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FERTILIZERS:

THEIR

Source, Purchase and Use

BY

CARROLL B. SMITH

SECOND EDITION

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This illustration is from a photograph of the root system of an orange tree exposed by a flood washing the soil away. It shows the tendency of roots under the present methods of irrigation and cultivation, to develop near the surface. Those in the background of the picture still cling to the soil in their natural positions, while those in the foreground fell when the soil was removed.

FERTILIZERS:

Their

Source, Purchase, and Use

Written for the Use of Farmers and Fruit Growers, With Special Reference to Citrus Culture. :: ::

By

CARROLL B. SMITH

SECOND EDITION

Revised and Enlarged

REDLANDS, CALIFORNIA:
CITROGRAPH BOOK PRESS
1911

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TO THE READER.

This work is designed expressly for those who are forced to use fertilizers and yet have not the time to investigate the subject as they would like to. It is intended to be brief and suggestive of thought to the reader rather than complete and final.

Technicalities are avoided and illustrations simplified as much as possible.

All the facts and deductions contained are based on the highest authorities on the subjects mentioned, and largely on the results of actual experience in California.

The author hopes that the matter here given will aid the farmer to choose and purchase his fertilizers most wisely, and help him to get the best possible results from their use. There is no final authority in Nature. Every farmer's problems are his own and he must do his own thinking. The author has tried to present only the well established facts and general PRINCIPLES. A fuller knowledge of these, properly applied, will lead to better results and larger profits.

CARROLL B. SMITH.

Redlands, California.

579459

NOTE: This book has cross references throughout; that is, when a number in parenthesis follows a sentence or paragraph it refers to some other paragraph or sentence having the same number, and treating of the same subject. Any phase of the Fertilizer question can thus be followed throughout the book.

FERTILIZERS:

Their Source, Purchase and Use

SOMETHING ABOUT PLANTS.

CIRCULATION.

1. The higher plants (Fruit and Forest trees) have a well defined circulatory system. Beginning with the absorption by the root hairs of soil moisture, containing dissolved plant food, one set of tissue termed xylem carries this moisture or sap upward into the leaves and is there lost. In the leaf the sap is transformed or elaborated largely by sunlight, according to the plant's nature and needs, and returned to the branches and trunk of the tree and its fruit, by another distinct set of tissue termed phloem. Both these sets of tissue are, roughly speaking, found in the "Cambium" or sap layer of the bark. They are between the real bark and the wood of the tree. Wood is built up on one side and bark on the other. In a cross section of a limb or trunk of a tree these different tissues might be illustrated, as in Fig. 1.

The life of the tree is in the cambium. When we bud or graft it is cambium layer contact we want in both stock and scion. If the cambium is severed completely around the tree it dies. All of the soil derived plant foods enter the tree through its xylem tissue, found in the cambium layer.

RESPIRATION.

2. Plants have a respiratory system. They absorb oxygen and give off carbonic acid, mostly at night, but during the day more oxygen is given off and carbonic acid absorbed. The leaves and some of the green bark are the respiratory system. Carbon and oxygen thus enter the plant directly from the air as well as by water from the roots.

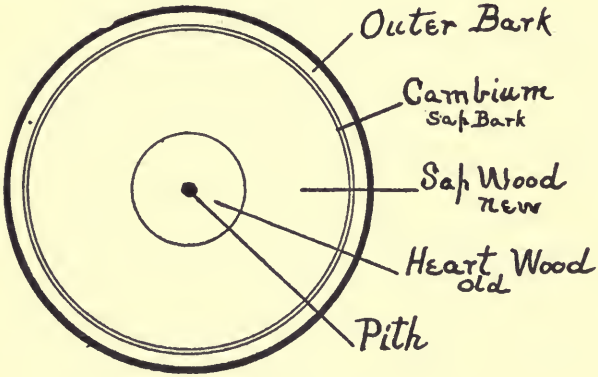

FIGURE 1

TRANSPIRATION.

3. Plants give off water (Transpiration) at all times of day and night. The water escapes at certain pores, called Stomata, of the leaf contained also in very young bark. Water carries the plant food into the plant by way of the roots. The plant foods, changed and elaborated, are retained in the tissue as new growth while the water passes off through the leaves as a vapor. When transpiration exceeds the supply from the roots the plant wilts. If the air is saturated with moisture, plants give off less, but

on hot days give off more. The leaves of fruit trees may be made large or small by an adequate or inadequate supply of moisture. The larger and healthier the leaves, the more plant food is elaborated and the better the growth and the crop. So the transpiration system and its healthy activities are very directly connected with the production of fruit.

4. Any serious or prolonged check to the process of transpiration necessitates a long time for full recovery, frequently several years. A severe wilting will show for a year, but a slight wilting usually fully recovers after watering. Thus the importance of a regular and sufficient supply of water is evident.

Water is the common carrier of all the plant's food, whether the food is derived from the air or from the soil (13), the only positively known exceptions being the absorption of carbon and oxygen by respiration.

The whole movement of water from the root hairs to the leaf and back to other parts of the plant and fruit, is confined to the cambium layer in which are contained the xylem (upward flow) and phloem (downward flow) tissue.

LEAVES.

5. A good leaf is essential to the best results. Leaves put the plant in communication with sunlight, under which influence sap is changed and many products, incident and essential to growth, are manufactured. It is believed that all of the plant food brought into the tree by water, undergoes some change in the leaf (digestion) before it is finally added to the various tissue of the plant. If the leaf has been stunted or impaired by drought, frost or fire, it manufactures less of the products essential

to growth. Less water can come into it; therefore, less water and less food enter the plant. Less sunlight can act on it, and all of the activities of the plant are so reduced that the result is a small crop of undersized fruit. Consequently, a good leaf is essential to the best results.

BARK.

6. What has been said of the function of leaves is true, to some extent, of green bark. Old, corky bark may be regarded as the armor or shield to the cambium layer. But young, tender bark can carry on the process of respiration of carbon and oxygen, and of transpiration of moisture, and to that extent the transformation of the sap and plant food. Although these activities in bark are very limited, they are sufficient to continue the life of the tree should it ever become defoliated for purposes of transplanting or on account of disease or frost. Under the young bark's continued activity new leaves may start, until finally the plant renews its full health and vigor.

ROOTS.

7. The distribution of plant food throughout the soil influences directly, and, with water, the entire development of the root. The absorptive power of the root is in the young, tender rootlets or fibres, by means of root hairs invisible to the eye. These root hairs are distributed along the length of the tender, growing fibre. The end of the fibre has a cap which protects it as it develops and crowds its way between the smallest soil particles. The very tips of roots and fibres cannot absorb moisture or food.

FIBROUS ROOTS.

8. If the soil is poor, the roots are very long and develop very few fibres and root hairs. But in a rich soil they are short and well branched, often forming a perfect mat of fibres. Under such fertile conditions the root hairs are more numerous and the plant's contact with the soil and its feeding powers are much greater. Consequently, roots develop where the food is. Fertilizers should be applied as deep as possible, so that root development will not be encouraged near the surface. (63) (79).

SHALLOW WORK.

9. If the application of fertilizers and water is limited to the top foot the most of the fibres are developed there, and deep ploughing and cultivation become questionable policy. Thick water conserving mulch becomes impossible. (see frontispiece). This is the actual condition where impervious strata or "hard pan" lies near the surface.

DEEP WORK.

10. In open, deep soils where water can go down easily, the plant food is more widely distributed and likewise the fibrous roots. Here, deep work and a deep mulch are possible, and in case of water shortage, would be found a great advantage, as there is a better reserve supply in the sub-soil.

APPLY FERTILIZER DEEPLY.

11. Present practice applies all fertilizer between the surface and the bottom of the plow furrow. This is unavoidable, even in open soils where the water is easily absorbed. Methods of effecting

deeper applications without serious root disturbance are unknown. As a result roots are encouraged near the surface, and this fact is the best argument advanced for the use of the most water soluble forms of fertilizer obtainable, as they are more widely distributed by the movement of water. (77) (79).

SOILS AND ROOTS.

12. The permeable character of the soil influences the root development, aside from the question of plant food. In clay or adobe soils there is a limited root development and a resultant smaller tree. "Hard pans" near the surface have the same limiting influence. In such soils, more trees can be planted to the acre.

Open, free loams or gravelly, sandy loams permit a larger root development and trees should be placed further apart. These are usually local questions, but should be considered by the intending planter. The mechanical or physical nature of the soil should be known to a considerable depth. (20-22).

SOMETHING ABOUT SOILS.

13. Of more than seventy elements known to chemistry, fourteen have been found to be essential to plant life. Ten of these are soil derived, and four are derived from the air:

Air Derived.	*Soil Derived.*
Carbon	Calcium
Oxygen	Silicon
Hydrogen	Iron
Nitrogen	Magnesium
	Manganese
	Sulphur
	Chlorine
	Sodium
	Potassium
	Phosphorus

These fourteen elements, in varying portions, are peculiar to all plants so far as different species have been examined.

14. All soils, for convenience, may be considered as composed of various portions of:

Rock Powder Silt		Sand
Clay	or simply	Clay
Humus Plant food		Humus

Sand is rock powder and may or may not contain silt. Clay is a chemical compound and a very important element of soils, as it retains large amounts of moisture. If too abundant, the soil is intractable

and hard to manage, and bakes easily and while sand alone is too porous to retain moisture, the addition of a little clay with sand makes the proper balance for retaining moisture and for friability.

15. Humus, decayed organic matter, is absolutely essential as it is the source of the necessary nitrogen. It is a fundamental truth in connection with this subject that there is no fertility without humus. It also influences favorably, as nothing else will, the soil's mechanical condition and moisture content, besides supplying essential plant foods.

The humus which plants contribute to the soil not only furnishes all of the soil nitrogen, except that artificially added, but gives life to numerous forms of bacterial life, with which every healthy soil is teeming. We cannot discuss this subject here (86-89), but it will suffice to say that, without the contribution made by plants to the soil, the microscopic forms of life could not exist and they are now regarded as essential to fertility. Indeed, it is possible to inoculate soils with beneficial bacteria, and improve their fertility.

A soil may contain sand, clay and humus and yet lack some essential plant food, hence the last division. But as a rule, sand, clay and humus in proper proportions will, for a time at least, supply all the requirements of plant life.

The plant requires of the soil that it furnish the ten named soil derived elements, and the soil requires of the plant that it supply humus and such of the air derived elements as are necessary to its own health and fertility. Just what amounts of hydrogen, oxygen, carbon and nitrogen are absorbed

directly from the air, and how much is contributed by plant life, is not known. But it is generally believed that most of these elements as found in soils are derived from plants, either through the agency of beneficial bacteria or from the decay of vegetable tissue.

16. The character of vegetation changes with the soil. Pure clay soils support very little plant life, as there is no drainage, no ventilation and no yielding to root penetration. The right degree of porosity, due to the presence of sand and humus, allows the roots to enlarge rapidly which in turn nourishes a large plant. Hence the same species of plants will vary in size and appearance according as the nature of the soil encourages or restricts their growth. A well developed root means a well developed plant and vice versa.

If potassium or sodium or chlorine are in excess, the soil is alkaline and tolerated by certain classes of plants like the salt bushes, some of the mallows, tussock grass, etc.

Peat lands, bogs and meadows have a characteristic vegetation. Peat may contain as high as 80% humus or decayed organic matter. Here, nitrogen is naturally in excess and moisture plenty, so that the growth is vigorous and succulent. Tall grasses, and willows thrive here.

The well drained "mesa" of the arid west, supports another variety of vegetation and a dense forest cover or leaf mould, still another, according to their moisture holding powers. The various combinations of sand, clay, humus and plant food are almost infinite.

17. Soils vary in chemical composition according to depth. The surface foot or two feet usually contains the bulk of the nitrogen, due to the fact that the nitrates are water soluble and the evaporation of moisture at the surface leaves the nitrates and all soluble plant foods there for the benefit of young plants whose roots have not gone deep. Young plants must grow first, and nitrogen produces growth. As the plant matures, its roots penetrate lower into the region where the nitrogen is scarce and where the phosphates, silicon, lime and insoluble elements are more evenly distributed. There, fruit production and maturing of tissue take place.

During the time growth is vigorous, fruit production is limited or impossible even in the case of mature trees when artificially forced to an abnormally vigorous growth.

18. While nitrogen is the chief element of growth, other elements of the soil favor fruit production. Phosphorus is definitely known to be one of these. (70). If the fruit producing elements of the soil were abundant on the surface, and nitrogen, relatively deficient there, then fruit trees would be heavily laden before they were taken from the nursery. There is abundant evidence of order and design in the methods of nature. "First the blade, then the ear, then the full corn on the ear," and the soil is so arranged as to effect the order.

19. It is interesting to note briefly that the function of potassium is to mature the growth that nitrogen produces. Where nitrogen is in excess of potassium, as in bogs and peat lands, the growth is soft and watery, whereas if potash is abundant and

the nitrogen supply less, the growth is hard and firm. As illustration: note the strength of chaparral wood, compared with marsh land growth. Nitrogen is deficient (comparatively) where the chaparral grows and the mineral or soil derived elements, including potassium, relatively abundant. In a word, potassium gives starch or stiffness to the plant. Young peppers, acacias and eucalyptus trees bend frequently to the ground because their roots are in the surface soil, feeding on the excess of nitrogen and water. Older trees with deeper roots have not this tendency. (71).

Sulphur, iron, calcium and silicon also perform special parts in the building of plant tissue, but a discussion of these would extend our subject unnecessarily; They are not "essential" plant foods. (23).

PHYSICAL CONDITIONS.

20. In California the mechanical or physical condition of the soil is of greater importance than the chemical composition. Especially is this true of citrus culture, where irrigation and cultivation are so frequent and thorough. The first sign of trouble is usually a slight yellow color of the foliage and is usually traceable to loss of humus and its consequent nitrogen. Yet the cause may be due to the roots entering a "hard pan" or coarse gravelly strata, less favorable to growth. (99). In any event the soil's mechanical condition should be known to a depth of at least five feet, and deeper if possible. The loss of humus so changes the soil's condition that the trees cannot derive the benefit of the water, the cultivation or the labor gives to it, and the first sign is the loss of the healthy green color.

Applications of nitrate are helpful but not lasting unless applied in organic forms, capable of making humus. (86) (96).

DRAINAGE.

21. Citrus soils must be well drained. The top soil may be free from gravel for a considerable depth as long as it does not hold free water. The "mesa" or "bench" soils of California, usually situated near the foot hills, are ideal in this regard. Figure 2 is a photograph of a stream bank, running through a "mesa." The top soil, free from rock, is here about 5 feet deep, below which there is excellent drainage.

HARD PANS.

22. Occasionally the best situation and soil for fruit culture is underlaid at a few feet with an impervious strata, so that orchards soon show lack of vigor. These "hard pans" may be at the very surface or at any depth below. Blasting with powder or dynamite to break up the fixed condition is effective, but must be repeated from time to time. Perhaps the best remedy where water is sufficient, is to prepare it long before planting trees, by raising a one or two year old stand of alfalfa, the roots of which penetrate hard soils to a considerable depth. Though the orchard is already established, alfalfa might be grown in alternate spaces between the tree rows for two years, then ploughed under and the remaining spaces planted for the next two years.

"Hard pans" are usually deficient in nitrogen, but may be well supplied with the other plant foods, and especially with lime and iron. The latter gives a very noticeable deep red tint to the orange.

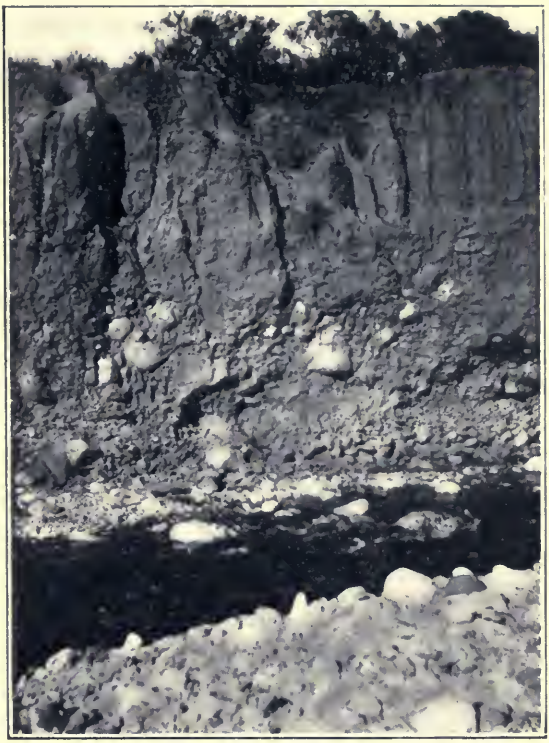

FIGURE 2

ESSENTIAL PLANT FOOD.

23. Each of the three plant foods, nitrogen, phosphoric acid and potash, are called *essential* ingredients in fertilizers, as they are the elements first exhausted from the soil by plants. There are eleven other elements just as essential to perfect plant growth as these three, but the soil never becomes depleted of them, and it is not necessary to supply them, except in rare cases. Sometimes lime is supplied to the soil, though not regularly, to set free nitrogen, phosphoric acid and potash, when they are known to be in the soil in insoluble condition and large amounts. But, as lime adds no necessary ingredient, its continued use alone will exhaust a soil. If a soil is known to lack iron, this may be added to make green foliage and to deepen the color of oranges.

If a soil becomes unproductive under conditions of good tillage and water, it is usually because one or more of the essential plant foods has become exhausted. Hence commercial fertilizers have come to be composed of various amounts and forms of nitrogen, phosphoric acid and potash. Commercial fertilizers are simply concentrated forms of plant food. A good top soil contains every element essential to plant growth and is a fertilizer, but it is not sufficiently concentrated to pay for handling and transportation.

24. Each of the three plant foods, nitrogen, phosphoric acid and potash, have their respective market values for each 1 per cent., or unit, of 20 pounds to the ton. If a ton of fertilizer contains 3 per cent. of an element that means 60 pounds. The purchaser

will have to know in addition to the amount, the *market value* and the *source* of the nitrogen, phosphoric acid and potash, before he can determine the value of a ton of certain analysis. The source is very important, because the most available forms have the highest market value. Without this knowledge, a certain brand may sell for $40 a ton and another worth only one-half its value ($20 per ton) may sell more readily for $38.

25. Each of the three essential plant foods has its special part to do in the building of the plant. One cannot do the work of the other. As an illustration: Nitrogen in the absence of potash may produce a luxuriant and rapid growth but it will be weak, and broken down by the first wind; add potash and that same succulent, weak growth will be matured and have strength enough to carry its load of fruit. Potash alone will not produce the growth, but will mature it. Both nitrogen and potash have many other functions to perform. (69), (71).

Phosphoric acid, or phosphorus, must be present in order that the plant may assimilate its nitrogen. The process (osmosis) by which nutrients pass through the plant from cell to cell is facilitated by the presence of phosphoric acid. Phosphorus is necessary for the seed's embryo development and for the formation of chlorophyl (the green coloring matter of plants). (70).

Thus, while the essential plant foods each have many independent functions to perform, they are mutually dependent upon each other, and mutually helpful in the building of the plant tissue.

The condition in the soil may be such that the purchase of only one fertilizing element is necessary, and since the source of nitrogen and phosphoric acid and their functions are so many and varied, the question, "What fertilizer to use," and "How to purchase it most economically," is of vital interest to the farmer and one difficult to solve.

SOURCE OF FERTILIZERS.

THE SOURCE OF NITROGEN.

26. Nitrogen may be obtained from these sources: Air, ammonia, nitrates, and animal matter. In certain forms of animal matter, such as hoofs, horns, coarse bone, leather and wool waste, the nitrogen becomes available too slowly to be of much value. But as green manure, ammonia, nitrates, blood, fine bone, tankage, or blood and bone, fish and finely ground and screened guano, the nitrogen is in good form and soon becomes available.

27. As these forms require different lengths of time to become available, judgment must be used in their application. Nitrate of soda and sulphate of ammonia dissolve almost immediately in water, so the full amount of a year's supply should not be applied at once, as some will be sure to be lost in waste water. Blood and bone, as a source of nitrogen and phosphoric acid, would be a better combination than nitrate and bone. Blood and fish require more time to become available than nitrates, and bone, a longer time than blood. (43)

The most valuable sources of organic nitrogen, from the standpoints of uniformity in composition, richness in the constituent, and availability, are dried blood, dried meat, and concentrated tankage, fish and animal, which are produced in large quantities in slaughter houses and fish canneries.

28. The most concentrated form of nitrogen is ammonium sulphate, containing about 19% or 24% of ammonia. Nitrate of soda contains as high as 16% nitrogen, blood 14%, hoof and horn meal, 14%, slaughter house tankage from 5% to 10%, raw bone 3½%, bat guano 3% to 20%, sea fowl guano 12%. There are numerous other sources of nitrogen, but the above are those most generally used. The contents as given are in terms of nitrogen and approximately the maximum.

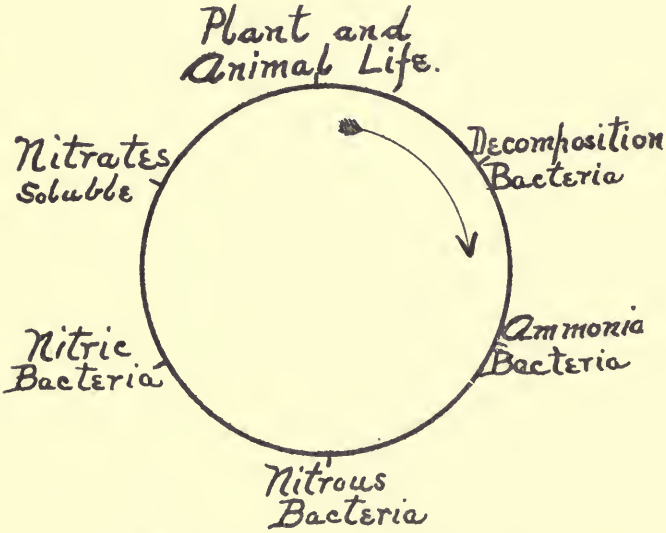

FIGURE 3—THE NITROGEN CYCLE

NITRIFICATION.

29. This is the process by which the nitrogen of organic matter is changed into nitrates. The ammonia and nitrogen of all fertilizers comes from organic matter, and all organic materials contain more or less of those substances in some form. Nitrate of soda in the nitrified product of some organic material, whether of seaweed or animals, is not definitely known. Ammonium sulphate also has an organic origin, being a by-product of carbonizing works.

Humus (which is decayed animal or vegetable matter) is the main source of the plant's nitrogen. When organic matter is applied to the soil it must first decay and then nitrify before its nitrogen becomes available to the plant. These two processes are necessary. The decay is produced by one set of bacteria and their product is humus. Then the substance is attacked by another set of bacteria which form nitrates. This latter process is nitrification. The nitrates thus formed are water-soluble and can be absorbed by root hairs into plant tissue. (See Figure 3.)

NITROGEN FROM AIR.

30. Certain plants of the leguminosæ group have power to accumulate nitrogen from the air in the process of growth. Such plants are the lupins and vetches, which with peas, clover, alfalfa and others, when grown as catch or cover crops and ploughed under, add to the store of nitrogen in soils. But in this case, as with other organic substances, the two processes of decay of tissue and nitrification, are necessary before the nitrogen thus gathered becomes

available. As nitrogen is the most expensive of all fertilizing elements, the importance and economy of a green cover crop ploughed under is considerable.

NITROGEN FROM BLOOD AND TANKAGE, GUANO, ETC.

31. The nitrogen from organic sources such as blood, tankage, guano, is prompt and decided in its action under ordinary growing conditions if the materials are finely ground. If drilled or ploughed under with the soil reasonably moist and warm, the effect, of added growth or better color may be seen in 30 days. The finer particles decay and become available first, the coarser particles taking more time. The plant thus has a steady, long feeding period. Where fruit trees are grown during a long growing period as in arid countries, the organic forms of nitrogenous fertilizer are most satisfactory.

NITROGEN FROM NITRATE OF SODA.

32. This is an immediately available form of nitrogen. It dissolves easily in water and can thus be carried down to the subsoil and leached away according to the course the water takes. It is therefore, not so steady or long timed a feed for plants if it is all applied at one time. It is better, therefore, to make at least two applications during the growing period. One objection to its continued use, as shown by Dr. King, is that in time the accumulation of the soda will combine with the soil carbonates and form carbonate of soda (black alklai) which in certain quantities is deleterious to all forms of vegetation. Such a harmful accumulation may require years but it will finally become positive. Neither rains or irrigation will leach the soda away, if, as it is claimed, all the rains of England have not leached it away from the soils of Rothampstead Station.

SOURCES OF PHOSPHORIC ACID.

33. Phosphoric acid, or phosphorus, in fertilizers, is always found in combination with other elements. Usually it is obtained from bone or phosphate rocks. As rock it cannot become readily available without treatment with sulphuric acid. As bone, unacidulated, it must be very finely ground to be available, and when thus ground is undoubtedly the best form for citrus culture, as it is *all* equally available and its ability to rot or ferment has not been destroyed by the acid. (40)

ACIDULATED PHOSPHATES.

34. These are made by treating bone or phosphate rock with sulphuric acid. Their value may vary according to the amount of acid used by the manufacturer, and the phosphorus content of the mother rock. If 800 pounds of acid were used with 1200 pounds of bone or rock, it would be a 40% acidulation, as 800 is 40% of 2000.

In acidulated goods whether rock or bone, there are always three forms of phosphoric acid—a soluble form, a "reverted" form, and an insoluble form. The last is of least "commercial" value, but may have very great agricultural value under proper soil conditions. The "reverted" is of doubtful value, as it has to first undergo a chemical change before becoming available. An insoluble portion is necessary in order to obtain the soluble, but does not add value to the fertilizer. State laws allow the reverted to be estimated as available with the water soluble, so that the soluble and reverted forms constitute the commercial or "available" phosphoric value of a fer-

tilizer but not necessarily the agricultural value. (67).

Most authorities claim as great a value for the insoluble form, in finely ground materials, provided there is a normal or plentiful supply of humus in the soil. (40).

REVERSION.

35. It must be remembered that in using acidulated goods (bone or rocks) if an abundance of lime be present in the soil, the soluble form of phosphoric acid unites chemically with the lime and is made again insoluble as if it had never been treated. Iron and alumina, and other bases, produce the same effect on acidulated phosphates. The reversion, however, depends on the amount of acid used by the manufacturer and the quantity of lime, iron, etc., in the soil. (77).

"FIXING" POWER OF SOILS.

36. The following table will show the "fixing" power of a lime soil :

PHOSPHORIC ACID "FIXED" BY SOIL.

Kind of Soil.	Grains.	Grains of Soluble Phosphoric Acid Used.	Phosphoric Acid retained by the Soil. After	Grains.
Deep Red Loam	5250	40.67	24 hours	24.29
			8 days	31.49
			26 days	38.23
Lime soil	10500	81.17	24 hours	72.81
			8 days	80.31
			26 days	81.17

Even a rich peat soil, high in either lime or iron, will "fix" or hold phosphoric acid in an insoluble condition, as shown in 49.

STEAMED BONE.

37. Steaming bones removes the fat and gelatines, thus facilitating decay and availability, as such bone can be ground finer than raw bone, and thus becomes more subject to the attack of soil moisture and various dissolving agents.

Raw bone contains from 3% to 4½% nitrogen and about 22% or 23% phosphoric acid. Steaming reduces the nitrogen and correspondingly increases the phosphoric acid, so that steamed bone may run as low as 1% nitrogen and as high as 25% or 30% phosphoric acid. The best effect from the phosphoric acid of steamed bone is had when the bone is used in connection with some ammoniate such as blood, tankage or manure. Nitrogen increases the efficiency of phosphoric acid, and for this reason phosphoric acid from animal or vegetable sources is regarded as the best, the most effective and the most readily available form. If mineral phosphates are used, there must be humus in the soil. (40.)

THOMAS PHOSPHATE SLAG (POWDER).

38. Thomas slag, a product from iron furnaces, is a good source of phosphoric acid, though not so generally used as bone or rock. This material has to be finely ground to be of value, as it is not acidulated. It will analyze as high as 20% phosphoric acid, usually 17%. Thomas slag also contains much lime, which fact should be considered when it is used in the presence of ammonium sulphate, or barn manures, as the lime will drive off the ammonia. An average analysis might show 17.28% phosphoric acid, 46.20% lime and iron oxide 18.37%.

It may be used to best advantage on trees which have made strong, nitrogenous growth at the expense of fruit production, and also on peaty soils, poor in lime. Water will not dissolve slag, therefore it should be put in as deeply as possible.

PHOSPHATE GUANOS.

39. The guanos of bats and sea fowl are also valuable sources of phosphoric acid. These materials, however, vary in analysis very much. Each consignment should be analyzed and its price based on its contents. The first shipments from a guano deposit are usually the richest and most valuable, and may deteriorate as the deposit is drawn upon.

CHEAPEST FORM OF PHOSPHORIC ACID.

40. The Pennsylvania State Department of Agriculture, in Bulletin No. 94, gives the results of 12 years' experiments with phosphates, both acidulated and unacidulated, and seems to show conclusively that the best form in which to purchase phosphoric acid is the untreated bone or rock. This is only on condition that there is plenty of organic matter, or humus-forming material, in the soil.

Under such conditions (with humus in the soil) finely ground rock (unacidulated) gave better results than acidulated rock or bone. This was from the standpoint of both original cost of material and the results obtained, and was true of all crops tried, except wheat. Unacidulated fertilizers always contain *more* phosphoric acid than the same fertilizers acidulated, as the weight of the acid used displaces some of the material, and if organic matter is used with the former, the conditions thus created in the soil give it additional life which takes the place of

acidulation, and results in greater fertility. A number of lay experiments and actual practice in California agree with the results of the Pennsylvania State Experiment Station. Where there was little or no humus-forming material in the soil, acidulated forms gave the best results. Dr. Hopkins of the Illinois State Experiment Station and many others strongly advocate the use of finely ground, unacidulated phosphates with plenty of humus material, rather than the acidulated forms. (7),(8),(11).

SOURCES OF POTASH.

41. Potash is found as a chloride, or muriate, as a sulphate, and in a crude form called kainit. The latter contains 12½% actual potash. The muriate and sulphate analyze about 50% actual potash. The Strassfurt mines in Germany supply the most of this product.

The potash of manufactured fertilizers is never all animal matter. All commercial forms dissolve readily, so there is no danger of buying potash in unavailable form. It takes about two pounds of sulphate, or muriate of potash to make one pound actual potash, or 10% sulphate to make 5% "actual."

Wood ashes and stable manure are also sources of potash, obtainable, however, in very limited quantities. Wood ashes, unleached, will contain from 4½% to 7% potash: mixed stable manure contains about 0.4% potash.

The sulphate of potash is the best form in which to purchase. It has no ill effects on many plants,

while the muriate or chloride form does. The sulphate can also be used as a "fixer" of ammonia in stables and manure pits, while the muriate might cause the escape of ammonia.

AVAILABILITY.

42. Buyers of fertilizers should always know the *source* and *form* of the different plant foods. This knowledge and the results obtained will determine their availability. Nitrogen from nitrate of soda is the most available form of any. Nitrogen from blood is more available than that from tankage.

Phosphoric acid from acid phosphates (rock or bone) is more soluble than the non-acid phosphates.

Steamed bone finely ground is more soluble than raw bone, as the latter is seldom finely ground.

43. All nitrogenous substances become available easily. The most highly nitrogenous are the most readily available. For this reason it is difficult to say whether steamed bone or raw bone as a source of phosphoric acid is most readily available. The former is always more finely ground and the latter always higher in nitrogen, but as raw bone is usually quite coarsely ground, it is less readily acted upon by the various dissolving agents of the soil, notwithstanding its higher nitrogen content. The phosphoric acid from tankage is more available than that from raw bone. Both the nitrogen and phosphoric acid, as found in animal tankage and guanos, finely ground are very available forms.

44. Soil moisture, root acids and fermentation, are the dissolving agents in all soils. The high temperatures of summer increase their action. Humus is essential to fermentation and to the carbonic acid in soil water which is a very active solvent.

Roots cannot take up plant food unless it is provided in solution, and different forms of fertilizers respond differently to these dissolving agents. Fine grinding is very important. As a rule organic forms are most available. There are some exceptions, such as sulphate of ammonia, nitrate of soda, and the acid phosphates. The latter act best in soils that do not contain enough lime, or iron, or other bases to cause rapid reversion to insolubility. (33) (34).

If the farmer knows the source and form of the nitrogen and phosphoric acid, he has a guide to their availability.

All forms of potash as usually purchased in fertilizers are readily dissolved and there is no danger of buying this ingredient in an insoluble form.

45. Some substances, as lime carbonate and gypsum, make all fertilizers more available but they do not add plant food to the soil, and their use alone will in time exhaust a soil. Better results will be obtained by using commercial fertilizers with some humus material than by using either one alone, because the conditions of availability will be increased.

46. Probable order of availability, nitrogenous substances:

Nitrate of soda
Dried blood
Tankage (high in nitrogen)
" (medium in nitrogen)
" (low in nitrogen)
Guanos, same as tankage, unless greatly nitrified.
Bone meal (finely ground)
" " (coarse)

47. Probable order of availability. Phosphates:

Double super phosphate } if watered
Acidulated phosphates } at once
Phosphorus from tankage, high in nitrogen.
" " " low " "
" " guanos (as in tankage.)
Thomas slag
Steamed bone meal
Raw " "

48. Probable order of availability. Potassium, (potash) substances:

All commercial forms { Sulphate, Muriate, Kainit }
Wood ashes
Silicates (natural soil forms)

49. The amount of potash and phosphoric acid carried by drainage and "run off" waters of good, bad and indifferent soils, bear directly on this question of availability.

Table:—"Matters dissolved by water from 100,000 parts of various soils." (From Johnson's 'How Crops Feed.')

Soils	Lime	Mag.	Pot.	Phos. A.	Silica	Iron	Organic	Total.
Rich	18	2	13	2	11	5	53	134
Good	34	7	8	—	22	—	36	136
Garden	23	1.5	7	1.5	38	2	30	110
Peat	164	11	47	trace	trace	77	449	1095
Poor	10	trace	1	—	—	3	18	46
Fair	6	1	4	—	2	2	23	43
Sandy	1	2.5	2	trace	trace	—	33	39.5

The matters least soluble are those found in the ash of plants. Where organic and volatile matter is carried in more appreciable amounts there is

greater solubility. There is no element less soluble than Phos. A. while potash is present in the drainage water in quantity greater than a trace. Even silica is more soluble than phosphoric acid.

CONCLUSIONS.

50. The amount of soluble matter is greater in wet, peaty soils. Poor soils yield to water the least amount. Very rich soils, and well manured soils yield more to water than poor soils. From the table it is seen that where water extracted most organic matter, it extracted large quantities of other elements. Cultivation and irrigation use up organic matter rapidly. So the supply of humus materials must be constantly renewed. Humus and organic matter are the key to availability but are also probably the means of exhausting other plant foods through the production of larger growth and crops. (86).

INSOLUBILITY DESIRABLE.

51. It is well known that the nitrates may easily be lost by leaching, because they are soluble. This is not the case with the phosphates, or phosphorus compounds, as these are always insoluble even in the most fertile soils. Numerous analyses of the "run off" waters show this. The nitrates being always available to the plant, stimulate its feeding powers and force it to act on such insoluble compounds as the phosphates, which, in turn, by yielding slowly, regulate growth and maintain for a longer time the soil's productive power.

It can readily be seen that the loss would be many times greater if the phosphates and other compounds were soluble as well as the nitrates.

The phosphoric acid of fertile soils is practically always insoluble. This is true of new lands, the richest and most productive known. It is nature's method. All fertile soils contain such bases as lime, iron and others that hold phosphorus in insoluble compounds from whence it is released only by the processes of plant growth and the chemical activities of fertile soils, due to a sufficient supply of humus. (35) (36).

THE PURCHASE OF FERTILIZERS.

52. Fertilizers should be purchased by the unit of plant food contained, with due consideration of its source, and not simply by the ton or brand, as is usually the case. Each twenty pounds of a ton is called one unit or 1%; 5% is five units or one hundred pounds. The value of a fertilizer depends entirely upon the *amount* and *source* of plant food contained. High grade analyses are worth more than low grade. Freight, sacking, storing and handling are fixed expenses on low or high grades. Therefore, high grades are cheapest.

All the simple forms of fertilizer material, such as bone meal, tankage, blood, sulphate of potash, nitrate of soda, etc., carry definite amounts or percentages of their respective plant foods. (28).

53. If, for instance, blood is pure and cleanly handled, its nitrogen content is from 13% to 14%, or 260 lbs. to 280 lbs. per ton. Pure bone meal (raw and steamed) varies in nitrogen from 1% to 5% and in phosphoric acid from 20% to 30%. If the nitro-

gen is as low as 1% the phosphoric acid will be about 30%. If the nitrogen is as high as 5% the phosphoric acid will be about 20%: and so with all the simple materials. Their limits are known.

It is quite possible with these limits known, to tell from the guarantee given by a dealer, whether the highest grade materials have been used in a given mixture. Suppose a dealer guarantees, as found on the bag, or tag:

Nitrogen, 5% (from high grade blood)
Phosphoric acid, 10% (from steamed bone meal)
Potash (K_2O), 2% (from the sulphate)

High grade blood contains at least 13% nitrogen pure, or 260 lbs. to the ton. To obtain the 5% or 100 lbs. guaranteed will require $\frac{100}{260}$ of a ton of blood or 769 lbs.

The phosphoric acid guaranteed is 10.% As steamed bone meal may contain 30%, to obtain 10% will require $\frac{10}{30}$ of a ton or 666.66 lbs.

Sulphate of potash usually runs 50% actual (K_2O) potash, so that the guarantee of 2% or 40 lbs. could be obtained from 80 lbs. of sulphate. Altogether the above guarantee of: 5% nitrogen,
10% phosphoric acid,
2% potash
can be obtained from:

Blood,.....	769.	lbs.
Steamed bone,.....	666.66	,,
Sulphate of potash,.....	80.	,,
or, total material.....	1515.66	lbs.
Make weight to one ton.....	484.34	,,
	2000.00	lbs.

The foregoing illustration shows that from a given guarantee it is possible to prove whether a full ton of high grade materials was used or not. It would be interesting also to figure how much higher the analysis would be if the amounts of blood, bone and sulphate of potash were increased proportionately, so that there was no room for "make weight."

It is only fair to the dealer to say that the 484.34 lbs. "make weight" is not necessarily worthless filler. Low grade material may have been used. They are offered in the same market with the best. Blood can be so carelessly handled as to be full of floor refuse and foreign matter. The source of tankage influences its grade. Both low and high grades are legitimately bought and sold in the same market and the low grade often takes the place of "filler." To make the foregoing guarantee without filler, we could substitute 1150 lbs. of Thomas slag for 666.66 lbs. of steamed bone meal so the weights would be:

Blood,	769 lbs.	@13%=	99.9 lbs.	or	5. %
Thomas slag,	1150 "	@18%=	207. "	or	10.25%
Sulphate of Potash	80 "	@50%=	40· "	or	2. %
Total	1999 lbs., or no room for filler.				

54. If ammonia is given instead of nitrogen, you can find its equivalent in nitrogen by multiplying by .825%; for instance, 5.5% ammonia equals 4.54% nitrogen.

Do not confuse sulphate of potash with the actual (or K_2O) potash. The sulphate usually runs about 50% actual. So, it takes 2 pounds of sulphate to make one pound actual, or 2% sulphate to make 1% actual.

The muriate contains about 48% actual potash and kainit about 12%.

Bone phosphate must not be confused with phosphoric acid. The latter is derived from bone phosphate and is 45.8% of the bone phosphate; for instance, 40% bone phosphate=18.32% phosphoric acid.

55. Allowance must be made for phosphoric acid if it is derived from raw bone. It is then worth about 2c. per pound, while if taken from steamed bone would be worth fully 5c. per pound. In acidulated goods the phosphoric acid is in three different forms, with market values from 2c. up to 5½c. per pound: the water-soluble being worth 5½c. per pound, the insoluble, 2c. per pound.*

The *source* is just as important a consideration as the *quantity* when considering the value. Both the quantity of plant food (that is of nitrogen, phosphoric acid and potash) and its source, which determines its form, are really the only factors which compose the value of a ton of fertilizers. (67)

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*No attempt is made to give market values. These figures are simply for comparison of the different forms of phosphoric acid and are those usually used by State Agricultural Stations.

Here are two analyses of different total value which will illustrate the foregoing:

ANALYSIS I.

Nitrogen in terms of ammonia, 5%.
Equivalent in nitrogen (5×.825)
4.13% or 82.60 pounds at 20c.....$16.52
Phosphoric acid (from steamed bone)
12% or 240 pounds at 5½c..... 13.20
Equivalent to bone phosphate 26%
Potash (actual, K_2O)
3% or 60 pounds at 6c..... 3.60
Sulphate of potash, 5.9%

Total value of ton.....$33.32

Note.—No account is taken of either the 26% of bone phosphate or of the 5.9% sulphate of potash as they are only repetitions of the 12% phosphoric acid and the 3% actual potash respectively.

ANALYSIS II.

Nitrogen in terms of ammonia, 5½%.
Equivalent to nitrogen (5½×.825)
4.54% or 90.80 pounds at 20c.....$18.16
Phosphoric acid (from raw bone)
13% or 260 pounds at 2c..... 5.20
Equal to bone phosphate, 31%.
Potash, (actual, K_2O)
4% or 80 pounds at 6c..... 4.80
Sulphate of potash, 7.95%.

Total value of ton.....$28.16

Although Analysis II is higher in its percentage of plant food, the form of the phosphoric acid is against it and cheapens it so much that the total value of the ton is considerably less.

Either of these analyses might be offered to the

grower for, say, $35 per ton and No. 1 would be the best buy for the grower, and No. 2 the best sale for the agent or manufacturer.

It is quite possible for the nitrogen to be in cheap form also and worth considerably less than 20c. per pound. The nitrogen from raw bone is worth less than that from blood, or guano, or tankage.

So the value of a ton of fertilizer is based upon the *source* or form of the nitrogen, phosphoric acid and potash, and the *quantity* of each.

COST OF NITROGEN.

56. Nitrate of soda, 96% pure, 16% nitrogen at $50 per ton. This yields 307 pounds of nitrogen, which at $50 per ton, equals 16.3c per pound or $3.24 per unit of 20 pounds.

Dried, ground blood, analyzing 14% nitrogen, or 280 pounds at $60 per ton, equals 21c. per pound, or $4.20 per unit. Market values change constantly. At times, nitrate may be worth $60 and blood worth $55 per ton.

COST OF PHOSPHORIC ACID.

57. Steamed, ground bone (not acidulated) at $35 per ton, containing 25% phosphoric acid (500 pounds (equals 7c. per pound, less the value of 1% nitrogen (20 pounds) contained in steamed bone at 20c. per pound would make the net cost of phosphoric acid about $1.24 per 20 pounds, or 6⅕c. per pound. Thomas Phosphate Powder, 17% phosphoric acid, at $22.50 per ton, would cost $1.30 per unit, or 6½c. per pound.

COST OF POTASH.

58. The sulphate yielding 49% actual potash can be bought for $60 per ton, making the actual potash cost 6c. per pound or $1.20 per unit, (20 pounds).

COST OF COMBINATIONS

59. Based on the foregoing, a tankage containing 5.5% nitrogen and 13% phosphoric acid would have value as follows:

5.5% (units)	nitrogen @ $4.20 per unit.....	$23.10
13% "	phosphoric acid @ $1.24.....	16.12
		$39.22

The nitrogen and phosphoric acid are in much the same form as found respectively in blood and steamed bone.

A guano containing 5% nitrogen, 10% phosphoric acid and 2% potash, would have a value as follows:

5% (units)	nitrogen, @ $4.20 (21c. per lb.)	$ 21.00
10% "	phosphoric acid @ $1.24.....	12.40
2% "	potash @ $1.20.....	2.40
		$35.80

MOST ECONOMICAL FORM OF FERTILIZERS.

60. If the price of nitrogen is the same in nitrates, and bone and blood, the cheapest is that which becomes available just as fast as the crop requires it, neither faster nor slower. Is nitrate too quickly soluble for the crop to use all of it before a part of it is carried away by wasted water? Is ground bone too slowly available or blood and bone just right? are questions to be answered by crop and conditions.

If a form of plant food becomes available too rapidly, the moisture holding it in solution rises and evaporates, leaving this *soluble*, valuable food on the top of the ground, whence it is partly lost by escaping surface waters and part carried back into the soil by penetrating moisture. That is why slow-running water gives the most profitable irrigation.

A "waste water" right on one ranch from another may become also a fertilizer right.

If, however, some form of plant food, not so quickly soluble in running water as nitrate of soda, and yet readily soluble by soil moisture and root action, is used, there is much less actual loss during a season, and its effect is more sure and lasting. Yet there are times when a quick-acting fertilizer is needed. This would then be the most economical form. It depends upon the needs at the time, and the farmer should know enough about the nature of the different forms of plant food to exercise judgment in the selection. (46-48) (68-71).

GENERAL PURCHASING PRINCIPLES.

61. The market value of every brand depends upon the amount, or percentage of plant food contained, and its form. The nitrogen, phosphoric acid and potash each have their own market value per pound, and these must be known to the grower, in order to purchase economically.

Be sure the food elements are of proper *source* and *form* to be available as fast as wanted by the trees. This availability depends upon soil conditions.

Purchase high grade materials.

EXAMPLE OF FERTILIZER WORTH $6.50 PER TON.

Fresh water mud, 2000 pounds, contains:

30 pounds	nitrogen (1½%) at 20c	$6.00
4½ "	phosphoric acid (.23%) at 5½c	.23
4½ "	potash (.23%) at 6c	.27
		$6.50

EXAMPLE OF FERTILIZER WORTH $41.10 PER TON.

Eighteen hundred pounds of blood and bone, containing 7% nitrogen and 10% phosphoric acid,

added to 200 pounds of sulphate of potash, will make one ton, analyzing as follows:

Nitrogen, 6.3 % or 126 lbs. @ 20c.....	$25.00
Phosphoric acid, 9% or 180 lbs. @ 5½c....	9.90
Potash (K_2O) 5% or 100 lbs. @ 6c.....	6.00
	$41.10

62. ILLUSTRATION NO. I—A HIGH GRADE FERTILIZER CONTAINING NO FILLER.

ANALYSIS.		OBTAINED FROM	LBS.
Nitrogen 5½% (110 lbs.)	from	1400 lbs. raw bone, 3.5% nitrogen.....	49.00
		400 lbs. nitrate soda (96 % pure — 16 % nitrogen).....	61.00
			110.00
Phosphoric acid 16%.	from	1400 lbs raw bone @ 23% phosphoric acid..	320.00
Potash 5 % (100 lbs.) actual	from	200 lbs. sulphate @ 50% actual potash....	100.00

COST OF ABOVE MATERIALS.

1400 lbs. bone.....	@ $35.00 per ton.....		$24.50
400 " nitrate...	@ 50.00 " "		10.00
200 " sulphate	@ 60.00 " "		6.00
2000 lbs.	Total.....		$40.50

ILLUSTRATION NO. II—A LOWER GRADE FERTILIZER CONTAINING 230 LBS. FILLER.

ANALYSIS.		OBTAINED FROM	LBS.
Nitrogen 5% (100 lbs.)	from	1300 lbs. raw bone, 3.5% nitrogen.....	45.00
		390 lbs. blood, 14% nitrogen.....	54.60
			99.60

Phosphoric acid 15%, 300 lbs.	from	1300 lbs. bone, 23% phosphoric acid.....	299.00
Potash (actual) 2%, 40 lbs.	from:	80 lbs. sulphate.....	40.00

COST OF ABOVE MATERIALS.

1300 lbs.	bone.....	@ $35.00 per ton..	$22.00
390 "	blood.....	@ 50.00 " "	11.70
80 "	sulphate of potash	@ 60.00 " "	2.40
1770			
230	filler		
2000 lbs.		Total.....	$36.85

Illustration No. I shows that if the analysis is high, only high grade materials can be used. Illustration No. II shows that if the analysis is low, either low grade materials or fillers were used. In No. II, high grade materials up to 1770 lbs. were used, and their value, pound for pound, is the same as in No. I. A filler used with high grade materials is equivalent to the use of low grade goods and the resulting analysis in No. II shows it. Less blood and bone could have been used in No. II, and more filler, but the resulting analysis would have been still lower.

63. If, however, the fertilizer is acidulated, the percentage of plant food may be low, as the weight of acid used displaces some of the material, yet the fertilizer should be considered high grade on account of the more soluble condition of its phosphoric acid. Here, the better form of plant food compensates for the smaller quantity. If the acid phosphate should revert to insolubility on account of the lime or other bases in the soil, its purchase would be equivalent to low grade materials, as the advantage of greater

solubility is largely lost and the total amount of phosphoric acid purchased is small, yet its better distribution in the soil by water, may compensate for reversion. (8).

THE "SIMPLES" AND HOME MIXTURES.

64. The "simples" are the original materials or the bases of which factory-mixed fertilizers are composed. They are such materials, as nitrate of soda, pure blood, sulphate of ammonia, potash, salts, bone, phosphate rock, super phosphates, etc. Tankage and the guanos are "simples," as they are the bases of manufactured brands. There are low and high grades of the "simples" as well as of brands, and guarantees should always be obtained by the buyer.

Sometimes these materials can be purchased cheaper separately than when mixed. Such is the case if the buyer is near a seaport or near the source of the material. The advantages are, the buyer knows what he is getting; he buys only the ingredients he needs and he buys direct. Such advantages however, do not always hold if the quantity wanted is less than a carload.

If, however, a complete fertilizer is needed, it is better to buy of a reliable manufacturer, as the goods are then mixed and blended more evenly and cheaply. If several ingredients are needed and these can be purchased to advantage separately, it would be better to apply them separately than to attempt home mixing, for a shovel and a barn floor will not mix materials evenly and uniformly without extreme care.

As a rule home mixing pays when compared with the purchase of *low grade* brands. If the manufac-

turer offers HIGH GRADE fertilizers it is time and money saved to use them.

WHY THE ANALYSIS DOES NOT ADD TO ONE HUNDRED PER CENT.

65. The Vermont Agricultural Experiment Station Bulletin No. 47 says: "The question is often asked why the plant food contained in a fertilizer does not add up to 100. For instance, the average Vermont goods this year contain in a hundred, 2.22 pounds nitrogen, 10.93 pounds total phosphoric acid and 3.46 pounds of potash, a total of 16.61 pounds. Of what did the other 83.39 pounds consist, and is it needed for plant food? It will be remembered that nitrogen is a gas, and phosphoric acid and potash respectively strong acid and alkali, and they can only be useful in *combined* forms. If medium grade materials were used in the manufacture of the average fertilizer, as stated above, it might be made up as follows:

440 pounds of organic matter (blood, tankage, etc.)
850 pounds of ground S.C. rock and sulphuric acid.
110 pounds of muriate of potash.

1400 lbs.

This would leave 600 pounds, or 30 per cent of the gross weight in every ton for moisture, dirt and useless material on which freight, mixing and bagging expenses, storage, etc., must be paid by the consumer.

A complete analysis of the above 1400 pounds would probably resemble the following:

Water	16.0	(combined with organic matter and sulphuric acid)
Nitrogen	2.0	
Phosphoric acid	10.6	
Potash	2.9	
Volatile and organic	33.0	(Combined with nitrogen)
Gypsum	16.0	(Formed by action of sulphuric acid on rock.)
Lime	7.1	(Left combined with phosphoric acid)
Sand	4.0	(Impurity prosp. rock.)
Chlorine and Salts	3.0	(Combined with potash.)
Miscellaneous	5.2	
	100.0	

Of the ten substances which compose the above 100 per cent, only three are of interest to the farmer. The value of the whole ton is based on the value of the nitrogen, phosphoric acid, and potash, only.

In raw bone, for example, it is impossible to give a farmer the 3% nitrogen and the 24% phosphoric acid contained without giving him the 73% of lime, gelatines and fats, etc., found in bone, for these substances are in combination and the process of separation would be too costly.

HOW TO UNDERSTAND A FERTILIZER ANALYSIS

66. Manufacturers often state the analysis of their fertilizers in a confusing way. They use two terms to express the same thing. Nitrogen and ammonia both mean one thing, and the analysis should read, for example, "nitrogen 4.95% equal to ammonia 6%," showing that there is *not both* the 4.95%, and the 6%, but only one or the other. That the one repeats the other. Multiply the percentage of ammonia by .825 and the result will be the equivalent

in nitrogen, as for example, 6% ammonia, ×.825= 4.95% nitrogen, It takes 4.95% nitrogen to equal 6% ammonia. In figuring the value of a ton in dollars and cents, if the nitrogen from blood or nitrate of soda has a market value of 16 cents per pound, its equivalent in ammonia is worth only 13⅕ cents per pound. Only one should be included in the estimate.

And so with the terms bone phosphate and phosphoric acid. The phosphoric acid comes from the bone phosphate. For example, it takes 30% of bone phosphate (sometimes called 'bone phosphate of lime') to make 13.74% of phosphoric acid. When both terms are employed by the manufacturer the words "equal to" should be used thus: "Bone phosphate of lime, 30%, equal to phosphoric acid, 13.74%," which means that the manufacturer used 600 pounds of bone phosphate or bone—30% of the ton—to obtain 13.74% of phosphoric acid.

Multiply the percentage of bone phosphate by .458 and the result will be the equivalent in phosphoric acid thus: 30% bone phosphate of lime ×.458=13.74% phosphoric acid.

In estimating the value, for comparison, of a ton in dollars and cents, phosphoric acid from fine bone is worth about 5½ cents per pound, while its equivalent in terms of bone phosphate is worth only 2½ cents per pound. Only one should be included in the estimate.

Where the "soluble," the "reverted," and the "insoluble," and the "total" phosphoric acid are all given, it is understood that the "total" is made up of the first three mentioned.

The sulphate and muriate of potash will analyze in round numbers about 50% actual potash (sometimes expressed as K_2O). In other words it takes two pounds of sulphate or muriate of potash to make one pound of actual potash (K_2O). When an analysis states: "Sulphate of potash 8%, actual potash 4%," it means simply that there is only 4% of actual potash in the ton, or 80 pounds, and that the manufacturers used 8% or 160 pounds of sulphate of potash to get it. The actual potash is worth about six cents per pound, while the sulphate is worth only three cents per pound.

When both terms are used in stating the analysis, only one of them should be included in the estimate of the value of a ton.

COMMERCIAL VS. AGRICULTURAL VALUE.

67. Farmers frequently confound the agricultural and commercial value of a fertilizer. If one is high it does not necessarily imply that the other must be.

The commercial value of any commodity is its market price, its purchase price, and depends entirely upon "supply and demand."

The agricultural value of a fertilizer is its ability to improve the fertility of the soil and the condition of the crop in question.

As an illustration, suppose a steady, long-lived food were wanted for some perennials as an orchard, blood would answer the purpose while nitrate of soda would be soon exhausted or lost by leaching. Now, if the price of both nitrate and blood is about the same, the agricultural value of blood is far greater. If a quickly acting manure was wanted, the nitrate of soda would have the higher agricultural value.

Again, if phosphoric acid was not needed for a particular soil and crop, it would then have no agricultural value in that case, but would still have a market, or commercial value.

In the selection of a fertilizer, the agricultural value should be considered first and the commercial value second. *Good results* are of first importance and depends on the agricultural value.

THE USE OF FERTILIZERS.

68. In order to use fertilizers intelligently, it is necessary to know the specific action of the three plant foods; nitrogen, phosphoric acid, and potash, their sources, and when and how to apply them. The few experiments which have been made with various fertilizers on citrus trees confirm the same general principles that hold with reference to other crops. They will be briefly stated.

EFFECT OF NITROGEN.

69. The presence of available nitrogen is shown by a dark, healthy, green color of leaves and stems. Growth is vigorous. The feeding power of the plant is increased. If an excess of nitrogen is available at the time of flowering, and the supply of phosphoric acid insufficient, the bud and bloom and fruit will be imperfect and the total amount of fruit lessened. The fruit will then be rough and thick-skinned. Constant use of stable manure, without the addition of phosphoric acid, will produce thick-rind fruit. The size of fruit may be increased by nitrogen. A

lack of nitrogen is shown by yellow trees and small growth, or lack of vigor. Nitrogen will not give its best effect unless phosphoric acid and potash are present.

EFFECT OF PHOSPHORIC ACID.

70. Phosphoric acid helps a plant to assimilate other plant foods. It is also essential to the final maturity of the plant or its seed production, and hastens this maturity, if abundant and available at blossoming time. Although the navel orange contains no seed, phosphoric acid is as essential as though it did. What usually thus goes into seed is needed elsewhere in the development of the fruit.

If maturity is hastened by the presence of an abundance of available phosphoric acid at the time of blossom, the early ripening of the orange can be likewise effected, though plant food effects are directly dependent upon culture and water.

Phosphoric acid will not give its best effect unless there is some nitrogen present. Plants well supplied with phosphorus, vegetate faster and are earlier. If an over abundance of nitrogen is making fruit rough or "puffy," phosphoric acid will help to correct this. Its tendency is to make thin-skinned, smooth fruit.

EFFECT OF POTASH.

71. Potash is necessary to the full development of the wood of the tree. If potash is wanting, the wood not only will not mature, but is subject to frost and disease; neither can immature wood carry much fruit. Potash aids in the formation and transfer of starch, first to the leaves and from there to the flesh of the fruit, which would be imperfect other-

wise. The best authorities agree that potash increases the sweetness of fruit and their shipping quality. (19).

Plants, undoubtedly, begin their growth in the spring on the food that was stored in their tissues the previous fall. Potash is largely the source of this stored food, and is consequently necessary to the full growth and health of the tree.

It is generally admitted, however, that applications of potash are unnecessary in most California soils. Many cases are reported in which heavy applications of wood ashes gave no appreciable results. If the land in question has been continuously cropped many years, as in a fifteen or twenty years' old orchard, the potash question should be carefully investigated.

72. Besides its effect on the plant as potash or potassium, increasing the starches and sugars, the use of potash salts has another *indirect* fertilizing effect similar to that of lime and common salt, by causing the soil to yield more quickly, its natural and other plant foods. Potash salts while neutral, may increase the alkalinity of the soil and thus foster and encourage the work of nitrifying and other bacteria which transform decayed organic matter into useful forms. Carbon is one of the resultant products, so that the carbonic acid which soil moisture carries, may be increased thus making it a better solvent of many other plant foods. This increased alkalinity of the soil may therefore increase the formation of the nitrates and more vigorous growth will result. Potassium as such, did not produce this result, which was due rather to the added

alkaline effect of the potash salt. Lime carbonate or gypsum or common table salt might have produced the same effect.

GENERAL PRINCIPLES.

73. In a general way, both phosphoric acid and potash influence the quality and fineness of the fruit, while nitrogen produces the vegetable tissue, such as the skin and pulp of fruit, and leaves and bark of trees. The juice and seed and smoothness and the number of the fruits, and earliness, can be increased by phosphoric acid and potash. The size and coarseness and large growth and late maturity can be secured by the excessive use of nitrogen. These effects are noticeable only when there is an *excess* of one element and a *deficiency* of the others.

AVOIDING PURCHASES OF UNNECESSARY FERTILIZERS.

74. Knowing the specific effect of the three essential plant foods, as just stated, and by observing the condition of an orchard, a grower may frequently avoid the purchase of unnecessary plant food.

Bottom lands are usually rich in nitrogen. Sandy soils are apt to lack potash. Clay soils usually contain much potash, etc. Coarse, thick-rind fruit, with deep green color of leaves and a too vigorous growth may indicate that nitrogen could profitably be omitted one season, or used very lightly. An over abundance of smooth fruit on yellow trees of slow growth may indicate an excess of phosphoric acid for the nitrogen present, or a lack of nitrogen. Iron is as essential as nitrogen to green leaves and stems, so yellow foliage may, in rare cases, be caused by the absence of iron as well as nitrogen. The amount of iron necessary for green foliage is so small, that lack

of nitrogen is usually the cause of yellow color in citrus orchards.

A careful record of previous applications, namely: The amount and analysis of the fertilizer, time of application, and its effects on growth and crop will be a guide to selection.

TIME TO APPLY FERTILIZERS.

75. In the book of nature we read that growth is dormant for some months preceeding the blossom and fruit setting period. This is naturally the time of most moisture in soils, which with root acids and fermentation, are rendering available the unavailable plant foods natural to the soil. So, when the important time of blossom comes, the plants have their greatest store of available plant food to draw upon, so that fertilizers should be applied long enough before the blossom time to become available.

76. Nitrate of soda requires the least time. Blood requires more time than nitrate, and raw bone more time than blood. Coarse bone, and hoof and horn meal, are slowest in their action. Acidulated phosphate acts more quickly than any other form (that is the soluble portion.) Steamed, fine ground bone, used with some ammoniate, is next in order, while fatty, raw bone takes still more time to decompose. (46-48).

Many apply a part of the fertilizer in early summer. This is intended to feed the latter growth of tree and crop. It is a practice that undoubtedly gives better results and is gaining in favor.

77. Acidulated forms should always be applied just before an irrigation or rain, for then the water

will carry the soluble portion to the deepest roots, wherever, in fact water can go. There, reversion to insolubility may and probably does occur in a few days, but the phosphoric acid is where the roots can act on it directly. (8) (35).

Nitrate of soda should not be applied in late fall or winter months while growth is dormant, as it would probably be leached away before the tree could take it up. Organic forms should be applied in January or February.

AMOUNT TO APPLY.

78. The quantity of fertilizer that should be used varies with the conditions. It depends upon :

1. The percentage richness of the fertilizer.
2. Record of past experience.
3. Natural richness of soil.
4. Age and number of trees per acre.
5. Kind of tree or crop.

One popular way of estimating the amount to use is to say one pound of high grade fertilizer to each year of age of the tree. This, while very inaccurate, gives good results, but the practice of citrus culture has demonstrated the wisdom of using considerably more than this amount, probably two pounds for each year of age of citrus trees will be fully warranted in most cases.

This is particularly true of trees over twelve and fifteen years old. If the fertilizer is low grade, the amount used should be increased.

If trees have been topped for budding or very severely pruned, the amount may be reduced accorddingly.

METHODS OF APPLICATION.

79. The best method of application is undoubtedly by drill, on account of its labor saving and uniformity.

Though not over five inches deep, the drill covers the fertilizer, which can be placed deeper by subsequent plowing. The use of drill obviates the unpleasantness of applying in any winds which may prevail. No hand process is so uniform or inexpensive, though some other methods place the fertilizer deeper. It is well worth the extra cost to hire a hand to follow each plow furrow and place the fertilizer that depth.

STABLE MANURE.

80. An average analysis of one ton of horse manure would be :

Nitrogen—0.50% or 10 lbs. of a ton at 20c.....	$2.00
Phosphoric acid—0.25% or 5 lbs. of a ton at 6c.	.30
Potash—0.40% or 9.6 lbs. of a ton at 6c.....	.58
	$2.88

The commercial value of the plant food is then about $2.88 per ton. Barn yard manure when cared for properly, is a most profitable form of fertilizer, because of its humic and mulch value. It is a bi-product of every ranch, costs nothing, and is worth about $2.88 per ton for the actual plant food contained. In dry countries it has a still greater value in its moisture saving properties. As a source of humus it is worth considerably more than its plant food value.

81. The more decomposed the manure, the more available is its plant food. If, however, decomposition is too rapid, the nitrogen escapes in the air as ammonia, and humus-forming matter is destroyed.

High temperatures produce rapid decomposition, especially in a loose heap, so that the rate of decay may be regulated by compacting the heap and sprinkling with water to exclude the air and reduce the temperature. If compacted too tightly, decomposition may be too slow. Moderate fermentation is the object desired. Loss of nitrogen, as ammonia, may be detected by the strong odor arising from the heap.

If it is desired to obtain the benefits of the plant food in manure quickly, it should be stored under cover to prevent loss by leaching, and the temperature kept down by frequent wetting, and air excluded by settling the heap: decomposition may thus take place with a minimum loss of ammonia. If from one to two pounds of either gypsum, or sulphate of potash be sprinkled on the heap each day as it accumulates from one or two animals, the ammonia is converted to the sulphate form and thus prevented from escaping. The gypsum must be moist for this use to be effective.

If, however, it is not desired to get the benefits of plant food quickly, the manure had better be applied fresh and incorporated with the soil at once. Decomposition may be slower in such cases, but loss of ammonia is surely prevented and a much better mulch obtained. This is the most practical method.

GREEN MANURING.

82. The object of sowing the leguminous, or pod-bearing plants is chiefly four-fold.

1. For humus, which is always necessary for any form of crop because of its various functions in the soil, such as: (a) nitrification; (b) Rendering insoluble forms of plant food available by the process of

decay, (29); (c) Increasing the moisture holding power and friability of the soil. (90.)

2. To obtain the nitrogen which they gather during their growth. (30).

3. To set free unavailable plant foods by the direct action of their roots. (Insoluble substances are coroded, and dissolved and taken up into the plant tissue and later become available as the plant decays.)

4. To prevent soil washing and leaching by winter rains.

83. The common vetch (Vicia Sativa) is at present the most popular legume for the California orchardist. Field peas, some clovers, and other varieties of vetch are also used. Barley and other non leguminous plants have not the same nitrogen gathering power but are beneficial as far as their roots set free unavailable forms of potash and phosphoric acid.

The volunteer non-leguminous plants and weeds such as alfilerea mallow, foxtail and others, are perhaps as beneficial as legumes plants for their humus value and root petetration and while it is not certainly known just now how much nitrogen may be added by various legumes it is probably safe to assume that they add some and for this reason are preferred to the non-leguminous plants.

COVER CROPS AND WATER.

84. It is well known that the winter cover crops use up a good portion of the rain that falls so that comparatively the clean culture orchards begin the dry season with more moisture in the ground. While this loss is usually more than compensated for by

the many advantages of the cover crop already cited there may be special situations where the water is all necessary to the orchard. If the water right were limited by the capacity of the ditch or if the season's rainfall were too short to risk the loss of water necessary to a cover crop, straw or damaged hay could be hauled and spread and plowed under as a fair substitute. Any amount of humus could be added in this way and all of the rainfall conserved for the summer months.

SUMMER COVER CROPS.

85. It is difficult to maintain the supply of humus material under conditions of constant irrigation and cultivation. Cover crops have been raised in summer as well as in winter in a few instances. Horse beans and cow peas have been used for the purpose. They are planted in May or June and turned under in August, and while the results are undoubtedly beneficial the extra water necessary will prevent the practice from becoming general.

The United States Government has found by experiment in California orchards, several legumes that promise a greater tonage of green matter, under equal conditions, than the present Oregon or common vetch so generally used. These include two species of Vicia; one pea, and one bean. So that this phase of agriculture will no doubt be improved and modified from time to time.

The green manure wanted by orange growers is one that will grow quickly as California winters are short and dry, and growers cannot afford to let the ground rest undisturbed very long.

HUMUS FERTILIZERS—NECESSITY OF ORGANIC MATTER.

86. Humus is decayed organic matter. It is necessary for fertility, because all the nitrogen in soils comes from either an animal or vegetable source. (Very minute quantities are absorbed from the air as ammonia and as nitrogen). The nitrates come from humus. They are water soluble and can be taken up by the roots. Thus the plant gets its nitrogen. (15) (29)

All fertile soils are rich in organic matter. The exceeding richness of new lands is due to the humus deposited by succeeding crops for generations. This is true of both the high mesa and the valley land. It is possible to use some chemical form of nitrogen and raise a plant, but it is expensive, requires close watching and is not practical. The nitrogen from organic fertilizers is yielded to the plant gradually, with greater certainty, and is more lasting.

87. Organic manures, whether of blood and bone, or stable manure, or green cover crops, not only furnish nitrogen to plant life, but their decay generates several well known acids, notably carbonic, which combine with the soil moisture and dissolve other forms of plant food. Without these acids, phosphorus, potash and other necessary elements would not be so available to the plant. Direct root and water action would then have to do the work alone, and the plant would not thrive so well. Humus influences the availability of the phosphoric acid and potash and converts them into forms more readily utilized by the plant. (49-50).

88. Organic fertilizers lighten soils. Their decay leaves the soil open and porous. More oxygen is thus admitted, which gives more life to the micro-organisms, which, after all, are the cause of all fertility. Better cultivation is possible in such soils. Light, porous soils are more retentive of moisture. Thus, organic matter literally builds up a soil. It increases its depth. A "worn-out" soil is simply a soil devoid of humus. It is lifeless. Liberal applications of organic matter restore it and change it from a tax to an income.

89. Humus forming-materials are, therefore, *necessary* to successful and practical farming. The best results from inorganic fertilizers, such as rock and acid phosphates, Thomas slag and sulphate of potash, are obtained when they are used with manure, or blood, or blood and bone, or a green cover crop turned under.

90. "Humus is not only the principal source of nitrogen in soils, but it influences to a marked extent the available potash and phosphoric acid. Humus forming materials, like green manures and yard manure, have the power, when they decompose in the soil, of combining with the potash and phosphoric acid of the soil and thus converting them into forms which are readily utilized by the plants."(82).

CULTIVATION AND FERTILIZERS.

91. Cultivation increases the availability of fertilizers by aiding nitrification and by saving soil moisture. All organic forms must first decay and then be turned into nitrates (nitrification), and

other salts before water can carry their elements to the roots of plants. (29).

The decomposed matter (humus) is attacked by nitrifying bacteria and these require oxygen for their work. Cultivation increases this supply of oxygen so that nitrification proceeds faster, and better growth results. The more frequent and deep the cultivation, the better the nitrifying bacteria can work. The size of fruit can be increased in this way, or a short season made equal to a long one.

Cultivation therefore uses up humus very rapidly so that the supply must be frequently renewed. The extra growth and yield are probably proportional to the supply of humus and frequency of cultivation.

92. This principle of aiding nitrification applies to all forms of animal and vegetable fertilizers such as yard manure, blood, raw bone, guano, tankage, and peas and clover, planted for their fertilizing value when ploughed under.

Frequent, deep cultivation increases the supply of water in soils. Several well-known acids, resulting from decomposition, unite with soil moisture and dissolve what ordinary water will not. Insoluble forms of fertilizers, such as phosphate of lime and silicate of potash, are probably thus made available to the plant.

93. Moist soils swell and are more permeable. Roots can develop faster in them, and the fertilizers, applied to the top, six inches, as they gradually dissolve, can be carried more easily and deeply, increasing the feeding area of the roots and the development of the plant.

Frequent and through cultivation, helps and multiplies these beneficial effects of soil moisture.

IRRIGATION AND FERTILIZERS.

94. Plants can take up food, only when it is provided in solution. The food may be dissolved by water, or by direct root action, or by the process of fermentation, which is almost constant in all soils. In either case water is essential, and the common carrier, and the way in which it is used, seriously effects the results of fertilization. Especially is this true because the top foot of soil contains the most valuable fertilizing ingredients.

There are three kinds of water in soils : free water which moves by gravity ; hygroscopic water, detectable only by laboratory methods even in the dryest earth, and capillary water, which moves by the power of attraction between particles of matter. This capillary water is what plants feed and depend upon mainly. It travels up and down freely with very little motion, sideways, carrying with it the soluble fertilizers.

95. It is useless to apply fertilizers on dry ground that is not dampened by irrigating water, as for instance ; far under very old trees or on the midway spaces in young orchards where furrows are not made.

As moisture evaporates at the surface, it is constantly supplied from below by the capillary movement. The dissolved fertilizers contained, remain at the surface from which the water evaporates ; hence they accumulate so that top soils are always the richest. The next rain or irrigation carries the plant food down only to rise again as evaporation progresses at the surface. There is thus an oscillation of water containing many kinds of plant food, up and down many times a year.

96. Certain forms of fertilizers, such as the nitrates (both soda and potash) ammonium sulphate, the sulphate of potash, and the acid and super-phosphates are easily carried by water. If applied just previous to an irrigation they go to the deepest roots, or wherever water can go. If there is any waste water a part of them is lost.

If the grade from the flume is very steep for fifty feet or more, the trees in that space will be the first to turn yellow, although they are nearest the flume and receive the most water. The nitrates have been washed to lower levels. Manure or straw should be used in such places so that the water will move more slowly and the nitrates retained where they belong.

On account of the solubility of many forms of plant food, irrigation water should be handled very carefully. Do not turn a heavy head of water into a furrow until after the furrow is soaked a little and the fine earth compacted. This will lessen washing. The ideal movement of water is up and down, with as little movement on the surface as possible. In this way the rich top soil with its humus and fertilizers will be retained where it belongs.

VALUE OF SOIL ANALYSIS.

97. Soil analyses are valuable for determining in a general way the needs of a crop. The greater the number of samples examined, the more accurate will be the information obtained. Very little can be concluded from one sample. Taken in connection with the appearance of trees and vegetation raised on the soil, many a useless expenditure for fertilizing ingredients may thus be avoided.

If samples of soil be taken according to the directions of the State Experiment Station the results may be relied upon as indicating that soil's capacity for various crops. This information, with the owner's knowledge of previous treatment, together with the appearance of the vegetation and growth gives a pretty thorough diagnosis. Each of these sources of information acts as a check or supplements the other two.

98. Soil analysis should be interpreted by an expert for where $\frac{1}{10}$ of 1% would be considered a sufficiency of some element, it would be regarded as a deficiency of other elements. A soil containing ¾ of 1% humus is lacking in that substance, while that amount of potash or lime would be considered ample for fertility. (100).

Again, soil analyses may reveal the presence of some poison, such as carbonate of soda, or chlorine, in the midst of otherwise fertile conditions. An excess of either acid or alkali can likewise be determined. Plant food may be present in abundance and yet the results be unsatisfactory on account of poor cultural conditions, or lack of humus. This, also, soil analysis would reveal.

Whenever there is uncertainty about the needs of crops or orchard, soil analysis should always be taken. One element, only may be lacking and thus discovered, and the purchase of the element unnecessary be avoided. The California State Experiment Station has advised farmers that sufficient potash is present in nearly all California soils. General experience has confirmed this statement, thus saving the farmers many dollars annually.

99. The mechanical analysis of soils is always important. Most California soils are sedimentary and composed of irregular strata varying in thickness from a few inches to many feet. They may be impenetratable and poorly drained, or too open and coarse to hold the requisite moisture. The subsoil conditions should be known. (20-21-22).

100. The following table is compiled mainly from the records of the California State Experiment Station and from Dr. Hilgard's book, "Soil," which state quite positively that when the chemical determination of certain elements in soils run below a certain amount that soil is quite sure to be unproductive. These figures are the result of a large number of analyses representing years of work.

ADEQUATE PLANT FOOD.

	RICH PER CENT.	ADEQUATE PER CENT.	INADEQUATE PER CENT.
Humus in soil	2.00	1.00	0.85
Nitrogen in humus	9.00	4.00	2.00
Lime	1.50	1.00	0.40
Phosphoric acid	0.20	0.10	0.05
Potash (K_2O)	1.00	0.45	0.25

These figures will vary for different crops. Adequacy for one kind of crop might be inadequate for another. But they are averages for a large number of determinations and very suggestive. It has been well established also that when the per cent. of lime is high, much smaller amounts of the other plant foods will suffice.

FERTILIZING VALUE OF STRAW, STABLE MANURE, ORANGE CULLS, AND CERTAIN LEGUMES. †

101.	N.	P.A.	Pot.*	
‡Pea vine hay	3.00			$12.00
‡Vetch hay	2.55			10.20
Burr clover hay	2.68			10.72
Alfalfa hay	2.19	1.51	1.68	11.37
Wheat straw	0.59	0.12	0.51	3.12
Stable manure	0.50	0.25	0.50	2.87
Orange culls	0.18	0.12	0.21	1.10

*(Nitrogen @ $4.00 per unit. Phos. acid @ $1.00 per unit and potash @ $1.25 per unit.)

†The value of the above materials for humus is probably equal to, or greater than their fertility value as judged by the results obtained from their use.

‡It is assumed in the table that the pea, vetch and burr clover were raised as a cover catch crop in the orchard, and that this nitrogen is all gain, which fact is not yet established beyond doubt. Their phosphoric acid and potash are not reported, as what they take of these from the soil is returned with them.

INDEX.

INDEX.

INDEX.

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