The phosphoric acid in basic slag is often rated as valuable as the phosphoric acid in bone-meal. The composition of this product is variable depending on the amount of phosphoric acid in the iron ore, but it is possible to obtain this product containing 23 per cent. of phosphoric acid, but the lower grades are most common. It averages about 14.20 per cent. of phosphoric acid. On account of the large amounts of iron oxide present, it is not suitable for manufacturing artificial fertilizers.*

Phosphatic Guanos.—These guanos are of the same origin as nitrogenous guanos. They are the excreta of sea fowls. Before the phosphate deposits were discovered in the United States these guanos were imported into this country and used largely by the manufacturers. All of these guanos originally contained nitrogen. However the nitrogen, soluble phosphates, and alkalies have disappeared by decomposition of organic matter and leaching of water, so that most of them only contain traces of nitrogen. The phosphoric acid is in the form of tricalcium phosphate and insoluble in water. Some of these guanos contain too much iron and alumina oxides to manufacture profitably. They are not imported into the United States very much now, as many of the deposits are exhausted or else too expensive to compete with our native mineral phosphates.*

It should be understood that there are many other phosphates used in other countries but they cannot compete with our mineral phosphates and therefore are not found on the American market.

¹ Wiley. *Principles and Practice of Agricultural Analysis*. Vol. II.

Classification of Phosphates.—From the foregoing it is shown that there are three classes of phosphates used for fertilizing purposes.

- | | | | |
|--------------------|---|---|--|
| 1. Bone phosphates | { | Raw bone-meal
Steamed bone-meal
Bone-black
Bone-ash
Bone tankage
Dry ground fish | |
| | | Florida | { Land pebble
River pebble
Hard rock |
| | | South Carolina | { Land rock
River rock |
| 2. Rock phosphates | { | Tennessee | { Brown rock
Blue rock
White rock |
| | | Apatite
Rodunda phosphate
Phosphatic guanos. | |

3. Basic slag phosphates.

Of the bone phosphates, bone-ash is not found much on the

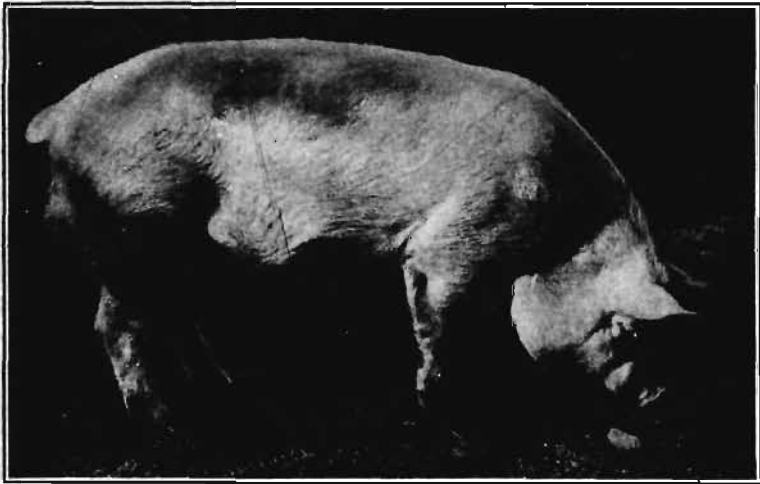


Fig. 8.—The hog: one of the sources of bone phosphate.—Courtesy of the Wisconsin Exp. Station.

American market and bone-black is usually acidulated (treated

with sulphuric acid) before being applied as fertilizer. The production of rock phosphates in the United States has almost entirely discouraged the importation of the mineralized or phosphatic guanos.

Form of the Phosphates.—The phosphoric acid in bone phosphates and rock phosphates is in the form of tricalcium phosphate. Bone phosphates are always as phosphate of lime while rock phosphates contain more or less impurities as iron, alumina and silica. It is customary to apply the name, "bone phosphate of lime," to the phosphate present in rock phosphates, although tricalcium phosphate is the correct name. The phosphoric acid in basic slag is not in the same form as in the other phosphates. It was formerly accepted that the phosphoric acid in basic slag existed as tetra-calcium phosphate, but Hall¹ claims that the phosphoric acid is in the form of double phosphate and silicate of calcium $\text{Ca}_3(\text{CaO})(\text{PO}_4)_2\text{CaSiO}_3$.

Availability of the Phosphates.—All of the phosphates are slowly available as plant food and practically insoluble in water. The phosphoric acid in phosphates is not entirely used the first year so that maximum crop returns cannot be expected immediately, but the continued use of phosphates give good results. For quick growing crops the phosphates are not always desirable. The phosphates from bones are perhaps more readily decomposed than the rock phosphates. There is more or less organic matter in bones which decays quite rapidly and attacks the phosphoric acid with which it is closely associated. In the rock phosphates there is no organic decay and the impurities as iron and alumina retard to a certain extent the fermentation and decomposition of the phosphoric acid present. Basic slag phosphate as shown by the statistics in this chapter, is used extensively in Europe. European experiments show that this material is of higher availability than the insoluble bone and rock phosphates.

The nature of the soil has a great deal to do with the availability of phosphates. Soils in good tilth will disintegrate the phosphates more readily than those in poor physical condition. The sandy and gravel soils are liable to give poorer results than

¹ Fertilizers and Manures.

clay soils or soils containing considerable organic matter and potash. Organic matter tends to promote fermentations which attack the phosphates and make them available as plant food, and with the aid of potash, it tends to act upon the lime of the phosphates. The kind of crop also influences the rate of decomposition of phosphates. Some plants are more able to make use of the phosphoric acid of phosphates than others.*

CHAPTER VIII.

SUPERPHOSPHATES AND EFFECT OF PHOSPHORIC ACID.

The phosphates mentioned in the previous chapter, with the exception of basic slag, are not always used in the raw condition for fertilizing purposes, but are treated with sulphuric acid in the manufacture of commercial or artificial fertilizers to make the phosphoric acid available; that is, to convert the phosphoric acid into forms that may readily be used by the plant as food.

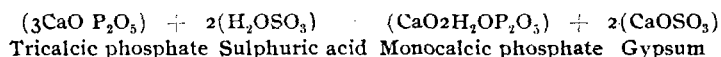
Manufacture of Super or Acid Phosphate.—The manufacturing of artificial fertilizers began some time after 1840 in which year Liebig, a German scientist, discovered that by adding sulphuric acid (oil of vitriol) to bones the phosphoric acid was made soluble. This discovery paved the way for the manufacture of commercial fertilizers which are sold in such large quantities to-day.

Manufacturing Sulphuric Acid.—The manufacture of superphosphate is rather technical but a knowledge of this important industry may prove of interest. To begin with, the manufacturer purchases pyrites or brimstone and phosphate rock. Pyrites is a compound of sulphur and iron and is obtained from Spain and mines in this country. The pyrites or brimstone are burned in special burners and the sulphurous gases are mixed with nitrous gases obtained from nitrate of soda. These mixed sulphurous and nitrous gases are introduced into large high lead towers and then into lead chambers which are also large and high. Steam is introduced into the lead chambers, mixed with the gases and sulphuric acid is formed which falls to the bottom as a liquid. These lead towers and lead chambers are very costly.

Making Superphosphate.—The manufacturer purchases phosphates that contain sufficient tricalcium phosphate to warrant profitable treatment. Phosphates that contain considerable impurities as iron and alumina are avoided. The phosphate rock is broken into small pieces and then pulverized. Certain amounts, say 1,000 pounds, of phosphate powder and dilute sulphuric acid

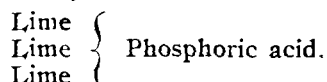
are thoroughly mixed together by special machinery and conveyed to a pit where the mixture is allowed to remain until ready for shipment.

Chemistry of the Process.—The phosphoric acid is in the form of tricalcium phosphate in phosphates, or three parts of lime are united with one part of phosphoric acid. When the sulphuric acid is added it attacks the phosphate and dissolves it, setting free two parts of lime (that were originally combined with the phosphoric acid) which unite or combine with the sulphuric acid forming superphosphate (one lime phosphate or mono-calcic phosphate) and gypsum (sulphate of lime). In other words the phosphoric acid in superphosphate is only combined with one part of lime as the remaining two parts of lime, with which the phosphoric acid was formerly combined, have been set free. From the above it is evident that superphosphate is made up of one lime (mono-calcic) phosphate and gypsum (sulphate of lime). Or the reaction is:



Phosphates of Lime.—In the phosphoric acid fertilizers used there are four different forms of phosphates of lime, all of different availability. These phosphates of lime are known as the insoluble, soluble, reverted, and basic slag forms.

1. **Insoluble Phosphoric Acid.**—The most common form of phosphate of lime is that which is found in bones, mineral phosphates, guanos, etc., and is called insoluble. The lime and phosphoric acid are combined as three parts of lime and one of phosphoric acid. This is called tricalcic, tribasic, bone phosphate and three lime phosphate. We may represent this form as follows:

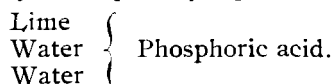


This is the most insoluble form of phosphate of lime and is called insoluble phosphoric acid.

2. **Soluble Phosphoric Acid.**—When insoluble phosphate of lime is acted upon by sulphuric acid, two parts of lime are replaced by two parts of water and soluble phosphate of lime is formed.

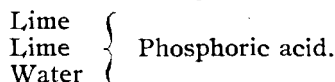
This soluble phosphate is called super or acid phosphate and is a saturated compound. It is also known as monobasic, monocalcic, and one lime phosphate.

This compound may be graphically represented as:



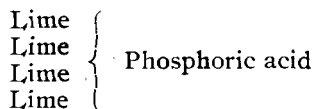
This form is entirely soluble in water and readily available as plant food. It is the highest valued form of phosphate of lime and is called soluble phosphoric acid.

3. **Reverted Phosphoric Acid.**—Between the soluble and insoluble phosphate of lime there is another form known as reverted, citrate soluble, dicalcic, and two lime phosphate, in which there are two parts of lime and one part of water as represented:



The name reverted is applied to this form of phosphate of lime because it is formed by reversion or retrograding of some of the soluble towards the insoluble. This form is not as soluble as the soluble phosphoric acid and is more soluble than the insoluble form. It is insoluble in water, but the weak acids of the soil render it favorable for plant food. The sum of the soluble and the reverted is called *available*, because both forms may be used by plants.

4. **Basic Slag Phosphate.**—It used to be accepted that the three forms just described were the only forms of phosphoric acid. However, the phosphate of lime in basic slag is in another form. It was supposed that one part of phosphoric acid was combined with four parts of lime, and in this form it was known as tetracalcic, tetrabasic, and four lime phosphate.



Recently, however, there seems to be some uncertainty as to whether or not the phosphoric acid in basic slag exists as tetra-

calcic phosphate of lime. Hall¹ says it exists as double silicate and phosphate of lime $(\text{CaO})_5 \text{P}_2\text{O}_5\text{SiO}_2$. Whatever may be the form of combination of the phosphoric acid in basic slag, it is easily attacked by soil water, and is more available than any of the forms of tricalcium phosphate, though usually less than superphosphate.*

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

Difference Between Phosphates and Superphosphates.—It is customary among some farmers to call every fertilizer a phosphate and among others this name is used for the product—superphosphate. A phosphate is a product containing phosphoric acid as its main ingredient, in the insoluble form, as bone phosphates, rock phosphates and basic slag phosphates. A superphosphate is a fertilizer containing principally soluble phosphoric acid. The phosphates, except basic slag and Rodunda phosphate, may be manufactured into superphosphates by the addition of sulphuric acid as previously mentioned in this chapter. Thus we have superphosphates from bones and minerals, as raw bone superphosphate, steamed bone superphosphate, bone-ash superphosphate, bone-black superphosphate, Florida hard rock superphosphate, Florida pebble superphos-

¹ Fertilizers and Manures.

phate, Florida soft rock superphosphate, South Carolina land rock superphosphate, South Carolina river rock superphosphate, Tennessee brown rock superphosphate, Tennessee blue rock superphosphate, Tennessee white rock superphosphate, etc. Of course all of these superphosphates will not contain the same amounts of soluble phosphoric acid, as the mode of manufacture and content of phosphoric acid in the raw products determine this. A superphosphate made from bone-black containing 30 per cent. of phosphoric acid will be richer in soluble phosphoric acid than one made from South Carolina land rock running 23 per cent. of phosphoric acid. Bone-black and bone-ash because of their higher phosphoric acid contents make richer superphosphates than those manufactured from most of the mineral phosphates.

Some Names Applied to Superphosphates.—Acid phosphate, dissolved bone, dissolved bone-black and dissolved bone-ash are names that are used indiscriminately by the trade. A manufacturer may call a product made from rock phosphate, "dissolved bone," and sell it under this name. Dissolved bone, strictly speaking, is dissolved bone superphosphate, or a superphosphate made from raw or steamed bones. Dissolved bone-black is a superphosphate manufactured from bone-black. Dissolved bone-ash is a superphosphate made from bone-ash. The superphosphates made from rock phosphates are usually called acid phosphates by the trade, although this latter term is applied to any superphosphate and is perhaps a more common name in the United States than superphosphate. For superphosphates made from ground rock phosphate, acid phosphate is perhaps a more correct name as it is the phosphate acted upon by acid.

Available Phosphoric Acid.—There seems to be a great deal of confusion among farmers over what constitutes available phosphoric acid and this is not to be wondered at when one considers the number of terms applied to reverted and insoluble phosphoric acid. Reverted phosphoric acid is soluble in the weak acids of the soil. The chemist uses a solution called ammonium citrate or citrate, which has a similar action to the weak soil acids, in dissolving out this form of phosphoric acid. For this reason the term citrate soluble is often applied to reverted phos-

phoric acid. The insoluble phosphoric acid is not soluble in this citrate solution but it is soluble in strong acids, hence the names citrate insoluble and acid soluble are applied to insoluble phosphoric acid.

Reverted phosphoric acid is equivalent to citrate soluble phosphoric acid.
 Insoluble phosphoric acid is equivalent to $\left\{ \begin{array}{l} \text{citrate insoluble phosphoric acid} \\ \text{acid soluble phosphoric acid.} \end{array} \right.$

The sum of the soluble and reverted phosphoric acid is called available phosphoric acid, or the sum of the soluble and citrate soluble phosphoric acid is available phosphoric acid. The farmer often confuses the term acid soluble as belonging to the available phosphoric acid on account of the use of the word soluble. Again, the difference between the total phosphoric acid (which is the sum of the soluble, reverted and insoluble forms) and the insoluble phosphoric acid is available phosphoric acid.*

The Difference of the Forms of Phosphoric Acid in Superphosphates.—In the manufacture of superphosphates not all of the tricalcium phosphate is converted into soluble phosphoric acid. The manufacturer generally calculates to add just enough acid to convert most of the phosphoric acid into the soluble form. However, he does not wish to add too much acid in order to put out a profitable marketable product. Hence most of the superphosphates found on the market contain some insoluble phosphoric acid, ranging perhaps from a few hundredths to as high as four per cent. in poor acidulation. This insoluble phosphoric acid in superphosphates is different. That in the bone superphosphates is of more value as regards availability than the insoluble phosphoric acid in the mineral superphosphates. The insoluble phosphoric acid is also of different value in the mineral superphosphates depending upon the nature or purity of the rock from which they were made. However, the insoluble phosphoric acid in super or acid phosphates is generally present in small amounts and would only have to be seriously considered when the acidulation proves insufficient. The soluble phosphoric acid in all superphosphates is the same, whether the superphosphates are made from bones, bone-ash, bone-black, or any of the mineral phosphates. It is an erroneous opinion among some, that the

material from which the superphosphate is made influences the value of the soluble phosphoric acid. Many farmers would rather purchase soluble phosphoric acid as superphosphates manufactured from bones than soluble phosphoric acid from mineral superphosphates. There is not any difference in the soluble phosphoric acid of superphosphates no matter what raw material is used in making it. Of course a dissolved bone superphosphate will perchance give better results than a raw rock superphosphate of equal soluble phosphoric acid composition as the dissolved bone superphosphate will contain in addition to the phosphoric acid, a certain amount of nitrogen, so if we judge the value of soluble phosphoric acid in this way we are assuming an unequal and unfair task.

Some Farmers Favor Bone Superphosphates.—Many farmers seem to be prejudiced against the mineral superphosphates and always demand superphosphates made from bone. Often the price is much higher for the bone superphosphates on account of the greater price bones bring when sold for bone-black, manufacturing interests, etc. These farmers could generally purchase their phosphoric acid more cheaply from mineral superphosphates. Of course when dissolved bone and mineral superphosphate of equal available phosphoric acid content, are offered for the same price, it is more economical to select the dissolved bone; but it is seldom that one can get such a bargain as the dealers in fertilizers always charge for the ammonia content. Generally phosphoric acid can be purchased cheaper from mineral superphosphates than from dissolved bone superphosphates.

Double Superphosphate.—This is sometimes called double phosphate. This double superphosphate is manufactured as follows: Phosphates are treated with an excess of sulphuric acid (chamber-acid) and the phosphoric acid is dissolved out as free phosphoric acid. The fluids, sulphuric acid and phosphoric acid are filtered or separated from the insoluble matter and concentrated. This concentrated solution is then used in dissolving high grade phosphates and the resulting product is called double superphosphate because the phosphoric acid content is more than double

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and generally three times as much as in superphosphates. Wiley¹ suggests that superphosphate is a more correct name for this class of material as it is a phosphate acted upon by free phosphoric acid and superior to acid phosphate. Phosphates containing too low a percentage of phosphate of lime for profitable manufacture of acid phosphate may be utilized in obtaining the free phosphoric acid.

Not much double superphosphate is found on the American market but it is quite popular in Germany where it is manufactured principally. Double superphosphates contain about 40 to 45 per cent. of available phosphoric acid. They contain less impurities than acid phosphates. The phosphoric acid is present in the same forms as in acid phosphate, namely as soluble, reverted and insoluble phosphoric acid. Double superphosphates are expensive but sometimes economical to purchase when freight is high.

No Free Acid in Treated Phosphates.—Acid phosphates and double superphosphates when well manufactured do not contain any free acid as all of the sulphuric acid is united with lime and forms gypsum. Of course it is possible for a manufacturer to make a product that will contain free acid, but this is not done and the product delivered to the trade does not contain any free acid.

The Color of an Acid Phosphate.—There seems to be a preference among some for a light colored acid phosphate while others demand a dark colored product. The color and nature of the raw material from which acid phosphates are made determine their final color. The manufacturers in order to satisfy the trade often carry two different colored acid phosphates of the same chemical composition which are made from the same raw product. The dark or black color is obtained by mixing in lamp-black when the final product is not sufficiently dark. Some raw materials as bone, bone-black, etc., produce a black superphosphate without the addition of any coloring substance. The color of an acid phosphate does not indicate its fertilizing value.*

¹ Principles and Practice of Agricultural Analysis, Vol. II.

How to Make Superphosphate at Home.—Sometimes farmers live far away from places where fertilizers may be purchased and should such farmers save the bones that accumulate on the farm, superphosphate may be made at home. The process may be conducted as follows: Break up the bones in as small pieces as possible and add one-third their weight of water to them in a long wooden trough lined with sheet lead or with a thick coating of pitch; the lead is better. To the bones and water, add very slowly sulphuric acid (oil of vitriol). This acid must be added very slowly as great heat is evolved on the addition of sulphuric acid to water. The amount of acid to add depends upon its strength or concentration. About one-third the weight of the bones of strong white sulphuric acid or one-half of the brown sulphuric acid should suffice. The whole mass should be thoroughly mixed with a wooden shovel, allowed to stand for an hour and removed to some dry place and stored for two months when it will be ready for the land. If sulphuric acid gets on your clothes it will ruin them and it will burn the skin wherever it touches it.*

Amount of Phosphoric Acid in Soils.—The phosphoric acid in soils is generally found in largest amounts in the surface soil and is usually derived from the disintegration of rocks. It is often deficient and many soils show only traces of phosphoric acid. Even fertile soils only contain small amounts of this constituent. Soils average from traces to 0.25 per cent. of phosphoric acid. We may figure that an average soil contains about 3,500 to 4,000 pounds phosphoric acid per acre. Only a small amount of this is available. Some soils may contain larger quantities of phosphoric acid but the poor condition of the soil keeps this locked up so that plants cannot utilize it. Organic matter, lime and good tillage help to increase the available supply of phosphoric acid.

Fixation of Phosphoric Acid.—When soluble phosphoric acid is added to soil it becomes fixed and does not wash out readily. It is generally supposed that soluble phosphoric acid from fertilizers becomes readily distributed and unites with the minerals forming compounds insoluble in water; the phosphoric acid in soluble phosphoric acid is in a very finely divided state and the

distribution takes place before the insoluble compounds are formed. Soils rich in lime readily fix phosphoric acid and a certain amount is probably fixed in combination with iron and alumina. Experiments show that phosphoric acid is not carried away by leaching to any extent. All soils are not of equal fixation value; most soils fix phosphoric acid but some are better equipped to perform this process than others. Clay soils rich in lime fix phosphoric acid very rapidly while soils deficient in lime act much slower in this respect. Sandy and gravel soils, lacking in organic matter and clay, *do not fix the phosphoric acid rapidly.**

Functions of Phosphoric Acid.—Phosphoric acid hastens maturity of crops. It has a ripening effect and seems to hasten grain and fruit formation; it increases the yield of grain; it stimulates root development in young plants.

Phosphoric acid helps in transferring substances from the stalks, leaves, and other growing parts to the seed. Certain substances are aided by phosphoric acid by being rendered soluble enough to pass through the plant tissues.

Phosphoric acid helps to build up protein substances in the plant as certain proteid bodies require phosphoric acid for their complete development. Therefore a lack of phosphoric acid would necessarily cause the plant to suffer.*

The kind of phosphate to use depends upon the crop and the soil. As a general rule the best immediate results are secured from those phosphates that are acidulated and the raw phosphates are slower acting and not so suitable for weak feeding crops. To get the full benefit from raw products sometimes requires two or three seasons, so that a farmer employing slowly available products should plan to add enough each year to supply the crop with sufficient available phosphoric acid.*

CHAPTER IX.

POTASH FERTILIZERS.

Before the discovery of the potash mines in Stassfurt, Germany, the main source of supply of potash was wood ashes.

History.—The following description tells how the deposits of potash salts were formed.

The Stassfurt salt and potash deposits had their origin, thousands of years ago, in a sea or ocean, the waters of which gradually receded, leaving near the coast, lakes which still retained communication with the great ocean by means of small channels. In that part of Europe the climate was then tropical, and the waters of these lakes rapidly evaporated, but were constantly replenished through these small channels connecting them with the main body. Decade after decade this continued, until by evaporation and crystallization the various salts present in the sea water were deposited in solid form. Overlying the deposits is a layer of impervious clay which acts as a water-tight roof to protect and preserve the very soluble salts.*

Potash Salts Used for Fertilizing Purposes.—The principal potash salts obtained from these mines that are used as fertilizers in the United States are:

1. Kainit
2. Sylvinit
3. Muriate of potash
4. Sulphate of potash
5. Double sulphate of potash and magnesia
6. Potassium—magnesium carbonate.

These products may be classified as crude and manufactured as follows:

Crude salts	{	Kainit
Natural products		Sylvinit
Manufactured salts	{	Muriate of potash
Concentrated salts		Sulphate of potash
		Double sulphate of potash and magnesia
		Potassium—magnesium carbonate.

There are many other salts as carnallit, polyhalit, krugit,

hartsalz, sylvin, kieserit and schönit found in these deposits but are not usually sold on the American market.

1. **Kainit** as sold in this country is a finely ground, gray colored and contains small red and yellow particles. This potash salt has been used more extensively in this country than any of the others, but the kainit deposits are gradually becoming exhausted so that it is not so common on our markets as formerly. Kainit is made up of potassium, sodium and magnesium chlorides, and potassium, magnesium and calcium sulphates. The potash is present chiefly as sulphate but on account of the large amounts of sodium and magnesium chlorides present, the potash has the same action as if it were chloride. Kainit usually contains 12 to 12.5 per cent. of potash.*

2. **Sylvinit**.—This salt when ground is much more red in color than kainit. It is being used more in this country than formerly because of the scarcity of true kainit. It is often sold in the United States by the fertilizer manufacturers under the name of kainit. Sylvinit consists chiefly of chlorides; in fact is composed principally of sodium chloride and potassium chloride. It carries from 12.5 to 15.5 per cent. of potash.*

3. **Muriate of Potash**.—As has been said, this product is a manufactured one. It is sold in large quantities in this country. The crude salts of the mines are refined, during which process most of the useless impurities are removed, as lime, magnesia, soda, etc. The principal grades of muriate of potash as manufactured are:

Muriate of potash (KCl) Per cent.		Actual potash (K ₂ O) Per cent.
70 to 75	=	46.7
80 to 85	=	52.7
90 to 95	=	57.9
98	=	62.0

The product sold in the United States usually contains 80 per cent. of muriate of potash which is equivalent to 50.5 per cent. of potash.*

4. **Sulphate of Potash**.—This is a yellow, dry, almost powdery substance. It is sold containing 90 to 97 per cent. of sulphate of

potash which is equivalent to 46 to 52 per cent. of potash. High grade sulphate of potash containing 50 per cent. of potash is mostly used in America.

Sulphate of potash is more expensive than muriate because



Fig. 9. -Tobacco: a crop that is injured by excessive chlorides.—After Conn. Exp. Station.

the cost of manufacture is more, but it is desirable for tobacco, potatoes, citrous fruits, and other crops that are injured by excessive chlorides.*

5. **Double Sulphate of Potash and Magnesia.**—This product is somewhat similar in action on crops to high grade sulphate of potash. It contains considerable sulphate of magnesia which is believed to exert a beneficial effect. It usually carries about 26 per cent. of potash. It is not used to any great extent in this country, except by some fruit growers who prefer it to sulphate of potash.*

Potash Manure Salts.—There are other potash salts that vary from 20 to 30 per cent. of potash called double manure salts and

potash manure salts which are not used extensively in fertilizers; although a potash manure salt containing 20 per cent. of potash is sometimes sold which acts like kainit.*

6. Potassium-magnesium Carbonate.—This is a dry, white manufactured product. It is not sold as extensively as kainit, sylvinite, muriate of potash and sulphate of potash, but it is well liked by tobacco growers. It is also used in Florida on oranges and pine-apples. This product is an excellent source of potash for any crops that chlorides prove injurious to. It usually contains from 20 to 25 per cent. of potash in the form of carbonate. On account of its dry nature, and because it does not absorb water from the atmosphere, it is always easy to distribute.*

Potash from Organic Sources.—Most of the potash used in fertilizers is derived from the mineral sources but a small amount is sometimes purchased in the form of wood ashes, tobacco stems, cotton-seed hull ashes, and beet molasses.

1. Wood Ashes.—Before the discovery of the Stassfurt deposits wood ashes were used more extensively than now and were practically the chief source of potash to be found on the American market. The potash in wood ashes is in a form (as carbonate) which is very desirable for all plants. The product offered to the trade is not uniform as different woods, parts of the same wood as bark, twigs, etc., and methods of handling, all influence the composition. The ashes from soft woods usually contain a lower percentage of potash than the ashes from hard woods. Leached wood ashes naturally carry much less potash than unleached ashes. Ashes contain about 1.9 per cent. of phosphoric acid, 5.5 per cent. of potash and 34 per cent. of lime. They usually contain more or less dirt and moisture which lower the composition. The main source of wood ashes is Canada as not much wood is burned in the United States.*

Value of Wood Ashes.—From a chemical standpoint the value of wood ashes is represented in the contents of potash, phosphoric acid and lime. Ashes have another value in improving the condition of the soil. They seem to help to conserve moisture, improve the texture of soil and correct acidity, thereby increasing

the action of the organisms that promote nitrification. Most soils are benefited by an application of wood ashes. Grasses and legumes especially do well when wood ashes are applied as a top dressing.

2. Tobacco Stems.—Wherever cigars, cigarettes, smoking and chewing tobacco are manufactured there are considerable wastes of stems and stalks collected. This material was formerly thrown away or burned. The burning of tobacco wastes caused the nitrogen to be lost. To-day these wastes are saved and used as fertilizer.* Tobacco stems contain 2.5 per cent. of nitrogen, 0.6 per cent. of phosphoric acid and 8 per cent. of potash. Tobacco stalks carry 3.5 per cent. of nitrogen, 0.4 per cent. of phosphoric acid and 4 per cent. of potash.

3. Cotton-seed Hull Ashes.—A few years ago, before the value of cotton-seed hulls as a feed for live-stock was known, it was the custom to burn these hulls in the furnaces of the gins of the Cotton Belt, and dispose of the ashes for fertilizing purposes. In those days considerable cotton-seed hull ashes was to be found on our markets, but to-day it is rarely used. This product contains on the average, 24 per cent. of potash and 8.7 per cent. of phosphoric acid.*

4. Carbonate of Potash.—This fertilizer is used to some extent by the tobacco growers of the Connecticut Valley.

It usually carries 63 to 65 per cent. of potash and is very alkaline. It is a white substance and soluble in water. It takes on moisture readily and for this reason it is usually put up in casks.*

5. Beet Molasses.—The molasses obtained from the manufacture of sugar from the sugar-beet is quite rich in potash which gives this product its bitter taste thus making it unpalatable for human consumption. Beet molasses contains from 10 to 15 per cent. of ash of which 7.5 to 12.25 per cent. is in the form of potash salts.

Amount of Potash in Soils.—Soils generally contain from 0.1 to 0.5 per cent. of potash, which is equivalent to 3,500 to 18,000 pounds of potash per acre to a depth of one foot. Most of this

potash is not available to plants and so a soil apparently rich in potash will often be helped by a supply in artificial forms. The addition of lime often increases the supply of available potash in soils, by promoting certain favorable chemical changes. The condition of the soil also influences the amount of available potash. Light sandy soils are more apt to be deficient in potash than heavy soils.

Forms of Potash.—A review of this chapter teaches us that potash exists chiefly in three forms in fertilizer materials.

- As chloride in { Muriate of potash
Sylvinit
- As sulphate in { Sulphate of potash
Double sulphate of potash and magnesia.
- As sulphate and chloride in Kainit (action same as chloride)
- As carbonate in { Potassium-magnesium carbonate
Wood ashes
Potassium carbonate.

The form of potash is an important consideration in the purchase of fertilizers, as potash in the form of chloride is injurious to the marketable value of certain crops as tobacco, potatoes, sugar beets, and oranges. Muriate of potash seems to make potatoes waxy; with sugar beets it seems to lessen the percentage of sugar as sucrose; for tobacco the flavor is spoiled for smoking it sometimes forms calcium chloride in the soil which is not relished by plants.

The form of potash does not seem to work any injury on crops as legumes, grasses, corn, etc., and for such crops potash should be purchased in its cheapest form. Muriate of potash diffuses better in the soil than sulphate of potash. It should be understood that actual potash (K_2O) is not injurious to plants, but the form or elements it is associated with are the cause of its effect on crops.

Fixation of Potash.—Potash is quickly fixed in the soil; it replaces the sodium and calcium in soils and forms compounds insoluble in water. The chlorides of potash are liable to render the lime content of a soil deficient, as the chlorine unites with lime and forms a soluble compound that is readily leached from the

soil. In experiments at the Massachusetts Experiment Station, Goessmann found that continued applications of muriate of potash produced sickly crops which were made well and healthful by an application of lime. Therefore acid soils should always receive an application of lime before the use of potash as chloride. As potash is quickly fixed in the soil and the chlorides washed out, it is often advisable to apply chloride of potash some time before the crop is planted, especially when the crop that is to be planted is injured by chlorine. The fixation of potash usually occurs in the surface soil and so rapidly does this fixation take place on some alluvial soils, that it is necessary to work it in soon after applying to insure an even distribution.

Functions of Potash.—The intelligent use of potash fertilizers requires a knowledge of the effect of this constituent on crops. Potash is essential to the formation of starch, sugar and cellulose (pure fiber) in plants. When there is a deficiency of available potash in soils, certain plants do not mature well.

Potash Favors Seed and Straw Formation.—Hall¹ says: On grass plots another very striking effect of potash manuring is also very manifest. On the potash-starved plots the grasses fail to a large extent to develop any seed, and the heads are soft and barren, presumably because of the deficiency in carbohydrate formation. For the same cause the straw, not only of the grasses, but also on the similarly manured wheat and barley plots, is also weak and brittle when potash is wanting.

Potash Effects the Leaves.—Grass grown on soils deficient in potash tends to show the effect of this constituent by producing a brown sickly appearance. The grass blades often turn brown about 2 inches from the tip and die off. The leaves of root crops also often show a lack of potash when they are nearing maturity, by a spotted or brown coloration.

Potash Effects Maturity.—Experiments show that soils without sufficient potash do not produce as valuable grain crops in dry seasons as soils rich in this constituent. This is probably due to the fact that potash causes a longer growing period and holds back maturity. With root crops the opposite effect has been

¹ Fertilizers and Manures.

found to exist. That is the maturity of these crops is hastened by a supply of potash.

Potash Helps to Neutralize Plant Acids.—Many plants contain acids; for example, in the grape there is tartaric acid; in the apple, malic; in the orange, citric; and potash helps to neutralize these plant acids and form acid salts.

Potash Sometimes Checks Insect Pests and Plant Diseases.—Experiments show that certain forms of potash are distasteful to some insects and tend to check their ravages. Potash seems to make plants better able to resist attacks of certain fungi, especially when soils are deficient in this constituent, by producing a stronger and more vigorous growth.*

CHAPTER X.

MISCELLANEOUS FERTILIZER MATERIALS.

The fertilizer materials discussed in the previous chapters are those products most commonly used and constitute the main sources of nitrogen, phosphoric acid and potash. There are, however, other substances that are occasionally utilized that have some value. Some of these materials are used at times by fertilizer manufacturers while others are employed directly by farmers. Some of them furnish one or more of the essential elements in amounts sufficient to warrant their use, when they can be obtained cheaply, while others are not applied for their fertilizer value but to improve the condition or texture of the soil, to increase the available plant food supply or to conserve moisture. There are some products discussed in this chapter that have no particular value as fertilizer but are taken up to set clear impressions that are prevalent among some who feel that these products can be used to replace to a certain extent the more important fertilizer materials. It should be remembered that many of these materials we are about to discuss do not contain sufficient amounts of the essential elements to produce paying crops but they may be used to partially replace commercial fertilizers.

Compost.—A compost is usually made up of layers of manure and vegetable matter. Sometimes lime, acid phosphate, ground raw rock phosphate, cotton-seed, gypsum, and similar fertilizer materials are added to it. A compost can be made in the following manner. First select a shady place and provide a good drainage. Then make a foundation with a layer of earth. On top of this place a layer of leaves or manure then a layer of earth, another layer of leaves, cotton-seed and manure, a layer of earth, etc. The top of the compost should be covered with earth and it should be shaped to shed water. The compost should be kept moist to prevent the loss of nitrogen as ammonia. The manure, leaves, cotton-seed, raw rock phosphate, etc., will decay or undergo changes due to the action of organisms similar

to what would take place in the soil, when the compost is kept thoroughly moist. Before applying any of the compost to the land it should be well mixed to make it uniform. The earth is used in layers to absorb the ammonia that may be set free in the process of decay of the organic materials. The amount of fertilizing material obtained from a compost will be equal to the amount of fertilizer material added to it, provided there is no loss; but the availability of these materials will be greater.

Seaweed.—In states bordering on the ocean seaweed is used a great deal for fertilizer. Stormy weather throws considerable quantities on the beach and the states of Rhode Island, New Jersey, New Hampshire, and Massachusetts have used this fertilizer for many years.

The best way to apply seaweed is in the fresh state. The different varieties of seaweed contain from 70 to over 80 per cent. of moisture and when it is to be transported any considerable distance it may be spread thin and sun-dried to avoid carting so much water. They contain from 0.25 to 1.25 per cent. of nitrogen, about 0.20 per cent. of phosphoric acid and 0.60 to 1.4 per cent. of potash. About 20 to 25 per cent. of the ash of seaweeds is chlorine.*

Marl.—There are two principal classes of marls, namely shell marls and green sand marls. The shell marls contain less phosphoric acid and potash and more lime than the other marls. Marls average about 0.40 per cent. of phosphoric acid and 1.40 per cent. of potash. Marls improve the physical condition of some soils.*

Peat and Muck.—In low wet places where vegetable matter accumulates, decomposition sets in and the substance formed is called peat or muck. This material does not run high in the essential elements; it averages about 0.7 per cent. of nitrogen and about 75 per cent. of water. The phosphoric acid and potash contents approximate what is contained in good soil. The value of this substance depends upon its nitrogen content which in turns depends upon the amount of organic matter. The nitrogen is not perhaps as available as that in cultivated soils and unless it is easy to obtain it is doubtful whether it pays to use it.*

Pulverized Manures.—Pulverized sheep manure, poultry manure, and pigeon manure are found on the market in some sections. These manures usually carry a higher price than the regular commercial fertilizers although they are not so valuable. These products should be saved on the farm but it will hardly pay to purchase them unless the price is much less than for commercial fertilizers. The value of these manures is often exaggerated because they are quick acting. They are to be found for sale in seed stores and are purchased generally in small amounts by those having small gardens or house plants.*

Fresh Fish Scrap.—Farmers living near the sea coast use a great deal of fresh fish scrap and whole fish. This material contains nitrogen and phosphoric acid but an average composition is impossible to give because the moisture content is so variable. The main value in fish is derived from the nitrogen they contain. Lobster shells, mussels, shrimp waste and King crab are other wastes that are used for fertilizer. These are economical fertilizers when they can be had for nothing, or at a low price, provided they do not have to be carted a great distance.*

Sewage and Sewage Sludge.—Sewage contains about 0.40 per cent. of nitrogen, 0.27 per cent. of potash, 0.85 per cent. of phosphoric acid and 75-80 per cent. of water. It is not a valuable fertilizer and requires either ditches or porous pipes for its proper distribution on the land.

Sewage sludge is a product obtained by precipitating the suspended matter in sewage with certain chemicals and squeezing out the excess of water. This product contains from 0.60 to 2.3 per cent. of nitrogen, 0.60 to 2.3 per cent. of phosphoric acid and traces of potash. It has some value as fertilizer.*

Coal ashes sometimes helps to improve the condition of certain soils. This material does not contain enough of the essential elements to be valuable as fertilizer but its indirect action may help to produce better physical properties in soils. This material is perhaps more valuable for walks and roads than for fertilizer.

Lime-kiln Ashes.—When lime and wood are burned together in making quicklime the resulting product is known as lime-kiln

ashes. This product is richer in lime than wood ashes and it may be used on soils requiring lime when the price is reasonable. It averages 2 per cent. of potash, 0.75 per cent. of phosphoric acid and 40 per cent. of lime.*

Rice Hull Ashes.—In the rice sections the rice hulls are often used as fuel in the boilers of rice mills. This product contains about 1.2 per cent. of potash, and 0.6 per cent. of phosphoric acid.

Corn Cob Ashes.—In certain sections of the country corn cobs are sometimes used in place of wood for fuel. This product carries about 7 per cent. of potash, 2.4 per cent. of phosphoric acid and 11 per cent. of lime. It is evident that these ashes are valuable for soils in need of potash. It also contains an appreciable amount of phosphoric acid. Farmers burning corn cobs will do well if they save these ashes and apply them to their land.

Brick kiln ashes are sometimes used for fertilizer. The kind of wood burned in brick kilns will influence the value of these ashes. They are worth purchasing by those living near brick kilns who wish to apply lime, when they can be purchased right.*

Soot is the black deposit that collects in flues and chimneys when coal or wood is burned and is used in England quite extensively as fertilizer. Soot from coal averages about 3 per cent. of nitrogen in the form of ammonia. It is more valuable in improving the physical condition of soils than as a fertilizer. Its dark color increases soil temperature by absorbing the rays of the sun, thus helping plant growth and the action of the soil organisms. It lightens heavy soils and is not relished by certain insects that damage crops.*

Street sweepings are sometimes used by gardeners. When they contain a large proportion of horse manure they may have a little value. However the liquid portions are not saved so that they are not as valuable as farm manure. Street sweepings usually contain other debris than horse manure which of course decreases their value. Generally speaking, street sweepings should not be used unless the expense of hauling is very small. Most people would not care to utilize this waste because of the unsanitary nature of it. Debris from houses etc. are liable to contaminate it in which case it would not be a safe fertilizer.

Potassium nitrate, or saltpeter, contains from 12 to 13 per cent. of nitrogen and 40 to 45 per cent. of potash. It is an excellent fertilizer but the market price prohibits its general use.*

Ammonium nitrate is a rich nitrogenous salt but it is too expensive to employ for fertilizing purposes.

Silicate of Potash.—Some minerals as feldspathic rock contain considerable amounts (12 to 15 per cent. and more) of potash. These potash feldspars have been ground to a powder and put upon the market for fertilizer from time to time. Experiments show this material to be of very low crop producing value.*

Iron sulphate is produced quite extensively as a by-product in the manufacture of steel. Although iron is necessary for plant growth most plants do not use more than 15 pounds of iron oxide per acre and average soils contain 15 tons of this material per acre in the surface soil to a depth of 9 inches. So it is evident that soils contain abundant amounts of iron for the needs of plants.

Common salt, or sodium chloride, has been used for many years in some of the older countries as a fertilizer. In this country a product called agricultural salt has been on the market, which is mainly common salt. Most of our soils are rich enough in sodium so that applications of common salt are not necessary. This material does not furnish any nitrogen, phosphoric acid or potash.*

Powder waste is another product that is principally made up of common salt. Some of this material may contain nitrates in which case it is more valuable than common salt, although it should not be considered unless it can be had for nothing, or very cheap. It should be applied in small quantities because of the deleterious action that large applications of sodium chloride have on vegetation.

Sulphates of Soda and Magnesia.—The use of either sulphate of soda or magnesia is hardly to be considered on American soils except when some special crop is grown that depletes the soil of them, which is indeed very rarely. When fertilizers are used there is enough of these constituents supplied for the needs of

the crop. Most of our soils are well furnished with these constituents. Common salt is cheaper than sulphates of soda or magnesia and when needed will serve the same purpose, namely, to render potash available.*

Carbonate of magnesia is sometimes found on the market but carbonate of lime performs the same functions except that magnesia is not supplied, so that we need not consider this material in our fertilizer problems.

Ammonium chloride and ammonium carbonate are not good fertilizers because they injure plants. Ammonium chloride is sometimes called sal-ammoniac and in the pure state it is rather expensive.

Manganese Salts.—Manganese is found in small amounts in plants and it is said to stimulate their growth. This element is not necessary to apply as soils contain enough of it to satisfy the wants of the plant.

CHAPTER XI.

LIME, GYPSUM AND GREEN MANURES.

Lime has been used for agricultural purposes for many centuries, but for how long we do not know. Records show that it was used on land before the Christian Era. During the sixteenth and seventeenth centuries the practice of liming the land was common in Great Britain and at that time lime was one of the principal fertilizers and large applications were often supplied.

Forms of Lime.—Lime is obtained by burning limestone, chalk, or shells. These are all substances rich in carbonate of lime (CaCO_3). When they are burned the carbonic acid (CO_2) passes off, leaving the oxide of lime (CaO), which is called quicklime, caustic lime, store lime and burned lime. The oxide of lime is usually known as lime. When water is added to this product it is readily absorbed and high heat develops forming hydrate of lime ($\text{Ca}[\text{OH}]_2$) which crumbles to a powder. This is known as slaked lime. Quicklime readily absorbs water and therefore slakes when exposed to the air. This is known as air slaked lime and is not as completely slaked as when treated with water. Quicklime is apt to change to limestone on standing as it absorbs carbonic acid from the atmosphere. When quicklime is applied to the soil it changes to carbonate of lime.

One hundred pounds of limestone make about 50 to 56 pounds of quicklime which produce about 75 to 85 pounds of water slaked lime. The purer the limestone, the more quicklime and water slaked lime are obtained.*

* **When Soils Need Lime.**—A certain amount of calcium carbonate should be present in soils as this compound helps to make plant food available and keeps the soil in a condition favorable for producing crops. When there is a deficiency of calcium carbonate, the soil will most likely be acid or sour. Most farm crops do not grow well on sour soils, but certain weeds seem to thrive on them, and so it is important to keep soils sweet or stocked with a sufficiency of carbonate of lime. The addition of ordinary fertilizers will not benefit crops on sour soils because the nitrifying

organisms cannot work to advantage in an acid medium. There may be an ample supply of nitrogen, phosphoric acid and potash in a sour soil and yet good crops cannot be produced because of the need of lime. Soils that run as low as 0.2 per cent. of calcium carbonate generally need lime.

How to Find Out When Soils are Acid.—A simple method that is often effective consists of testing the soil with blue litmus paper. A few cents worth of this paper may be purchased at a drug store. Test the soil as follows: Collect some earth from those portions of the field where the plants are poor or sickly. Mix the samples of earth together, take a small portion and add water to form a paste. Place one end of the litmus paper in this mixture and let it remain for about 45 minutes. If the soil is sufficiently acid the color of that part of the litmus paper which was dipped in the paste will be changed to red. This is not a delicate test and is only an indication of a soil badly in need of lime. Another way to find out whether your soil needs lime is to express about one-half a pound of the suspicious soil to your State Experiment Station requesting them to find out if your soil needs lime. Or a plot of the suspicious land may be spread with a liberal application of lime and the effect on the crop noted. This last method is perhaps the best test.

▷ **How to Apply Lime.**—Finely ground limestone, quick lime, or water slaked lime may be used to correct acidity in soils. If water slaked lime is used it should be applied just as soon as it becomes powdered. If quicklime is preferred, it may be dumped into small heaps and kept covered with earth until the lime slakes or crumbles.

Lime should be spread in a thin even layer and harrowed in. If slaked lime is used it should be harrowed in immediately as it changes to the carbonate form on exposure to the air. Some farmers use a lime spreader which machine is very effective. Lime should be applied some time before planting as it is liable to injure the seed.

The Form of Lime to Use.—Marble dust, ground limestone, ground oyster shells, etc. (calcium carbonate), are preferable

for soils rich in organic matter, to prevent the loss of nitrogen. Should you desire to correct the acidity of a soil and decompose the organic matter quickly, caustic lime or slacked lime should be used. On peaty land, old forest land, and other places where considerable vegetable matter has accumulated, lime is very beneficial as it helps to liberate the nitrogen and form nitrates.*

Amount of Lime to Apply.—The nature of the soil regulates to a certain extent the amount of lime to apply. On soils that are acid it should be understood that the rains have carried the acidity to the subsoil. Therefore during dry periods the capillary water will bring up acid from the subsoil. Enough lime should be added to correct the acidity of the surface soil and allowance should be made for that which may be brought up from the subsoil. A small application will not last as long as a large quantity but will in all probability give greater profits per ton of lime. If land must be improved quickly, large applications are the most desirable. The nature of the crops grown should also determine the amount of lime to use. On sandy soils 800 to 1,000 pounds of slaked lime or 1,600 to 2,000 pounds of ground limestone per acre should prove sufficient and for heavy clay soils, 1,600 to 2,000 pounds of slaked lime or 3,000 to 4,000 pounds of ground limestone per acre will prove beneficial. Sometimes smaller or larger amounts are used with good results. Some farmers use light applications every four or five years while others apply large quantities at eight, ten or fifteen year periods. The farmer should be the best judge and he can find out after one trial the amount of lime necessary to satisfy his conditions and when to apply it.*

Legumes Require an Alkaline Soil.—It is a well known fact that alfalfa, clovers, etc., require a soil well supplied with lime for the best returns. One has only to visit an alfalfa field in a limestone section to find out the benefit of an alkaline soil for producing leguminous crops. On acid soils the legumes become sickly and do not develop tubercles or nodules on their roots. These helpful bacteria which gather nitrogen from the air are not active

Mechanical Action of Lime.—On a heavy clay soil lime loosens the soil and makes it lighter and more porous. It relieves somewhat the tendency of these soils to puddle. It renders them easier to work and lessens the stickiness or adhesiveness a great deal. We learned that puddling is due to the fine state of division of the particles in clay soils. Lime tends to cause a coagulation or flocculation of these fine soil particles. This action is easily demonstrated by placing some clay soil in a glass of water and adding a pinch of lime. When the lime is added and the contents of the glass well stirred, the soil particles precipitate and settle to the bottom of the glass leaving a clear solution of water.

Lime lessens the tendency of clay soils from cracking because it does not shrink in dry weather. For this reason the addition of lime to clay soils makes them easier to work. On sandy soils lime has an entirely opposite effect than on clay soils. Instead of making the soil lighter and more open it binds together the soil particles. It increases the capillary power of light soils and thus makes these soils better able to stand dry weather.

Lime does not add any nitrogen, phosphoric acid or potash to the soil but sets these constituents free. Therefore the continual use of lime will make a soil less productive, hence the saying, "Liming makes the father rich and the son poor."

Lime Decreases Many Fungus Diseases.—Many fungi and moulds that prosper in an acid soil are destroyed when lime is added and the soil kept alkaline or sweet. Certain rusts, smuts, club root, etc., are due to fungi that require a sour soil for their development. Lime seems to favor the potato scab fungus and potatoes grown on limed soils usually produce scabby tubers. This fungus may be checked in alkaline soils by dipping the seed potatoes in a solution of formalin or corrosive sublimate before planting.*

Gas lime is the refuse lime from the manufacture of coal gas. Coal gas is passed over fresh slaked lime which absorbs the impurities, principally sulphur compounds and gases, from the coal gas. The presence of sulphur compounds in this product makes it unsafe to use because it has a poisonous effect on young plant growth. It may be applied to the soil provided it is allowed to

thoroughly oxidize (by exposing it to the air for a long time in heaps mixed with earth) in which case the injurious compounds are changed so that they are not harmful. Sometimes it is put on the land before being oxidized to get rid of insects and if so it should be applied a long time before planting.*

Gypsum.—This product is sometimes called land plaster. The lime is as sulphate in this compound. Gypsum does not contain as much lime as good limestone. It is a good fertilizer for leguminous crops as clover, alfalfa, etc. The use of gypsum instead of lime (CaO) is not to be recommended as the real value of gypsum is in liberating locked-up potash. Super-phosphates contain gypsum and when they are used it would not be necessary to apply gypsum. Gypsum seems to keep the soil moist in dry weather by absorbing moisture from the air or conserving it in the soil. On soils low in potash, gypsum does not seem to be beneficial and when soils fail to respond to gypsum an application of potash may be needed.*

Green Manures.—Any crop that is grown and plowed under in order to benefit the soil is called a green manure. A green manure may help the soil in any of the following ways:

1. By keeping up the humus supply by furnishing organic matter.
2. By improving the texture of soils, by making heavy soils lighter and sandy soils more retentive.
3. By utilizing the soluble plant food that would otherwise be lost if the land was left bare.
4. By ridding the land of many weeds and thus serve as a cleaning crop.
5. By bringing up plant food from the subsoil to the surface soil.
6. By using a leguminous crop the nitrogen content of the soil may be increased, by utilizing the nitrogen from the air.
7. By preventing the washing of soils, or erosion.

Classes of Green Manures.—There are many crops used as green manures and the section of the country determines to a great ex-

tent what crops to select. Green manure crops may be classified as leguminous and non-leguminous.

1. The leguminous green manure crops are those that have the power of securing nitrogen from the air and are represented in the clovers, cowpea, soy bean, alfalfa, vetches, velvet bean, Canada field pea, etc.

2. The non-leguminous green manure crops are those that draw on the soil entirely for their supply of food, and rape, rye, oats, buckwheat and mustard are examples of this class.

Of the leguminous crops the red clover is the most popular in the North and the cowpea and clovers in the South. Crimson clover and alfalfa are also popular. The vetches and soy beans are not used so much as the other mentioned legumes.

Rye is the most common non-leguminous crop and is often pastured in the fall or early winter.

Leguminous Crops are to be Preferred.—The leguminous crops are better than the non-leguminous because they can secure nitrogen from the air and increase the soil supply of this constituent. They also return more nitrogen to the soil when plowed under. The non-leguminous plants simply draw on the soil for food and when plowed under only add non-nitrogenous matter. The principal benefit derived from the non-leguminous plants is to save the loss of soluble plant food when a legume cannot be selected. The non-leguminous plants are more expensive to grow because they require a supply of nitrogen and generally of phosphoric acid and potash to insure good growth. The legumes only require potash and phosphoric acid and sometimes only phosphoric acid. So it is evident that rye, oats, rape, mustard, etc., cannot take the place of the legumes in supplying green manure as they cost too much to grow and do not return as much fertility to the soil.*

The Best Time to Plow Under a Green Manure.—Crops used for green manuring should be plowed under before they become dry. When they are plowed under while green and fresh they are more readily decayed and prevent the loss of water somewhat from light soils. Dry crops plowed under interfere with the use of water from the subsoil and on light sandy soils may lower the

yield of the crop that follows. If possible the green manure should be plowed under some two or three weeks before planting time to give it a chance to partially decay so as not to injure the planted crop and to furnish some food for the young seedlings.

The Best Time to Grow a Green Manure.—If the soil is poor and run down it is sometimes advisable to keep it in a green manure for a season or two. Generally, however, green manures fit well into rotations and may often be grown when the land is



Fig. 10.—Pear orchard with cover crop.

ordinarily idle or between money crops. In the South, crops like rye, crimson clover, red clover, vetch, etc. may be grown in the winter and turned under in time for the summer crop. In the North, rye and vetch may be used as winter crops. Sometimes it is advisable to sow a green manure at the time another crop is laid by. Then when the crop is harvested the green manure crop

will have grown sufficiently to turn under and the land may be sowed to some small grain crop; or the green manure crop may be planted after harvest and remain on the land all winter and plowed under in the spring.

In fruit orchards green manure crops (cover crops) as rye, oats, clover, etc., are often sown about mid-summer to absorb moisture and available plant food from the soil and to cause the buds to mature and cease growth of the wood and leaves. This crop is allowed to remain on the soil all winter and in the spring it is plowed under. By keeping the land covered during the winter leaching of plant food and washing away of soil is lessened.

Deep Rooted Plants Valuable.—Alfalfa, clover, etc., have very long tap roots which penetrate the subsoil, thus securing a great deal of plant food that would not be within reach of many cultivated plants. These leguminous plants also bring a great deal of plant food from the subsoil to the surface soil and leave it there for succeeding crops. When these deep roots decay they leave openings in the soil which help to increase drainage and aeration and thus improve the physical condition of soils.

CHAPTER XII.

COMMERCIAL FERTILIZERS.

Since 1860, when fertilizers were used on a comparatively small scale, the fertilizer industry has increased until to-day it is of great importance. In 1860 the wholesale cost of the output of the fertilizer factories was \$891,344, in 1890, \$39,180,844, in 1900, \$40,445,661 and in 1905, \$50,506,294 or a difference of \$49,614,950 between the years 1860 and 1905. These figures do not represent what the consumer paid for fertilizer during these years as these amounts cover practically the wholesale cost. The above figures are only approximate at the best and in all probability they should be larger for the years 1900 and 1905, but they will serve to impress one with the magnitude of the fertilizer industry in the United States to-day.*

Causes for the Large Consumption of Fertilizers.—The causes for the large and increasing use of commercial fertilizers are many. Single crop farming has caused many farms to run down in fertility. Many crops have been principally raised. Legumes have been grown occasionally or not at all. Green manuring has not been practiced enough. Poor drainage has caused losses of fertility. Some farms have lost much of their fertile soil by erosion. Farm manure has not always been saved and when saved it has not been preserved properly. According to Bulletin 140 by the Kentucky Experiment Station, it is estimated that the annual production of farm manure in the United States is equal in value to the corn crop at \$1.05 per bushel, or nearly two and one-half billions of dollars. The most conservative estimate would put the waste of farm manure at one-third, an annual loss of about \$800,000,000.00. This is about eight times the amount spent annually in this country for commercial fertilizers. There is little wonder that so much of our soil is becoming unproductive. The crops have also been sold away from the farm instead of being fed to live-stock. Cover and catch crops have not always been grown. To sum up, we may say that the fertility of the soil has not been maintained, and farms that formerly yielded

profitable crops with applications of 200 pounds of commercial fertilizer per acre, now require 400 to 600 pounds and sometimes 800 to 1,200 pounds to produce the same results.

With the market gardener and trucker conditions are different. The demand for vegetables in our large cities has caused the market gardener in the north and the trucker in the south to use heavy applications of fertilizers to produce profitable crops. Many of these crops are heavy feeders and require to be marketed or shipped as early as possible, as a few days often means a great difference in the prices received, and so high priced quick acting fertilizers are generally used. The truckers are often located on sandy soils of low fertility that must have plenty of fertilizer to produce money crops. The market gardener, who usually lives near or in a city or town, produces crops on lands that would bring a high price for building and other purposes, and can hardly ever afford to allow his land to be idle or to be sowed to some soil improving crop, but must have a money crop growing continually. The market gardener cannot afford to raise live-stock on such high priced land. So with the market gardener and trucker the consumption of fertilizer will increase with the demand for their products, and as the population of this country is increasing every year we may expect more artificial fertilizers to be used in producing market garden and truck crops. With these farmers, and especially the market gardener, the use of large quantities of commercial fertilizers is a necessity.

How the General Farmer May Lessen the Use of Commercial Fertilizers.—The consumption of commercial fertilizers may be reduced a great deal by many farmers. A better system of farming should be adopted. A rational rotation system including money crops and soil improving crops should be practiced. Legumes should be included whenever possible in rotations to add to the supply of nitrogen and organic matter in the soil. Live-stock should be kept and the farm crops marketed through them. In this way a two-fold or full value will be obtained, namely, the feeding and fertilizer values. Farm manure should be saved and preserved. It should be saved to supply humus and fertility

to the soil and it should be preserved to prevent losses of the essential elements by fermentation and leaching. The land should be well drained and tilled. Crops should occupy the land continually. Erosion must be prevented. Use commercial fertilizers only to supplement the organic matter and those constituents which should be contained in the soil. Fertilizers are not expected to produce crops alone, unless increased amounts are used every year. This is well illustrated by an experiment conducted at the Louisiana Experiment Station on corn. For four years commercial fertilizer only was applied to one plot and legumes and farm manure was used on another plot. The yield on the plot receiving commercial fertilizer alone, showed 12 bushels per acre and that on the plot receiving organic matter, 52 bushels, at the end of four years.

Fertilizing Materials Used by Manufacturers.—The fertilizing materials described in the previous chapters are those that the manufacturers draw on for making their mixtures. The farmer generally purchases his fertilizer in the mixed state under some brand name, as Corn Fertilizer, B. C. Brand, etc., which does not indicate the materials of which it is composed. The fertilizer materials usually predominate in one constituent while the manufactured fertilizers show usually two or three of the constituents, as nitrogen, phosphoric acid and potash. The manufacturers may employ materials that furnish large amounts of a particular constituent, as nitrate of soda, sulphate of ammonia, dried blood, sulphate of potash, muriate of potash, kainit, and Tennessee or Florida rock phosphate. He may choose some high grade materials as those just mentioned and some low grade materials as beet refuse, leather preparations, low grade cotton-seed meal, soluble hair and wool waste, low grade bone-meal, etc. So when a mixed fertilizer reaches the farmer the identity of the materials of which it is composed is not known.*

Basis of Purchase of Fertilizers.—There are two systems used in purchasing fertilizers, namely, the unit system and the ton system.

1. **The Unit System.**—A unit is 20 pounds or one per cent. of a ton. Manufacturers and dealers in fertilizer materials use the

unit system almost entirely. Tankage, bone products, blood, azotin, steamed horn and hoof meal, potash salts, nitrogenous salts, superphosphates, dry ground fish, raw rock phosphates, cotton-seed meal, castor pomace, etc., are all purchased on the unit basis. For example, muriate of potash will be quoted at 80 cents a unit. This means that the actual potash in muriate of potash will cost 80 cents for 20 pounds, or 4 cents for one pound. Dried blood perhaps will be quoted at \$3.30 per unit of nitrogen. This means that 20 pounds of nitrogen in dried blood will cost \$3.30, or 16½ cents for one pound.

In the unit system of purchasing and selling, the buyer and seller usually employ a competent neutral chemist to draw a representative sample of the material and settlement is made on the chemist's findings. This is indeed an excellent system because the buyer pays for just what is present in the material and the seller receives compensation for what his product contains. It may be said that this system is very satisfactory to the fertilizer trade.

2. **The ton basis** of purchase is the one commonly used by the manufacturer, dealer, etc., in selling to the consumer. The products, both mixed and unmixed, are sold to the consumer at a fixed price per ton of 2,000 pounds. This system is not as satisfactory as the unit system because the purchaser does not always receive a stipulated amount of the constituents contracted for. To be sure, the manufacturers guarantee their products to contain given amounts of fertilizer constituents and aim to meet or even to exceed their guarantees, but sometimes the fertilizers do not reach them in every particular. The prices of the fertilizers sold on the ton basis to the consumer do not usually fluctuate with the market, as the manufacturer tries to fix a price that will guard against loss, although many of them sell their fertilizers at times with very small and sometimes no profit when they have a large stock which they do not wish to carry over for another season.

Fertilizer Laws.—In order to protect the consumer and the honest manufacturer, several states have passed laws regulating

the sale of fertilizers. The enforcement of these laws is generally controlled by the Experiment Stations or the State Boards of Agriculture, through a staff of chemists and inspectors. The inspectors, who may or may not be chemists, draw samples of the various fertilizers, forward them to the laboratory, and the chemist analyzes them to find out if they are as represented. The results of the chemists' findings are published in bulletins or reports which are sent to the consumers, manufacturers, dealers, and other interested parties.*

The Meaning of the Guarantee.—It has been said that the manufacturer, dealer, or jobber must have printed on the bags or tags attached to the bags, his name and address, the weight of the package, the name, brand or trade mark, and the chemical composition of the fertilizer. This guarantee does not mean that each particular shipment, or lot, or bag, that the consumer may purchase has been analyzed by the state chemist and that he found the stipulated amounts of nitrogen, soluble phosphoric acid, reverted phosphoric acid and potash, as the case may be, that are printed as the guaranteed chemical analysis on the bags or tags. It does mean that the manufacturer says he has furnished at least those amounts of plant food as stated.

The Interpretation of the Guarantee.—Some manufacturers do not make a simple statement of the guaranteed chemical composition of their brands of fertilizers, but use other terms which are equivalent, to be sure, but are misleading to the ordinary person not familiar with fertilizer parlance. A few examples may serve to illustrate this point.

GUARANTEED CHEMICAL ANALYSIS, NO. 1.

	Per cent.
Nitrogen.....	1.00
Ammonia.....	1.22
Equal to nitrate of soda.....	6.06
Total phosphoric acid.....	12.00
Equivalent to bone phosphate.....	26.00
Available phosphoric acid.....	10.00

To simplify this guarantee we would state it as:

	Per cent.
Nitrogen as nitrate	1.00
Total phosphoric acid	12.00
Available phosphoric acid	10.00

All the other statements omitted in the simplified chemical guarantee are correct but unnecessary and misleading. The percentage given under "equal to nitrate of soda," and "equivalent to bone phosphate" are simply restatements.*

GUARANTEED CHEMICAL ANALYSIS, No. 2.

	Per cent.
Total phosphoric acid	11-14
Equivalent to total bone phosphate	24-30
Available phosphoric acid	10-12
Equivalent to available bone phosphate	22-26
Soluble phosphoric acid	8-10
Equivalent to soluble bone phosphate	17.5-22
Insoluble phosphoric acid	1-2
Equivalent to insoluble bone phosphate	2-4.25
Potash	4-5
Equivalent to sulphate of potash	7.4-9
Total nitrogen	2-3
Equivalent to total ammonia	2.4-3.6

This is not an exaggerated guarantee but one that is often found in the fertilizer trade.

Simplified the above reads:

	Per cent.
Total phosphoric acid	11.00
Available phosphoric acid	10.00
Soluble phosphoric acid	8.00
Insoluble phosphoric acid	1.00
Potash	4.00
Nitrogen	2.00

Or we may further simplify this to read;

	Per cent.
Available phosphoric acid	10.00
Potash	4.00
Nitrogen	2.00

It will be noticed that the simplified statements contain the minimum percentages; for example, available phosphoric acid is guaranteed as 10 to 12 per cent, and in the simplified statement it is given as being 10 per cent. This latter figure 10 per cent.

is all the manufacturer guarantees and the maximum guarantee of 12 per cent. is misleading and does not mean anything. It seems to be common practice with the manufacturers to use both the minimum and maximum guarantees.

GUARANTEED CHEMICAL ANALYSIS, No. 3.

	Per cent.
Total phosphoric acid	10-12
Available phosphoric acid	9-10
Insoluble phosphoric acid	1-2
Soluble phosphoric acid	6-8
Equal to available bone phosphate	19.7-22
Potash	3.5-5
Nitrogen	0.82-1.65
Ammonia	1-2

Simplified this guarantee would read:

	Per cent.
Available phosphoric acid	9.00
Potash	3.5
Nitrogen	0.82

GUARANTEED CHEMICAL ANALYSIS, No. 4.

	Per cent.
Total bone phosphate	32.7-43.7
Yielding total phosphoric acid	15-20
Soluble bone phosphate	22-28
Yielding soluble phosphoric acid	10-13
Reverted bone phosphate	8.7-10.9
Yielding reverted phosphoric acid	4-5
Insoluble bone phosphate	2.2-4.4
Yielding insoluble phosphoric acid	1-2

Simplified this would read:

Soluble phosphoric acid	10.00
Reverted phosphoric acid	4.00
Insoluble phosphoric acid	1.00

Or we could state it as follows:

Available phosphoric acid	14.00
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There are many manufacturers who put guarantees on their brands that are not misleading and may be easily interpreted by the ordinary person.*

CHAPTER XIII.

VALUATION OF FERTILIZERS.

Interpretation of Chemical Analyses.—A chemical analysis of a fertilizer may indicate to a great extent the value or suitability of it. The following two analyses illustrate this point.

CHEMICAL ANALYSIS, NO. 1.

	Per cent.
Nitrogen as nitrate	1.00
Nitrogen as ammonia.....	1.00
Organic nitrogen.....	2.00
Total nitrogen	4.00
Water soluble phosphoric acid	8.00
Reverted phosphoric acid.....	2.00
Insoluble phosphoric acid	2.00
Available phosphoric acid	10.00
Total potash	9.00
Potash as chloride.....	2.00
Potash as sulphate	7.00

CHEMICAL ANALYSIS, NO. 2.

	Per cent.
Nitrogen as nitrate.....	—
Nitrogen as ammonia	—
Organic nitrogen.....	4.00
Total nitrogen	4.00
Water soluble phosphoric acid	2.00
Reverted phosphoric acid.....	8.00
Insoluble phosphoric acid.....	2.00
Available phosphoric acid	10.00
Total potash	9.00
Potash as chloride.....	8.00
Potash as sulphate	1.00

Both of the above fertilizers contain equal amounts of nitrogen, phosphoric acid and potash and could be stated as follows:

	Per cent.
Nitrogen.....	4.00
Available phosphoric acid.....	10.00
Potash	9.00

Fertilizer No. 1 contains nitrogen as nitrates and as ammonia while No. 2 does not. Both brands contain organic nitrogen;

No. 1 containing 2 per cent. and No. 2 carries all of its nitrogen in this form. The chemist cannot always tell the source of the organic nitrogen. When the organic nitrogen is derived from dried blood, azotin, cotton-seed meal, steamed horn and hoof meal, and similar nitrogenous organic materials it is valuable but when derived from leather preparations, dissolved wool and shoddy wastes, etc., it is not so desirable. Therefore the purchaser would perhaps select Brand No. 1 for its nitrogen content as it is to be supposed that the manufacturer using high grade materials as nitrate of soda and sulphate of ammonia would furnish organic nitrogen from high grade materials.

A glance at the phosphoric acid constituents shows that both run 10 per cent. available phosphoric acid but No. 1 contains 6 per cent. more phosphoric acid in the soluble form. As soluble phosphoric acid distributes more readily in the soil than reverted phosphoric acid and is more available as plant food, we would naturally prefer Analysis No. 1 from the phosphoric acid standpoint. Glancing at the potash we find that No. 1 carries 2 per cent. as chloride and 7 per cent. as sulphate, while No. 2 shows 8 per cent. as chloride and 1 per cent. as sulphate. For crops like tobacco, potatoes, sugar-beets, oranges, etc., No. 1 would be the most suitable, since these crops do better with sulphate of potash than with muriate of potash. The potash in No. 1 was in all probability derived mostly from sulphate of potash while that in No. 2 came mostly from muriate of potash.

Here is another statement that is used by some chemists in reporting analyses.

CHEMICAL ANALYSIS, No. 3.

	Per cent.
Nitrogen	3.00
Soluble phosphoric acid	7.00
Reverted phosphoric acid.....	3.00
Insoluble phosphoric acid.....	2.00
Available phosphoric acid.....	10.00
Potash.....	9.00

This statement is not so valuable as Nos. 1 and 2 because the forms of nitrogen and potash are not given. The nitrogen may all be from nitrate of soda, or sulphate of ammonia, or organic

sources, or from any two or perhaps be furnished from all of these sources. The potash may be as sulphate, or as chloride, or as carbonate, or as a mixture of any two or three of these forms in any proportion.

Here is still another statement.

CHEMICAL ANALYSIS, NO. 4.

	Per cent.
Nitrogen	4.00
Available phosphoric acid ...	10.00
Potash.....	9.00

This analysis besides *not* furnishing the amounts of the forms of nitrogen and potash does not give the forms of phosphoric acid. Of this 10 per cent. available phosphoric acid all of it may be as soluble, or as reverted. It may contain both soluble and reverted phosphoric acid but in just what amounts we do not know.

The chemical analysis, when the different forms of plant food are reported, may often prove of value to those farmers who can interpret them and who understand the influence of the plant food forms on profitable crop production.

Agricultural Values.—The agricultural value of a fertilizer is represented by the crop produced. The price that is paid for a fertilizer has no bearing on its agricultural value. The agricultural value will vary with the season, the amount of fertilizer used, the nature of the soil, kind of crop, care of the crop, locality, insect damage, plant diseases, and many other conditions. It cannot be estimated and is often beyond the control of man. However, the nature of the materials that make up a fertilizer may influence its agricultural value. Market garden crops will no doubt do better with fertilizers containing plant food in available and soluble forms. For example, available phosphoric acid will give quicker returns than insoluble phosphoric acid. Nitrogen in a soluble form will be taken up more readily than nitrogen in an organic form and some organic forms of nitrogen will be more quickly available than others. In other words fertilizers that give up their plant food slowly will not have a high agricultural value for quick growing crops.

Again, the crop to be raised may have a long growing season. If such is the case it would not pay to use fertilizer whose plant food is all in soluble forms. If the nitrogen is all soluble, as in nitrate of soda and sulphate of ammonia, it may be used up or lost before the crop has finished growing and some slower acting form of nitrogen, as is contained in dried blood, cotton-seed meal, tankage, etc., would no doubt give greater crop returns.

The value of the crop must also be considered, for crops of low market value cannot be expected to give profitable returns with high priced fertilizers. The cost of a fertilizer of low agricultural value may be greater than one that has a high value in producing crops. Farm manures, wood ashes, land plaster, etc., may be comparatively high in price for the amount of plant food they contain or the good they do.

Commercial Values.—The commercial value of a fertilizer is entirely different from the agricultural value. It represents the retail cost of raw materials of standard quality in the market, from which the commercial or trade value of plant food may be calculated. For example, nitrate of soda may be quoted at \$50 a ton. This represents its commercial value. As nitrate of soda contains 15.5 per cent. of nitrogen or 310 pounds of nitrogen in a ton, its nitrogen has a commercial or trade value of a little over 16 cents a pound. An acid phosphate containing 14 per cent. of available phosphoric acid may carry a retail price of \$14 a ton, which is its commercial value. The commercial or trade value of the available phosphoric acid would be 5 cents a pound, since 14 per cent. of available phosphoric acid is equal to 280 pounds of available phosphoric acid in a ton. Or an acid phosphate may be quoted at \$1 per unit. This is its commercial value. This means that the retail cost of 20 pounds of available phosphoric acid is \$1. The commercial or trade value is then 5 cents a pound. The commercial or trade value does not mean that nitrogen at 16 cents a pound will produce 16 cents worth of crops, or available phosphoric acid at 5 cents a pound will produce crops that will bring 5 cents. These constituents may produce crops valued at more or less than 16 and 5 cents respectively, depending upon many conditions as season, locality, kind or crop,

condition of the soil, tillage, etc. The commercial or trade value only serves as a comparison of the relative values of the different forms of plant food in the raw materials. This valuation does not represent the cost of the mixed goods. In the manufacture of fertilizers the cost of mixing, sacking, dryers, manufacturers' profit, long credits, freight, insurance, agents' profits, etc. are all added to this commercial or trade value, so that the farmer pays much more for plant food than is represented in the commercial or trade valuation. But the farmer may purchase the plant food contained in the raw materials (unmixed), for the prices as represented by the commercial or trade values, at those points where the retail prices are quoted. To get the fertilizer to his farm he will of course have to pay freight.

Trade Values.—The Experiment Stations of Connecticut, New York, Rhode Island, Massachusetts, New Jersey and Vermont make out trade values every year for those materials that are most commonly used in the manufacture of mixed fertilizers. These values are arrived at by calculating the prices of fertilizer materials for the six months preceding March 1st, and are obtained from the leading markets of southern New England and the middle northern states.

TRADE VALUES OF FERTILIZING INGREDIENTS IN RAW MATERIALS
AND CHEMICALS FOR 1909.¹

	Cts. per lb.
Nitrogen in nitrates.....	16½
Nitrogen in ammonia salts	17
Organic nitrogen in dry and fine ground fish, blood and meat and in mixed fertilizers	19
Organic nitrogen in fine ground bone and tankage....	19
Organic nitrogen in coarse bone and tankage	14
Phosphoric acid soluble in water.....	4
Phosphoric acid soluble in ammonium citrate	3½
Phosphoric acid in fine ground bone and tankage....	3½
Phosphoric acid in coarse bone and tankage.....	3
Phosphoric acid insoluble (in water and in ammonium citrate) in mixed fertilizers.....	2
Potash as high grade sulphate and in mixtures free from muriate (chloride).....	5
Potash as muriate.....	4¼

Vermont Experiment Station.

How Obtained.—To give an idea of how these trade values are obtained we may presume that the wholesale price of sulphate of ammonia for the six months preceding March 1st averaged \$56.80 per ton, or 14.2 cents a pound for the nitrogen. A certain amount, usually 20 per cent. is added to this wholesale price to cover the cost of handling, insurance, etc., which would raise the price to \$68 per ton, which would be the retail or commercial value of ammonium sulphate. The nitrogen then would be represented as carrying a commercial or trade value of 17 cents a pound. The trade values on all other fertilizer materials are calculated in the same way as described for sulphate of ammonia.

A Discussion of the Table of Trade Values.—A study of the table is interesting. It shows that valuations are given for nitrogen as nitrate, as ammonia and as organic nitrogen. The trade values for organic nitrogen are also different depending upon the source. Soluble phosphoric acid is valued higher than reverted phosphoric acid and there is also a trade value for insoluble phosphoric acid. In some states there is no distinction made between soluble and reverted phosphoric acid in trade valuation and the insoluble phosphoric is often not considered at all. The bone products in the foregoing table are valued on their degree of fineness; the finer bone-meals command higher market prices than those that are coarse as is shown in the trade valuations of nitrogen and phosphoric acid. The potash as sulphate carries a higher trade value than potash as chloride, but this is to be expected because sulphate of potash costs more to manufacture than muriate of potash. There are many fertilizer materials not included in the above table. Those included in the table are high class products commonly used in New England and New Jersey.

How to Calculate the Commercial Value of a Fertilizer.—Let us suppose a chemist analyzes a mixed fertilizer and finds its composition to be as follows:

CHEMICAL ANALYSIS.

	Per cent.
Nitrogen as nitrates	0.50
Nitrogen as ammonia.....	1.30
Nitrogen as organic	2.00
Water soluble phosphoric acid	6.00
Phosphoric acid soluble in ammonium citrate (reverted)	1.80
Phosphoric acid insoluble (in water and ammonium citrate).....	1.50
Potash as sulphate.....	0.40
Potash as chloride.....	3.60

The commercial valuation of the above fertilizer would be obtained by multiplying each ingredient by 20 to change to a ton basis, and multiplying this product by the trade value of each. The sum of these values would be the total commercial value as derived from the raw products.

COMMERCIAL VALUATION.

	Pounds per 100 or per cent.	Pounds per ton	Trade value per lb. cents	Commer- cial value per ton
Nitrate nitrogen.....	$0.50 \times 20 =$	10	$\times 16.5 =$	\$1.65
Ammonia nitrogen	$1.30 \times 20 =$	26	$\times 17 =$	4.42
Organic nitrogen	$2.00 \times 20 =$	40	$\times 19 =$	7.60
Soluble phosphoric acid	$6.00 \times 20 =$	120	$\times 4 =$	4.80
Reverted phosphoric acid	$1.80 \times 20 =$	36	$\times 3.5 =$	1.26
Insoluble phosphoric acid	$1.50 \times 20 =$	30	$\times 2 =$	0.60
Potash as sulphate.....	$0.40 \times 20 =$	8	$\times 5 =$	0.40
Potash as chloride.....	$3.60 \times 20 =$	72	$\times 4.25 =$	3.06
Total commercial value*.....				<u>\$23.79</u>

CHAPTER XIV.

HOME MIXTURES.

Definitions.—When fertilizer materials such as tankage, dried blood, nitrate of soda, sulphate of ammonia, superphosphate, bone meal, muriate of potash, etc., are purchased and mixed at home the process is called home mixing and the product a home mixture. When these fertilizer materials are mixed by the factory the product is called a fertilizer or a mixed fertilizer. Most of the fertilizer materials contain either one or two constituents and only a few carry all three constituents. Most of the mixed fertilizers contain three constituents, namely, nitrogen, phosphoric acid and potash and are called complete fertilizers because they contain the three essential elements. There has been a great deal of discussion as to whether fertilizer materials or mixed fertilizers are the best for the consumer to purchase.

Manufacturer's Claims.—The manufacturers claim that mixed fertilizers are the best for the farmer to purchase because :

1. The factory mixed fertilizers are in a fine mechanical condition. The mixed fertilizers are ground fine and uniformly mixed, which is indeed an important consideration to permit of an even distribution on the land.
2. The mixed fertilizers can generally be purchased in the locality at most any time and in any amount.
3. The mixed fertilizers are specially treated with acid and the constituents in substances like tankage, dry ground fish, etc., are made partially available.
4. The mixed fertilizers are claimed to be made up in such proportions as to satisfy the needs of crops.
5. The manufacturers often allow the farmer some time to settle and often wait until harvest time before getting their money. The credit system is in vogue in the South where enormous quantities of mixed fertilizers are used.

Reasons Why the Farmer Should Mix Fertilizer Materials at Home.—The mixing of fertilizer materials at home is becoming

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more popular among the farmers. Some of the reasons why the farmer should mix his own fertilizer materials follow:

1. Plant food is obtained at a lower price.
2. The farmer knows the materials used.
3. Unnecessary constituents are not purchased.

Mechanical Condition of Factory and Home Mixed Fertilizers.—

The factory mixed fertilizers are usually much better mixed than those that are mixed at home. Fertilizer factories are well equipped with special machinery to insure producing a uniform product that may easily be distributed on the farm. However, the careful farmer may mix his fertilizer materials uniformly enough for all practical purposes.

Mixed Fertilizers More Easily Purchased.—Mixed fertilizers can generally be purchased in the locality and the raw materials must be ordered away from home which of course takes some time. Sometimes certain raw materials are hard to obtain. If the farmer starts early enough, say in the winter, the raw materials can generally be obtained.

Mixed Fertilizers Compounded for the Needs of the Crop.—When a manufacturer makes up his formulas he has to allow for the general existing conditions of soil, climate, and needs of the crop, and he cannot expect to make a particular brand that will suit each farmer's requirements. When he makes up a potato brand he must make a mixture that will suit most of the farmers growing potatoes and he cannot expect to meet every condition of soil.

Manufacturers Often Allow Credit.—On the whole, the credit system is a poor system for the farmer, for when his crop is made he may or may not be ahead financially. Those that live on the credit system are usually a year behind and two or three poor crops results in the loss of the farm. The manufacturers, however, are often too lenient in selling their mixed fertilizers on the credit basis as they often have large losses which take away much of their profit.

Plant Food is Obtained at a Lower Price in Home Mixtures.—The work of the Experiment Stations has proved conclusively

that plant food is obtained at a lower price when the fertilizer materials are purchased and mixed at home than when mixed fertilizers are employed. Of course in using home mixtures, freight on fillers is saved.*

Home Mixing Acquaints the Farmer with the Materials Used.—

When a farmer buys a factory mixed fertilizer he does not always know just the sources of the nitrogen, phosphoric acid and potash. He may desire his potash wholly as sulphate; he may want a part of his nitrogen as nitrate and a part in the organic form from dried blood. When he buys factory mixed fertilizers he has to take the word of the agent or the manufacturer. Most manufacturers are honest men who give what is asked for but when you mix at home you know just the amount and kind of materials you are using. Again, when you mix your own fertilizer materials you deal in the subject "plant food," that is, so much nitrogen, so much available phosphoric acid and so much potash, and you do away with your old bad habit of purchasing fertilizer for a given amount per ton regardless of its plant food value.

Home Mixing Does Away with the Purchase of Unnecessary Constituents.—Manufacturers make many brands of fertilizers but as previously said they cannot make one brand that will suit the requirements of every individual farmer. For example, two farmers in the same locality wish to purchase a mixed fertilizer for their corn. One of these farmers may have applied farm manure or he may have plowed under a leguminous crop, while the other farmer has not supplied his soil with any organic matter and his soil may be poor and in need of humus. The fertilizer agent or merchant in this particular locality is selling a corn fertilizer guaranteed to contain nitrogen, phosphoric acid and potash in stipulated amounts. Is it reasonable to suppose that this one brand of corn fertilizer is the best fertilizer for both soils under the above conditions? The first farmer who has supplied farm manure or plowed under a leguminous crop would be wasting money in purchasing nitrogen, unless a little in the form of nitrate, which may help to give the crop a start. The other farmer would need a fertilizer containing both nitrogen as

nitrate and nitrogen in some desirable organic form to help produce a crop. Again, a farmer may be growing cotton, corn, sugar-cane, etc., on a soil that is very rich in available potash.



Fig. 11.—Corn is a crop that thrives on farm manure.

It would certainly be a waste of money for him to purchase a fertilizer containing potash.

When home mixing is practiced the farmer can purchase those fertilizer materials that supply the needed constituents and in the most desirable forms for the needs of his soil and crop.

How to Purchase Fertilizer Materials—The large consumer should certainly try home mixing and find out its advantages. The small farmer may find it impracticable to purchase other than factory mixed fertilizers. However, several small consumers may often advantageously club together and purchase fertilizer materials in mixed carload lots. Many manufacturers will gladly mix fertilizer materials for the farmer when the order is large enough. Of course the farmer must know just the amounts and kinds of materials he wishes when he orders in this way.

To purchase fertilizer materials to mix at home, it is necessary to start early, say in the early winter, so that they may be mixed before the heavy spring work starts. Quotations should be secured from different parties in the nearest or nearby fertilizer markets. In most large cities bids can be secured. Be ready to pay cash because these raw materials are not usually sold on credit. Buy on the guarantee and if the constituents, nitrogen, phosphoric acid and potash fail to reach their guarantees demand a rebate. This can be easily arranged by making a contract with the manufacturer or broker.

How to Mix Fertilizer Materials at Home.—The fertilizer materials may be mixed in a wagon box, or better, on a tight barn floor, or a floor covered with canvas. Whenever chemicals as nitrate of soda, potash salts, etc. are used, they should be well broken up and rendered as fine as possible. In mixing, the light bulky materials as dried blood, cotton-seed meal, dry ground fish, etc., should be put on the bottom of the floor and on top of these spread the other materials. The materials should be spread evenly and then turned over and over and thoroughly mixed by shoveling. It takes considerable time to mix fertilizer materials so that the mixture is uniform. After the mixing is completed the fertilizers should be bagged and kept in dry storage until ready for use. If the mixture predominates in concentrated salts, some

earth may be incorporated to insure a more even mixture. It should be remembered that the chief advantage of buying factory mixed fertilizers is that they are better mixed and the farmer cannot spend too much time in the process of thoroughly mixing his fertilizer materials.*

How to Calculate Percentages from Known Amounts.—Suppose you want to find out the analysis of a mixture made up of the following:

MIXTURE.

600 lbs. acid phosphate analyzing 14 % available phosphoric acid
 150 lbs. sulphate of ammonia analyzing 20 % nitrogen
 100 lbs. sulphate of potash analyzing 50 % potash.
 ———
 850 lbs. Total.

To find out the number of pounds of available phosphoric acid, nitrogen and potash in the above mixture, make the following multiplication.

6 \times 14 = 84 lbs. available phosphoric acid
 1.5 \times 20 = 30 lbs. nitrogen
 1 \times 50 = 50 lbs. potash,

To calculate the percentages of available phosphoric acid, nitrogen and potash, divide the amounts of the constituents by the total amount of the mixture.

Available phosphoric acid, lbs. $84 \div 850 = 9.88$ % available phosphoric acid
 Nitrogen lbs. $30 \div 850 = 3.53$ % nitrogen
 Potash lbs. $50 \div 850 = 5.88$ % potash.

If percentages are wished when one of the materials contains two constituents, the calculations may be made as follows:

MIXTURE.

200 lbs. dissolved bone analyzing { 15 % available phosphoric acid
 { 2.5 % nitrogen
 100 lbs. nitrate of soda analyzing 18.84 % ammonia
 50 lbs. carbonate of potash analyzing 64.00 % potash.
 ———
 350 lbs. Total.

The dissolved bone superphosphate furnishes two constituents, available phosphoric acid and nitrogen, so we must take these into consideration in our calculations.

We have only 1,703 pounds and not 2,000 pounds the amount desired. To make 2,000 pounds an addition of 297 pounds of some make weight material as sand, earth, gypsum, etc., is necessary.

Supposing we wished to substitute kainit, analyzing 12 per cent. of potash, for the muriate of potash in the above mixture. By calculating as explained above we find that it would require 1,000 pounds of kainit to analyze 6 per cent. of potash. This amount would make our total add up to 2,463 pounds, or 463 pounds more than we wish. This shows that kainit could not be used to supply all of the potash in a 2,000 pound mixture of the above analysis made from such materials. We could however supply one-third of the potash from kainit and two-thirds from muriate of potash.

Potash lbs. from kainit $40 \div 12 \% = 333$ lbs. kainit

Potash lbs. from muriate $80 \div 50 \% = 160$ lbs. muriate of potash.

Assembling the potash salts, acid phosphate and calcium cyanamid we have:

	Pounds
Acid phosphate	875
Calcium cyanamid	588
Kainit	333
Muriate of potash	160
Total	1,956

By using kainit and muriate of potash in the above proportions only 44 pounds of filler would be necessary to add to make 2,000 pounds.*

CHAPTER XV.

A FEW REMARKS ABOUT FERTILIZERS.

Brand and Trade Names.—There are too many farmers who purchase fertilizers on the brand or trade name and not on the plant food these fertilizers contain. The manufacturers are well acquainted with the importance of selling their fertilizers under attractive names. Some of the manufacturers even go so far as to have their brand names copyrighted to prevent their competitors from using them. Some of the older brand or trade names are well known by all the farmers in the locality where they have been sold from year to year and many of these farmers purchase Dixie Cotton Fertilizer, Great Western Wheat Fertilizer, Home Mixture, Standard Special Tobacco Manure, Celebrated Potato Fertilizer, Royal Corn Special, etc., from year to year without ever knowing their plant food content. The name sounds good to these farmers, the fertilizer has a good strong odor, the right color, and with some farmers the proper taste. These are brand and ton farmers and not plant food farmers. These farmers will tell you that their fathers used these same fertilizers.

To show that the name is no indication of the composition and suitability of a fertilizer for a crop, the following data is submitted. In the state of Massachusetts for the year 1909, out of 66 brands sold as potato fertilizers, 46 contained potato as the only crop name, and 20 were sold in conjunction with other crop names as potato, hop, and tobacco; potato and root crop; potato and tobacco; potato and vegetable; corn and potato; potatoes, roots and vegetables; onion and vegetables. Twelve companies put out 2 brands, 5 put out 3 brands, and 3 put out 4 brands. The nitrogen guaranteed varied from 0.80 to 3.71 per cent., the available phosphoric acid from 4 to 9 per cent., and the potash from 2 to 10 per cent. All of these potato fertilizers could not have been the best for the farmer to purchase. The manufacturers evidently cater to the trade and some of them put out 2 to 4 brands so as to be able to sell one of them to the farmer,

the brand depending upon the price the farmer is willing to pay. Many of these fertilizers were high grade but the farmer should consult the plant food guarantee and not the name in selecting fertilizer. Those that were sold for corn and potato, tobacco and potato, vegetables, root crops and potatoes, etc., either do not meet the requirements of these crops, or else the purchaser is wasting money in buying excesses of plant food.

Some manufacturers put out two or three different brands made from the same goods and guaranteed the same. Thus we will find Dixie Cotton Fertilizer and Corn King Guano on the market with the same guarantee bagged from the same pile of goods, and sold for different crops. Sometimes two different brand names are used for the same material to be sold for one crop. For example, Golden Imperial and Special Mixture may be sacked from the same material, carry the same guarantee, and be sold for one crop. The writer has seen two agents, one a merchant and the other a farmer, selling the same fertilizer under different names in the same village. The farmer, who was the least successful in disposing of his lot thought and I guess still thinks that the merchant had a better brand. These fertilizers of course sold for the same price and the merchant sold three times as much as the farmer, because he was a bit more popular and had a better stand. So you see the brand name helps to sell fertilizer. The farmer should buy on the plant food content and not by the name or per ton.

The manufacturers also often sell superphosphates made from rock phosphates under the name of dissolved bone, and mixtures of superphosphates (made from rock) and potash, as dissolved bone and potash. We have learned that dissolved bone contains nitrogen and phosphoric acid and superphosphates made from rock only carry phosphoric acid. So when dissolved bone or a dissolved bone and potash are sold without any nitrogen guaranteed you can rest assured that the material was made from rock. However, the soluble phosphoric acid from rock superphosphates is just as valuable as that from dissolved bone, and the reverted is perhaps about equally valuable from these two phosphates.*

How to Purchase a Fertilizer.—Some time before you intend to purchase your fertilizer write to your Experiment Station or State Board of Agriculture for bulletins on the crops you intend to raise and also for a fertilizer bulletin. These bulletins may be had free of charge. Study these bulletins. In the bulletins on crops you will no doubt learn the plant food requirement, that is, the amounts and kinds of plant food most suitable for the crops you are interested in. The fertilizer bulletin will no doubt acquaint you with some timely suggestions on how to purchase fertilizers and will also give you the names, guarantees, analyses, and valuations of the fertilizers sold in your state. You can in all probability select a fertilizer that will meet your requirements. If any element as nitrogen, phosphoric acid, and potash is not needed, do not waste your money by purchasing a complete fertilizer but select one that contains the constituents you need and in the form or forms you desire. You are now ready to talk business with your merchant or dealer. Find out from him if he has the particular fertilizer you wish. Perhaps he has not it in stock and he will no doubt tell you he has something just as good. If the amount and kind of plant food that you wish is present in the brand that he has, why it is just as good and if not it is not what you want. No doubt the factory for which he is agent puts out a fertilizer of the composition you desire; you can find this out by referring to your fertilizer bulletin. If so, you may be able to get your merchant to order it for you. If his factory has not got it buy from one that has. You have your fertilizer bulletin and you can easily write for your fertilizer and perhaps save the agent's profit.

Study the Guarantee.—You have learned that many of the fertilizer materials as cotton-seed meal, tankage, bone-meal, dry ground fish, etc., do not always contain the same amounts of fertilizer constituents and are quite variable in composition. Therefore do not buy any of these products just because they are so named. Consult the guarantee and find out how much plant food is offered for a certain price.*

Fertilizers Should Reach their Guarantees.—The manufacturers,

as a whole, are endeavoring to do an honest business. In making their mixtures they aim to give a little more plant food than they guarantee, so that the fertilizer will meet the guarantee under reasonable conditions. The bulletins of the different states setting forth the results of fertilizer inspection, show that the majority of the factory mixed fertilizers exceed the guarantee. But sometimes fertilizers fail to reach the guarantee in all constituents. Factory mixed fertilizers often fall below the guarantee in one element but exceed the guarantee in other elements so that the relative value is above the guaranteed value. Of course the manufacturer should furnish the consumer with fertilizer that reaches its guarantee in all elements as the purchaser has a right to expect this. Such variation is often due to poor mechanical mixture as the manufacturer usually puts in enough of the raw materials to exceed the guarantee in all constituents. When a shipment of fertilizer fails to meet its guarantee in one or more elements, and runs above the guarantee in one or more elements, the purchaser should give the manufacturer some consideration and settle on an equitable basis and allow the manufacturer for whatever excess that may be present in any of the elements, within reasonable limits. If the purchaser contracts for a certain amount or amounts of constituents and they fall materially below the guarantee a rebate should be demanded.*

Fertilizers do not Deteriorate Much on Standing.—The mixed fertilizers and the raw materials do not change much when kept in dry storage. The mixed fertilizers are usually compounded from materials that do not attack and set free the nitrogen present. The soluble phosphoric acid may revert and change to insoluble phosphoric but not to any appreciable extent. Therefore should a farmer have some fertilizer left over from a past season he may rest assured that it is still valuable provided it has been kept in a dry place. If fertilizer gets wet from rain or becomes very moist from any cause, there may be considerable losses of plant food.*

• **The Time to Apply Fertilizer.**—Nitrate of soda, sulphate of

ammonia, and calcium nitrate are soluble in water and are not fixed in the soil. They should be applied in small quantities and at the proper time, or when nitrogen is needed, to give the best results. When large applications of these materials are made, some of the nitrogen may be lost by leaching. These fertilizer materials should never be worked into the soil too deeply as they may be lost by leaching before the plant can appropriate them. The organic materials furnishing nitrogen all have to be oxidized and converted into nitrates before they may readily be acquired as plant food. These materials may be applied early enough so that they may be acted upon by the soil organisms and partially decomposed to furnish food for the young plant. The very slowly available organic substances will of course be decomposed more slowly than dried blood, cotton-seed meal, tankage, steamed horn and hoof meal, castor pomace and similar substances. One of the functions of nitrogen is to produce growth. It would be wasteful to apply any nitrogenous substance to hasten maturity. It seems almost unnecessary to make this statement but some farmers use nitrate of soda late in the season to help fill out ears of corn after the crop has been made. If nitrate of soda is added in the middle of the growing period before the ears are formed it will help to produce more vigorous growth. Generally speaking, the nitrogenous fertilizers may be applied in the spring at planting time and during the growing period when needed.

Phosphoric acid is readily fixed in the soil. When soluble phosphoric acid is added from superphosphates, it becomes well distributed in the soil, because of its fine mechanical condition, and changes to insoluble forms which are not apt to be lost by leaching. Superphosphates are very beneficial to young crops and tend to produce strong plants that can better resist the attacks of fungi and insects. Superphosphates may be applied before or during planting time. Raw bone-meal and ground rock phosphate may be applied at most any time because they are slowly available; but other fertilizers carrying phosphoric acid in the available form should be applied just before, or at planting time.

Potash is very quickly fixed in the soil by the double silicates, so that it is difficult to distribute it evenly. Potash may be applied sometime before planting so that the plowing and harrowing may help to mix it with the soil and insure a uniform distribution.

In mixed fertilizers we have found that any combination of fertilizer materials may enter into their composition. There may be nitrate of soda, organic materials, superphosphates, and potash salts present in these fertilizers and so in the application of them we must consider the properties of all the fertilizer materials. It is generally best to apply these fertilizers in the spring. Sometimes an additional application during the growing period will help to force the crop. When much fertilizer is to be applied, especially on sandy soils, part of it may be applied in the spring and part later on when the crop may be backward or need forcing.

Crops like wheat which are sown in the fall need fertilizer at that time and also a light dressing of some nitrogenous fertilizer in the spring to help it recover from the winter. Some of the market garden crops require fertilizer at planting time and at short intervals during the growing period.

How Fertilizers are Applied.—Fertilizers are usually broadcast, partly broadcast and partly in the drill or hill, and in the drill or hill. When heavy applications are applied, broadcasting is perhaps the best method. The fertilizer may be applied after the last plowing and harrowed into the top part of the surface soil with a wheel harrow or some kind of a cultivator. In this way the fertilizer will become well mixed with the soil. If a broadcast distributor is not used, one-half of the fertilizer may be applied by walking north and south and the other half by walking east and west. In this way the fertilizer should be uniformly applied. When home mixtures containing farm manure or fertilizers mixed with manure are used, the manure spreader may be employed to distribute the fertilizer.

Some farmers apply fertilizer partly by broadcasting and partly in the drill or hill. This is an excellent practice for some

crops and on some soils. That which is applied in the drill or hill furnishes plant food during the first growth before the roots are developed and that which is sown broadcast helps the later growth when the roots spread out. In this system of applying fertilizers it is perhaps better to apply most of the fertilizer broadcast. When farm manure is used it may all be spread broadcast and the fertilizer used to supplement it, which is no doubt quick acting, put in the drill or hill. Potatoes, corn and market garden crops are often fertilized in this way.

With small grain, roots and other crops with small root systems, fertilizers are often applied wholly in the drill or hill. Great care should be taken in applying fertilizer in this way to keep the fertilizer away from the seed. Most fertilizers contain some nitrate of soda, potash salts, or other materials that will injure the seed if they come in contact with it. Therefore a little earth should separate the seed from the fertilizer. The fertilizer distributors usually cover the fertilizer sufficiently to protect the seeds. When fertilizer is applied in the hills it should be spread over the place where the hill is to be and not applied all in one place. Earth should be spread over it as in drill application.

When fertilizer is to be applied during the growing season it may be distributed on both sides of the plants to the center of the row and worked in with a cultivator. On many hoed crops this method is used. It is also advisable on light soils that are subject to leaching. On these soils sufficient fertilizer may be applied at planting time to give the crop a start and the remainder during those periods in the growing season when the crop needs nourishment or wishes to be forced for an early market.

When fertilizers are applied to trees and bushes they should be distributed in a circle around the tree; the radius of which is equal to the height of the tree or bush. They should be worked into the soil by shallow cultivation. The feeding roots of many trees are near the surface and extend to quite a distance from the base of the tree so that by applying the fer-

tilizer for some distance from the tree, the roots are better able to assimilate it and the soil organisms which render it available can act upon it more readily.

It is Profitable to Use Fertilizers?—Every farmer should be able to decide this question for himself. The nature of the crop and the condition and fertility of the soil will determine whether fertilizers should be used. If extensive farming is



Fig. 12.—Liberal fertilization is usually profitable when growing truck crops.

practiced and large crops are grown on small areas fertilizers are generally required. Market garden and truck crops generally more than pay for the liberal use of fertilizer. When market garden and truck crops are grown on high priced land large applications of fertilizer are necessary to produce maximum crops to insure profitable returns on the investment. In some sections potatoes, onions, tobacco, oranges, and other crops receiving large amounts of fertilizer give profitable returns.

If the soil is kept in good physical condition the use of fertilizers is more profitable than on soils not properly cared for. On poor soils the use of fertilizers is necessary for crop production, for without them a profitable crop cannot be produced. On farms where a systematic rotation is practiced, and farm manures and green manures are employed, the use of fertilizer to supplement the deficiencies of the soil is usually very profitable, while on farms where one crop farming is continued, the response to fertilizers is not so satisfactory. The farmer can keep his soil in good condition and profit by the use of fertilizers. Fertilizers should not always be blamed for unprofitable returns as the trouble generally rests with the farmer who is careless in his methods. Farmers should spend a great deal of time tilling the soil and not expect the fertilizer to do all the work.

Sometimes fertilizers do not prove profitable because the soil *is acid or too alkaline*. If these conditions are corrected the use of fertilizers is often profitable.

It should be remembered that some fertilizers like raw bone-meal, ground rock phosphate, etc., do not give up all of their plant food during the first season but may help the crops for two or three years and prove profitable in this way.

Amount of Fertilizer to Use.—Enough fertilizer should be used to produce profitable crops. This amount depends upon a great many factors, as the system of farming, the nature of the soil, the crop to be raised and its value, the fertility of the soil, the value of the land, etc. Frequent light applications are usually more profitable than occasional heavy applications. Market garden and truck crops require more fertilizer than the staple crops. From 500 to 2,500 pounds of fertilizer are used for market garden, truck and special crops, and 300 to 1,000 pounds for the staple crops, unless previous experience has shown that more or less than these amounts are necessary and profitable.

The following table shows in pounds per acre the quantities of the elements suggested for use in available form, in fertilizers for the crops indicated.*

Crops	Nitrogen	Phosphorus ²	Potassium ²
Alfalfa.....	5-10	12.5-25	30- 60
Apples.....	8-16	12.5-25	40- 80
Asparagus.....	20-40	12.5-25	30- 60
Barley.....	12-24	8.5-17	20- 40
Beans.....	5-10	12.5-25	30- 60
Beets.....	20-40	10-20	30- 60
Blackberries.....	15-30	12.5-25	30- 60
Buckwheat.....	15-30	12.5-25	30- 60
Cabbage.....	40-80	30-60	75-150
Carrots.....	15-30	15-30	35- 70
Cauliflower.....	40-80	30-60	75-150
Celery.....	40-80	20-40	50-100
Cherries.....	10-20	15-30	35- 70
Clover.....	5-10	12.5-25	30- 60
Corn.....	10-20	15-30	25- 50
Cucumbers.....	30-60	20-40	50-100
Currants.....	10-20	10-20	30- 60
Egg plant.....	40-80	20-40	75-150
Flax.....	10-20	10-20	25- 50
Gooseberries.....	10-20	10-20	30- 60
Grapes.....	8-16	12.5-25	35- 70
Grass for pastures.....	15-30	12.5-25	30- 60
Grass for lawns.....	20-40	10-20	25- 50
Grass for meadows.....	15-30	12.5-25	30- 60
Hops.....	20-40	15-30	80-160
Horse-radish.....	15-30	10-20	30- 60
Lettuce.....	40-80	20-40	60-120
Millet.....	15-30	12.5-25	30- 60
Muskmelons.....	30-60	20-40	50-100
Nursery stock.....	10-20	10-20	25- 50
Oats.....	12-24	8.5-17	25- 50
Onions.....	45-90	25-50	70-140
Parsnips.....	20-40	25-50	40- 80
Peaches.....	15-30	17.5-35	45- 90
Pears.....	8-16	12.5-25	40- 80
Peas.....	5-10	12.5-25	30- 60
Plums.....	10-20	15-30	35- 70
Potatoes.....	30-60	17.5-35	55-110
Pumpkins.....	30-60	20-40	50-100
Quinces.....	8-16	12.5-25	40- 80
Radishes.....	15-30	15-30	35- 70
Raspberries.....	12-24	17.5-35	50-100
Rye.....	12-24	8.5-17	25- 50
Sorghum.....	10-20	15-30	25- 50
Spinach.....	15-30	25-50	35- 70
Squashes.....	30-60	20-40	50-100
Strawberries.....	25-50	25-50	60-120
Tobacco.....	30-60	20-40	60-120
Tomatoes.....	25-50	15-30	30- 60
Turnips.....	20-40	10-20	30- 60
Watermelons.....	30-60	20-40	50-100
Wheat.....	12-24	8.5-17	10- 20

¹ Bul. 169, Kansas Experiment Station.

² To change phosphorus to phosphoric acid, multiply by 2.3, and to convert potassium to potash, multiply by 1.2.

NOTES.

The following notes refer to tables, experiments, statistics, discussions and other interesting data that may be found in Halligan's Soil Fertility and Fertilizers :

- Page 3—A discussion on evidence to show that other plants gather nitrogen from the air.
- Page 5—Distribution of elements in the earth's crust and air ; composition of the air.
- Page 8—Table showing the elements that make up plants.
- Page 9 —The distribution of the mineral elements in plants and a full discussion of the ash in plants.
- Page 11—The per cent. of ash and the mineral elements that constitute the ash are given for several vegetable substances.
- Page 14—Table of the amount of plant food in typical American soils from different states.
- Page 15—Estimates of plant food in soils with yields of crops.
- Page 18—Table of temperatures of different classes of soils.
- Page 18—The average mean monthly range in temperature of the air and soil for twelve years at Lincoln, Nebraska.
- Page 18—Standard measurements of soil particles and mechanical analyses of soils.
- Page 19—Table of chemical and mechanical composition of different types of soils.
- Page 21—Table showing the upward movement of water in different types of soils.
- Page 22—A table showing the number of bacteria found in a gram of soil during some part of the growing period.
- Page 22—Two tables that demonstrate how manure helps nitrification at different periods of the growing season.
- Page 26—Composition of drainage waters from plots of a wheat field.
- Page 26—Table giving the amounts of nitrogen removed by different farm crops.
- Page 27—Data showing the amount of nitrogen lost from bare soils and wheat land ; comments on the same.
- Page 34—Data concerning the effect of a rotation of crops on the humus supply.
- Page 34—Crop rotations practiced in different sections of the United States.
- Page 34—Fertility removed by farm produce ; loss of fertility by exclusive grain farming and stock farming.
- Page 36—Tables showing actual results obtained from different kinds of animals performing different kinds of work on the value of manure.
- Page 36—Composition of straws, leaves and sawdust.

- Page 37—Data given the amount of manure produced by the horse per year, the composition, and the amount of straw necessary to absorb the liquid portion. Also data on the amount of manure produced by the cow and the hog, and the composition of these manures.
- Page 38—The amount of manure produced by the sheep per year, its composition, and the amount of straw necessary to absorb the liquid portion.
- Page 39—Composition of hen, fowl and bat manures; amount of manure produced by different kinds of fowl.
- Page 39—Experiments by feeding steers different feeds, giving the variations in the nitrogen content of the manure produced and the crop returns from these manures. Table and discussion on the commercial value of manure.
- Page 40—Results of experiments on the lasting effects of manure for a period covering many years and the yield of crops from manured and unmanured plots.
- Page 41—Tables and data showing the losses by leaching on horse manure, cow manure, and a mixture of horse and cow manure.
- Page 42—Table of composition of gases in manure heaps and the effect of keeping manure heaps moist.
- Page 45—The percentage of water in unmanured and manured wheat and barley fields, together with considerable discussion on the losses and retention of water in these fields. Also, the effect of manure in dry and wet seasons, on the yield of crops for 51 years.
- Page 50—A description of the process employed in manufacturing cotton-seed meal.
- Page 50—Commercial classification of cotton-seed meal.
- Page 52—A description of rape meal.
- Page 54—Another method used in treating horns and hoofs. The production of fertilizers by packing houses.
- Page 56—Analyses of nitrogenous guanos, with a list of the deposits that have been and are being worked, with comments on guanos.
- Page 57—Composition of bat guanos.
- Page 57—New process for recovery of ammonia from coal. Extent of manufacture of ammonium sulphate.
- Page 57—How to detect adulteration. Table showing percentages of ammonia, pure ammonium sulphate, nitrogen and possible impurities in commercial sulphate of ammonia.
- Page 58—Origin of deposits, amounted exported to date, value of, process of manufacture, and analyses of crystals.
- Page 58—*Effect of continued use of nitrate of soda.*
- Page 59—A full description of the process of manufacture, output and value, and comments on calcium nitrate.
- Page 59—The process of manufacture, composition and comparative experiments with ammonium sulphate are given.

- Page 59—Table of composition of high grade nitrogenous products.
- Page 62—A full description of wool waste, shoddy, etc.
- Page 63—A more complete discussion on garbage tankage.
- Page 64—Vegetation and laboratory experiments with several high and low grade nitrogenous substances. Also a description and discussion of these materials.
- Page 67—Statistics giving the amounts of nitrogenous materials used in manufacturing commercial fertilizers for 1900 and 1905. The total ammonia contained in manufactured fertilizers; nitrogen removed by different farm crops.
- Page 68—Table showing the value of nitrogen in increasing yields for a period of 56 years, with a discussion of the same.
- Page 70—Composition of raw bones.
- Page 71—Composition of good and poor steamed bone-meals.
- Page 71—Composition of raw and steamed bones for comparison.
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- Page 75—Analyses of brown, blue and white rock.
- Page 75—Analyses of Canadian apatite.
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- Page 79—Influence of degree of fineness on value of phosphates, with experimental results.
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- Page 83—Amounts of acid to dissolve phosphates; the reversion of phosphoric acid.
- Page 85—Classification of terms used for available and total phosphoric acid; amount of available phosphoric acid contained in manufactured fertilizers.
- Page 87—Average composition of superphosphates and double superphosphates.
- Page 88—Amounts of phosphates used for manufacturing fertilizers. Phosphoric acid removed by crops.
- Page 89—Experiments showing the fixation of phosphoric acid. Discussion on the absorption of phosphoric acid.

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- Page 91—Composition of muriate of potash and a more complete description of it.
- Page 92—Composition of potassium sulphate and a more complete description of it.
- Page 92—Composition of double sulphate of potash and magnesia.
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- Page 94—Full discussion of the manufacture of this product.
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- Page 114—Output of fertilizer factories, cost of nitrogen, of phosphoric acid, and of potash ; classification of commercial fertilizers.
- Page 116—Discussion of the requirements of fertilizer laws, comparison of the laws, model fertilizer law, comments on model law, tentative definitions of fertilizers and of misbranding and adulteration.
- Page 117—Conversion factors.
- Page 118—A list of one manufacturer's brands with simplified guarantees. Purity of raw materials as a basis of purchase.
- Page 125—Commercial values of tankage and bone. Comments regarding valuations. Valuations show the cost of plant food. Objections to valuations. Points in favor of valuations. Valuations in other states. Chapter on high, medium and low grade fertilizers, including fillers, cost of different grades, the 100 per cent. of fertilizers and other interesting data.
- Page 128—Amount of plant food purchased for \$30 in factory and home mixed fertilizers. Selling prices and valuations. Analyses, cost, and valuations of home mixtures.
- Page 131—A system of rebating when materials fail to reach the guarantee.
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- Page 135—Number of brands sold in Georgia for several years.
- Page 136—Examples of different prices for grades of cotton-seed meal with comment.
- Page 137—Fertilizer recipes or patent formulas with a discussion of the same.
- Page 137—Table showing results on fertilizers kept in storage. Incompatibles in fertilizer mixtures, showing materials that may and may not be mixed together.

Page 142—Chapter giving the requirements of crops classified into staple and special crops; small grains; forage crops; market garden and truck crops; fruits; nuts. Fertilizer formulas for the several crops grown in the United States.

Appendix includes a list of the Experiment Stations; how to collect an exhibit of fertilizer materials; fertilizer constituents in feed stuffs; the number of pounds of a fertilizer required to furnish one pound of any element when the percentage of that element present in the fertilizer is known.

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