FERTILIZERS

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FERTILIZERS

THEIR

SOURCE, PURCHASE AND USE

An Elementary Treatise For The Use of Farmers and Fruitgrowers

BY

CARROLL B. SMITH

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Redlands, California.   CARROLL B. SMITH.

TO THE READER.

This pamphlet is written expressly for those who are forced to use fertilizers from year to year 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.

All the facts and deductions contained are based on the highest authorities on the subjects mentioned, or on the results of actual experience in California. Those interested are advised to study the subjects completely in such volumes as F. H. Storer's "Agriculture," 3 Vols.; L. H. Bailey's "Principles of Agriculture;" J. P. Roberts' "Fertility oi the Land;" C. M. Aikman's "Measures and Manuring," and bulletins of the U. S. Department of Agriculture.

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. She is always busy making exceptions; therefore, every farmer's problems are his own and he must do his own thinking. The author has tried to present only well established facts and general PRINCIPLES. A fuller knowledge of these, properly applied, will lead to better results and larger profits.

Redlands, California. *CARROLL B. SMITH.*

Essential Plant Food.

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 and iron are supplied to the soil, though not regularly. Lime is used to set free nitrogen, phosphoric acid and potash, when they are known to be in the soil in insoluble condition and in 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 color of oranges.

If a soil becomes unproductive under good tillage it is because one or more of the three 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.

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. potash, that means 60 pounds. The purchaser will have to know the *market value* and the *source* of the nitrogen, phosphoric acid and potash before he can determine the value of a ton of a 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.

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.

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 chlorophyll (the green coloring matter of plants).

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 of the soil may be such that the purchase of only one fertilizing element is necessary, and since the sources 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 SOURCES OF NITROGEN.

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 beeomes available.

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.

"The most valuable sources of organic nitrogen, from the standpoints of uniformity in composition, richness in the constituent, and availabilty, are dried blood, dried meat, and concentrated tankage, which are produced in large quantities in slaughter houses and rendering establishments." (Farmers' Bulletin, No. 44, U. S. Dept. Agriculture.)

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 9%, 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.

NITRIFICATION.

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. 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.

NITROGEN FROM AIR.

Certain plants of the leguminosæ group have power to accumulate nitrogen from the air to the process of growth. Such plants are the lupins and vetches. Peas, clover, alfalfa and the native wild lupins when grown as catch or cover crops and ploughed under maintain the store of nitrogen in soils. But, in this case, as with other organic substances, the two processes of decay 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.

(See also "Humus.")

SOURCES OF PHOSPHORIC ACID.

Phosphoric acid, or phosphorous, 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.

ACIDULATED PHOSPHATES.

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. 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 pounds.

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 no commercial value. The "reverted" is of doubtful value, as it has to first undergo a chemical change before becoming available. The soluble is immediately available. A dealer giving an analysis should not mention the amount of insoluble phosphoric acid, as it is confusing. An insoluble portion is necessary in order to obtain the soluble, but does not add value to the fertilizer. State laws, as a rule, allow the reverted to be estimated as available with the water-soluble, so that the soluble and reverted forms constitute the phosphoric value of a fertilizer.

It must be remembered that in using acidulated goods (bone or rock) 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.

STEAMED BONE.

Steaming bones removes the fats 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, or blood and bone, or manure. Nitrogen or ammonia 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.

THOMAS PHOSPHATE SLAG (POWDER).

Thomas slag, a product of 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. Thomas slag also contains much lime, which fact should be considered when it is used in presence of ammonium sulphate, or barn manures, as the lime will drive off the ammonia. One brand offered for sale in Los Angeles contains 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.

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 the richest and most valuable, but deteriorate as the deposit is drawn upon.

CHEAPEST FORM OF PHOSPHORIC ACID.

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 organ icmatter, 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.

SOURCES OF POTASH.

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 Stassfurt mines of Germany supply the most of this product.

The potash of manufactured fertilizers is seldom all animal matter. All 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 $4\frac{1}{2}\%$ to 7% potash: 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.

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 raw bone.

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. 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.

Soil moisture, root acids and fermentation are the dissolving agents in all soils. The high temperatures of summer increase their action, and hence the availability of fertilizing elements.

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.

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.

Some substances, as barnyard manure and lime, make all fertilizers more available, but they do not add plant food to the soil in the amounts, nor as fast as required, and their use alone will in time exhaust a soil. Especially is this true of lime. Better results will be obtained by using commercial fertilizers with manure than by using either one alone, because the conditions of availability will be increased. (See also "Cultivation and Fertilizers.")

INSOLUBILITY DESIRABLE.

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 phosphorous 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 nitates.

The phosphoric acid of 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 phosphorous in insoluble compounds from whence it is released only by the processes of plant growth and the chemical activities of fertile soils.

THE PURCHASE OF FERTILIZERS.

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. Growers often ask, "Can we afford to pay $40 per ton for fertilizer?" It depends entirely upon the amount and source of plant food contained.

We cannot afford $40 per ton for low grade analysis, but can well pay $40 for high grade-goods. Freight, sacking, storage and handling are fixed expenses on low or high grades. Therefore, high grades are cheapest.

The way to figure the difference in value between several brands of fertilizer is as follows:

Take nitrogen at 16 c. per pound, phosphoric acid at 5½ c. per pound, potash (actual) at 6 c. per pound.

(Note.—These values are based on the cost of nitrate of soda, and sulphate of potash laid down in inland California points.)

Remember that 1 % or one unit of a ton is 20 pounds.

If ammonia is given instead of nitrogen you can find its equivalent in nitrogen by multiplying by .825 %; for instance, 5½ % ammonia equals 4.54 % nitrogen.

Do not multiply the percentage of ammonia by 20 and then by 16c. as it then would read too much, but must first be reduced to terms of nitrogen.

Also do not confuse sulphate of potash with the actual (or K_2O) potash. The sulphate usually runs about 49 % actual. So, in round numbers, it takes 2 pounds of sulphate to make one pound actual, or 2% sulphate to make 1 % actual.

Allowance also 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.

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

ANALYSIS I.

Nitrogen in terms of ammonia, 5 %.
Equivalent in nitrogen ($5 \times .825$)
  4.13 % $\times 20 = 82.60$ pounds at 16c.............$13.21
Phosphoric acid (from steamed bone)
  $12 \times 20 = 240$ pounds at 5½c.................. 13.20
Equivalent to bone phosphate 26%
Potash (actual, K_2O)
  $3 \times 20 = 60$ pounds at 6c........................ 3.60
Sulphate of potash, 5.9%

Total value of ton...................$30.01

Note.—No account is taken of either the 26% of bone phosphate or of the 5% 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, $5\frac{1}{2}$%.
Equivalent to nitrogen ($5\frac{1}{2} \times .825$)
$4.54 \times 20 = 90.80$ pounds at 16c.............$14.53
Phosphoric acid (from raw bone)
$13 \times 20 = 260$ pounds at 2c.......................$5.20
Equal to bone phosphate, 31%
Potash, (actual, K_2O)
$4 \times 20 = 80$ pounds at 6c..........................$4.80
Sulphate of potash, 7.95%.

Total value of ton...................$24.53

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 16c. per pound. The nitrogen from raw bone is worth less than that from blood, or bird 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.

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 15% nitrogen, or 301 pounds at $50 per ton, equals 16.6c. per pound, or $3.32 per unit. From horse manure containing .5% nitrogen, at $2 per ton, equals 20c. per pound, to say nothing of the phosphoric acid and potash contained. The New York Experiment Station gives the price of nitrogen in nitrate as 15c. per pound, in meat and blood as 16c. per pound, in bone and tankage (ground) as 16c. per pound.

COST OF PHOSPHORIC ACID.

Steamed, ground bone (not acidulated) at $35 per ton, containing 25% phosphoric acid (500 pounds) equals 6c. per pound, less the value of 1% nitrogen (20 pounds) contained in steamed bone at 16.4c. per pound would make the net cost of phosphoric acid about $1.10 per 20 pounds, or 5½c. 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.

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, or 20 pounds of a ton.

MOST ECONOMICAL FORM OF FERTILIZERS.

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 tree wants it, neither faster nor slower. Is nitrate too quickly soluble for the tree to use all of it before a part of it is carried away by waste water? Is ground bone too slowly available or blood and bone just right? Who will tell, and how? It is a fine problem.

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 becomes also a fertilizer right, provided the other man fertilized.

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.

GENERAL PURCHASING PRINCIPLES.

1. The market value of every brand depends upon the amount, or percentage, of plant food contained. 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.

2. Be sure the food elements are of proper *source* and *form* to be available as fast as wanted by the trees.

3. Purchase high grade materials.

EXAMPLE OF FERTILIZER WORTH $5.30 PER TON.

Fresh water mud, 2000 pounds, contains:

30 pounds nitrogen (1½%) at 16c....................	$4.80
4½ pounds phosphoric acid (.23%) at 5½c.......	.23
4½ pounds potash (.23%) at 6c................	.27
	$5.30

EXAMPLE OF FERTILIZER WORTH $36 PER TON.

Eighteen hundred pounds of blood and bone, containing 7% nitrogen and 10% phosphoric acid, added to 200 pounds sulphate of potash, will make one ton analyzing as follows:

126 lbs. nitrogen (6.3% @16c)	$20.21
180 lbs. phosphoric acid (9% @5½c)	9.90
100 lbs. potash (5% @6c.)	6.00
	$36.11

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

ANALYSIS.	OBTAINED FROM	LBS.
Nitrogen 5½% (110 lbs.)	1400 lbs. raw bone, 3.5% nitrogen	49.00
	400 lbs. nitrate soda (96% pure—16% nitrogen)	61.44
		110.44
Phosphoric acid 16% (322 lbs.)	1400 lbs. raw bone, 23% phosphoric acid	322.00
Potash 5% actual (100 lbs.)	200 lbs. sulphate, 50% actual potash	100.00

COST OF ABOVE MATERIALS.

1400 lbs. bone at $30.00 per ton		$21.00
400 lbs. nitrate at $50.00 per ton		10.00
200 lbs. sulphate at $60.00 per ton		6.00
2000 lbs.	Total	$37.00

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

ANALYSIS.	OBTAINED FROM	LBS.
Nitrogen 5%, 100 lbs.	1300 lbs. raw bone, 3.5% nitrogen	45.00
	390 lbs. blood, 14% nitrogen	54.60
		99.60
Phosphoric acid 15%, 299 lbs.	1300 lbs. bone, 23% phosphoric acid	299.00
Potash (actual) 2%, 40 lbs.	80 lbs. sulphate	40.00

COST OF ABOVE MATERIALS.

1300 lbs. bone at $30.00 per ton	$19.50
390 lbs. blood at $50.00 per ton	9.75
80 lbs. sulphate of potash at $60.00 per ton	2.40
1770	
230 filler	
2000 lbs. Total	$31.65

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.

If, however, the fertilizer is acidulated, the percentage of plant food may be low, as the weight of the 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.

THE "SIMPLES" AND HOME MIXTURES.

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. Farmers can then club together and effect the saving.

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 foods evenly and uniformly.

As a rule home mixing pays when compared with the purchase of *low grade* brands. If the manufacturer offers HIGH GRADE fertilizers it is time and money saved to use them.

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

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 that 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 about 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	2.2	
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 phosp. 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.

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 a m monia by .825 and the result will be the equivalent in nitrogen, as for example, 6% ammonia $\times$ .825= 4.95% nitrogen. It takes 4.95% nitrogen to equal 6% ammonia. In figuring the value of a ton in dollars and cents, nitrogen from blood or nitrate of soda has a market value of 16 cents per pound, while 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 $\times .458 = 13.74\%$ phosphoric acid.

In estimating the value 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 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 the ton.

COMMERCIAL VS. AGRICULTURAL VALUE.

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, while the price of both nitrate and blood is about the same, ($55.00 per.ton) 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 as they repay the cost many times.

THE USE OF FERTILIZERS.

In order to use fertilizers intelligently, it is necesssary to know the specific action of the three plant foods, nitrogen, phosphoric acid, and potash, and when and how to apply them. So far as the author knows, there have never been any exhaustive experiments made to this end in California with special reference to citrus fruits. However, by the help of agricultural colleges, certan general principles have been discovered, and certain conclusive results obtained, in connection with deciduous fruits and other plants, which are a guide and help in citrus culture. The few experiments which have been made with various fertilizers on citrus trees confirm these same general principles. They will be briefly stated.

EFFECT OF NITROGEN.

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, as manure is relatively high in nitrogen. 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 is present.

EFFECT OF PHOSPHORIC ACID.

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.

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

EFFECT OF POTASH.

Potash is necessary to the full development of the wood of the tree. If potash is wanting, the wood will not mature, and 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 otherwise. The best authorities agree that potash increases the sweetness of fruits.

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.

GENERAL PRINCIPLES.

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 can be increased by phosphoric acid and potash. The size and coarseness and large growth and late maturity can be secured by the extensive 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.

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. 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 be caused by 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.

TIME TO APPLY FERTILIZERS.

In the book of nature we read that growth is dormant for some months preceding 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 and 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. Why, then, should not fertilizers be applied long enough before the blossom time to become available?

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.

Many apply a part of the fertilizer in early summer. This is intended to feed the later growth of tree and crop and lessen the risk of loss by winter waste waters.

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.

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 before.

AMOUNT TO APPLY.

As to the quantity to apply, no one can tell this without careful experiment. Much depends upon the character of the soil, the condition and age of trees, and variety of fruit in question. The most vigorous growth requires the most food. Each grower must be his own authority.

A pound of high grade fertilizer to each year of age of the tree is the amount usually recommended for navel orange trees in full bearing. Orchards otherwise well cared for, supplied with this amount, increase their yield each year. Usually, however, where two pounds per year of age of tree is used, the yield of navel oranges is sufficient to warrant such application with profit.

This is particularly true of trees over ten years old. If the fertilizer is low grade, the amount used should be doubled.

METHOD OF APPLICATION.

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.

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

Nitrogen—0.50% or 10 lbs. of a ton at 16c........	$1.60
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
	$2.48

The commercial value of the plant food is then about $2.50 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 $2.50 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.

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, lime, or sulphate of potash be sprinkled on the heap each day as it accumulates, the ammonia is 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.

"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." (From Experiment Station Work, V. of the U. S. Department of Agriculture.)

GREEN MANURING.

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

1st. To obtain the nitrogen which they produce by their growth.

2d. To set free unavailable plant food by the action of their roots.

3d. To lighten the soil by plowing them under while green. The capacity of soils for absorbing and retaining moisture is thus increased, part of the cost of nitrogen is saved, and danger of washing by winter rains is lessened.

4th. For humus, which is always necessary for any form of crop.

The Canadian field pea is the most popular plant for this purpose. Beans and clover are also used. Barley and other grains have not the same power to absorb nitrogen from the air, and, unless turned under green, dry out the soil and render it hard to work. Barley is beneficial as far as its roots set free unavailable forms of potash and phosphoric acid.

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.

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.

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.

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 soil moisture and dissolve other forms of plant food. Without these acids, phosphorous, 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.

Organic fertilizers lighten soils. Their decay leaves the soil open and porous. More oxygen is thus admitted, which gives more life to the microorganisms 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.

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.

CULTIVATION AND FERTILIZERS.

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.

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 may be inereased in this way, or a short season made equal to a long one.

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 or 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.

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.

IRRIGATION AND FERTILIZERS.

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 affects 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 and sideways, carrying with it the soluble fertilizers.

As moisture evaporates at the surface, it is constantly supplied from below by the capillary movement. The dissolved fertilizers contained remain on the surface after 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 up and down many times a year.

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, wherever water can go. If there is any waste water a part of them is lost.

If the grade at the flume is very steep for fifty or a hundred feet, the trees in that space will be the first to turn yellow, although they are nearest the flume and received 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.

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.

Soil analysis should be interpreted by an expert, for where 1/10 of 1% would be considered a sufficiency of some elements, 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.

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. This, also, soil analysis would reveal.

Whenever there is uncertainty about the needs of crops or orchard, soil analyses should always be taken. One element, only, may be lacking and thus discovered, and the purchase of the element unnecessary be avoided. The 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.

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EXPLANATORY NOTE.

The statement made in the paragraph near the top of page 12, that the insoluble form of phosphoric acid has "no commercial value" should be modified. State agricultural stations usually attribute some commercial value to this form of phosphoric acid, say about 2 cents per pound, while the water soluble form would be regarded as worth considerably more. The agricultural value of insoluble, or tri-basic, phosphoric acid is very much greater than the commercial value or the station value. (See also "Cheapest Form of Phosphoric Acid," page 14, and "Commercial vs. Agricultural Value," page 32.)