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CHEMISTRY.

Composition and Use of Fertilizers

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COMPOSITION AND USE OF FERTILIZERS,

BY G. W. SHAW.

In the history of every state there is a time when the soils begin to indicate exhaustion, and this time marks the beginning of the use of commercial fertilizers. This time has now come to Oregon. That this is true is attested by the increasing use of fertilizers by gardeners, orchardists, etc. as well as by the questions sent to the Station, and asked at Institutes. It is always true that these inquiries start with those who are cultivating small plats of land and are working that land intensively. It is also probably true that these people are securing relatively much greater returns from their lands than those who are cultivating a much larger acreage. Until recently it has been the same with Oregon farmers as with those of the older states in years long past. They had little necessity of a knowledge of Agricultural Chemistry to enable them to obtain remunerative crops, but to-day the soil does not always smile when her back is scratched as she did in years agone. The system of farming that obtained in those days, and in most cases still in vogue, might properly be styled "Extensive Farming," and may do well for a time where land is cheap and abundant. The system—if it *is* a system at all—requires large areas, and there is a prominent idea that it is necessary to cultivate more land to obtain a larger crop. In many instances this has been carried to such an extent, without returning any equivalent to the soil for the valuable plant food which has been constantly dipped out, that the farmer has become literally "land poor." It has brought on a condition unsatisfactory to many farmers, a remedy for which condition cannot be obtained in political reform, or legislative enactment, but in a very radical change in the system of farming. The new system requires concentration, and demands more thorough and better cultivation. In short it is "intensive" instead of "extensive." The intensive system does not necessarily require more labor but requires that the labor now employed be more concentrated, and also an intelligent comprehension by the farmer of his entire business, which is probably more multiform than that of any other calling. The manufacturer who refuses to keep abreast of the times and to adopt the modern intensive system is doomed to failure, and this is no truer of the manufacturer than of the farmer who holds to a like principle.

In the "good old times" the soils were quite abundantly supplied with all the plant food necessary for the crops and the farmer reaped abundant harvests. The time was in the East when it required as little care and thought to raise farm and fruit crops as is now given to such matters by the average farmer of this coast. The farmers in the Eastern States several years ago came to realize the immense robbery they had perpetrated upon their lands, and more recently the horticulturists of the same states have been brought face to face with this fact. An article recently appeared in the "Rural Northwest" from the pen of Prof. W. F. Massey, from which I quote:

"There is no doubt that the many failures in fruit production in the East are largely due to the exhaustion of important elements of plant food in the soil. All farmers realize the importance of keeping up the fertility of the soil for the production of their annual crops of grain and vegetables, but somehow the idea has been prevalent that a tree can take care of itself. Men look at the great trees of the forest and see how they grow and how the soil increases in fertility under their influence, and think that the same should be the result in the growing of fruit trees, while they are carrying off continually, not only the fruit that the orchard produces, but in many cases expect the land also to produce food for their stock. And then when the orchard fails to give the expected fruit, and its decrepit condition makes the trees alike the prey to insects and fungus diseases, they declare that the climate has changed and we can no longer produce crops for that reason. It has really been because they and their fathers have robbed the soil until the needed food for the production of healthy trees and perfect fruit is no longer available."

Recognizing this condition of things it seems important that the farmers of this state should be made acquainted with some of the recognized facts concerning soils and fertilizers, and their relation to plant life and especially the conditions which obtain in our own state. This bulletin aims to give in a brief form some of the more important facts, and will be followed by others dealing with kindred subjects.

FOUNDATION LAWS OF MODERN AGRICULTURE.

(1) "A soil can be termed fertile only when it contains all the materials requisite for the nutrition of plants, in the required quantity, and in the proper form."

(2.) "With every crop, a portion of these ingredients is removed. A part of this portion is again added from the inexhaustible store of the atmosphere; another part, however, is lost forever, if not replaced."

(3.) The fertility of the soil remains unchanged, if all the ingredients of a crop are given back to the land. Such a restitution is affected by manure."

(4.) "The manure produced in the course of husbandry is not sufficient to maintain permanently the fertility of a farm; it lacks the constituents which are annually exported in the shape of grain, hay, milk and live stock."

It is the science of chemistry which has told us what we know of this subject, and it was not till these facts were determined that agriculture became a science. The improvements that have resulted since the foundation of these principles are marvelous.

SOIL AND PLANT FOOD CONSTITUENTS.

In all nature there are now recognized about 70 elementary substances which are known as

ELEMENTS—*A chemical element is such a substance as cannot be separated into more than one kind of matter.* For example, iron, the smallest conceivable portion of which is just as truly iron as the largest mass.

These elements may be chemically combined in a great variety of ways to form an endless number of *compounds*, which may be defined as *substances consisting of two or more elements chemically combined in definite proportions.* The properties of these compounds differ from those of the elements of which they are composed, and from those of one another. These compounds are called *bases* or *acids* according as they possess certain characteristics.

Of the 70 elements only fourteen are considered essential to plant life. These are divided into two classes according as they do or do not form acids

Acid Forming Elements. (Non-metallic.)	*Base-Forming Elements.* (Metallic.)
Oxygen,	Calcium,
Hydrogen,	Potassium,
Carbon.	Sodium.
Nitrogen,	Iron,
Phosphorous,	Magnesium,
Sulfur*	Manganese.
Chlorin*	
Silicon.	

ACIDS.—Now if an *acid forming element* unites with oxygen and hydrogen, or sometimes with hydrogen alone, a substance is formed which is known in chemistry as an *acid.* Thus, nitrogen combined with hydrogen and oxygen forms nitric acid; phosphorous, hydrogen and oxygen from phosphoric acid.

BASES—A *metallic* element combined with oxygen and hydrogen forms a *base*, known as a *hydrate* of that metal. Thus, calcium united with oxygen and hydrogen would be calcium hydrate. Sometimes the term base is applied to the compound of a metal and oxygen.

SALTS.—The two classes of compounds above mentioned are very active in a chemical sense, and having opposite properties they always tend to neutralize each other so that neither acids nor bases are found to any great extent free in nature, but rather in the form of compounds resulting from their combination, such compounds being called *salts.* It would be out of place for us to discuss here the relation existing between acids, bases, and salts further than to say that an acid differs from a salt only in having its hydrogen replaced by a metal, and that every acid has a salt corresponding to it. For example phosphoric acid consists of phosphorous, hydrogen and oxygen: now, if the hydrogen be replaced by calcium, the composition would be phosphorous, calcium, and oxygen, and the compound would be a calcium salt of phosphoric acid.

The subject of soil origin and composition was discussed at length in Bulletin No. 21, and therefore I shall only summarize here.

*This spelling is that which is now recognized by the American Chemical Society and is used in all chemical publications.

First, the soil acts as a mechanical support for plauts. *Second*, the soil furnishes ash constituents to the plant. *Third*, the soil aids in developing the plant by modifying and storing the sun's heat, regulating the food supply and securing other important conditions.

THE OBJECT OF FERTILIZERS OR MANURES.

A rich soil contains an abundant supply of the elements above described and supplies all the necessary plant food. A virgin soil is usually rich, but as soon as the land is brought under cultivation the plant begins to draw from the soil and the materials are not all returned. Sooner or later the land becomes infertile and it is necessary to return a part of the ingredients which have been removed by the plants. Experience has shown that there are but three ingredients which need close attention, viz: phosphorus, potash and nitrogen. Therefore it is only these, together with calcium, oxygen, hydrogen and carbon which will be discussed at this time. The reason for including the four substances last mentioned is that the three critical ingredients may be the better understood.

In worn soils or such as do not give good returns (provided the soils be in good physical condition) it will usually be found that one or all of the first three ingredients mentioned are deficient, or if they are present they are not in an available (soluble) form. In all cases care should be taken to have the soil in a proper physical condition. Here in Oregon this matter is too often neglected; large quatities of wheat and other crops being allowed to drown in the water which should be removed by under-drainage.

To prevent the deterioration of soils is the aim of all modern agriculture. Soil exhaustion, however, is rather a relative term than an absolute one, and usually applies to a certain crop, since a change of crops developes latent soil resources, and upon this fact is based the principle of rotation. Any soil will maintain its fertility so long as the annual depletion is returned in an available form either naturally or artificially, the degree of fertility being dependent upon the minimum quantity of any essential plant food. "*The plant can make no substance out of nothing, or without a sufficient supply of each and every one of all the essential in-ingredients of its composition,*" *It is the object of manures and fertilizers to furnish to any soil a larger supply of the essential food ingredients.*

CLASSIFICATION OF FERTILIZERS.

- FERTILIZERS
  - INDIRECT
    - Lime
    - Gypsum
    - Salt
  - DIRECT
    - *Artificial*
      - Complete
      - Special
    - *Natural*
      - Stable Manure
      - Refuse Matter
      - Green Manures
      - Ashes
      - Muck, Marl, etc.

EXPLANATION OF TERMS.

A *fertilizer*, in general terms, is any substance which added to the soil tends to produce a better growth of plants.

An *indirect fertilizer* is one, which, while it may not furnish to the soil plant food, so acts upon the matter already in the soil as to change more or less of it from an unavailable to an avaible form. A substance is said to be *available* when in a soluble form, although it is probable that no actual solution, in the common acceptance of the term, occurs.*

A *direct fertilizer* is one which is in such a condition that the roots of the plants can take it up readily, or the food material is *available*.

Artificial fertilizers are also called *chemical* or *commerical fertilizers*, and are prepared mixtures sold under trade names, the material of which they are composed being largely the waste products of many industries, and substances found in natural deposits.

Complete fertilizers are such as contain all three of the critical ingredients, nitrogen, potash, and phosphoric acid.

Special fertilizers contain only one or two of the above mentioned ingredients. They are also called *incomplete fertilizers*.

THE ELEMENTS AND THEIR RELATION TO FERTILIZERS.

OXYGEN.—Oxygen is by far the most abundant of all the elements. It forms about one-fifth of the atmosphere, where it exists in a free and uncombined state as a *gas*. It is the vital principle of the air we breathe. It constitutes about one-half of the solid crust of the earth, and eight-ninths of all the water. In these latter forms, it exists in a state of chemical combination with other elements. It combines' chemically with nearly every known element. and is especially important in building up, and destroying all forms of organic matter. In a free state it is an invisible gas, posessing neither taste nor smell. It is called a supporter of combustion, because wöod, and other burning substances, when plunged into it, will burn with increased brilliancy. Chemically considered it is a very active substance. In all forms of burning the oxygen of the air is combining with other elements, the heat being the result of the chemical union,

HYDROGEN is the element, which when chemically combined with oxygen, forms water. It constitutes about one-ninth, by weight, of all water, and enters into the composition of all plant and animals. It is the lightest substance known. Like oxygen, it is an invisible gas, without color, taste, or odor; but unlike oxygen, instead of being a supporter of combustion, it will, itself, burn when brought into contact with a flame. It is seldom, if ever, found in a free, or uncombined state.

HYDROGEN AND OXYGEN AS FERTILIZERS.—These two elements are supplied to plants in the form of water, which is the largest constituent of the growing plant. The plant tissue receives the necessary amount of each element by the separation of the water stored in the plant. There are several ways in which water is related to the fertility of the soil, but as directly related to fertilizers it bears no importont part, except that it should be

*Missouri Bulletin No. 19.

present in as small an amount as possible. When irrigation is practiced the water may fulfill an important office as a fertilizer. Usually the water from rain furnishes all the oxygen and hydrogen that is needed, and much more.

I cannot refrain here from calling attention to the fact that too much water may be nearly, if not quite, as bad for a soil as too little, and this is particularly applicable to certain parts of Oregon. There are immense bodies, of so called "white land," which can be made excellent farming lands, equal to any, by ridding themof the superfluous amount of water by means of tile drainage. It is not only that the plant is likely to die from drowning, but the excess of water prevents the formation of available plant food, and also renders the physical condition of the soil unfit for supporting plant life. If the water does not flow off, it must evaporate at the surface, which tends to cool the soil. A proper system of drainage will not only remove the water, but keep the soil warm by preventing a too rapid surface evaporation; and when the ground is dry will allow a more perfect circulation of air and atmospheric moisture, thereby not only nourishing the plant, but also enabling the oxygen to act upon the latent plant food, rendering it available. This matter of tile drainage is a matter of paramount importance to farmers, and we recommend all to secure and read Bulletin No. 26 of this Station.

CARBON.—The element exists quite abundantly in a free state, and occurs under three forms (1) diamond, (2) graphite, (called black-lead,) (3) charcoal, lamp-black, coal, etc. It is the central element of all animal and vegetable material. There is not a thing endowed with life which does not contain this element. In plants it is combined with oxygen and hydrogen forming starch, sugar, wood fibre, etc. Most products of animal life contain these same elements, but united differently, as casein, fats, fibrin, etc. The element also occurs combined with oxygen alone in the form of a gas called carbon di-oxid, or often carbonic acid gas. Analysis shows that carbon constitutes about one-half of the solid portion of plants consequently it must be an important plant food. But extended experiments have shown that notwithstanding the element is so intimately associated with plants it may be left out of consideration in direct fertilizers for the carbon of the plant is taken from the carbon di-oxid of the atmosphere, which furnishes an inexhaustible supply.

NITROGEN.—This is a colorless, invisible gas without taste or color. It composes about four-fifths of the atmosphere. In addition to occuring in the atmosphere, it is found also in plants and animals. Animals cannot exist when left to breathe nitrogen alone, and yet it is not poisonous. Unlike oxygen and hydrogen, this gas will neither burn, nor will it support combustion. Nitrogen, when chemically combined with hydrogen, forms a gas known as *ammonia*, which is a very interesting compound to the farmer, because it constitutes a very important source of nitrogen as a plant food.

Ammonia exists in the atmosphere in small quantities, being formed when animal and vegetable matter containing nitrogen decomposes. With acids ammonia deports itself much like a metal in that it forms *salts*, which are called *ammonium salts.* Thus, ammonia combines with hydrochloric acid to form *ammonium chlorid*, or *muriate of ammonia*; with sulfuric acid it forms *ammonium sulfate*.

FORMS OF NITROGEN USEFUL TO PLANTS.

There are three forms of nitrogen which are useful to plants:—

(1) Atmospheric nitrogen: (2) nitrogen in ammonium salts: (3) nitrogen in nitrates. Each of these forms is found to be useful to certain kinds of plants. The number of plants that can utilize atmospheric nitrogen is not large. In general terms leguminous plants, such as peas, beans, clover, alfalfa, and the like, can use the uncombined nitrogen. Hence, such plants are frequently spoken of as "nitrogen gatherers." This is one of the reasons why such crops are often used as green manures.

Although some plants have the power to absorb nitrogen both directly and from ammonium salts through the medium of the soil. yet *by far the largest amount of nitrogen is derived from nitrates in the soil.* The nitrates are formed by a process known as *nitrification*, which is brought about by the oxidation of ammonia compounds and of organic matter in soil through the agency of microscopic organisms, bacteria, which exist every where in enormous numbers. The process is favored by warmth and moisture, no action taking place at a temperature below 40° F., nor in very dry soils, nor below 10 inches.

HUMUS A MEASURE OF NITROGEN.

Humus is a term applied to certain organic matter in soi's. It expresses no definite product, but applies rather to the entire product of organic decomposition, or rather an intermediate stage of this decomposition. This process of organic decomposition results in the production of ammonia which combines with certain acids and is absorbed. Thus the humus may be taken as a measure of the nitrogen in a soil.

More or less ammonia escapes into the atmosphere from the organic matter decaying near the surface of the earth. This atmospheric ammonia is brought back to the earth by the rain and dew, which are seldom free from this compound, although the amount is small and variable. The experiments of Sir J. B. Lawes indicate that an average of about 5 lbs. of combined nitrogen per acre is brought to the soil annually by rain and dew, but in ordinary farm districts the supply of nitrogen from this source would probably not amount to a third of the combined nitrogen removed from soil by an average crop of wheat.

Under ordinary agricultural conditions the loss of nitrogen considerably exceeds that of natural supply and finally profitable crops cannot be grown without the use of nitrogenous manure.

REMOVAL OF NITROGEN.

The following table shows the average amount of nitrogen removed from the soil by one ton of several of the leading farm products. In the the same table, for the sake of reference, I have inserted the number of pounds of the other critical ingredients removed and also the value of the fertilizing material which would be required to replace this same matter.

TABLE I.

Showing fertilizing material removed by one ton of some leading crops, and its market value.

NAME.	Potash. lbs.	Phosphoric acid lbs.	Nitrogen. lbs.	Value per ton.
Wheat kernels	11.4	18.8	36.8	$ 8.93
Wheat straw	12.4	5.0	11.0	3.13
Wheat chaff	2.8	3.8	22.0	4.38
Wheat bran	34.6	28.4	49.2	13.16
Oat kernels	9.8	15.2	38.0	8.90
Oat straw	20.2	5.0	16.6	3.88
Oat chaff	20.8	4.0	12.8	3.62
Timothy hay	25.4	15.2	23.6	6.88
Red clover	41.6	11.2	45.4	11.93
Alfalfa	42.2	13.4	49.4	12.87
Seradella	15.6	13.0	54.0	12.23
Corn stover	24.2	0 6	16.6	4.68
Corn kernels	7.4	11.8	33.0	6.75
Cabbage	34.2	15.0	4.8	3.59
Turnips	8.2	2.4	4.4	1.45
Potatoes	5.8	1.4	4.2	1.23
Linseed meal	23.2	28.4	49.2	24.30
Hops	4.0	3.5	50 6	10.52
Hop refuse	2.2	4.0	19.6	4.24
Grapes	10.0	3.0	3.4	1.38
Apples	1.6	0.06	1.2	.33
Pears	3 6	1.0	1.2	.49
Plums	3.4	8.0	8.4	1.91

In addition to the removal of nitrogen from the soil by plants it may be lost in soil water, provided it is combined in the form of nitrates, since soils have little power of fixing them in insoluble combinations. When the soil is covered with a green crop, however, there is little loss since plants absorb the nitrogen very rapidly. The practice of bare fallowing, then, is one which on this account alone is not to be recommended, and especially is this true in a climate which is very moist.

DIRECT NITROGENOUS FERTILIZER MATERIAL.

NITROGENOUS FERTILIZERS
- MINERAL
  - Sodium Nitrate
  - Ammonium Sulfate
  - Guano
- ORGANIC
  - (Origin) *Animal*
    - Dried Blood
    - Meat Scraps
    - Tankage
    - Azotin
    - Dried Fish
    - Ground Fish
    - Wool Waste
    - Horn Dust
  - *Vegetable*
    - Cotton Seed Meal
    - Tobacco

SODIUM NITRATE (*Chili Saltpetre*) occurs in enormous deposits in Peru. The commercial salt contains about 16 per cent actual nitrogen. It is an excellent fertilizer, quick in action, but easily washed out of the soil, and therefore should be applied while the crop is growing, and in small quantities at a time.

AMMONIUM SULFATE, is a waste or, bye-product, from the manufacture of illuminating gas. It contains about 20 per cent nitrogen and is much used in commercial fertilizers.

GUANOS containing nitrogen are now very limited, and practically out of the market.

ANIMAL MATTERS.—These are sufficiently described by their names, with perhaps the exception of tankage and azotin, the former of which is slaughter house refuse, and the latter a preparation of meat and membrane from which the fat has been extracted. All animal matter comes mainly from the slaughter house and fish oil factories. Some fertilizers contain horn, hair, and leather scraps, as a source of nitrogen, but this is not as valuable as most other forms of animal matter.

VEGETABLE MATTER.—But a limited amount of this is employed in fertilizers. The main form used is cotton seed meal, but this cuts a very limited figure in our markets.

POTASSIUM.

POTASSIUM.—This metallic element is never found free in nature, but is a constituent of many natural and artificial fertilizers. It is a soft metal, lighter than water, and possesses a great affinity for oxygen. Plants consume potash in relatively large amounts, yet in some soils the supply is nearly, if not quite, equal to the demand. The supply is mostly from the decomposition of feldspar which contains from 10 to16 per cent.

In the feldspars the potash is united with aluminum and silicon and is not immediately available as plant food, but under the combined action of air, water and frost the feldspars are so changed as to render the potash available. There is little loss of potash in drainage water, since soils are found to have the power of removing it from solutions and storing it in insoluble forms.

Plants vary much in the amount of potash they consume, and experiments show that where it is deficient the plants suffer greatly, the woody portion of plants, and the fleshy part of fruit, being dependent upon the influence of potash compounds.

As a fertilizer it is especially useful to the leafy crops as potatoes, beets, clover, etc., while grain is much less benefited.

POTASH FERTILIZING INGREDIENTS.

Patassium Chlorid	Potassium Sulfate
Kainite	Potassium Nitrate
Wood ashes	Cotton seed hull ashes

POTASSIUM CHLORID (*Muriate of Potash*:)—This furnishes the main supply of potash for most commercial fertilizers. It is obtained from the town of Strassfurt, in Northern Germany, where there is an inexhaustible supply of this and other grades of potash salts. Muriate contains about 50 per cent of actual potash, (K_2O,) from which it will be seen that it is a concentrated form, and really the cheapest per pound of potash, although a high priced product.

POTASSIUM SULFATE (*Sulfate of Potash*,) comes from the same source as the muriate and as found in the fertilizer market contains from 30 to 35 per cent of actual potash. The price is higher than that of the muriate, but on certain crops it is found to act more favorably,

KAINITE.—This is the most common of the German potash salts, and is a mixture of several compounds, chiefly chlorids and sulfates of potash, sodium and magnesium. It is comparatively of low grade containg from 2 to 15 per cent of potash. It cannot be used with impunity since it contains sulfate of magnesia which is deleterious to some germinating seeds.

POTASSIUM NITRATE (*Saltpetre*,) is valuable not only for the potash, but also for the nitrogen it contains. Because of its high price it is very little used for a fertilizer.

WOOD ASHES.—For a cheap potash supply nothing is better than good unleached wood ashes, and it is practically the only American supply for potash. The amount of potash varies with the kind of wood, ranging from 7 to 14 per cent., with a small amount of phosphoric acid in addition. The potash is in the very soluble form of the carbonate. Leached ashes contain much less potash, often not more than 2 per cent. "Good wood ashes which have not been exposed to weather or otherwise wet * * * weigh about 48 lbs. to the bushel and carry about 8 per cent potash besides nearly 2 per cent phosphoric acid." They are worth at least 25 cents per bushel. Our orchardists could use nothing more beneficial for their small fruits and orchards. No farmer should waste the ashes produced on his farm.

PHOSPHOROUS.

PHOSPHOROUS.—In a chemically pure state phosphorous is a soft yellow, waxy solid, and extremely inflammable on account of its great affinity for oxygen. When it burns it simply unites with the oxygen of the air, the compound formed being commonly called *phosphoric acid* and it is this compound which is of such great value to the farmer.

The element never occurs free, but is combined with oxygen and lime. In this form it is known as phosphate of lime. It also occurs as phosphate of magnesia, and also of lime and alumina. These phosphates are only slightly soluble in water, so the quantity in the soil is only removed by the plants as it becomes available.

From a fertilizing standpoint the phosphates are second only to nitrogen in importance, and in particular cases may even exceed that element. The phosphates of fertilizers exist in three forms:—

1st, SOLUBLE PHOSPHATE.

2d., REVERTED "

3d., INSOLUBLE "

THE SOLUBLE FORM does not occur to any extent in nature. It is known under the names *acid phosphate of lime*, and *calcium superphosphate*. The phosphates of this form being soluble in water are of great great value as fertilizers. When a soluble phosphate is added to the soil it gradually changes to a form insoluble in water, which is probably the form known as REVERTED PHOSPHORIC ACID. This is not the ordinary form of insoluble phosphate, for while a reverted phosphate is quite insolule in water, it is readily soluble in dilute acids or solution of salts containing ammonia. The roots of plants contain a small amount of acid which renders them quite capable of using this form of phosphate, hence it is considered nearly as valuable as the soluble form. The *two taken together* constitute what is known as *available phosphoric acid.*

INSOLUBLE PHOSPHORIC ACID (*Calcium Phosphate,*) is so-called because it will not dissolve in water. It is the form in which phosphorous exists in most soils, bones, and rocks, and from which it is yielded to the plants with great difficulty. In this form the phosphates in fertilizers are of the least value to the puchaser. Insoluble phosphates may be converted into the soluble forms by treatment with sulfuric acid, which should be handled with extreme care.

Of the three forms the soluble contains the greatest amount of phosphorous; the reverted form the next greatest supply; and the insoluble form the least. As to the removal of phosphates from the soil, the insoluble form is, of course, not carried away by the soil water; the same is true of the reverted phosphates, but were it not for the fact that the soluble form is very quickly changed to the reverted condition it would doubtless be more or less removed by drainage water.

In general it can be said that soils become deficient in phosphoric acid quicker than in any other ingredient. In the case of basaltic soils there is often a very abundant supply of insoluble phosphates in the form of *apatite* crystals (calcium phosphate.)

BONES.—These are used extensively as a source of phosphoric acid. The usual form on the market is ground bone of various degrees of fineness—the finer the better. Bones are of a double value as they contain not only phosphoric acid, but also potash and nitrogen. They also occur in different conditions as stated below.

Raw Bones (of animals) consist of approximately:

Phosphate of lime	50.00
Carbonate of lime	25.00
Animal matter (containing Nitrogen, 4.00)	25.00
	100.00

Steamed Bones (animal bones which have been steamed to extract a part of the animal matter in the manufacture of glue, etc.) containing approximately:

Phosphate of lime	65.00
Carbonate of lime	20.00
Animal matter (containing nitrogen)	15.00
	100.00

Bone Black—known also as Animal Black and Animal Charcoal, made by heating bones in closed vessels—containing approximately:

Phosphate of lime	60.00
Carbonate of lime	10.00
Charcoal, etc	30.00
	100.00

Bone Ash (made by burning bones) containing approximately:

Phosphate of lime	75.00
Carbonate of lime, etc	25,00
	100.00

Of late there has arisen quite a demand for bones for various industrial uses which has brought about a tendency in some instances to adulterate by the use of coal ashes, oyster shells, etc. Bones form valuable material and even those small amounts which occur about a farm should be husbanded by burying them in the orchard near trees where they will decay. Other ways of utilizing them are by burying them in an ash or manure heap and allowing them to become softened before putting them in the earth.

DISSOLVED BONE (*Bone Superphosphate*) is simply raw bone or bone ash which has been treated with sulfuric acid whereby the phosphoric acid is made more soluble. Fertilizers thus prepared are commercially known as "*superphosphates.*"

ROCK PHOSPHATE (*South Carolina Rock*) is used quite extensively in making superphosphates by treatment with sulfuric acid. Unless the rock has been so treated the phosphoric acid is mostly in the insoluble form.

BASIC OR THOMAS SLAG is now used to some extent. It is a waste product in the manufacture of iron. It is often sold under the name of '*Odorless phosphate.*" It usually contains about 50 per cent of phosphate of lime.

INDIRECT FERTILIZERS.—The most important substance under this head is *Lime in one or more of its forms.* It is the oxygen compound of calcium, *calcium oxid*, which is commonly known as lime. It is probably true that no other single substance has been so much used on land as lime, with the single exception of stable manure. Lime is made by burning limestone, and it is this burned or calcined form which should be used whenever it is deemed necessary. It has a three-fold action as a fertilizer:

First, as a direct source of plant food.

Second, rendering available inert plant food in the soil.

Third, improving the texture of the soil.

While a certain amount of lime is essential to the growth of plants yet experience has shown that as a direct fertilizer it does not fulfill all that might at first be expected, therefore it is classed as an indirect fertilizer. It is in the second action that lime produces the greatest chemical effect. It is a strong base, and therefore tends to neutralize any acidity of the soil, which occurs especially in wet boggy places, rendering the soil "sour." It facilitates nitrification and decomposing certain insoluble salts in the soil.

In many cases it can be used to advantage in improving the texture of soils. This is especially true of the heavy clays, which it tends to pulverize and lighten. Used on peaty or adobe soils, it will tend to decrease the organic matter by causing it to decompose more rapidly. It is in this office that lime could be used in many instances by the Oregon farmers in improving the clays of the Willamette Valley. Tile draining and lime, I am confident, would furnish to the State a large increase of available land. Care, however, should be taken to supply organic matter to such soils after liming or the last state will be worse than the first, for it is a trite and true saying that "Lime enriches the father but impoverishes the son."

Gypsum (*Calcium Sulfate.*)—This substance has been a bone of contention, and disputes have waxed warm and loud as to the cause of its beneficial action, for this it certainly possesses. It is largely used in some parts of the country to encourage the growth of clover. One writer speaks of the use of this substance, commonly called "gypsum," as follows: "There is reason to believe that gypsum causes the decomposition of certain compounds containing potash, whereby it, and some other bases, are made available for the use of crops—the lime taking the place of these in the compound decomposed—the sulfuric acid combining with them to form salts soluble in water. Admitting this to be the action, it tends to impoverish the soils to an extent far greater than is brought about by the use of most other manures."* It has been pretty conclusively proven that a portion, if not all of the above reaction take place in the case of *black* "alkali" soils, spots of which are not of unfrequent occurrence in certain parts of Eastern Oregon. The most profitable use of gypsum would doubtless be in such cases. In California it has been conclusively proven that it is a valuable remedy in such "spots," and when followed by active cultivation, will, in a large measure remedy this very undesirable condition. The use of gypsum together with underdrainage and irrigation if this be possible, and a proper selection of crops will cure in a comparatively short time the most of this hated *black* alkali.

Gypsum can also be used with profit to aid in obtaining a good "stand" of clover on the farms of the Willamette Valley to the cultivation of which crop farmers can profitably give their attention.

The great cost of gypsum at present will not permit its coming into general use, but there may be cases in which its use would doubly repay the expense. It is to be hoped that there are deposits in this State which will soon be opened, and for one who is fortunate enough to discover it in workable quantities, there is a rich harvest in store. It has been reported from Eastern Oregon—the very part of the State in which it could be used to great advantage—and samples of excellent quality have been sent to us for analysis, but so far we have not been able to verify "the find."

Salt, (*Sodium Chlorid.*)—Its application is likely to be useful in a limited number of cases, and with certain crops. It is usually best used in a compost. It has a very destructive action on vegetation if applied in excess, and should be used, if at all, with great care.

Fertilizing Material Produced on the Farm.

It is not our purpose to deal particularly with this topic at this time, but to issue a special bulletin on the subject later, yet there is one phase of the matter which I deem of so great importance that I take occasion to touch upon it now. I refer to the unnecessary waste of valuable material, which, with a little care and forethought, might serve as a valuable fertilizing material. While it is probably impossible to utilize *all* the straw produced on the farm without burning, yet it is equally true that every farmer could use much more than he does, and it should be the policy to use as much as possible. It is a wasteful process to burn, and still more suicidal

*Bulletin No. 19, Ark. Experiment Station.

to sell it from the farm without returning anything to replace it. In burning the straw the valuable element nitrogen is dissipated in the air, while it would serve a valuable office in the soil. If the straw *must* be burned *it should be burned in very small piles instead of in large stacks*, as is so often the case, so that the ash material may not be fused and form *insoluble* silicates, but may furnish as much soluble plant food as possible.

Wheat and oat straw remove from the soil the following amounts of fertilizing material per acre, and the last column of the table gives the value of the straw from an acre of land upon this basis.

TABLE II.

RIND.	Potash in pounds.	Phosphoric acid in lbs.	Nitrogen in pounds.	Value.
Wheat straw	31.62	12.75	28.05	$7.29
Oat straw	22.22	5.50	13.86	$3.91

Therefore reckoned at the market price of nitrogen in the commercial forms it would cost to replace the nitrogen lost by burning the straw produced on one acre of ground $5.61, while it is a frequent occurrence to sell this same amount for not more than $2.00. Farmers of the east have paid for this by experience dearly bought, and the time is not far distant, when the farmer of this coast will realize its truth. Relative to this same matter I quote from Mo. Experiment Station Bulletin No. 19.

TABLE III.

Showing the value of plant food (phosphoric acid, potash and nitrogen) removed from one acre.

Wheat, kernels	$ 6.00	Timothy	$12.57
" straw	7.29		
	$13.24	Clover	$26.98
Oats, kernels	$ 3.81	Alfalfa	$23.17
" straw	3.62		
	$ 7.73	Potatoes	$ 7.07
Corn. kernels	$11.94	Carrots	$ 4.52
" cobs and husks	.96		
Stalks	$ 6.40	Cabbage	$18.35
	$19.30		

"To take care, therefore, of straw and other vegetable refuse and return it to the land in a proper manner, is a matter of great importance; to sell timothy, clover, and alfalfa as such, rather than to feed it and sell it as flesh or milk, is bad policy and self-destruction. To value a crop simply by its market price, is crude and unscientific. The price which the farmer pays for it, is not only its cost of production, but in addition to it, its manurial value, which we have often neglected, and which the conditions of the case begin now to force upon us for serious consideration."

CONDITION OF OUR FERTILIZER MARKET.

While there is not a large consumption of fertilizers in this State, as compared with other states, yet the demand is on the increase and the business will always be an increasing one. The fact that there are large orchards planted in our state is one reason why the fertilizer question will be brought forward soon, and will be a question of importance to the state. This is true because the wear to which the soil will be subjected is one-sided and will be continuous. At present there is no law of any force bearing on the sale of fertilizers in this state, and therefore there is no way the farmer may know what he is purchasing, except to rely on the honesty of the dealer. It is also true that there is no material which offers a greater opportunity for adulteration than these same fertilizers. While the Station has made analyses of most of the fertilizers offered for sale in the state yet *it cannot guarantee that the analysis printed in the table below represents each lot sold*, for the samples sent by manufacturers prove little or nothing, except for that individual sample, so that although the analyses are published under the name of the fertilizer, we cannot guarantee that another sample would give the same analysis or even approximating the same.

Still we have no reason to question the integrity of any dealer in this State. *Be it remembered, however, that the figures given in this bulletin are not in any sense to be taken as representing anything beyond the individual sample analysed.*

The *State should have enacted an adequate fertilizer law* in justice not only to the farmer, but to the manufacturers themselves, which would compel the manufacturers to make their standard, and thereafter hold to that standard. This is done in other states and should be done here.

At present the purchaser should be very careful to deal with reputable firms who are willing to *guarantee* a certain amount of fertilizing ingredients.

We publish below, without comment, a statement of the results of the analysis of certain fertilizers found in the Oregon market.

TABLE IV.

Showing analysis of fertilizers sold in Oregon.

Laborato'y No.	NAME OF FERTILIZER.	Moisture.	PHOSPHORIC ACID.					Nitrogen.	Equivalent to Ammonia.	Potash.	Value per ton.
			Soluble.	Reverted.	Insoluble.	Total.	Available.				
431	Complete Fertilizer for light Soil	6 64	2.78	2 65	8.19	13.62	5.43	2.65	3.21	3.49	$29.80
432	Webfoot Hop Grower	8.67	2.15	8.23	2.94	13.32	10.38	2.06	2.50	4.07	33.34
433	Dried Blood	12.72						8.90	10.80		35.80
434	Muriate of Potash		.50				.50				55.00
435	Webfoot Potato Grower	6.03	4.90	3.11	8.11	16.16	8.05	3.25	3.98	2.33	34.10
436	Sodium Nitrate							8.08	10.68		35.80
437	Kainite		.19								20.80
438	Fruit and Vine Posphate	6.19	2.70	6.23	7.07	16.00	8.93	2.38	2.90	2.91	32.14
439	Vegetable Fertilizer	12.20	3.36	3.61	2.99	9.96	6.97	2.62	3.18	1.80	31.44
440	Fruit Fertilizer	15.79	5.60	5.14	4.10	14.84	10.74	2.34	2.84	2.19	32.48
441	Webfoot Potato Grower	7.11	2.55	3.73	1.21	7.49	6.28	2.20	2.67	4.65	25.32
442	Webfoot Orange Grower	8.05	2.84	2.82	3.61	9.27	5.66	2.46	2.99	6.40	28.66
443	Webfoot Complete Fertilizer	8.07	2.20	5.20	5.04	12.74	7.70	2.76	3 55	2.91	31.24
444	Complete Fertilizer for Light Soil	5.88	4.05	3.34	0.75	8.16	7.41	2.31	2.80	7.37	31.88
445	Webfoot Hop Grower	4.68	6.99	1.08	4.92	12.99	8.07	3.46	4 20	6.21	39.02
446	Webfoot Vine Grower	7.30	4.60	2.43	3.20	10.23	7.03	4.85	5.89	5.24	40,62
448	Mineral Fertilizer	.97	5.20	4.02	3.16	12.38	9.22	.65	.79	1.90	18.00
468	Fish Guano	9.91	2.41	1.00	2.60	6.01	3,41	5.49	6 65	3.32	32.96
466	Bone Meal Fertilizer	7.21	3.15	2.09	2 91	8.15	5.24	1.79	2.17		17.81
470	Odorless Phosphate	9.60	1.86	1.86	12.68	16.40	3.72				13.92
471	Grain Fertilizer	7.57	2.03	.84	3.63	6.50	2.87	1.84	2.23	2.34	17.99

THE CHEMICAL VALUE OF A FERTILIZER.

Each of the three essential ingredients of a fertilizer has a commercial value, and the worth of any given ingredient may be stated in dollars and cents. These values are estimated from the essential ingredients in the fertilizer, and they express the *commercial value* based upon what the ingredient would cost in the open market The values do not pretend to express the agricultural value, which would of course be represented by the profit they would give the user, which would be a very variable quantity. The price upon which these values are based are as follows:

Available Phosphoric acid, per pound	8½	cents.
Insoluble " " " "	3	"
Potash from Muriate	5½	"
Potash from Sulfate	7	"
Nitrogen	20	"

The total cost of a ton of fertilizer (to the consumer) is made up of three elements: 1st the cost of material mixed; 2d. the cost of mixing; 3d. the cost of transportation, storage, etc., but the valuation takes into account only the first of these elements.

To figure the commercial value of a fertilizer, multiply the price of each ingredient by the number representing its per cent in the fertilizer, add together these results and the sum will represent the value in cents of the fertilizing material in 100 lbs. of fertilizer. Multiply the sum by 20 and the product will be the value in cents of one ton of the fertilizer.

Example:—A fertilizer was found to contain 7 per cent available phosphoric acid; 3 per cent nitrogen; and 4 per cent potash.

(1) Phosphoric acid	7x8½	59.5
(2) Nitrogen	3x20	60.0
(3) Potash	4x5½	22.0
(4) Value of 100 pounds		141.5

(5) Value of 2000 lbs, one ton, 141.5x20=2830 cents, or $28.30, to which should be added about $3.00 for bagging, etc.

In some cases there is a guaranteed amount of *ammonia* instead of nitrogen, in which case the number representing the ammonia should be multipled by the decimal, .8235 before applying the above calculation. Again, the amount of *potassium chlorid* (or *muriate*) may be guaranteed instead of actual potash. In such a case the amount of the chlorid should be first multiplied by .6318 to obtain the actual potash. To convert from the sulfate to actual potash it is necessary to multiply by .5404.

The Needs of Oregon Soils.

In the first place let it be remembered that the value of a *mere chemical analysis* of a soil is at most doubtful. An analysis of a soil reveals what and how much of a given ingredient is present in a soil but *it does not show* how much of the plant food is available. There is, however, more or less value attached to investigations of so-called "virgin soil," and an accumulated number of analyses on this class of soils gives very valuable data upon which to base a judgement of probable success or failure. This matter has been more fully discussed in Bulletin No. 21, to which the reader is referred. In all cases chemical analysis should be followed by careful field tests, and in this way any one may become familiar with the individual needs of his soil. Experiments in the field have been very limited in this State, yet based upon the ordinary methods of judging deficiency of plant food in soils, chemical analysis of a large number of soils seems to indicate a limited amount of potash in the Willamette Valley soils, and this would doubtless be the first ingredient needed on the lowland, and the higher land seems to point toward a need of phosphoric acid. These results must however, be taken as only indicative, although these chemical results have been verified in instances where the experiment has been tried. The loams of Clackamas county have shown a good supply of potash, and a number of Lane county soils have shown a high content of phosphoric acid.

There is a common idea abroad that our soils are deficient in lime, yet the analysis of a large number of soils has not shown that to be true. The soils of the Willamette Valley possesses in nearly all instances a fair amount of lime and on passing into Eastern Oregon the lime content is nearly doubled. In general potash is to be the first element to be suspected as being deficient on the lowlands of the Willamette Valley and phosphoric acid on the uplands. It should also be said that the uplands are not in *all* cases well supplied with nitrogen, which is very essential to fruit production. The red hill lands possess a great power to absorb this element and ammonia and are naturally excellent fruit lands, yet when the fruit begins to shrink in size this element should be supplied. On the lower lands there is a greater supply of humus which is a very fair measure of nitrogen and when these soils are well drained they are likely to possess great capacity for production if potash is supplied. The conditions are so varied however, that, in order for any farmer or gardener to decide *positively* what kind of fertilizer will be best for him to use, it will be necessary for him to do some special experimenting. It is not best in all cases to select a complete fertilizer for often a portion of the material is not needed at all and the farmer may be "*carrying coal to Newcastle.*"

There is one thing that should be said relative to many of the valley lands. viz: that for lasting benefit in increased return and ease of handling careful attention would best be given to the physical condition by proper tile draining before turning attention to fertilizers, for in many instances the improvment of these conditions will be all that is necessary for some time to come.

Of the soils of Eastern Oregon but a limited number of analyses have been made, but acting upon experience in other states having similar climatic conditions and taking into account the origin of the soils of that part of the state we can say that the basaltic rocks would naturally produce a soil well supplied with phosphoric acid, and from this reason it will doubtless be found that when the soils fail it will be rather on the side of potash than phosphoric acid.

We trust that the matters discussed in these pages will prove of benefit to the farmer in not only paving the way for a better understanding of the principles of agricultural chemistry, but also in calling attention to some sources of waste in the economy of the farm. For reference we insert some tables which will prove of value to those who consult them with an earnest desire to understand the more modern practice of agriculture.

TABLE V.

Compiled Analyses of Commercial Fertilizing Material.

SUBSTANCE	Moisture	Nitrogen	Potash	Phosphoric Acid			Value per ton
				Available	Insoluble	Total	
Materials containing phosphates.							
Apatite						36.08	$14.43
Bone ash	7.00					35.89	14.35
Bone black	4.60					28.28	11.31
Bone black (dissolved)				16.70	0.30	17.00	21.84
Bone meal	7.47	4.12		8.28	15.22	23.50	40.56
Bone meal (dissolved)		2.60		13.53	4.07	17.60	30.27
Peruvian guano	14.81	7.85	2.61	8.36	6.90	15.26	39.21
S. Carolina rock, ground	1.50			0.60	27.43	28.03	11.69
S. " " dissolved				11.60	3.60	15.20	16.52
Basic Slag						21.37	8.55
Material containing potassium.							
Carnallite			13.68				12.31
Kainite	3.20		13.54				29.92
Muriate of potash	2.00		52.46				47.20
Nitrate of potash	1.93	13.09	45.19				81.25
Spent tan bark ashes	6.31		2.04			1.61	3.85
Sulfate of potash	1.25		38.60				42.46
Wood ashes, unleached	12.00		5.50			1.85	7.90
" " leached			1.10			1.40	2.61
Material containing nitrogen.							
Azotin	5.88	11.33				3.43	43.09
Cotton seed meal	6.80	6.66	1.62			1.45	25.20
Dried blood	12.50	10.52				1.91	38.73
Dried fish	12.75	7.25	0.45	3.05	5.20	8.25	34.12
Horn and hoof waste	10.17	13.25				1.83	20.38
Meat scrap	12.09	10.44				2.07	38.61
Nitrate of soda		16.47					51.05
Sulfate of ammonia	1.00	20.50					69.70
Tankage	13.20	6.82		5.02	6.23	11.25	31.71
Wool waste	9.27	5.64	1.30			0.29	9.62