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THE TREATMENT OF SOILS WITH LIME COMPOUNDS AND FERTILIZERS

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A fertilizer is any material which when added to the soil will be absorbed by the growing plant in a way to cause increased crop production. Additional growth in any part of a plant may be brought about by supplying plant food known to be lacking, or by overcoming some abnormal condition. Sometimes all the food essential to the plant is already in the soil, but not in an available form. This is abnormal and some fertilizers have the power to overcome it. The true fertilizers have for their object the furnishing of plant food in such a form that it will be readily assimilated by the growing plant.

The use of fertilizers will not insure a crop. They cannot be expected to make up for poor cultivation and improper treatment of the soil. The plants must be protected from insect pests and fungus growth of all kinds. All harmful influences must be carefully guarded against.

In regions where there is but a light rainfall, the growing plant, in order to survive, must send its roots deeper into the soil than in sections where there is abundant rain at regular intervals throughout the growing season. If the roots remain near the surface in semi-arid countries they may be injured by the heat of the sun's rays, and as the moisture supply is soon exhausted, the plant will not thrive. Crops which are grown with success in Oklahoma are known to send

their roots deep into the soil in search of moisture and the necessary plant food. It has been stated that roots of the alfalfa plant have been found 150 feet long, and that kafir roots may extend twenty feet beneath the surface.

The adaptability of the plants to their environment has an important bearing on the application of fertilizers. The best method in Illinois, Ohio, Mississippi or South Carolina will not meet with success when applied to Oklahoma soils. Experience has demonstrated that the soil moisture is conserved by deep plowing and by keeping the surface well pulverized. This treatment aids the plant toward deep rooting and the use of fertilizers must be influenced by this fact. If fertilizers are placed near the surface of the ground, the roots will tend to remain shallow in order to be near the food supply, but the plant will then suffer when the first drouth comes along. On the other hand, if the fertilizing materials are placed deep in the soil the plants will be stimulated to grow in the direction of the available food supply and will not spend their strength by sending out rootlets in every direction near the surface.

Money Value of Fertilizers

The value of any fertilizer depends on its chemical composition. The many substances used in the business make it appear reasonable that some of the raw materials may not be as valuable as others, and that the selling price must be influenced by the market fluctuations in the cost of these raw materials. Freight rates also have some bearing on the cost to the farmer in Oklahoma. Any figures showing the cost, under the conditions indicated, must be approximate, and their principal value is supposed to be for comparison.

It is believed that the sums mentioned below will represent the normal delivered value of most fertilizers within the State of Oklahoma:

VALUE PER POUND OF THE ESSENTIAL ELEMENTS

Phosphorus	10 cents
Nitrogen	20 cents
Potassium	6 cents

These values may be applied in this way: Suppose a fertilizer of the 2-8-2 type were offered for sale. This would represent nitrogen 2%, phosphorus 8% and potash 2%. The approximate value for forty pounds of nitrogen in each ton would be $8.00; 160 pounds of phosphorus $16.00, and forty pounds of potassium $2.40. Then the total value becomes $26.40 a ton.

Acid Soils

Occasionally a condition will be found to exist in the soil which cannot be remedied by the addition of the ordinary fertilizer mixtures. For example, applications of fertilizers to strongly alkaline

or to acid soils are not worth while. Soils that have been cultivated for a long time, particularly lowlands which remain damp and upon which vegetation is permitted to decay, are more liable to become acid than those well drained and that have grown crops but a few years. Substances which are used to neutralize the acid in a soil or to overcome the bad effects caused by alkali cannot be classified as fertilizers—correctives would be a more appropriate name. A corrective puts the soil in a state ready for cultivation, and it may be necessary to follow the corrective treatment with applications of special fertilizers. Limestone, quick lime, hydrated lime and burnt gypsum are used as correctives.

Litmus Test for Soil Reaction

The natural reaction of a fertile soil should be slightly alkaline. Acid soils do not produce well. It is an easy matter to determine whether a given soil is acid or alkaline by means of the litmus paper test.

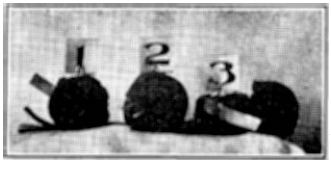

Figure 1—Testing Soil with Litmus Paper

Litmus paper may be purchased at a drug store in two colors, red and blue, and should be of good, strong color. To apply the test it is necessary to knead a handful of the soil into a ball with the aid of a small quantity of rainwater. (Do not use wellwater). Break open the ball and place a piece of red paper between the halves so that one-third of the length will remain uncovered. Press the two portions together and set aside. Repeat this with another portion of the same soil, but insert a piece of the blue litmus paper. Examine the test papers at the end of an hour, or after standing over night, and note if they have changed color. If the red paper has become **blue,** the soil is **alkaline;** but if the blue paper has changed to **pink** or **red,** the soil is **acid.**

The method of using the litmus paper test is illustrated in Figure 1. Ball No. 3 has been opened and shows where the paper has changed color. The test papers may be seen in place in the balls numbered 1 and 2.

Lime

The substances that have an agricultural value on account of their lime content are, quick lime, or calcium oxide; limestone, or

calcium carbonate; hydrated, or slaked lime, and gypsum, or calcium sulfate. The percentage composition of these forms of lime is shown in the following table:

COMPOSITION OF THE FOUR FORMS OF LIME COMPOUNDS

NAME	FORMULA	QUANTITY OF CALCIUM (Ca) PRESENT
Quick lime	CaO	71%
Limestone	$CaCO_3$	40%
Slaked lime	$Ca(OH)_2$	54%
Gypsum	$CaSO_4$	29%

The above substances would contain, if pure, in each ton, 1,400 pounds of calcium when in the form of quick lime, 800 pounds in the form of limestone, 1,080 pounds as slaked lime, and 580 pounds as dried gypsum. All of these forms of lime vary in composition. Samples of quick lime and hydrated lime have been found on the market ranging from 40% to 90% in purity.

Gypsum is suitable for special purposes in agriculture, and these will be described in the section on page 6.

The powdered limestone is the most convenient and satisfactory form of lime to handle because the other forms are caustic. Moreover the quick lime and the hydrated lime will change in the course of time to the carbonate form when exposed to the atmosphere. The caustic limes are used because the lime (calcium) is in a more concentrated form, and on this account the cost of freight and hauling will often permit them to be delivered for less money when the actual amount of calcium present is considered.

Probably the most important agricultural use of lime is as a corrective. Lime serves to stimulate the action of the nitrifying bacteria. Very few soils are actually deficient in calcium, but when a condition of this nature exists, some form of lime should be applied as a fertilizer. Alfalfa and the clovers in general require more calcium than many crops (see table on page 8). For this reason the various compounds of calcium may be regarded as fertilizers for special crops.

Lime has a beneficial physical action on the soil. It acts so as to granulate and break up a clay soil, making it easier to work, and thus renders the soil more pervious to water.

Application of Lime

A good time to put lime on the soil is during the fall and winter plowing. A convenient method by which any form of lime may be spread on the soil is first to attach a large piece of burlap or canvas

to the tailboard of a wagon and shovel the material from the wagon on this drag curtain while it is being hauled across the field. This method will give a very even distribution at a low cost.

Figure 2—Spreading Lime
(Courtesy Kentucky Wagon Company)

The machine shown in Figure 2 may be used for spreading lime, limestone, phosphate rock and fertilizers.

It is the practice in some of the older States to put from two to five tons of crushed or powdered limestone on each acre, and repeat the application every three to five years. The land in Oklahoma has been under cultivation but a very short time, so the acidity is seldom great enough to require treatment with very large quantities of lime. Occasionally a local condition may be found where applications of five tons of limestone to the acre will pay, but most of our soils will respond to one ton. If the other forms of lime are used, 100 to 300 pounds of quick lime should answer, or from 200 to 500 pounds of hydrated or slaked lime may be used.

The various forms of lime may be obtained from the Oklahoma kilns at approximately the following prices:

Limestone	$ 1.25 a ton
Hydrated lime	.50 a barrel
Quick lime	.50 a barrel

Burnt Gypsum

This substance is also known as land plaster and plaster of paris. It is made by heating the natural gypsum under special conditions. Occasionally the raw mineral is ground and applied to the land without being heated. The mineral gypsum is essentially calcium sulfate ($CaSO_4$), containing 14% water. During the heating process most of the water is removed.

Soils close to large deposits of gypsum are often unproductive. This condition is thought not to be due to any action of the gypsum, but probably results from the excessive amount of clay in the soil or the presence of some harmful substance such as salt or alkali.

While gypsum does not contain so much lime as ordinary limestone, it is a very good fertilizer for the leguminous crops, such as cowpeas, clover and alfalfa. Gypsum acts chemically on the mineral substances in the soil, changing the potash and phosphorus from an insoluble to a soluble form, and on this account performs a valuable function in making more plant food available. This action is limited and a large quantity of gypsum should not be applied to land with the idea of greatly increasing an improved condition which has resulted from the application of comparatively small amounts. Large applications may cause the soil to become hard and dense.

Another valuable function of gypsum in agriculture is its power to overcome the affect of black alkali, or carbonate of soda, which dissolves the humus and causes the formation of puddles which remain wet long after the surrounding soil has become dry. The amount of gypsum which should be applied to land affected with black alkali spots must necessarily depend upon the number and extent of the spots, which should be treated direct if possible. Two

Figure 3—Gypsum Quarry, American Cement Plaster Company, near Watonga, Oklahoma
(U. S. Geol. Survey)

hundred pounds to the acre may be used at a time, and the application should be made every sixty days until the spots begin to swell and lose their black appearance. The treatment for alkalies should be followed by applications of acid phosphate, and then other fertilizers, according to the needs of the soil and the particular crops which are being grown.

Powdered gypsum, especially in the form of land plaster, should be used when making a compost, and should be spread over every layer of manure placed in a pile or pit for storage. It may be used to advantage by spreading it around the stalls and throughout the bedding at the rate of five pounds a day to each animal.

One of the most valued ingredients of manure is ammonia, which is often lost by evaporation, and is easily washed away by rain because it is not combined. In the presence of burnt gypsum it is changed into the compound sulfate of ammonia, which is not volatile like common ammonia, and thus the valuable ingredient is changed into a form in which it will keep much better and yet is readily available for plant food. Moreover, the gypsum tends to prevent decomposition, and also helps to conserve the phosphorus and potash always present in manure.

Why Fertilizers Are Used

Most Oklahoma soils contain enough plant food to raise any crop suitable to the zone, provided the rainfall is sufficient and properly distributed. Some of the virgin soils are low in phosphorus, and here and there nitrogen should be more abundant. Occasionally a soil needs potash. There can be no question but that enough of the lacking elements should be added to such soils to put them in balance.

When good crops are grown on a soil year after year it is not easy to recognize the need of plant food; however, kafir, milo, wheat and the cereals in general remove large quantities of the valuable elements from the land. About three-fourths of the nitrogen and phosphorus in such plants is found in the seed, but the greater part of the poatssium remains in the stem or straw. So, then, when the cereals are sold, part of the nitrogen and phosphorus supply of the farm go along, and in time a deficiency of these elements will be noticed. Where livestock is kept and the manure spread over the soil, the principal loss will be in the phosphorus content.

If fifty bushels of kafir are produced on one acre, and the stalks removed, the plant food lost from each acre amounts to sixty pounds of nitrogen, ten pounds of phosphorus and nearly thirty pounds of potassium. These substances have a money value in the neighborhood of $15.00. Other crops have a similar influence, as shown in the table.

PLANT FOOD REMOVED FROM ONE ACRE BY REPRESENTATIVE CROPS

	Yield	Nitrogen Pounds	Phosphorus Pounds	Potassium Pounds	Value of Total Plant Food Removed
Cotton	250 lbs.*	42.0	7.4	20.5	$ 10.37
Corn	30 bu.	46.0	7.1	8.0	10.39
Oats	35 bu.	38.0	5.0	5.0	8.40
Wheat	20 bu.	40.0	5 0	5.2	8.81
Kafir	30 bu.	33.0	4.5	5.5	7.38

*Lint 250, seed 500, stalks 1,000.

Chemical analyses have shown that those elements of value in agriculture do not become available at a constant rate. The demands on the soil vary with the season and the rotation. With normal soils, ordinary crops and favorable seasons it may be assumed that 2% of the nitrogen, 1% of the phosphorus and about a quarter of 1% of the potassium becomes available each year. In many cases the quantity made available will not equal the quantity removed.

The gradual depletion of the store of plant food is usually noticed in the falling off of the yields. The practice of taking everything away and putting nothing back is not good, and it is no more than reasonable that a system should be adopted providing for the replacement of the plant food removed by each crop.

In the table of values it is shown that the nitrogen is the most expensive element to buy, consequently it is good business not to purchase any more of this element than necessary. Any reduction of nitrogen in a fertilizer will lower the cost. Study the crops and learn if there are any signs of a deficiency of this valuable element. Conserve the nitrogen supply of the farm by the use of manure and leguminous crops. Plow under vines and stalks.

QUANTITIES OF FERTILIZERS NEEDED BY SOME CROPS

	Pounds to One Acre		
	Nitrogen	Phosphorus	Potassium
Alfalfa	5-10	12-25	30-60
Corn	10-20	15-30	25-50
Oats	12-24	8-15	25-50
Wheat	10-25	8-17	10-20
Cotton	20-40	22-45	12-25
Kafir, Milo and Feterita	5-15	10-30	15-25

The Need of Fertilizers

Many people are of the opinion that the proper way to determine whether a certain piece of land needs fertilizer treatment is to pick up a handful of the soil and send it to a chemist for analysis. This is not true because every farmer knows that the soil on his farm is not all alike. He has obtained this information from the yields, and it is a most valuable opinion. In the first place, if a soil is to be tested by a chemist, portions must be collected with great care from different parts of the field and in a way that they will represent the tillable portion. Again, the results obtained by the chemist may show the amount of plant food present without reference to condition or availability. Also the quantity of plant food may exceed the normal amount and yet the land would respond to an application of fertilizer. Moreover, the correct interpretation of a chemical analysis of a soil requires special knowledge and experience.

How to Judge Soils By the Crops

It is known that the essential plant foods have each a marked influence, the effect of which may be easily recognized. The chief characteristics produced by the lack of nitrogen, potassium, phosphorus and calcium may be covered in a few words.

Nitrogen is essential for leaf formation, good color and hardy growth. Stunted plants with yellowish leaves and low grain yields indicate a need of nitrogen. A soil poor in nitrogen will give low yields of an inferior grade of cotton, because it is a crop which requires large quantities of nitrogen.

The leguminous plants have the power to add nitrogen to the soil, and for this reason are often included in the rotation to take the place of nitrogenous fertilizers. It is a good practice especially if, in addition, a large quantity of barnyard manure is worked into the soil and the vines are plowed under. Leguminous crops do not add nitrogen to the soil rapidly. If the growing season is short, or if the special crop requires large amounts of nitrogen, the nitrogen should be supplied by fertilizers.

Potash* has a direct relation to good and healthy sap in plants. For this reason plants growing in a soil well supplied with potash, but deficient in nitrogen, will often "go to leaf and stalk". This element is necessary to the formation of strong cells; the woody portion of all vines and trees, and the stems (straw) of such plants as oats and wheat; it is essential to juiciness, good flavor and sweetness of fruits.

It has been demonstrated that potash assists in the formation of starch and sugar in plants. The starch is formed first in the leaves

*This word is used here as a common name for potassium.

and finally passes to the fruit. Starch contains the same elements as sugar, and no doubt the two substances are closely related to each other during the growth of the plant.

Plants well supplied with potash will, according to Golte, better withstand the harmful action of frost. Plants having weak and thin stems, small and unnaturally sour fruits, or which do not fruit at all, indicate a need of potassium in the soil.

Phosphorus occupies a position with relation to the plant structure similar to the powerful function of lime in the growth of animals. An animal deprived of lime will not grow, but will soon weaken and die before maturing. This element acts as a tonic to the young plant and aids in the assimilation of the other plant foods. It brings the plant to early maturity by hastening growth.

Phosphorus is essential to the production of good yields of all the cereal crops. The phosphorus taken by plants of the grain producing group is for the greater part, approximately 75%, stored in the seed, and but a small part, 25%, remains in the stem or stalk. When the grain is sold a large part of the phosphorus supply of the soil is lost, but if the cereals are purchased and fed to the cattle, the amount of phosphorus on the farm is increased. No kind of rotation or crop will add phosphorus to the soil. If it is taken away in the form of crops, additional quantities should be applied to the land to counterbalance the amount removed. When kafir, milo, corn, wheat or other grains are not removed from the farm, but fed to the cattle, and this practice is supplemented by the application of fertilizers, the amount of phosphorus may not only be kept in balance, but actually increased. In this way the fertility will be improved and the productive power increased as the years go by.

A deficiency of phosphorus in the soil may be indicated by a good growth and a failure to fruit; small, thin grains which do not germinate well, and, in general, poor yields of the grain crops.

Selection and Application of Fertilizers

The question to be answered in reference to the selection and application of a fertilizer is not one concerning the cost of the material, but must have to do with the land itself, and the character of the crops. Applications of fertilizers to thin and washed lands will not pay unless some precautions are taken to keep the fertilizers in place. It is a waste of labor and money to put heavy applications on a hillside devoid of terraces. Level land, properly drained, will usually respond to fertilizer treatment. Liberal applications of high grade fertilizers on good land will, in most cases, pay better than extra large quantities of low grade fertilizers on the same land.

The kind of crop has much to do with the selection of fertilizers. The grains require large amounts of phosphorus in addition to nitro-

gen and potash. The fruits and small vegetables need extra quantities of potash. When the crop depends on the leaf part of the plant there must be a plentiful supply of nitrogen, together with the other plant food. Plants which produce high protein substances, like cottonseed, need large amounts of nitrogenous fertilizers.

It will not be worth while to apply fertilizers to a soil if it is not in proper physical condition. Fertilizers cannot overcome unfavorable climatic conditions. All things being otherwise satisfactory, no fertilizer will make up for lacking sunshine or an abnormal rainfall.

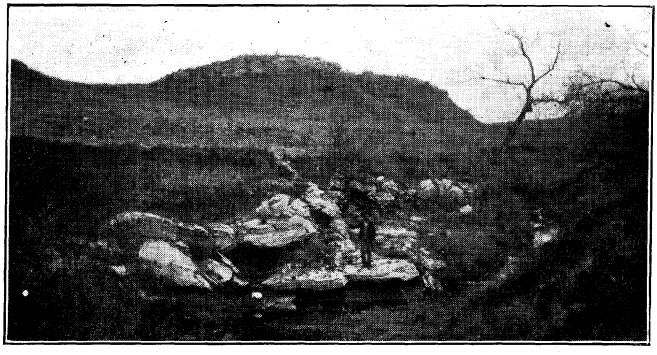

Figure 4—Gypsum Deposit near Indianapolis, Oklahoma
(U. S. Geol. Survey)

Large quantities of fertilizers should not be put on poor soil. The soil should be built up with care, much in the same way as is the custom in the feeding of animals. In the first place, a poor soil is not worth a large initial expenditure, and in the second place, heavy applications of fertilizers often do more harm than good—it may be that the tonic acts similar to an overdose of medicine. A rich soil will often give good returns when treated with large quantities of fertilizers. Land in Illinois yielding seventy bushels of corn has been made to yield over one hundred bushels; a boy in South Carolina raised over two hundred and thirty bushels on one acre at a profit.

The fertilizer in common use for cotton is known as 8-2-2. This grade has been very popular, but a fertilizer of the 9-3-3 variety would no doubt be a much better investment. The lower the grade the more filler there must be present because the fertilizer manufacturer cannot prepare the mixture on the ton basis without the use of a filler.

The filler is the material used to make up the difference between the actual plant food present and 2,000 pounds. Fine dirt, sand, dried muck, powdered limestone are some of the substances which are used as fillers. A fertilizer to contain nitrogen 2.5%, available phosphoric acid 7% and potash 5% may be made from pure material, but will require over 25% filler, as shown in the following table:

Raw Materials	Amount	Plant Food
Sodium nitrate	329 lbs.	2.5% N
Acid phosphate	875 lbs.	7.0% P_2O_5 (available)
Potash muriate	200 lbs.	5.0% K_2O
	1,404 lbs.	
Filler of dry dirt	596 lbs.	
Total	2,000 lbs.	

The fertilizer should be dry and free from lumps in order to insure an even distribution and so as to not clog the drill. Many seed drills are provided with a fertilizer dropping attachment so that the fertilizer may be applied at the same time the seed are planted. This attachment is especially valuable when seeding the small grains, such as feterita, kafir, milo, oats and wheat. Good results may be obtained by broadcasting, followed by disking and dragging. Fertilizers should be broadcasted in two directions, that is, put on one-half of the material while walking north and south and the other half while walking east and west. Broadcasting requires approximately twice as much fertilizer as when put on by means of a drill.

For such crops as corn, kafir and milo, one-half of the fertilizer should be put on when the land is plowed. The remainder may be put on at the side of the rows at the time of planting through the fertilizer attachment to the planter, taking care that none of the seed comes in direct contact with the fertilizer.

For potatoes and, in fact, all vegetables, the fertilizer material should be put in the rows at the time of planting, or during the spring plowing. Put the fertilizer as deep as possible to stimulate deep rooting.

Fertilizers containing a large amount of nitrogen derived from animal matter may be put on in the spring, but when the mineral nitrates, soluble nitrates, are used, they should be applied in part at planting time, and additional quantities will have to be added about every four to six weeks during the growing season.

The phosphorus fertilizers,—raw bone meal, phosphatic slag and ground phosphate rock—may be used at any time, but the fall is probably the best time. Materials containing available phosphorus,

such as acid phosphate and acidulated brands, should be put on the soil at planting time.

The potash fertilizers should be thoroughly worked into the soil. It is a good plan to apply them about a week before planting the seed.

Usually the mixed fertilizers are applied in the spring, but, of course, this practice does not apply to oats and wheat; the mixed fertilizers for these crops should be put on at planting time. Some farmers obtain good results by using 25% to 50% of the mixed fertilizer during the growing season.

German Potash Not Essential to Oklahoma Farms

The great European war has affected our agricultural interests to a great degree in several ways; one of the most serious is the cutting off of the potash supply obtained from the mines in Germany. The United States, under normal conditions, consumes approximately 3,000 tons of potash daily, a large part of which goes into fertilizers for which the farmers of this country pay about one million dollars a year. In many of the States east of the Mississippi river the potash supply of the soil has been practically exhausted, or at least used to such an extent that yearly applications of potash fertilizers are considered to be necessary for the growing of good crops.

As Germany holds a monopoly on the potash business of the world, the sudden cessation of all shipments from there is indeed serious to many sections of the United States. There are peculiar conditions existing in the soils of Oklahoma which make this matter of less importance to our farmers than to those further east. When a soil contains 0.2 of 1% potash, the supply is considered to be good. Numerous samples of Oklahoma soils have been examined in this department and most of them have shown a potash content of about 0.4 of 1%; or, in other words, very rich in potash. Most of our soils contain some form of lime which has the power to render the potash in the rocks more soluble, and in this way small additional amounts are made available for plant food each year.

Because the soil may contain abundant potash at this time, it is not good practice to fail to supplement the natural supply, which may be exhausted in the course of years. A good barnyard manure contains considerable potash, something over ten pounds in each ton, but this is easily lost through exposure and drainage. It is, therefore, advisable to take special care not to lose it, a well covered pit being an excellent place for storage. Many of the soils need organic matter, and liberal applications of barnyard manure will supply potash and organic matter at the same time. It will pay the farmer to take particular care of the manure and to apply it to the land.

More fertilizers are being sold in Oklahoma each year with profit to the farmer, but it must appear that proper conservation of our home fertilizing materials and proper soil treatment are more essential at this time than the necessity for devising ways and means to obtain potash supplies from Europe.