459-1008-30m

TEXAS AGRICULTURAL EXPERIMENT STATIONS.

BULLETIN NO. 112.
SEPTEMBER, 1908.

Nature and Use of Commercial Fertilizers

BY

G. S. FRAPS, PH. D., Chemist.

POSTOFFICE:
COLLEGE STATION, BRAZOS COUNTY, TEXAS.

AUSTIN, TEXAS:
VON BOECKMANN-JONES COMPANY, PRINTERS
1908.

TEXAS AGRICULTURAL EXPERIMENT STATIONS.

OFFICERS.

GOVERNING BOARD.

(Board of Directors A. and M. College.)

K. K. LEGETT, President.................................Abilene.
T. D. ROWELL, Vice-President............................Jefferson.
A. HAIDUSEK...La Grange.
J. M. GREEN...Yoakum.
WALTON PETEET...Dallas.
E. R. KONE..San Marcos.
L. L. McINNIS...Bryan.
W. B. SEBASTIAN...Breckenridge.

STATION OFFICERS.

H. H. HARRINGTON..Director.
W. C. WELBORN....................Vice-Director and Agriculturist.
J. W. CARSON.........Assistant to Director and State Feed Inspector.
M. FRANCIS..Veterinarian.
G. S. FRAPS...Chemist.
O. M. BALL..Botanist.
C. E. SANBORN...Entomologist.
JOHN C. BURNS...Animal Husbandry.
H. NESS...Horticulturist.
N. C. HAMNER......................Assistant Research Chemist.
E. C. CARLYLE...Assistant Chemist.
C. W. CRISLER...Chief Clerk.
F. R. NAVAILLE..Stenographer.
A. S. WARE..Stenographer.

STATE SUBSTATIONS.

W. S. HOTCHKISS, Superintendent..............Troupe, Smith county.
S. A. WASCHIKA, Superintendent...............Beeville, Bee county.

NOTE.—*The main station is located on the grounds of the Agricultural and Mechanical College, in Brazos county. The postoffice address is College Station, Texas. Reports and bulletins are sent free upon application to the Director.*

TABLE OF CONTENTS.

[Blank Page in Original Bulletin]

NATURE AND USE OF COMMERCIAL FERTILIZERS.

By G. S. FRAPS, Chemist.

The use of commercial fertilizers is increasing in Texas. Constant demands are made upon the Experiment Station for information in regard to their nature and use, which is always cheerfully furnished, so far as possible. This bulletin has been prepared to aid those who use commercial fertilizers. We have endeavored particularly to give attention to the questions which have been asked. The matter of the fertilizer law and its operations are left to another bulletin.

FERTILIZERS SUPPLY PLANT FOOD.

It was learned about seventy-five years ago that plants are built up from certain materials from the air and the soil, water being one of them. While about 95 per cent of the dry plant comes from the air, the material required from the air is supplied freely and abundantly to every plant. The case is, however, different with the soil. The soil does not always supply the plant with sufficient material for its growth; material which we shall here term "plant food."

What food is essential to plants has been ascertained by growing the plant in water containing various materials which have been found in plants. If the plant grows well and produces seed abundantly without a certain material, that material is considered as not essential to the life of the plant. If, when all the other forms of plant food, or possible plant food are present, the plant does *not* do well in the absence of a certain material; this material is considered as essential to the life of plants.

The essential materials are ten in number. Seven come from the soil; namely, phosphoric acid, potash, nitrogen, sulphur, lime, magnesia, and iron. Carbon, hydrogen and oxygen the plant secures from the water or the air; the water, of course, being taken up by the plant from the soil.

When it was discovered that the plant, in order to grow well, must take up certain substances (called plant food) from the soil, attempts were immediately made to improve the quality of poor soils by the addition of various forms of plant food. Many of these attempts were very successful. This was the beginning of the use of commercial fertilizers.

It was found out by various tests made with the different forms of plant food that only three kinds need to be applied to soils. These are phosphoric acid, potash, and nitrogen. Lime is sometimes applied, but the object of the application is not to provide an extra supply of plant food, but to bring about changes in the character of the soil, which render it more suitable for the growth of plants.

The application of plant food thus became confined to phosphoric acid, nitrogen, and potash. Commercial fertilizers contain only phosphoric acid, potash or nitrogen or may be mixtures of two of these, or all three.

Plants cannot secure phosphoric acid from all forms in which it may be applied; the same is true of nitrogen and potash. It is necessary to distinguish between plant food which can be readily taken up by plants, and that which can be taken up only with difficulty, or not at all. We will discuss this side of the question later.

Commercial fertilizers may be defined as materials which supply phosphoric acid, nitrogen or potash to the soil in such forms that the plants can take them up readily.

WHY SOILS NEED PLANT FOOD.

Certain soils are naturally deficient in plant food even when first placed in cultivation; they do not supply a sufficient quantity of some one essential plant food to produce good crops. A great many soils of the Southern States are naturally deficient in phosphoric acid. This is particularly true of sandy soils.

If the store of plant food in the soil is drawn upon by crops and the crops taken away, in time the fertility of even the richest soil will be depleted unless the plant food is restored. A great many soils which were originally very productive have lost their fertility in this way.

Changes are going on in the soil which convert materials containing nitrogen into nitrates and ammonia. These can be taken up by plants, while the original nitrogenous matter cannot, but nitrates are very soluble in water and may be washed out of the soil. Under clean cultivation a considerable loss of nitrogen has been known to occur in this way; sometimes as much as 60 pounds per acre. Such loss would, of course, tend to deplete the store of nitrogen in the soil.

Truck crops, which must grow rapidly and mature early, make very heavy demands upon the soil for plant food. Even fertile soils may not supply the necessary plant food with sufficient rapidity. With crops of this nature the application of commercial fertilizers is usually profitable.

PLANTS HAVE OTHER NEEDS BESIDES FOOD.

The user of commercial fertilizers must not forget that plants have other needs besides the food supplied by the fertilizer. The best results with fertilizers are secured when the other needs of the plant are supplied as liberally as possible.

Plants must have water, and an abundance of it. They require about 500 pounds of water for every pound of dry matter they produce. The supply of water is often the controlling factor in the growth of plants; in arid climates, the size of the crop has been found within certain limits to be directly proportional to the quantity of water supplied to them by irrigation. It is outside of the plan of this bulletin to discuss the methods for controlling the water in the soil.

Plants must have air, the roots of plants must have air, and air must enter the soil to oxidize organic matter, and aid in the preparation of food for plants.

The depth of soil, the treatment it receives, its physical condition and its character, the relation of soil to drainage—these and other factors, are important in the production of plants. Plant food is necessary, but other conditions are equally necessary.

Fertilizers cannot take the place of good farming; they can only supplement good farming, and are most profitable when used in connection with it.

HOW PLANTS ARE BUILT UP.

Chemistry teaches us that the materials of which the earth is composed can be split up or decomposed until we secure about seventy substances, which we are unable to break down; these substances which cannot be decomposed into simpler forms are called elements. By the union of two or more elements compounds are formed. Most of the substances that we ordinarily see are compounds of two or more elements. A few are the elements themselves in a more or less impure form. Gold, silver, lead, iron, copper and sulphur are some elements with which we are familiar.

Plants are built up of a comparatively small number of elements. With two exceptions they are unable to take up and utilize the elements as such; these exceptions are oxygen and nitrogen, both of which may be taken up in elementary form under certain conditions. The other materials of which the plant is composed, including all of those which are secured from the soil, must be taken up as compounds. Phosphorus, for example, is taken up as phosphoric acid. The element phosphorus is dangerous to handle; it takes fire when exposed to the air and must be preserved under water. It is also poisonous. Plants cannot take up elementary phosphorus, but phosphoric acid is essential to their life and development.

The element potassium is likewise unsuitable for the use of plants as such. It must be kept under oil. If thrown on the water, it will combine with the water, take fire and burn. Potassium in combination is, however, essential to plants.

SOURCES OF PHOSPHORIC ACID.

Phosphoric acid is applied to the soil in combination, usually in combination with lime, the compounds being known as phosphates of lime. The commercial sources of phosphates are phosphate rock, bone and bone tankage, Thomas phosphate, and guano.

Phosphate rock is found in the earth in South Carolina, Florida, Tennessee, Arkansas, and various other places. The phosphoric acid is present as phosphate of lime. There are impurities of various kinds present. The quantity of phosphoric acid in phosphate rock varies from about 25 to 35 per cent.

Phosphate rock even when finely ground does not contain its phosphoric acid in such forms that plants can readily take it up. It has been claimed that, when used in connection with stable manure, the phosphoric acid has a much higher value. On acount of its low price, ground phosphate rock is used to some extent as a fertilizer in the Middle West. Its action, however, is very slow, even when used in connection with organic matter, and it has practically no effect the first year.

Phosphate rock is usually prepared for fertilizing purposes by treating it with sulphuric acid. This process will be discussed on a succeeding page.

Bones, like phosphate rock, contain phosphate of lime; unlike phosphate rock, bones contain organic matter. Phosphoric acid is more easily taken up by plants from bones than from phosphate rock. This may be partly due to the more porous character of the bones, and partly to the organic matter which is present. Bones are, however, slow in their action and are best used on such crops as will occupy the soil for some time.

Bone meal consists of crushed or ground bones. Several varieties of bone meal are on the market. *Raw bone meal* is prepared by grinding raw bones; it contains from 3 to 5 per cent of nitrogen, and from 17 to 20 per cent of phosphoric acid. It is slow in its action, and is best used on crops which occupy the soil two years or more—such as grasses, fruit trees, etc. The value of bone meal depends upon its fineness of division and its composition. The finer the bone is ground, the more easily is the phosphoric acid which it contains taken up by plants.

Bones which have been treated with super-heated steam in order to remove the fat and dissolve out the material which forms glue, are ground into *steamed bone meal.* This material contains less nitrogen and more phosphoric acid than raw bone meal. Phosphoric acid is more easily taken from it by plants, as the bone has been rendered much softer by the steaming. The removal of the fat is also an advantage. Steamed bone meal contains 1.5 to 2.5 per cent nitrogen and 22 to 29 per cent phosphoric acid.

Bone tankage is a product of slaughter houses, being composed of the bony residues of animals. It is usually treated with steam in order to remove the fat, which is more valuable than the tankage. The composition of bone tankage is variable. The phosphoric acid present is about equal in value to that in the steamed bone meal. Bone tankage contains more nitrogen than bone meal.

Thomas phosphate, also called basic slag, is a product of the manufacture of steel from iron containing much phosphorus. The compound of phosphoric acid in Thomas phosphate contains more lime than that in bone or phosphate rock. Thomas phosphate gives better results on soils which are acid or which contain more organic matter than on ordinary soils. It is little used in Texas. It is being tested by the Experiment Station in co-operative experiments on rice.

Bat guano ash is rich in phosphoric acid. Bat guano contains considerable nitrogen. Bat guano and bat guano ash will be described in connection with nitrogenous fertilizers.

HOW ACID PHOSPHATE IS MADE.

As we have said, the phosphoric acid in phosphate rock and bone is taken up very slowly by plants. In order to make the phosphoric acid more easily available, the material is treated with sulphuric acid. Phosphate rock or bone is first finely ground and then mixed with the sulphuric acid. The mixture is dumped upon the floor of the warehouse and allowed to remain there until the reaction is completed. It is then ground up and is ready for use as acid phosphate.

We have sometimes received inquiry concerning the preparation of acid phosphate at home. We do not consider it practical for any one to undertake this. The materials must first be ground, and that takes special machinery. The sulphuric acid must be purchased and shipped in. Sulphuric acid in small quantities is shipped in glass vessels, called carboys, holding about 10 gallons. The freight rate on acid is double first-class. The cost of the acid itself after paying the freight would probably be greater than the cost of the quantity of acid phosphate which could be prepared with its use. Sulphuric acid is also somewhat dangerous to handle; it eats up clothes when it gets on them, chars wood, acts readily upon most materials. We do not advise any one to attempt to prepare acid phosphate from bones or other materials at home. The best way to utilize the bones would be to compost them with manure, or use them for fruit trees.

FORMS OF PHOSPHORIC ACID IN ACID PHOSPHATE.

The phosphoric acid in acid phosphate is present in three different compounds.

Water-soluble phosphoric acid is that which can be extracted from the acid phosphate with water. It is combined with less lime than the other compounds of phosphoric acid in acid phosphate. Being soluble in water, it distributes itself in the soil. It is easily taken up by plants and is probably the most valuable form of phosphoric acid. Although the water-soluble phosphoric acid combines with some constituents of the soil, and becomes insoluble, this change takes place slowly, and the phosphates formed still have a high value for plants.

Reverted phosphoric acid is combined with twice as much lime in proportion to the phosphoric acid present as water-soluble phosphoric acid. Although it is insoluble in water, it can be readily taken up by plants.

Fertilizers containing large proportions of reverted phosphoric acid are prepared from bone and bone tankage instead of from acid phosphate, and are not considered as carrying their phosphoric acid in high-grade forms.

Available phosphoric acid is the sum of the water-soluble and reverted. It is the phosphoric acid which can be easily consumed by plants.

Insoluble phosphoric acid has three times as much lime in combination with its phosphoric acid as water-soluble. It is the phosphoric acid of the rock or bone which was not acted upon by the sulphuric acid. The phosphoric acid in this form is taken up by plants very slowly. In estimating the value of commercial fertilizers this form of phosphoric acid is given no value.

GRADES OF ACID PHOSPHATE.

Acid phosphate of three grades is sold in Texas. That containing 12 per cent available phosphoric acid is known as 12 per cent acid phosphate, or acid phosphate 12 per cent. The other grades are 14 per cent and 16 per cent, and contain 14 and 16 per cent of available phosphoric acid, respectively. The purchaser of acid phosphate should examine the tags on the goods carefully, in order to see what grade of goods he is getting. The value of the acid phosphate is, of course, proportional to the quantity of phosphoric acid it contains.

MATERIALS WHICH ARE SOURCES OF NITROGEN.

Like phosphoric acid, different forms of nitrogen have different values to the plant. Some of them are readily taken up by plants while others are taken up so much slower as to have little or no value.

The chief forms of nitrogen used in mixed fertilizers in Texas are nitrate of soda, cottonseed meal, dried blood, tankage, and bat guano.

Nitrate of soda comes from Chili, where it is found mixed with earth. It is removed by extracting the earth with water. After separation and purification it is put on the market, and contains 95 to 97 per cent nitrate of soda. It contains 15 to 16 per cent nitrogen. Nitrate of soda may be used to replace cottonseed meal in any formula given in this bulletin, using one-half as much nitrate of soda. This will change the percentage composition of the fertilizer, making it more concentrated, but smaller amounts may be used to compensate.

Nitrate of soda can be taken up by plants as soon as the roots can come in contact with it. It is, therefore, very quick in its action. Nitrate of soda is very easily soluble in water and distributes itself through the soil. But it is easily washed from the soil. Heavy rains may cause losses of nitrate of soda. Losses of this kind are more liable to occur with light sandy soils, such as are used for truck growing, than with heavy soils.

On account of the danger of losing it by washing, and since it is all in condition to be taken up by plants as soon as it reaches the roots, the most economical use of nitrate of soda is to apply it at such times as it is needed and in such quantities as will be completely used. It is profitable upon crops which grow during the winter or early spring when the bacteria which prepare nitrogenous plant food in the soil are not very active. Nitrate of soda is also of advantage in the production of early truck, or crops in which strong and vigorous early growth is desired. It is thus used for early tomatoes, beets, cabbage, celery, and other market garden crops. It is often profitably used as a top dressing for oats in the spring.

As nitrate of soda is best applied when it is needed, the entire quantity should not be placed in the ground when the crop is planted but should be applied as a top dressing when the plants are up. Two or more applications are often advisable and are more likely to give better results than a single large application. The quantity used, as a rule, is 50 to 100 pounds per acre for each application. The nitrate of soda should not come in direct contact with the plants or be placed too close to them, for it may kill the plant, for the roots to come in contact with a strong solution of it. Nitrate of soda is also used in connection with less quickly available nitrogenous fertilizers. It gives the plant an early start, and the other nitrogen feeds it later on.

Sulphate of ammonia is a by-product of the manufacture of gas from coal; it contains about 20 per cent nitrogen. It is easily soluble in water; but the ammonia is fixed and held by the soil so that it does not wash out, as is the case with nitrate of soda. Sulphate of ammonia is a good fertilizer.

Organic Materials.—Cottonseed meal, bat guano, and similar substances are termed organic nitrogenous fertilizers. They contain nitrogen in combination with carbon, hydrogen, oxygen, and perhaps other elements. Before organic fertilizers can be taken up by plants, they must undergo change in the soil and be converted into ammonia or nitrates. The nitrogen stored in the soil is also present in organic forms and must also be converted into ammonia and nitrates, if it is to be useful to plants. This change is brought about by the activity of living organisms, called bacteria. The rate of their action depends upon the nature of the soil, temperature, moisture content of the soil, and other conditions. They are much more active in the summer than in the winter or early spring. It is thus seen that the soil may contain a good store of nitrogen, but if the bacteria do not prepare it for the use of plants in sufficient quantity, the plants will suffer. If the bacteria are too active, the excess of nitrates may be washed from the soil and lost.

Materials which are quickly changed into ammonia or nitrates in the soil have a high value and are termed readily available.

Cottonseed meal is somewhat variable in composition. It contains on an average 7 per cent nitrogen, 2.5 per cent phosphoric acid, and 1.5 per cent potash. It is seen that cottonseed meal thus contains appreciable quantities of phosphoric acid and potash in addition to nitrogen. The nitrogen of cottonseed meal has a high fertilizing value.

Meal unfit for feeding, which has been made from over-heated seed, or which has been cooked too much in the process of manufacture, usually contains as much plant food, and is equally as valuable for fertilizing purposes, as choice meal. The more hulls present in the meal, the less is its fertilizing (and feeding) value.

The following table shows the fertilizing constituents of Texas cottonseed meal:

POUNDS OF PLANT FOOD IN 100 POUNDS COTTONSEED MEAL.

	Nitrogen.	Phosphoric Acid (Total).	Potash.
Average of 321 Texas samples (Bulletin No. 90)	7.53	....	.....
Average of 21 Texas samples*	....	.....	1.83
Average of 30 Texas samples§	....	2.63	.....
Average of 204 analyses, all States†	6.79	2.88	1.77

*Analyses by. S. E. Asbury, Assistant Chemist.
§Analyses by J. B. Rather, Assistant Chemist
†The Cotton Plant (U. S. Dept. Agriculture, 1896).

POUNDS OF PHOSPHORIC ACID IN 100 POUNDS COTTONSEED MEAL.§

Number.	Total.	Insoluble.	Water-Soluble.
4781	2.15	0.30	1.12
4782	2.35	0.30	1.35
4783	2.25	0.70	1.47
4804	2.45	0.50	0.95
4808	2.35	0.20	1.15
4813	2.50	0.50	1.17
Average	2.34	0.42	1.20

Cottonseed has nearly half the fertilizing value of cottonseed meal, but the ingredients are in different proportion. The average composition is as follows:

Nitrogen	3.13 per cent.
Phosphoric acid	1.27 per cent.
Potash	1.17 per cent.

Cottonseed meal may be replaced, if desired, by two and one-third as much cottonseed, in any formula given in this bulletin. This substitution will, of course, change the percentage composition of the fertilizer, but the quantities of plant food will be in nearly the same proportions, and a larger amount of fertilizer can be applied to the soil to compensate for the smaller percentages of plant food.

Tankage consists of refuse materials from slaughter houses and is very variable in composition. It contains some phosphoric acid in addition to its contents of nitrogen. Tankage is a valuable fertilizer but not as valuable as dried blood or cottonseed meal. It contains 5 to 10 per cent nitrogen and 6 to 15 per cent phosphoric acid.

Dried blood is obtained by drying the blood from slaughter houses. Its composition is not uniform. It contains 11 to 14 per cent nitrogen. It is readily transformed into ammonia and nitrates in the soil, and has a high fertilizer value.

Bat guano is the dried excrement of bats. It is found in certain caves in Texas, a few of which are now full of bats engaged in the production of this valuable manure. It is a very light material. Pure bat guano is rich in nitrogen and low in phosphoric acid. Bat guano sometimes takes fire through spontaneous decomposition, leaving bat guano ashes.

Bat guano ashes are rich in phosphoric acid, but do not contain nitrogen unless mixed with bat guano, as is often the case.

The earth from bat guano caves is sometimes taken to be bat guano. It may contain a small quantity of nitrogen, but it is of a very inferior value as compared with bat guano. Bat guano appears to be a fertilizer of good value. The composition of some samples of so-called bat guano is shown in the following table. On account of the variable composition of materials supposed to be bat guano, it should only be sold on analysis.

§Analyses by J. B. Rather, Assistant Chemist.

COMPOSITION OF SUPPOSED BAT GUANO.

	Phosphoric Acid, Per Cent.	Nitrogen, Per Cent.
I	.92	3.93
II	7.70	6.28
III	5.00	9.94
IV	6.07	5.38
V	4.10	10.06
VI	5.08	1.66
VII	3.97	6.49
VIII	2.97	11.55
IX	4.12	11.44
X	2.02	8.67

Numbers III, V, VIII, and IX represent high-grade bat guano. No I is probably a cave earth. Some of the other samples appear to be mixtures of bat guano and bat guano ash.

Hoof and horn meal, hair, wool waste, and leather contains high percentages of nitrogen, but they have little value as nitrogenous fertilizers on account of the slowness with which they change in the soil. The use of these materials in commercial fertilizers is prohibited in several States, and justly so, because they decay so slowly as to have little value for plants.

SOURCES OF POTASH.

Most of the potash used in fertilizers comes from Germany. Immense deposits of potash salts have been found near Stassfurt. The crude salts are mined and subjected to more or less purification, according to the grade of potash salts desired, and then placed on the market. The chief potash salts used in this country are kainit, muriate of potash, and sulphate of potash.

Kainit is a term applied to potash salts containing not less than 12 per cent of potash. Kainit is prepared by mixing crude salts of potash in proportion to secure the desired content of potash, although the term really belongs to a mineral containing sulphate of potash, sulphate of magnesia, and chloride of magnesia. As kainit is prepared from crude salts, no expense of concentration is attached to it. Since, however, 100 pounds of a kainit contains 12 pounds of potash and 100 pounds of concentrated potash salts contain about 50 pounds of potash, freight charges on potash in kainit are about four times as much as in concentrated salts. At a distance from the mines, the freight charges are greater than the cost of manufacture, so that the potash costs less per pound in the concentrated salts.

Muriate of potash contains from 45 to 55 per cent potash.

Sulphate of potash contains 45 to 55 per cent potash in the form of sulphate. It is somewhat more expensive than muriate of potash but is better adapted to some crops. The chloride in kainit, or in muriate of potash, is injurious to tobacco, as it impairs its burning quality and makes it liable to be damp. It also injures the quality of potatoes.

making them less crisp and starchy. For this reason sulphate of potash is preferred to muriate of potash for tobacco, potatoes, and some other crops.

The different forms of potash in fertilizers are all soluble in water and, therefore, do not differ in availability, although there may be some differences in their effects on account of the other materials which they contain.

Rice-straw ashes contain about 12 per cent potash, if they have not been exposed to rain. They thus have about the same value as kainit.

Tobacco stems contain from 6 to 8 per cent of potash, from 1.5 to 2.5 per cent nitrogen and from 0.3 to 0.5 per cent phosphoric acid. They may sometimes be secured at a sufficiently low price to warrant their use as a fertilizer.

Wood ashes, if they have not been exposed to the rain, and thereby leached, contain 4 to 9 per cent of potash and 1 to 2 per cent phosphoric acid. Wood ashes are very variable in composition, and should be sold by an analysis made of each shipment. The ashes of hard woods contain more potash and are more valuable than those from soft woods. Ashes also contain lime, which will correct the acidity of the soil if the soil is acid.

Ashes which have been leached by exposure to the weather contain 1 to 1.5 per cent phosphoric acid and about the same quantity of potash. The potash in ashes is very easily soluble in water, and taken out by rain.

Cottonseed-hull ashes are rich in potash, although they vary greatly in composition on account of the other fuel used together with them. Cottonseed-hull ashes may contain 7 to 44 per cent potash and 2 to 15 per cent phosphoric acid. On an average they contain 23.4 per cent potash, 9.1 per cent phosphoric acid, and 8.9 per cent lime.

FARM MANURE.

There are two ways in which plant food may be purchased: in fertilizers and in feeding-stuffs.

Feeding-stuffs contain plant food. After they are used by the animal, most of the plant food is excreted by the animal in the solid and liquid excrement. A small portion is retained by growing animals, and a portion is used by cows in the elaboration of their milk, but the largest part passes off. The plant food in the excrement is equally as valuable as that in the food, pound for pound. The farmer who feeds cottonseed meal and wastes the manure gets only the feeding value of his feed. One who buys cottonseed meal for use as a fertilizer gets only its fertilizing value. But one who feeds the meal and saves the manure secures both the feeding value and a portion of the fertilizing value of the feed. How much of the fertilizing value he may secure, depends upon the success with which loss is prevented, but since cottonseed meal has a fertilizing value of about $28 a ton, one who feeds meal and saves the manure should get at least $15 a ton more value from his meal than one who uses the meal for fertilizing purposes only, or who feeds the meal and wastes the manure.

The following table shows the content of plant food in some feeding-stuffs used in Texas, and their fertilizing valuation per ton calculated on nitrogen at 17 cents and potash and phosphoric acid each at 6 cents a pound:

PLANT FOOD IN POUNDS PER TON OF THE FEEDING-STUFF NAMED.

Name of Feed.	Phosphoric Acid.	Nitrogen.	Potash.	Valuation per ton.
Cottonseed meal ...	50	140	30	$27 60
Cotton seed	26	62	24	13 54
Corn chops	12	33	7	6 75
Wheat bran	54	49	28	13 25
Wheat shorts	27	54	12	11 52
Rice bran	40	35	5	8 65
Rice polish	40	37	14	9 53
Milo maize grain..	8	35	12	7 15
Kaffir corn grain..	12	34	10	7 10
Alfalfa hay	12	46	42	11 06
Clover hay	11	40	36	9 62
Meadow hay....	8	20	26	5 44
Corn stover	6	12	28	4 08
Forney hay	5	22	26	5 60
Johnson grass hay..	10	22	46	7 10

(With the exception of cottonseed meal the above are average analyses from various parts of the United States. Studies of Texas feeds are being made.)

A considerable part of the fertilizing value of the feeding stuff goes into the liquid excrement; in many cases over 50 per cent. (See Bulletin No. 104.)

Manure not only contains plant food, but it supplies the soil with organic matter, which is very necessary to enable the soil to maintain in good condition. Manure is very lasting and durable in its effects.

The following is the average composition of mixed stable manure:

POUNDS OF PLANT FOOD IN 100 POUNDS OF MANURE.

Phosphoric acid	0.4 per cent.
Nitrogen	0.6 per cent.
Potash	0.6 per cent.

The composition of manure is somewhat variable. It depends upon the kind and quantity of food fed, the kind of animal and the nature of absorbents used. It also depends upon the treatment to which it has been subjected. Manure which is piled up loosely and allowed to overheat loses a considerable portion of its fertilizing value. A considerable amount of plant food is washed out of manure exposed to rain.

A ton of barnyard manure contains from 4 to 9 pounds phosphoric acid, 9 to 15 pounds nitrogen, and 9 to 15 pounds potash. It, therefore, contains comparatively small amounts of plant food as compared with commercial fertilizers. Large applications of the manure must, therefore, be made in order to carry much plant food.

Manure has a great indirect action upon the soil; it adds a large amount of organic matter, which increases the power of the soil to hold water. It makes heavy clay soils more open and porous, and on such soils it should be best applied in the fresh condition. On light sandy soils it is best applied in the well rotted condition.

In the dry section of this State the manure should be well rotted and should not be allowed to dry out before it is plowed under. If it becomes too dry, it may be slow in taking up water and may have the effect of drying out the plowed surface of the soil.

We expect to discuss the subject of manure in detail in a succeeding bulletin.

HOW COMMERCIAL FERTILIZERS ARE PREPARED.

Commercial mixed fertilizers are prepared by mixing together acid phosphate, nitrogenous materials, and potash salts in the proportion necessary for the composition desired. In some fertilizers the phosphoric acid comes partly from bone or tankage. These fertilizers contain only a small proportion of their available phosphoric acid in the water-soluble form and they contain a considerable quantity of insoluble phosphoric acid. Fertilizers made with acid phosphate alone contain two-thirds or more of their phosphoric acid in the water-soluble form and only about one-sixth of the total quantity present is insoluble. Acid phosphate is considered as a more desirable source of phosphoric acid in mixed fertilizers than bones or tankage.

After the proper materials have been weighed out, they are mixed thoroughly and passed through a coarse sieve to insure a uniform degree of fineness. Any other material which does not pass through the sieve is ground up and added to the mixture. Sometimes the ingredients must be ground up before they can be mixed, as they may have become hard and lumpy.

HOME MIXTURES.

By home-mixed fertilizers we mean the purchase of ingredients and mixing them on the farm in proportions to form the complete fertilizer desired. It would hardly pay to grind bones or other hard materials on a small scale. We have already given reasons why the preparation of acid phosphate from phosphate rock or bones should not be attempted at home. In the home mixing of fertilizers, we simply mix the ingredients which have been purchased for that purpose.

The operation is very simple, the apparatus required being a clean floor, one or two shovels, a pair of scales, and a sand sieve with meshes of about four to the inch. The materials are first weighed out one by one and piled on the floor, any large lumps being broken down with the shovel. The pile is then shoveled over several times and the mixture passed through the sieve. Any lumps which fail to pass through the sieve are broken up and added to the mixture. The mixture is again shoveled over several times until thoroughly mixed. It is possible to prepare the mixture without using a sieve, but better results are secured with it.

Samples of mixed fertilizers prepared at home have been collected by various experiment stations and examined as to their mechanical condition and chemical composition. The mechanical condition, as a general rule, has been found to be good. The chemical composition did not vary any more from the composition calculated from the ingredients used than mixtures sold by manufacturers vary from their guaranteed analysis. The New Jersey Experiment Station says that it amply demonstrated in 1893, and corroborated in 1894, that farmers with their ordinary farm appliances can prepare mixtures that compare very favorably with purchased mixtures both in mechanical condition and chemical composition.

The Vermont and Maine Experiment Stations made similar statements. Although sometimes materials may become hard and lumpy and give a good deal of trouble in preparing a suitable mixture, it has been found, as a general rule, that farmers can mix their own fertilizers with good results.

Whether or not it is profitable to prepare home mixtures of fertilizers depends upon conditions. The question can be answered by any one who desires by calculating the cost of the unmixed materials and after allowing for the cost of mixing, compare the results with the price at which the mixed fertilizers could be purchased. The quantity of each ingredient to be used in making the mixture must, of course, be known, and the cost of the ingredients, including freight charges, must also be ascertained.

At this experiment station the cost of ingredients for six fertilizers was compared with the selling price of the mixed fertilizers, using the retail cash price of the ingredients and of the mixtures as actually found on the market. Some of the mixed fertilizers sold for about the same price as the cost of the ingredients. On an average the retail price of the ingredients for the six fertilizers was $3.38 per ton less than the selling price of the corresponding mixed fertilizers. If the wholesale cost of the ingredients had been used, the difference, of course, would have been greater, but it is not fair to compare wholesale or carload prices of ingredients with retail or ton prices of mixtures. It is also not fair to compare the cash cost of home mixtures with the credit prices of complete mixtures.

Whether or not home mixing will pay must be decided in each individual case.

The manufacturer has the advantage of purchasing his materials in large quantities at wholesale prices. He also has the advantage of possessing the necessary machinery and appliances for mixing at a lower cost per ton than the home mixer. In many cases the mixed fertilizers can be purchased cheaper from the manufacturer in carload lots than the mixed fertilizers can be prepared at home. In other cases, however, it will be more economical to make the home mixture. Many farmers have found it profitable to prepare their own mixtures, and most experiment stations advocate it.

It may be said further in favor of home mixtures that the grade of material used is known. It is also easy to vary the mixture for the purpose of testing the effect of different combinations upon the soil.

FORMULAS FOR FERTILIZERS.

In this section we will give formulas for mixing fertilizers, using ingredients which can be easily secured on the Texas market.

Formula I.—8-2-2 Fertilizer.

This fertilizer contains 8 per cent available phosphoric acid, 2 per cent potash and 1.65 per cent nitrogen. It may be prepared by mixing the following ingredients:

Acid phosphate, 14 per cent	1170 pounds.
Cottonseed meal	490 pounds.
Kainit	340 pounds.
Total	2000 pounds.

Formula II.—8-2-2 Fertilizer.

Acid phosphate, 14 per cent	900 pounds.
Tankage	560 pounds.
Kainit	340 pounds.
Filler	200 pounds.
Total	2000 pounds.

This formula differs from Formula No. I in that the nitrogen is secured from tankage instead of from cottonseed meal. The tankage is assumed to contain 6 per cent of nitrogen, and 6 per cent of available phosphoric acid. If its composition were different, the formula of the mixture would, of course, be different.

Any indifferent material can be used as a filler. In home mixing, however, it would be unnecessary to use a filler. Simply apply less of the fertilizer.

Formula III.—8-3-3 Fertilizer.

Acid phosphate, 14 per cent	1170 pounds.
Cottonseed meal	730 pounds.
Muriate or sulphate of potash	100 pounds.
Total	2000 pounds.

This fertilizer contains 8 per cent available phosphoric acid, 3 per cent of potash, and about 2.5 per cent nitrogen. It may be used on cotton or corn, or on vegetable crops that do not require much potash or nitrogen.

Formula IV.—8-3-3 Fertilizer.

Acid phosphate	1000 pounds.
Cottonseed meal	650 pounds.
Nitrate of soda	100 pounds.
Muriate or sulphate of potash	100 pounds.
Filler	150 pounds.
Total	2000 pounds.

This fertilizer has the same composition as No. III, but contains about one-fourth of its nitrogen in the immediately available form of nitrate of soda. This would be ready to give the plant a rapid start.

Formula V.—8-3.6-4 Fertilizer.

Acid phosphate, 14 per cent	1100 pounds.
Cottonseed meal	430 pounds.
Nitrate of soda	200 pounds.
Muriate or sulphate of potash	160 pounds.
Total	2000 pounds.

This fertilizer is used for truck crops, potatoes and other crops requiring more nitrogen than corn or cotton requires. One-half of the nitrogen is in the active form of nitrate of soda. If desired, the 200 pounds of nitrate of soda could be replaced by 430 pounds of cottonseed meal; this alters the composition of the fertilizer and the nitrogen is not so immediately available, but it is less likely to be washed out.

Formula VI.—8-4 Fertilizer.

Acid phosphate, 14 per cent	1100 pounds.
Cottonseed meal	900 pounds.
Total	2000 pounds.

This fertilizer does not contain any potash except a small quantity in the cottonseed meal. It is used for potatoes in some parts of the State.

Formula VII. 10-2 Fertilizer.

Acid phosphate	1500 pounds.
Kainit	350 pounds.
Filler	150 pounds.
Total	2000 pounds.

This fertilizer contains 10 per cent phosphoric acid and 2 per cent potash, and it is used when no nitrogen is desired.

Formula VIII.—10-4 Fertilizer.

Acid phosphate, 14 per cent	1500 pounds.
Muriate or sulphate of potash	170 pounds.
Filler	330 pounds.
Total	2000 pounds.

This fertilizer contains 10 per cent of phosphoric acid and 4 per cent of potash.

In the above formulas acid phosphate containing 14 per cent available phosphoric acid is used. If acid phosphate containing 12 per cent phosphoric acid is used, the percentage of phosphoric acid will be correspondingly reduced. If 16 per cent acid phosphate is used, the percentage of phosphoric acid will be increased.

If any other formulas besides those mentioned above are desired, they can be secured on application to the Chemist of the Experiment Station, College Station, Texas.

HOW TO CALCULATE THE INGREDIENTS TO BE USED FOR MIXED FERTILIZERS.

It is not a difficult matter to calculate how much of the various ingredients should be used to make a mixed fertilizer. Suppose it is desired to make a fertilizer containing 8 per cent phosphoric acid, 2 per cent nitrogen, and 2 per cent potash, using acid phosphate guaranteed to contain 14 per cent available phosphoric acid, kainit containing 12 per cent potash and cottonseed meal containing 7 per cent nitrogen, 2 per cent available phosphoric acid and 1.5 per cent potash.

A fertilizer containing 8 per cent phosphoric acid contains 8 pounds in 100 pounds or $8 \times 20 = 160$ pounds available phosphoric acid in a ton. The amount of nitrogen in this fertilizer would be $20 \times 2 = 40$ pounds per ton and the potash $2 \times 20 = 40$ pounds per ton.

Since cottonseed meal contains all three kinds of plant food, but is used chiefly for its nitrogen, we will begin the calculation with cottonseed meal and nitrogen. One hundred pounds of cottonseed meal contains 7 pounds of nitrogen, so 1 pound contains .07 pounds. To find out how many pounds of cottonseed meal must be used to get the 40 pounds of nitrogen desired in our fertilizer, we divide 40 by .07, which gives 572 pounds. This quantity of cottonseed meal contains $572 \times .02 = 11.4$ pounds phosphoric acid and $572 \times .015 = 8.6$ pounds of potash.

Since 160 pounds of available phosphoric acid must be present in a ton of fertilizer and the cottonseed meal contains 11 pounds, we need to secure 149 pounds of phosphoric acid from the acid phosphate. The 14 per cent acid phosphate contains .14 pounds available phosphoric acid in 1 pound. We divide 149 by .14, which gives us 1064 pounds acid phosphate. This quantity of acid phosphate contains 149 pounds available phosphoric acid.

The ton of fertilizer must contain 40 pounds of potash, of which 8 pounds has been furnished by the cottonseed meal, which we need to supply the nitrogen, leaving 32 pounds to come from kainit. Since 1 pound of kainit contains 0.12 pounds of potash, 32 pounds will be contained in 32 divided by $.12 = 267$ pounds of kainit.

A ton of this fertilizer would then be composed of the following ingredients:

Cottonseed meal	572 pounds.
Acid phosphate	1064 pounds.
Kainit	270 pounds.
Filler	94 pounds.
Total	2000 pounds.

In order to get the exact composition, 94 pounds of some indifferent material must be used as a filler.

The above illustration shows how the ingredients to make any desired fertilizer can be calculated exactly from a knowledge of the composition of the ingredients to be used. In practice, however, it is necessary to use somewhat more than the calculated ingredients in order to allow for variations in the material and also on account of the change in potash. In making a mixed fertilizer containing potash a small amount of potash usually becomes fixed so that it does not appear as water-soluble potash in the analysis.

DO NOT BUY RECIPES FOR MAKING FERTILIZERS.

From time to time parties go around selling formulas for fertilizers which they claim to be "secret" or "wonderful discoveries." Most of the recipes that have been sold in this way are worthless. Mixtures prepared according to the directions given are not worth the time and labor applied to them. Ingredients are called for which can only be purchased at high prices and likely as not are wholly without value to the plant or the soil.

The following is an example of a fertilizer recipe which has been offered for sale in this State:

Bluestone	2 pounds.
Saltpeter	2 pounds.
Nitrate of ammonia	2 pounds.
Soda ash	2 pounds.
Potash ball	4 pounds.

"Dissolve in five gallons of water and sprinkle on the sand; make a ton sufficient for one acre."

Not a single one of the substances mentioned is used in making fertilizers. Bluestone and soda ash do not contain any plant food. Saltpeter, ammonium nitrate, and potash contain potash and nitrogen, but they are too expensive to be used as a fertilizer. The potash would act upon the ammonium nitrate and drive off the ammonia, making the mixture smell like ammonia. The smell would not grow any plants. The mixture would contain about 3 pounds of potash, and 1 pound of nitrogen and would have a fertilizer valuation of 33 cents per ton. It would cost from $1.50 to $2.00 for the ingredients.

The Experiment Station will furnish without charge formulas for preparing fertilizers. The expenditure of money in purchasing them is useless.

PURCHASE FERTILIZERS FOR THE QUANTITY OF PLANT FOOD IN THEM.

There are two ways of buying fertilizers; one is to pay so much per ton and the other way is to pay so much per pound of plant food. Consumers of fertilizers usually buy on the ton basis. Manufacturers of fertilizers pay so much per pound for the plant food which they receive.

Too little attention is paid by consumers of fertilizers to the quantity of plant food in the fertilizer. Our inspectors have often found two grades of acid phosphate on the market, selling exactly for the same price per ton.

If an acid phosphate contains 12 per cent phosphoric acid, the purchaser of a ton gets 240 pounds of phosphoric acid; if it contains 14 per cent, the purchaser gets 280 pounds of phosphoric acid. If 12 per cent phosphoric acid is worth $1.00 per 100 pounds, the 14 per cent acid phosphate is worth $1.17 per 100 pounds, or very nearly 20 per cent more. Thus the consumer who purchases 14 per cent of acid phosphate, when both 12 and 14 per cent are selling at the same price, secures nearly 20 per cent more value for his money than he would have secured if he had purchased 12 per cent goods. The time should soon come when it would be impossible for two grades of acid phosphate to sell for the same price in the same town.

What has been said in reference to acid phosphate also applies to mixed fertilizers, although in this case the differences are not as plain. The valuation is a measure of the relation between the composition and the selling price, but the composition selected approach as nearly as possible to that desired. The following table shows the composition, valuation, and selling price of three fertilizers offered for sale at a certain town during the season 1907-08:

	No. I.	No. II.	No. III.
Available phosphoric acid	10.00	9.50	8.00
Nitrogen	1.65	1.65	1.64
Potash	2.00	1.50	2.00
Total plant food in 100 pounds	13.65	12.65	11.64
Valuation per ton	$20.01	$18.81	$17.58
Selling price	$27.50	$26.00	$27.00

These fertilizers have very nearly the same composition, the chief difference being in their phosphoric acid content. The purchaser of these fertilizers would secure the following number of pounds of plant food per ton at the price named:

No. I—273 pounds for $27.50.
No. II—253 pounds for $26.
No. III—232 pounds for $27.

The average cost of plant food in fertilizer No. I is 10.1 cents per pound; in No. II it is 10.3 cents; in No. III it is 11.6 cents. This example is sufficient to show that the purchase of commercial fertilizers involves some care and knowledge, if the money is to be expended to the best possible advantage.

TEXAS FERTILIZER LAW.

Full information in regard to the Texas Fertilizer Law and the work done under it is published from time to time in the form of bulletins. These bulletins can be secured free of charge, on request.

EFFECT OF KEEPING ON COMPOSITION OF FERTILIZERS.

We have had a number of inquiries in regard to keeping fertilizers. In 1907 we estimated the phosphoric acid in twelve samples of fertilizers, which had been kept for two years in a dry condition in sample bottles. These samples were then placed in pint jars, which were filled about two-thirds full. The jars were left open. The samples were kept in a basement which is at times rather damp. In 1908 these samples were again analyzed. The results are presented in the table below:

PHOSPHORIC ACID OF FERTILIZERS IN 1905, 1907 AND 1908.

Laboratory No.		Water-Soluble Phosphoric Acid. 1905.	1907.	1908.	Insoluble Phosphoric Acid. 1905.	1907.	1908.
66.	Capitol Bone and Potash Compound	1.47	1.09	.97	2.25	2.56	2.55
77.	Vegetable Special	6.40	6.35	6.05	.32	.99	1.17
51.	Blood, Bone and Potash	6.60	6.05	5.57	1.27	1.22	1.47
45.	Caddo Cotton	5.90	5.94	5.57	.52	.52	.55
17.	Meridian Home Mixture	8.20	7.22	6.80	1.24	.99	.85
116.	Texas Pride Soluble Guano	6.07	6.45	5.75	.28	.37	.45
79.	African Cotton Grower	7.07	6.81	6.12	.33	.82	.80
73.	Prime H. G. Raw Bone Superphosphate	7.47	7.11	7.15	.17	.50	.80
62.	Scott's Gossypium Phospho Special	6.27	6.22	5.57	1.44	1.51	1.40
50	Vegetable Grower	5.65	5.69	5.05	1.02	.75	.82
37.	Dissolved Bone and Potash	8.15	6.87	6.40	.52	.61	1.00
33.	Acid Phosphate	11.54	10.16	9.65	1.87	1.34	1.45
	Average	6.73	6.33	5.89	.94	1.02	1.10
	Widest differences	....	—1.38	—.70	....	+.67	+.39
		....	+.38	—.12	....	—.53	—.01
	Average difference	....	—.40	—.44	....	+.08	+.08

It is seen from the table that the average loss of available phosphoric acid was practically equal for the two periods, one of which, however, extended over two years and the other one year. The loss in insoluble phosphoric acid is likewise the same for the two periods, but the loss in both cases is very small.

Fertilizers that are kept over should be stored in a dry warehouse, and protected from moisture as much as possible. Under these conditions, there is little or no loss of plant food in fertilizers when carried over from one season to another.

HOW TO MAKE EXPERIMENTS WITH FERTILIZERS.

The users of commercial fertilizers should make such applications as he has found by experience to be best adapted to his soil and the crops which he is growing. Methods which he has found good should not be abandoned and new ones tried on large scale until he has carefully tested the new methods and found them good. There is no doubt that many improvements can be made in the application of fertilizers. The progressive farmer will make tests of different fertilizing mixtures on his soil, even if these tests are confined to a comparison of two different mixed fertilizers. Such experiments will prove profitable when properly conducted.

In making a fertilizer test the soil selected should be uniform, so that the difference in the crop will be due to the difference in the fertilizer and not to differences in the soil. The plot should not be located so that the fertilizing material from one plot may wash over from another. The products from the different plots should be weighed, as only by exact weighings can the exact difference in results secured by the different treatments be known.

The careful work that is done at experiment stations and experiment farms is mainly to ascertain scientific truth, and facts of general bearing, and is of great value and importance. The application in individual cases must depend upon individual knowledge, based on experience and experiments. Not only do the various agricultural crops differ widely in their requirements for plant food, but the various soils of the farm show different needs, and the same kind of soil may vary under different treatment, even from one season to another. Hence every progressive farmer, holding fast to what is good and seeking for what is better, must continuously study his soil and crop, and must himself become an experimenter on a more or less limited scale.

Decisive results are rarely obtained in one season and frequently the experiments are spoiled by unfavorable weather, insects, plant diseases, and other causes; for this reason the experiments should be continued from year to year. Fertilizer experiments are carried on in a variety of ways, from very simple tests in which one material is compared with another, and only two plots are used, to very thorough and complicated experiments, conducted on a uniform plan for a number of years. The Chemist of the Experiment Station will co-operate at any time in the preparation of plans for fertilizer experiments on any desired crop.

The following is a plan of experiment outlined for co-operative fertilizer experiments on corn and cotton:

Select a piece of land of about one acre of which the soil is uniform. For each application of fertilizer select four rows of cotton or corn 280 feet long, or eight rows 140 feet long, or sixteen rows 70 feet long. These rows are supposed to be 4 feet apart. Each application of fertilizer will then be made on approximately one-tenth acre of land.

1. To the first set of rows apply 20 pounds acid phosphate.
2. To the second set of rows apply nothing.
3. To the third set of rows apply a mixture of 20 pounds acid phosphate and 3 pounds cottonseed meal.

4. To the fourth set of rows apply a mixture of 20 pounds acid phosphate and 10 pounds cottonseed meal.

5. To the fifth set of rows apply a mixture of 20 pounds acid phosphate, 3 pounds cottonseed meal, and 2 pounds kainit.

6. To the sixth set of rows apply a mixture of 20 pounds acid phosphate and 3 pounds cottonseed meal and 5 pounds kainit.

The fertilizer should be mixed well, and applied in the row about a week before the seed is planted. The entire field should receive the same treatment, and if any of the plots are damaged by storms, insects, or anything else, the fact should be noted and considered. The only difference between the plots should be the quantity of fertilizer. The crop from each should be harvested and weighed separately.

The difference between plot 2 and the others shows the effect of the various fertilizers. The difference between 1 and 2 shows the effect of acid phosphate (containing phosphoric acid) alone. The difference between 1 and 3 shows the effect of nitrogen in cottonseed meal. The difference between 3 and 4 shows the effect of increasing the nitrogen. The difference between 3 and 4 shows the effect of potash (kainit). The difference between 5 and 6 shows the effect of increasing the potash.

This experiment should show which of these fertilizers would prove probably profitable for cotton and corn under the conditions prevailing on the soil tested, and it would give an intelligent basis for fertilizing next season.

PRECAUTIONS IN MAKING FERTILIZER EXPERIMENTS.

1. The greatest care should be taken to select land which is as uniform as possible in fertility. Lack of uniformity will give misleading results, and often render the experiment of little value.

2. If possible, select level land. If such cannot be had, the plots should run up and down the slopes, so that the washings by rain will not carry fertilizing material from one plot to the other.

3. The experimental plots should be measured off carefully, and each plot indicated by stakes or stones.

4. It is best to have the experimental plots long and narrow; because thus they will average up for unevenness of soil.

5. It is best to separate plots by paths or an unfertilized row to prevent roots of plants in one plot from feeding on the fertilizer supplied to adjoining plots.

6. Avoid windy days in applying fertilizer, so that they may not be blown and scattered unevenly over the plots.

7. All the plots must be treated alike in every respect, except as to the amount and kind of fertilizer applied. The same kind and quality of seed must be used over the entire area. The plowing or sowing on all the plots must be done the same day. If part be planted before and part after a rain, the experiment may become valueless. Use every precaution necessary to secure a full stand of plants, and if a good stand has not been secured at the first planting, plough up the whole field and plant over again. Arrange the same number of rows on each plot and the same number of hills and plants as nearly

as possible in each row. The plots should be plowed and cultivated alike and whatever operation is needed in the experimental plot should be carried out uniformly all over the plots.

8. The harvesting of the crop and weighing of yields must be accurate.

WHY DIFFERENT SOILS NEED DIFFERENT FERTILIZERS.

Soils differ in their requirements for plant food. Some respond to applications of phosphoric acid, others to nitrogen and others to potash. Sometimes a soil requires two or more kinds of plant food. The reason that soils differ in their requirements for plant food are as follows:

First. Soils are naturally different in their chemical composition, and their needs for plant food. As a rule, sandy soils are more likely to need potash than clay soils. They are also more likely to require nitrogen. The material of which clay soils is composed naturally contains more potash than the materials of sandy soils.

Second. Soils originally the same may become different through different treatment. One kind of crop may exhaust the soil of one kind of plant food and at the same time there is an abundance of the others. The cultivation of different crops in succession instead of the continuous culture of the same crop on the same soil, year after year, is more likely to utilize completely the plant food in the soil.

The needs of certain types of Texas soils have been discussed in Bulletin No. 100 of this Station.

WHY DIFFERENT CROPS NEED DIFFERENT FERTILIZERS.

Crops differ in their requirements for plant food. Some require considerably more potash or nitrogen or phosphoric acid than others. They also differ in the ability which they possess to secure plant food. Some plants grow quickly and must take up their plant food rapidly. They thus require an abundance of easily available plant food. Other plants grow more slowly and take a long time to mature. They can utilize the more difficultly available forms of plant food which would be almost useless to the plants first named.

These differences account for the fact that different plants require different fertilizers even on the same soil.

It is not possible to prepare formulas for fertilizers which are "best" for this or that crop. This is seen by the fact that fertilizers put up for special crops by different manufacturers may vary widely in composition. The best fertilizer to use depends both on the soil and the kind of crop, though it is always safe to apply an abundance of plant food, if the crop is valuable. However, this may lead to waste of plant food. Some fertilizer formulas are based on the analyses of the plants, but plants vary in their power to secure food, as well as in their needs, and they take up an excess (especially of potash) when they can get it.

DO FERTILIZERS INJURE SOILS?

We have sometimes been asked whether or not fertilizers injure the soil. We can answer this question by saying that if properly used they will not injure the soil.

There are, indeed, cases in which, apparently, the fertilizer has been injurious. A farmer, for example, finds that the application of 200 pounds per acre of acid phosphate will increase his crop considerably. He makes this application for three or four years, then finds that his cotton crop is smaller than it was to start with, or he discontinues the application of fertilizers and does not get much of a crop. Apparently, the acid phosphate had injured the soil.

The injury has been caused by the method of farming and not by the fertilizer. The acid phosphate supplied only phosphoric acid to the soil. The increased crop has increased the demand for nitrogen and potash so that the quantity in the soil has diminished until it is no longer the phosphoric acid but the nitrogen or potash which controls the yield of the crop. The one-sided application of plant food has aided in the exhaustion of the soil in the other plant food. The other plant foods can, of course, be restored by using fertilizers containing them.

The continuous cultivation of cotton has also decreased the organic matter in the soil, impaired its physical condition, and rendered it less suitable for the growth of cotton. This, however, is not due to the application of the fertilizer, but to the continuous cultivation of cotton. The remedy is to abandon the continuous cultivation of cotton and substitute a rotation of crops in which cotton may be followed by cowpeas or some other leguminous crop.

APPLICATION OF FERTILIZERS.

Crops may be divided into two classes with reference to the application of fertilizers.

The first class includes those crops which have a comparatively low value per acre and to which large applications of fertilizer cannot be made without costing a considerable proportion of the value of the crop. For these crops the plant food in the soil must be utilized as fully as possible and the application of fertilizer must be made as skillfully as possible. The cropping system should be arranged so as to utilize economically the residues from the previous application.

As a general rule, it may be said that it is not profitable to purchase all the nitrogen needed by crops of this character. The fertility of the soil must be maintained with nitrogen secured from the air, and nitrogenous fertilizers should be used only to supplement the supply secured in this way. This involves a rotation of crops, in which nitrogen-gathering plants are grown—cowpeas, vetch, bur clover, peanuts, etc.

The second class of crops includes those which have a high value per acre and for which even large applications of fertilizers may cost only a comparatively small proportion of the value of the crop. These crops, as a general rule, must be grown as rapidly as possible, and they require abundant supplies of plant food. Although attention should be paid to the needs of the soil, it is possible to make such heavy applications of plant food that the supply in the soil may be more or less disregarded. These crops can, of course, be followed by other crops to utilize the large residues of plant food.

It is not possible to make a strict classification of crops under these two groups, for conditions which place a crop in one group in one locality may place it in another group in another locality. A high price for a crop, due to market conditions, may change it from the first to the second group. Cotton, corn, rice, and alfalfa can be classed with crops of low acre value, and onions, sweet potatoes, tomatoes, melons, asparagus and similar crops with those of high acre value.

The suggestions given in the following paragraphs in regard to fertilizers for various crops should not be taken as rules to be followed, but as suggestions to be tried. Soil and conditions vary, and the best fertilizer should be ascertained by the experience and experiments of those concerned.

FERTILIZERS FOR COTTON.

Soils of the eastern part of this State are generally deficient in phosphoric acid first, next in nitrogen, and least of all potash.

Three kinds of fertilizers are used for cotton: acid phosphate, cottonseed meal, and mixed fertilizers.

Acid phosphate at the rate of 200 pounds per acre gives good results upon many soils which are deficient in phosphoric acid, but contain sufficient nitrogen and potash. This application is well suited to comparatively new lands, or well-drained bottom lands, or almost any soil which produces a large "weed" and little fruit.

Cottonseed meal at the rate of 200 to 400 pounds per acre gives good results on many Texas soils. This fertilizer supplies nitrogen. It is used more often on corn than cotton.

A mixture of equal parts cottonseed meal and acid phosphate also gives good results on many soils, especially in East Texas.

The complete mixed fertilizers used for cotton and corn in Texas usually approach the composition of 8 per cent available phosphoric acid, 2 per cent nitrogen, and 2 per cent potash. They are used at the rate of 100 to 300 pounds per acre for cotton, and 500 to 800 pounds per acre or over for truck crops.

The Georgia Experiment Station recommends the following fertilizer for cotton on old, worn uplands. It will no doubt give good results:

Acid phosphate	1000 pounds.
Cottonseed meal	671 pounds.
Kainit	296 pounds.

This fertilizer would contain 8 per cent phosphoric acid, 2.4 per cent nitrogen, and 2.4 per cent potash. It is applied at the rate of 400 to 800 pounds per acre by that station. Eight hundred pounds of this fertilizer will supply about one-half as much nitrogen as is removed in lint and seed of a crop of 300 pounds of lint. It should supply an abundance of potash and phosphoric acid.

MAINTAINING THE FERTILITY OF COTTON SOILS.

The soil loses fertility not only in the crop carried off, but also in the drainage waters. This loss falls principally upon nitrogen, the most expensive plant food. If we assume that 15 pounds of nitrogen are lost annually in the drainage waters, the total loss in growing a crop of 300 pounds of lint, when only the lint and seed are removed, may be estimated as follows:

Phosphoric acid	9 pounds per acre.
Nitrogen	37 pounds per acre.
Potash	9 pounds per acre.

If the stalks are burned, there is a larger loss of nitrogen, and if they are removed before burning so that the ashes are lost to the field, there is a larger loss of potash. The use of acid phosphate alone can only be considered as a temporary method of supplementing the plant food in the soil. The income and outgo of an acre of land planted to cotton and fertilized with acid phosphate alone is shown in the following table. We assume that the production is 300 pounds lint per acre:

	Phosphoric Acid.	Nitrogen.	Potash.
Loss when 300 pounds of lint is grown	9 lbs.	37 lbs.	9 lbs.
Income from 200 pounds acid phosphate per year	28 lbs.	......	......
Gain in per year	19 lbs.	......	......
Loss per year	.....	37 lbs.	9 lbs.

It is seen that the use of acid phosphate alone depletes the soil of its nitrogen and potash. After a comparatively short time the need of the soil for nitrogen will be greater than its need for phosphoric acid, and the application of acid phosphate will not give satisfactory results. The remedy is, of course, to supply the plant food which is needed; namely, nitrogen and potash. Thus acid phosphate, alone, will not maintain the fertility of the soil, and its use can be considered as a means of temporarily increasing the crop, when it is needed.

The use of an 8-2-2 fertilizer in continuous cotton culture will also in time fail to give satisfactory results. The income and outgo when 400 pounds per acre of this fertilizer are applied is shown in the following table:

	Phosphoric Acid.	Nitrogen.	Potash.
Outgo when 300 pounds of lint is grown per year	9 lbs.	37 lbs.	9 lbs.
Income in 400 pounds fertilizer	32 lbs.	8 lbs.	8 lbs.
Gain per year	21 lbs.	......	......
Loss per year	.....	29 lbs.	1 lb.

The soil will gain in phosphoric acid and lose little potash for a crop of 300 pounds of lint, but the soil will be depleted of its nitrogen. The use of this fertilizer cannot maintain the fertility of the soil when used for continuous cotton cropping.

Cottonsed meal alone could be used in sufficient quantities to maintain the fertility of the soil. Five hundred pounds of cottonseed meal would supply approximately the quantity of nitrogen lost in taking off a crop of 300 pounds of lint; provided, that the stalks and leaves are turned under and not burned. If they are burned, the loss of nitrogen would be greater and a larger quantity of cottonseed meal would be necessary.

The quantity of cottonseed meal mentioned would also be sufficient to restore the loss of phosphoric acid, and it would very nearly restore the loss of potash. As, however, many Texas soils are deficient in phosphoric acid, an addition of acid phosphate to cottonseed meal is advisable.

It is evident from what has been said that it is an easy matter to maintain the fertility of the soil so far as potash and phosphoric acid are concerned, but the quantity of nitrogen required is very expensive in commercial fertilizers.

When cotton is grown continuously with or without fertilizer the soil may not only lose plant food, but its store of organic matter is depleted. The organic matter has considerably to do with maintaining the soil in a favorable physical condition. The better condition the soil is in, the more effective will be the fertilizer applied to it.

ABANDON CONTINUOUS CULTIVATION OF COTTON AND CORN.

Continuous cultivation of cotton and corn must sooner or later be abandoned and replaced by a rotation of crops, in which crops that take nitrogen from the air, and put organic matter in the soil, are grown at suitable intervals. A suitable rotation of crops, supplemented with the necessary fertilizers, will maintain the soil in a productive condition. The rotation suggested by the Georgia Experiment Station is as follows:

First year, corn. Cowpeas are planted between the rows at time of laying by, and the peas are picked for seed or pastured off.

Second year, wheat or oats. These are sown in the fall. As soon as possible after they are harvested, cowpeas are planted, and made into hay when mature.

Third year, cotton.

The Georgia Experiment Station states that when this rotation is followed each successive cotton and corn crop will require a somewhat less quantity of nitrogen than is called for by their formula given above. This rotation is adapted to many localities in the South.

FERTILIZERS FOR CORN.

Acid phosphate at the rate of 200 pounds per acre gives good results for corn on well improved lands, or lands that are comparatively new, or some well-drained bottom lands which are deficient in phosphoric acid. This application will not maintain the fertility of the soil. In a comparatively short time the need of the soil will be for nitrogen rather than for phosphoric acid.

The following application is recommended for corn on worn soils:

Acid phosphate, 14 per cent	900 pounds.
Cottonseed meal	900 pounds.
Kainit	150 pounds.

This fertilizer would contain 7.2 per cent phosphoric acid, 1.6 per cent potash, and 3.6 per cent nitrogen. It is applied at the rate of 200 to 400 pounds per acre.

This fertilizer will not maintain the fertility of the soil unless used in connection with a rotation of crops such as was previously mentioned or some other rotation in which nitrogen-gathering crops are grown at frequent intervals.

FERTILIZERS FOR RICE.

The fertilizer best adapted to rice depends upon the nature of the soil and the treatment which it has received. The rice soils east of Houston, Texas, as a general rule, are deficient in phosphoric acid and respond well to applications of 100 or 200 pounds per acre of acid phosphate as long as the soil continues to supply sufficient nitrogen and potash. This supply lasts, however, a comparatively short time, and the use of acid phosphate can only be considered as a temporary method of fertilizing.

If the rice-straw ashes are removed from the soil, the potash will be rapidly depleted, but if they are returned, the loss of potash from rice soils is very small. Rice farmers who waste their rice-straw ashes will have to buy considerable amounts of potash sooner or later, while those who return the ashes to the soil will need to purchase comparatively little potash.

Fertilizers containing about 10 per cent phosphoric acid and 2 or 4 per cent potash also used in the rice belt, but the use of such fertilizers in continuous rice culture can only be considered as a temporary expedient, though if used in connection with suitable rotation they may be sufficient. Sooner or later the nitrogen of the soil will become deficient. The following table shows the yearly gain or loss of plant food in a soil fertilized with this kind of fertilizer. We assume that 1900 pounds of rice is secured per acre, and an application of 200 pounds per acre of 10-4 fertilizer is made. It is necessary to make two sets of calculations, in one the rice straw is removed and in the other the straw ashes is returned.

RICE STRAW REMOVED.

	Phosphoric Acid.	Nitrogen.	Potash.
Loss in growing 1900 pounds rice	15 lbs.	57 lbs.	42 lbs.
Gain from 200 pounds fertilizer	20 lbs.	......	8 lbs.
Gain	5 lbs.	......	......
Loss	.....	57 lbs.	34 lbs.

It is evident from these figures that the fertilizer referred to cannot maintain the nitrogen or potash in rice soils, if the rice-straw ashes are wasted, as they should *not* be.

RICE-STRAW ASHES RETURNED.

	Phosphoric Acid.	Nitrogen.	Potash.
Loss in growing 1900 pounds rice	12 lbs.	57 lbs.	5 lbs.
Gain in 200 pounds fertilizer	20 lbs.	......	8 lbs.
Gain	8 lbs.	......	3 lbs.
Loss	.....	57 lbs.	......

So far as the phosphoric acid and potash are concerned, the fertility of rice soils can be easily maintained. The amount of nitrogen required by the crop referred to above would be contained in 800 pounds of cottonseed meal.

It is seen that maintaining the fertility of rice soils is largely a question of maintaining the nitrogen supply. The best method of maintaining the nitrogen in rice soils will undoubtedly be rotation of crops in which leguminous crops are grown to take up the nitrogen from the air. This system of rotation must be worked out in the rice belt sooner or later, and the sooner the better for those concerned.

FERTILIZERS FOR POTATOES.

Some of the soils on which potatoes are grown in Texas need potash, while others require very little at present. Until the different kinds of soils are studied it is impossible to say which need potash and which do not. All of the potato soils appear to need phosphoric acid.

On soils which do not need potash, a mixture of equal parts of cottonseed meal and acid phosphate gives good results. This fertilizer is used extensively in East Texas for potatoes and also for tomatoes. The quantity applied is from 300 to 800 pounds per acre. The mixture is improved by replacing a part of the cottonseed meal with one-half as much of nitrate of soda.

Top dressings of nitrate of soda are also sometimes made on potatoes.

Soils on which potatoes are grown very often will sooner or later need potash, as the potato plant requires a good deal of potash. For soils deficient in potash a potato fertilizer contains from 3 to 4 per cent nitrogen, 6 to 8 per cent phosphoric acid, and 4 to 8 per cent potash. The following formula is recommended by the Georgia Experiment Station for Irish potatoes:

Acid phosphate, 14 per cent	1000 pounds.
Muriate of potash	250 pounds.
Nitrate of soda	420 pounds.

This fertilizer would contain about 8.4 per cent phosphoric acid, 4.0 per cent nitrogen, and 7.5 per cent potash. It is applied at the rate of 350 to 700 pounds per acre. It is doubtful if Texas soils need as much potash as is called for in the formula referred to.

Experiments at Troupe (Bulletin No. 101) show that phosphoric acid and nitrogen give good results, while potash was of little value. The following fertilizer is recommended for potatoes on soil such as that at the Troupe Station:

Acid phosphate, 14 per cent	1000 pounds.
Cottonseed meal	700 pounds.
Kainit	200 pounds.
Nitrate of soda	100 pounds.

This fertilizer contains 8 per cent available phosphoric acid, 3.2 per cent nitrogen, and 1.6 per cent potash, and should be used at the rate of 400 to 600 pounds per acre.

FERTILIZERS FOR ALFALFA.

Alfalfa is a plant which sends its roots deep into the soil, and thus has at its disposal a greater quantity of plant food than shallow-rooted plants. It also has the power of taking nitrogen from the air. For these reasons, fertilizers may not give good results on alfalfa in many soils, until it has been grown for some time.

Young alfalfa may receive benefit from fertilizers, especially on soils deficient in phosphoric acid. On such soils we would suggest the use of the following mixture:

Acid phosphate, 14 per cent	1000 pounds.
Nitrate of soda	100 pounds.
Muriate of potash	50 pounds.
Total	1150 pounds.

This mixture should be applied at the rate of 200 or 300 pounds per acre and harrowed in before the seed are planted. The nitrate of soda and potash aid in giving the young plant a vigorous start, and the phosphoric acid corrects the deficiency of the soil.

Alfalfa draws largely on the plant food of the soil. Four tons of alfalfa contains the following amounts of plant food:

Phosphoric acid	50 pounds.
Nitrogen	183 pounds.
Potash	143 pounds.

A large part of this is withdrawn from the lower parts of the soil. The nitrogen is taken from the air, and alfalfa enriches the soil in this valuable form of plant food instead of making it poorer. The organic residues left by the crop also improve the physical character of the soil. For these reasons, alfalfa is a fine crop to grow in rotation with crops which can use the nitrogen of the soil, and not the nitrogen of the air.

Alfalfa appears to need lime, and is most successful upon calcareous soils. The calcareous soils of Texas, which are most suitable for the growth of alfalfa do not, as a rule, respond well to commercial fertilizers.

FERTILIZERS FOR ONIONS.

The onion growers around Laredo, Texas, use fertilizers containing 8 per cent phosphoric acid, 3 to 4 per cent nitrogen, and 5 to 8 per cent potash, at the rate of 1000 to 2000 pounds per acre. Many onion growers of New York prefer a fertilizer containing 8 per cent phosphoric acid, 4 per cent nitrogen, and 10 per cent potash, at the rate of 1000 to 2000 pounds per acre. We doubt if such large quantities of potash are needed in Texas.

The New York (Geneva) Experiment Station conducted an experiment lasting four years to ascertain the most profitable quantity of fertilizer to use for onions. They used different quantities of a fertilizer containing 8 per cent phosphoric acid, 4 per cent nitrogen, and 10 per cent potash. The average of the four years' results is as follows:

Total Quantity of Fertilizer per Acre. Pounds.	Additional Quantity of Fertilizer. Pounds.	Additional Crop Secured. Pounds.	Cost of Fertilizer for each Additional 100 lbs. Onions.
None.	...	12,800	
500	500	5,000	$0.11
1000	500	1,000	0.55
1500	500	1,000	0.55
2000	500	400	1.36

The fertilizer cost $5.47 per 500 pounds. The increase of fertilizer from 500 to 1000 pounds increased the crop of onions 1000 pounds, at a cost of 55 cents per hundred. The increase from 1500 to 2000 pounds caused an increase of only 400 pounds onions, at a cost of $1.36 per hundred. These results are average of four years' work, and the New York Station concluded that 500 pounds of fertilizer was the most profitable quantity.

A crop of 30,000 pounds onions withdraws (in the bulbs) approximately the following amounts of plant food:

Phosphoric acid	37 pounds.
Nitrogen	72 pounds.
Potash	72 pounds.

In addition we may estimate the losss of nitrogen by seepage at 15 pounds per acre per year, making a total loss of 87 pounds per acre. It is seen that the *nitrogen* of the soil is lost to the greatest extent.

The loss or gain of an onion soil which receives 1000 pounds on an 9-3-8 fertilizer is shows as follows:

	Phosphoric Acid.	Nitrogen.	Potash.
Loss in growing 30,000 pounds onions	37	87	72
Gain from 1,000 pounds fertilizer	80	30	80
Net gain	43	..	8
Net loss		57	..

While this fertilizer increases the phosphoric acid and potash of the soil, the store of nitrogen is depleted. That is, this fertilizer will not maintain the nitrogen of the soil under continuous onion growing. The soil will, in time, need more nitrogen than is supplied in such a fertilizer. It appears that the quantity of nitrogen supplied in the fertilizer must be increased as time goes on.

Mr. T. C. Nye, near Laredo, states that he used cottonseed meal for onions at the rate of 1500 pounds per acre with very satisfactory results. The results of this fertilizer would be as follows:

	Phosphoric Acid.	Nitrogen.	Potash.
Loss in growing 30,000 pounds onions	37	87	72
Gain from 1500 pounds cottonseed meal	37.5	105	22
Net gain	0.5	18	..
Net loss		..	50

Considering the fact that the soils of Laredo are pretty well supplied with phosphoric acid and potash, and can furnish some to the plant, it is not a matter for surprise that cottonseed meal alone should give such excellent results. It is probable, however, that some phosphoric acid and potash in addition to that in the meal would be of advantage.

Onion growing also causes the soil to lose its organic matter, which is very important to maintain the soil in a good physical condition. Manure should be applied or leguminous crops should be grown to supply the nitrogen which will be needed, and also the organic matter which the soil needs. A rotation of crops, in which alfalfa, cowpeas or some similar nitrogen-gathering crop is planted, would be of advantage to onion soils. An uncultivated crop, such as alfalfa, enriches the soil in organic matter also.

FERTILIZERS FOR PEANUTS.

For peanuts we suggest the use of a fertilizer containing 10 per cent phosphoric acid and 2 per cent potash at the rate of 400 to 600 pounds per acre. Peanuts, on sandy soils deficient in lime, are greatly benefited by applications of lime. The lime may be applied in the form of quick-lime or air-slaked lime. The quantity of lime which gives the best results depends on the character of the soil. About 800 to 1200 pounds per acre should give good results.

FERTILIZERS FOR OATS.

On soils which need phosphoric acid, acid phosphate should be applied. Cottonseed meal, or cotton seed, often give good results on fall-sown oats. Since oats make a large growth in the spring, at a time when the agencies which prepare nitrogen for the use of plants are not very active, a top dressing of nitrate of soda at the rate of 100 pounds per acre has often proved profitable.

FERTILIZERS FOR OTHER CROPS.

Suggestions in regard to the use of fertilizers will be made by the Chemist of the Experiment Station upon application. Care should be taken to state the kind of soil, its location, depth, previous treatment, and any other information that will throw light on its probable needs. Such information aids greatly in suggesting fertilizers applicable to the crop and the conditions.

AVAILABLE BULLETINS.

The following is a list of the Bulletins available for distribution. The others are out of print:

74. Insects Mistaken for the Mexican Boll Weevil.
77. Onions and Bunch Crops.
79. Cotton Breeding.
84. Tomato Fertilizers at Troupe.
88. Munson's Bulletin on Grapes.
91. Food Adulteration in Texas.
92. A Test of the Producing Power of Some Texas Seed Corn.
95. Information Regarding the New Feed Law.
96. Commercial Fertilizers and Poisonous Insecticides 1906-07.
97. Kaffir Corn and Milo Maize for Fattening Cattle.
98. Summary of all Bulletins from No. 1 to No. 94, inclusive.
99. Composition and Properties of Some Texas Soils.
100. Chemical Composition of Some Texas Soils.
102. Texas Honey Plants.
103. Forage Crops in West Texas.
104. Digestion Experiments.
105. Notes on Forest and Ornamental Trees.
107. Commercial Fertilizers and Poisonous Insecticides 1907-08.
109. Alfalfa.
110. Steer Feeding Experiments.
111. Texas Fever.

— Pecan Culture for Western Texas.

Tenth Annual Report.

Eleventh Annual Report.

Twelfth Annual Report.