Phosphorus Lacking From Many Eastern Oklahoma Soils

Phosphate Fertilizers Are Needed For Maximum Yields, Tests Made in Field and Laboratory Show.

NITROGEN BEING RAPIDLY LOST, REDUCING STATE'S CROP YIELDS

Legumes Will Restore Nitrogen, But May Need Help of Phosphorus and Lime.

POTASH HELPFUL FOR PREVENTING WILT OF COTTON

COMMERCIAL FERTILIZERS FOR OKLAHOMA CROPS

BY HORACE J. HARPER

Effect of Fertilizers on Crops Tested by Experiment Station At 434 Places in 62 Counties

"PHOSPHORUS, LIME, LEGUMES AND LIVESTOCK" IS FERTILITY PLAN

Mineral Fertilizers Boost Legume Yields; Legumes Restore Nitrogen to Soil; Increased Nitrogen Makes More Feed.

No One Fertilizer Fits All Soils— Test Shows Needs

5-10-5 MIXTURE GOOD AS GARDEN FERTILIZER

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
OKLAHOMA A. & M. COLLEGE, STILLWATER
W. L. BLIZZARD, *DIRECTOR* LOUIS E. HAWKINS, *VICE DIRECTOR*
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Applying Phosphorus Boosts Alfalfa Yields

Fertility Lost When Crops and Livestock Are Sold; Must Be Replaced to Keep Up Production

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COMMERCIAL FERTILIZER FOR OKLAHOMA CROPS

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INTRODUCTION

Commercial fertilizers have been used for many years to a limited extent in eastern Oklahoma to increase crop production on phosphorus deficient soils. More commercial fertilizer will eventually be used as more farmers begin to replace plant nutrients removed from the soil by continued production of soil depleting crops.

To replace the nitrogen, phosphorus, potassium and calcium removed annually from Oklahoma soils by crops would require aproximately 530,000 tons of ammonium sulfate, 90,000 tons of superphosphate, 40,000 tons of muriate of potash, and 35,000 tons of agricultural limestone.** The cost of this material would be approximately $25,000,000, of which more than 80 percent would be for nitrogen. Some of the nitrogen can be returned by growing legumes for soil improvement. Fertilization will be needed to replace the losses of phosphorus, potassium and calcium.

This bulletin gives recommendations on kind and amounts of commercial fertilizers for most of the field, orchard and vegetable crops commonly grown in Oklahoma. The field crop recommendations are based on results obtained from 434 fertility experiments conducted in 62 Oklahoma counties during the past 21 years as shown in the map on page 4. The bulletin also includes a description of the different types of fertilizer materials and grades, and a discussion of conditions affecting the response of crops to fertilization, since an understanding of these factors will have an important influence on the economic use of commercial fertilizers.

Accurate recommendations concerning the use of commercial fertilizer in Oklahoma are difficult to make because of the many different factors which may affect plant development. Proper fertilization is only one of the important problems which must be solved in working out a better system of soil management on the average farm. Variations in soil fer-

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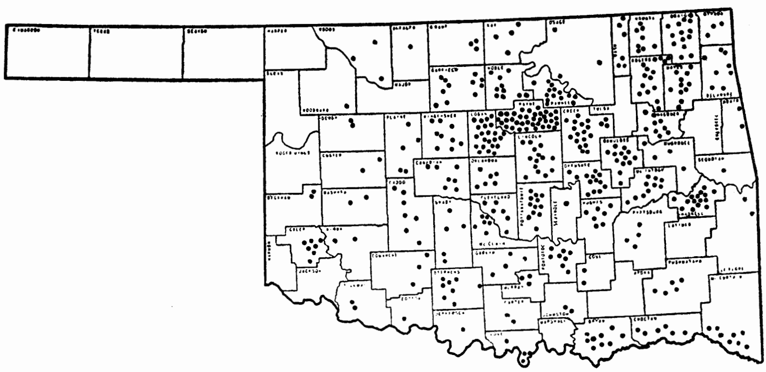
* Recommendations for the fertilization of field, garden and orchard crops were prepared in cooperation with H. F. Murphy of the Agronomy Department and F. B. Cross and H. B. Cordner of the Horticulture Department, Oklahoma Agricultural Experiment Station.

** This does not include the limestone needed to correct soil acidity. The amount of fertilizer needed to replace plant nutrients removed by crops is discussed in more detail on pp. 42 to 46.

tility, crop requirements, rainfall, temperature and depth and texture of surface and subsurface soil have an important influence on the probable response of crops to fertilization.*

Valuable information which can be used in determining whether the recommendations given in this bulletin will apply to a particular field or area on a farm can be obtained by chemical analysis of a carefully selected soil sample.**



Where Soil Fertility Experiments Have Been Made.

Soil fertility experiments in cooperation with individual farmers were conducted on 434 farms in 62 Oklahoma counties during the 21 years from 1923 to 1943, and will be continued in the future. Results obtained from these experiments, and from the analyses of more than sixteen thousand samples of soil, have been used in preparing many of the fertilizer recommendations given in this bulletin.

A field test is the best method to determine whether or not fertilizer will increase crop yields. In Oklahoma field tests must be made more than one season to obtain accurate results, because climatic conditions frequently restrict plant development.

General Fertilizer Needs of Oklahoma Soils

Phosphorus is usually the first limiting factor in the production of many crops on the prairie soils of central and eastern Oklahoma. An application of a phosphate fertilizer will increase crop yields on these soils until such time as some other

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* The influence of these factors is discussed more fully on pages 37 to 40.

** Arrangements for soil anayses should be made through the local county agent or vocational agriculture teacher. Many now have the equipment needed for making tests locally. Others can arrange to have tests made at the Soils Laboratory of the experiment station. Instructions for collecting soil samples for analysis are given in Appendix I, page 47.

essential plant nutrient* is exhausted from the soil and becomes a limiting factor in plant growth.

Many commercial fertilizers applied at the rate of 200 pounds an acre will supply as much or more phosphorus and sulfur than the average crop will remove from the soil, but they will provide only a small percentage of the nitrogen, potassium and other elements needed for best plant development. Good crop yields will be obtained from the use of superphosphate or a complete fertilizer so long as the natural fertility in a soil continues to supply an adequate quantity of the elements not present in the fertilizer. When the organic matter content of a soil declines below the climatic possibilities for crop production, legumes should be grown and returned to the soil. If legumes are not used, it will be necessary to use large quantities of nitrogen fertilizer. As the available potassium supply in a soil decreases, a fertilizer grade containing more potash should be used, or muriate of potash applied.

Phosphorus Deficiency in Oklahoma Soils

A high percentage of the soils in central and eastern Oklahoma are deficient in available phosphorus (See map, page 6). Phosphorus deficiency tends to decrease as rainfall decreases. None of the soils tested in Cimarron, Ellis and Texas Counties was low to very low in available phosphorus.

In Johnston, Love, McCurtain, and Marshall Counties the percentages shown in the map on page 6, may be affected by the relative number of samples collected from good and poor soils. These counties have a wide variation in soil types. The black clay soils on the uplands and a majority of the bottomland soils contain a good supply of available phosphorus. The sandy upland soils are usually low to very low in this plant nutrient.

Chemical analyses do not measure the *availability* of organic phosphorus, which is changed to an available form as a result of the decay of soil organic matter. A profitable response from phosphorus fertilization may not be obtained when warm season crops are planted on soil high in organic

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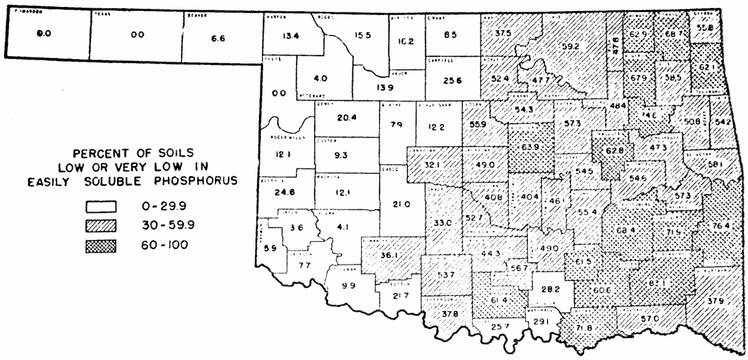
* Plant ash contains calcium, potassium, magnesium, phosphorus, sulfur, manganese, iron, copper, zinc and boron, which come from the soil and are known to be essential for growth. The organic matter which changes to gaseous form when crop residues are burned or decay in the soil contains carbon, hydrogen, oxygen and nitrogen. The carbon is obtained from the air by absorption of carbon dioxide through the stomata or openings on the under side of the leaves. The hydrogen and oxygen are secured in the form of water by plant roots. The nitrogen is dissolved in the soil moisture as nitrate or ammonium salts which are formed as a result of the complete decomposition of soil organic matter, plant or animal residues. Legume crops obtain a portion of their nitrogen through the fixation and subsequent release of soluble nitrogen compounds from the nodules produced on their roots by symbiotic nitrogen-fixing bacteria.



Where Oklahoma Soils Lack Phosphorus.

The map shows the percentage of surface soils collected from different counties which were low or very low in available phosphorus. A total of 16,174 soils was tested, from 77 counties.

matter, although chemical soil tests for inorganic phosphate may indicate a relatively low supply of this element.

Small grain and many vegetable crops will give a greater response to phosphorus fertilization than will be obtained from crops which grow during the summer months because the availability of nitrogen and phosphorus in soil organic matter is lower during the cool weather of late fall and early spring than it is in late spring and summer.

All soils do not begin to respond to fertilizer treatment at the same time even though they have been cropped in a similar manner, since there is a wide variation in the phosphorus availability of different soil types. Some farmers should use fertilizer to increase crop yields, whereas on adjacent land crop production can still be maintained at a high level for a long period of time because of the greater supply of total plant nutrients in the soil. Fields on the same farm may also require different treatments to maintain or increase crop production.

FERTILIZER MATERIALS AND GRADES

Chemical compounds which contain one or more of the elements known to be essential for plant growth are called fertilizer materials. A list of the fertilizer materials and grades approved for distribution in Oklahoma in 1944 is given in Table I. When different fertilizer materials are combined to produce a product containing a certain percentage of nitrogen, phosphoric acid and/or potash, the mixture is called a fertilizer grade.*

Materials

Chemical compounds containing the three elements, nitrogen, phosphorus or potassium, make up a major portion of the tonnage produced by the fertilizer industry. Calcium is present in superphosphate but it is not indicated in a fertilizer analysis. Magnesium is frequently added to fertilizer mixtures as dolomitic limestone. Other essential elements for plant growth are called "minor" elements because only small percentages are found in plants and large quantities are not applied to the soil.** Frequently these so-called minor elements are present in low analysis fertilizers in sufficient amounts to supply plant requirements but are absent in high analysis materials. Many of the so-called minor elements are added to fertilizer mixtures when they are known to be deficient in soils to which the fertilizer will be applied.

NITROGEN FERTILIZERS.—Nitrogen fertilizers are classified as inorganic or organic compounds depending upon their chemical composition. The inorganic nitrogen fertilizers include ammonium sulfate, sodium nitrate, ammonium nitrate, ammonium phosphate, liquid ammonia, and, to a limited extent, calcium and potassium nitrate. A nitrate fertilizer is more readily absorbed by growing crops than ammonium compounds. It may also be lost by leaching on deep, sandy soils during periods of abundant rainfall.

The more important organic nitrogen compounds include urea, cyanamide, and plant or animal residues such as cottonseed meal, fish scraps, and tankage. Fertilizer materials containing ammonium salts and organic nitrogen are used extensively in the manufacture of mixed fertilizers. Liquid ammonia is combined with superphosphate to form ammoniated superphosphate. It occurs in the superphosphate as ammonium phosphate.

PHOSPHATE FERTILIZERS. — Superphosphate, ammonium phosphate, finely ground rock phosphate and basic slag are the most important commercial phosphate fertilizers.

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* The same fertilizer grade may be prepared from several different formulae. The greatest variation between different formulae will normally occur in the quantity of organic nitrogen, ammonia and nitrate nitrogen in the different mixtures.

** Minar elements may be added to fertilizer mixtures in the following compounds: manganese as manganese sulfate, boron as sodium borate or borax, magnesium as magnesium sulfate or Epsom salts, copper as copper sulfate, and zinc as zinc sulfate. Iron is seldom a limiting factor in plant development except in soils high in lime and low in organic matter.

TABLE I.—Fertilizer Materials and Grades Approved for Distribution in Oklahoma in 1944.

FERTILIZER MATERIALS					
Nitrogen		**Phosphate**		Potash	
Fertilizer	Nitrogen percent or N-P-K	Fertilizer	Phosphoric acid percent or N-P-K	Fertilizer	Potash percent or N-P-K
Ammonium nitrate	30*	Ammonium phosphate	11-48-0	Manure salts	22*
Ammonium nitrate-limestone	20*	Ammonium phosphate	16-20-0	Muriate of potash	50*
Ammonium phosphate	11-48-0	Ammoniated super-phosphate	4-16-0*	Potassium nitrate	11-0-44*
Ammonium phosphate	16-20-0	Superphosphate	18, 20, 32 & 45	Sulfate of potash	48*
Ammonium sulfate	20	Rock phosphate	28 to 34	Sulfate of potash-magnesia	18*
Cyanamide	20 & 22				
Nitrate of soda	16				
Potassium nitrate	14-0-44*				
Uramon	42				
Uramon-limestone	20*				

FERTILIZER GRADES**		
0-14-7	4-12-0	4-12-6
2-12-6	4-12-4	5-10-5†

* Higher percentages may be sold if available.

** The first figure in the grade is percent of nitrogen, the second phosphoric acid (P_2O_5), and the third potash (K_2O).

† 5-10-5 has been designated as Victory Garden fertilizer in 1944, but is not limited to this use.

Effect of Superphosphate on Cotton.

The unfertilized plot at the left produced 233 pounds of seed cotton an acre. Superphosphate (45% P_2O_5) applied at the rate of 100 pounds an acre produced 645 pounds of seed cotton per acre on the plot at the right. (C. E. Barnhill farm, Hugo.)

Several grades of superphosphate are manufactured, depending upon the purity of the rock phosphate and the method of manufacture. Ordinary superphosphate is a chemical mixture of monocalcium phosphate and gypsum. The phosphorus content, calculated as phosphoric acid (P_2O_5),* varies from 18 to 20 percent. It is produced by mixing finely ground rock phosphate containing from 12 to 15 percent of total phosphorus, equivalent to 28 to 34 percent of phosphoric acid (P_2O_5), with sulfuric acid. When rock phosphate is mixed with phosphoric acid (H_3PO_4), superphosphate containing no gypsum and a phosphorus content varying from 45 to 50 percent of phosphorus pentoxide (P_2O_5) is produced.

Finely ground rock phosphate has a relatively low solubility in water, but it can be utilized efficiently by legumes, such as sweet clover, alfalfa and hairy vetch. It is not as effective as superphosphate in increasing the production of many nonlegume crops.

Basic slag is a byproduct from the manufacture of steel. It is much lower in phosphorus content than rock phosphate.

POTASH FERTILIZERS.—Muriate of potash is the cheapest potash fertilizer in Oklahoma. Sulfate of potash is recommended for certain crops and has a less harmful effect on the germination of seed than muriate of potash.

Manure salts and sulfate of potash-magnesia are potash fertilizers which have not been refined sufficiently to remove other salts which are present in the natural potash deposits. Low grade potash fertilizers may contain small quantities of other plant nutrients, such as magnesium and sulfur. The added cost of freight and handling charges on these materials will usually be much greater than their value for crop production. If needed, they can be obtained at lower cost in the form of dolomitic limestone and gypsum.

Oklahoma soils which are deficient in potassium are usually also deficient in phosphorus and nitrogen, consequently a fertilizer grade which will supply all of these essential nutrients should be used in most cases where chemical tests, plant symptoms or the results of field experiments indicate that a soil is deficient in available potassium.

Grades

A fertilizer grade is prepared by mixing different fertilizer materials according to a formula which will produce a

* The term "phosphoric acid" content of fertilizer is from the chemist's viewpoint incorrectly used by fertilizer control officials and manufacturers. All percentages are expressed as phosphorus equivalent to phosphorus pentoxide (P_2O_5) which changes to phosphate acid (H_3PO_4) when mixed with 3 molescules of water.

certain percentage of nitrogen, phosphoric acid, and/or potash in the mixture. A 4-12-4 is a fertilizer grade containing 4 percent of nitrogen, 12 percent of phosphoric acid, and 4 percent of potash.*

Different fertilizer grades are needed for different soils and crops. Therefore a knowledge of soil conditions and crop requirements** helps to determine which fertilizer grade should be used for different soils, or for different crops on the same soil, to produce maximum profitable yields. An ideal group of fertilizer grades for all Oklahoma soil conditions should provide a low, medium and high percentage of nitrogen in combination with medium and high quantities of phosphorus and with none, medium and high quantities of potassium.

The term "unit" is occasionally used to indicate the quantity of each plant nutrient in a fertilizer. One unit is 20 pounds of nitrogen, phosphoric acid (P_2O_5), or potash (K_2O). In other words, a unit is one percent of a ton. Four units of nitrogen would be 80 pounds of this element in each ton of fertilizer.

The Oklahoma fertilizer law does not permit the registration of fractional analysis for either fertilizer grades or materials. The law also requires that each fertilizer must contain the quantity of the various plant nutrients as indicated on the sack or tag in an available form, unless otherwise specified.†

Avoiding Plant Injury

When too much fertilizer is applied in contact with or near the seed or roots of a young plant, delayed germination or injury to early seedling development may occur. This is caused by competition for soil moisture. More damage will be observed when soils are relatively dry or no effective rain occurs for a considerable period after the crop is planted. More injury will occur in sandy soil than in fine textured soils such as a loam or silt loam. Potash and nitrogen fertilizers are more harmful than similar quantities of superphosphate. Rock phosphate has a very low solubility and will cause no injury to germination when placed in direct contact with the seed.

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* One formula which could be used to make a ton of 4-12-4 fertilizer would be 100 pounds of sodium nitrate, 16%N, 320 pounds of ammonium sulfate, 20%N, 1334 pounds of superphosphate, 18% P_2O_5, 160 pounds of muriate of potash, 50% K_2O, and 186 pounds of dolomitic limestone.

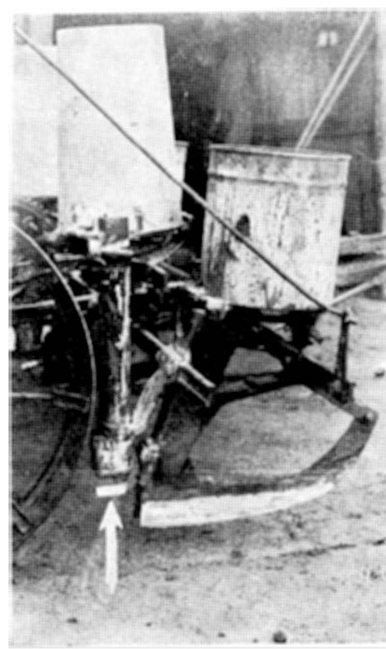
** These factors in the soil fertility problem are discussed on pp. 37 to 40.

† For information on the Oklahoma Fertilizer Law and regulations, see: *State of Oklahoma Seed Law, Commercial Feed Law, Fertilizer Law, Orchard and Nursery Law and Their Rules and Regulations,* published by the State Board of Agriculture, Oklahoma City.

Fertilizer containing soluble nitrogen or potassium salts applied above the seed may injure the stems or first leaves as they pass through the fertilized zone before the seedlings appear above the ground. Young roots which encounter a fertilized zone beneath the seed may also be severely injured.

Fertilizer injury to crops such as cotton, Irish potatoes, and corn can be eliminated by placing the fertilizer in a band one or two inches on each side of the row and at least two inches below the level at which the seed is planted.

When fertilizers are drilled with small grain in rows seven inches apart, the rate of application is usually too low to cause any harmful effects on germination although some of the fertilizer may come in direct contact with the seed. Irish potatoes and beans are very sensitive to fertilizer injury. Severe damage may also occur to young plants such as cabbage, tomatoes and sweet potatoes if the fertilizer is not mixed with a large area of soil before the plants are set.



Fertilizer Attachment, 2-Row Planter
The V-shaped casting behind the shoe (arrow) prevents the fertilizer from dropping on the seed. Improved types of fertilizer distributors for cultivated crops place the fertilizer to the side and at or below the level at which the seed is planted.

When crops such as spinach and onions are planted in narrow rows, it is frequently more desirable to drill or broadcast the fertilizer and disk it into the soil before the crop is planted. Where fertilizer is applied in a row or furrow and mixed with moist soil before the seed is planted, the concentration of soluble salts in the zone surrounding the seed is usually too low to severely injure the growth of young roots unless large quantities of ferilizer are applied and the soil is low in organic and clay content.

Fertilizer machinery designed to apply fertilizers so that they will not interfere with seedling development is illustrated on page 38.

FERTILIZER RECOMMENDATIONS

Field Crops

The fertilizer recommendations given in the following pages apply to land which has a favorable physical condition and where experiments or chemical tests indicate that a profitable response from fertilization should be obtained if climatic conditions do not seriously limit plant development. (See p. 37.)

ALFALFA.—Alfalfa may be grown successfully on a large acreage of land in central and eastern Oklahoma by proper soil treatment. The use of limestone to neutralize soil acidity, and an application of commercial fertilizer or farmyard manure to supply additional nutrients needed for plant development, will usually provide favorable conditions for the growth of alfalfa on well drained land.

Finely ground limestone should be applied to acid soils at the rate indicated by soil tests before alfalfa is planted. Limestone particles dissolve very slowly and cannot neutralize harmful soil acidity rapidly unless they are uniformly distributed through the soil. This material should be applied one year before the alfalfa is seeded for best results and the land

Effect of Superphosphate on Alfalfa on Upland Soil.
At left, fertilized with a top dressing of superphosphate at the rate of 150 pounds per acre about February 1 each year; yield, 5820 pounds per acre. At right, unfertilized; yield, 3,400 pounds an acre. (Five-year average.) (Experiment Station's Agronomy Farm, Stillwater.)

should be plowed and disked at least twice during that period, if possible, to mix the limestone thoroughly into the soil.

Either superphosphate or rock phosphate can be used to increase the yield of alfalfa on phosphorus-deficient land. The superphosphate should be applied at the rate of 300 pounds an acre and the rock phosphate at the rate of 500 pounds an acre. These fertilizers should be drilled or applied broadcast and disked into the surface soil several weeks before the alfalfa is planted.

Good stands of alfalfa are frequently obtained on land which is not acid but is low in available phosphorus. Superphosphate should be broadcast or drilled at the rate of 150 to 200 pounds an acre about February 1 each year on this type of land. No tillage is required to mix the fertilizer with the soil. The average response from a large number of experiments where superphosphate was applied to alfalfa growing on low phosphate soils has been five tons of hay for each ton of 20% superphosphate applied.

Top-dressing a good stand of alfalfa with barnyard manure at the rate of six or eight loads an acre, or with a combination of barnyard manure and superphosphate, will usually produce a large increase in the yield of hay on phosphate-deficient land. In some instances potash must be applied with the phosphate fertilizer to produce maximum yields. A 2-12-6 fertilizer applied at the rate of 200 pounds an acre as a top-dressing on alfalfa has produced a profitable increase in yield in some experiments. This fertilizer will return to the soil less than 10% of the potassium removed when three tons of alfalfa hay are harvested. It is quite evident that heavy potash fertilization will eventually be needed to maintain the production of alfalfa on soils containing a limited supply of available potassium.

The use of fertilizer to produce alfalfa on mineral deficient soil may appear to be an expensive procedure, but the cost is usually not more than one-third of the market price for good alfalfa hay. However, in some areas where the soils are low in natural fertility and the subsoils are strongly acid it will be more profitable to plant other legumes for forage.

In central and western Oklahoma, irrigation rather than fertilization may be necessary to improve the low yields of alfalfa frequently obtained following periods of limited rainfall.* On land not affected by overflow, alfalfa will utilize the

* In a subhumid region, the rainfall is not sufficient to replace subsoil moisture rapidly, hence after a period of limited rainfall the subsoil of land which has been producing alfalfa for several years will remain dry for a period of time after return of normal rainfall has restored surface moisture.

available subsoil moisture as deep as the roots can penetrate. When alfalfa is reseeded on an area, yields may be low because of a limited supply of available soil moisture rather than a deficiency of phosphorus or other elements required for growth.

AUSTRIAN WINTER PEAS.—See "Hairy Vetch," page 21.

BARLEY.—Ordinary superphosphate drilled in the row at the rate of 100 to 150 pounds an acre will increase the production of winter barley when planted on high-nitrogen, low-phosphate soils.

On soils where nitrogen is a limiting factor in crop production, barley should be grown in rotation with a legume such as sweet clover, alfalfa, or lespedeza. The residual effect of superphosphate applied to barley grown on phosphorus deficient soil will increase the growth of legumes and indirectly add more nitrogen to the soil.

Since winter barley cannot utilize the phosphorus in rock phosphate efficiently, this fertilizer should be applied to the legume crop. Sweet clover planted between rows of barley drilled 14 inches apart may be fertilized with rock phosphate at the rate of 150 to 200 pounds an acre, using a grain drill with a fertilizer attachment The fertilizer should be placed between the barley rows by closing every other opening in the fertilizer distributor. This will provide a more favorable condition for rapid growth of the sweet clover seedlings. An increase in the yield of winter barley will be obtained when planted on land where sweet clover residues have been disked into the soil. The sweet clover can utilize phosphorus applied to the soil as rock phosphate. When the legume residues decay, they liberate phosphorus which can be readily absorbed by barley roots. The cost of winter barley produced by this method of soil improvement has been lower than on adjacent plots where equivalent quantities of phosphorus were applied as superphosphate.

Barley will not make a good growth on strongly acid soils containing soluble aluminum. The harmful effect of the aluminum can be corrected by applying limestone and a soluble phosphate fertilizer to change the soluble aluminum to an insoluble compound. Soils containing soluble aluminum are usually deficient in available phosphorus; consequently phosphorus fertilization is necessary to produce a good yield of barley on this type of land.

CORN.—Early maturing varieties of corn will respond to phosphorus fertilization on high-nitrogen, low-phosphorus soils

Effect of Superphosphate and Limestone on Winter Barley.

The fertilized plot produced 31.1 bushels an acre of Michigan Winter barley, the unfertilized plot 20.9 bushels. (Experiment Station's Perkins Farm, 9 miles south of Stillwater.)

in the eastern part of the state. One hundred pounds of superphosphate an acre drilled in the row with the seed at time of planting will increase yields, but is recommended only as a temporary practice to exploit the nitrogen reserves in a soil. This treatment has increased corn yields about six or seven bushels an acre in a large number of field tests conducted on upland in central and eastern Oklahoma. Late corn does not usually respond to phosphorus fertilization under similar conditions because the yield is frequently limited by a lack of soil moisture and high temperatures during July and August.

When soils are low in organic matter, a large quantity of legume residues must be returned to the soil to supply the nitrogen required to produce as much corn as climatic conditions will permit in this region. Cowpeas grown in alternate rows with corn will supply sufficient nitrogen under favorable conditions to produce 20 to 25 bushels of corn per acre. Corn planted following the growth of alfalfa or sweet clover will not respond profitably to fertilizer treatment because the crop will obtain sufficient nitrogen and phosphorus from the decay of active organic matter added to the soil by these legumes Side-dressing corn with nitrate of soda when the crop is knee-high has not been profitable in experimental studies conducted on a large number of soils which apparently contain enough nitrogen to produce as large a crop as climatic conditions in this region will permit. On some farms where only a small acreage of cultivated land is suitable for corn, the use of low-cost synthetic nitrogen on low-nitrogen sandy loam may be the most profitable procedure to maintain or increase crop yields.

COTTON.*—When soils are low to very low in available phosphorus but contain a sufficient quantity of organic matter to produce a good stalk of cotton, superphosphate drilled in the row at the rate of 100 to 150 pounds an acre at time of planting will produce a profitable increase in yield in normal years on deep sandy soils in the central and eastern part of the state.

When cotton does not produce a vigorous vegetative growth, it should be fertilized with a mixed fertilizer containing nitrogen. Since many soils in Oklahoma are not deficient in potassium for cotton production, 200 pounds of a 4-12-0 fertilizer an acre would be recommended under such conditions.

* A crop like cotton which grows during hot weather is less responsive to phosphorus fertilization than wheat or oats planted on the same type of soil. Response from phosphorus fertilization depends to a very great extent on the rate at which organic matter in the soil is decomposed as a result of biological activity.

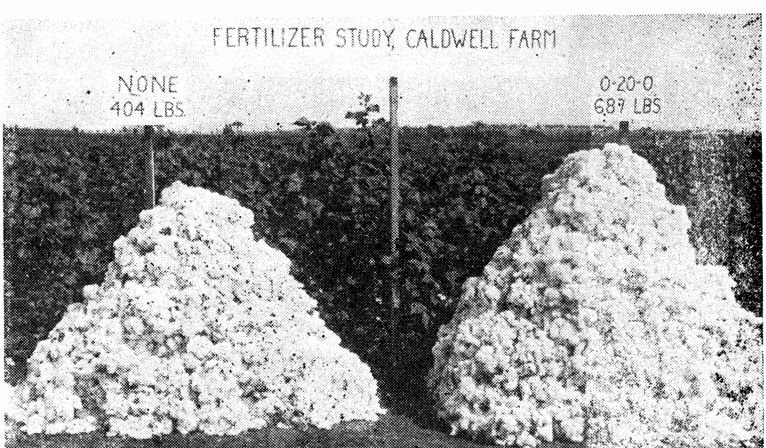
Effect of Fertilizer on Corn.

Left, no fertilizer, yield 18.0 bushels an acre. Center, 100 pounds of 16% superphosphate, yield 24.6 bushels an acre. Right, 133 pounds of 2-12-2 fertilizer, yield 24.1 bushels an acre. (J. O. Kimbro farm, Checotah.)

On acid sandy land with a strongly acid subsoil, a fertilizer containing nitrogen, phosphorus and potassium is usually needed to produce maximum yields.

In areas affected by cotton wilt, muriate of potash may be applied broadcast at the rate of 200 pounds an acre to control this disease, or a fertilizer grade high in potash may be drilled in the row at the time the cotton is planted.

A 4-12-4 fertilizer for medium and fine textured soils and a 5-10-5 fertilizer for sandy soils, applied at the rate of 200 pounds an acre, are excellent fertilizers for cotton where land has been farmed for a long period of time and no attempt has been made to improve the fertility of the soil. One pound of fertilizer will produce approximately one pound of seed cotton under average conditions when the rate of fertilizer application does not exceed 200 pounds an acre. Higher rates of fertilization are not profitable under average Oklahoma conditions because of the limiting effect of climate on plant growth. Soils in central and eastern Oklahoma which are deficient in inorganic phosphorus but contain enough organic matter to produce 1000 pounds of seed cotton an acre without fertilization will not produce a profit from fertilizer treatment over a period of years because unfavorable weather will frequently prevent optumum utilization on the fertilizer applied. Experiments indicate that a profitable increase in yield can be obtained from fertilizer applied to deep sandy land which does not produce



Effect of Superphosphate on Cotton.
At left, no fertilizer, yield 404 pounds of seed cotton an acre. At right, 200 pounds of 20% superphosphate, yield 687 pounds of seed cotton an acre. (George Caldwell farm, Stillwater.)

more than 400 to 600 pounds of seed cotton an acre on the unfertilized soil.

Cotton does not respond to fertilizer treatment when grown on shallow or eroded soils with dense clay subsoils or in regions which receive limited rainfall. Some of the sandy soils in western Oklahoma are low in available phosphorus, but a deficiency of soil moisture is such a frequent limiting factor in the growth of summer crops that a profitable increase in yield from fertilizer applied to these soils is only obtained when rainfall is above the average during the growing season.

COWPEAS, PEANUTS, AND LESPEDEZA.—The growth of cowpeas, peanuts and lespedeza has not been increased appreciably by different fertilizer treatments applied to a large number of soils on which these crops have been planted. These legumes grow during the summer, and yields depend to a very great extent on the distribution and quantity of rainfall during July, August and September. When there is an abundant supply of water in the soil, all of these crops make a good growth on soils which are too low in available plant nutrients to produce a satisfactory yield of corn or small grain. When water is the first limiting factor in plant development, no response from fertilization will be obtained.

When these legumes are grown in a rotation with cotton, corn, or small grain, the fertilizer should under average conditions be applied to the small grain or the row crop. Any residual effect of the fertilizer applied will remain in the soil and improve the growth of the legume the following season.

When peanuts are grown as a cash crop and the vines and nuts are removed from the soil, a 2-12-6 fertilizer should be applied in the row at the rate of 200 pounds an acre. Rock or superphosphate applied at the rate of 150 to 200 pounds an acre will increase the yield of peanuts on sandy, low-phosphate soils which are not deficient in available potassium.

In several experiments where Korean lespedeza has been planted with small grain, 150 pounds of superphosphate an acre has produced a greater beneficial effect on the growth of the small grain that it has on the lespeneza. These results indicate that superphosphate should be applied in the drill row with small grain, since lespedeza can utilize forms of soil phosphorus which are not readily available to small grain crops such as oats, wheat and barley.

FLAX.—Soils which are favorable for the production of flax contain an abundant supply of available nitrogen and are not acid. An application of limestone to correct soil acidity, the use of barnyard manure or a legume crop to

Residual Effect of Phosphorus Fertilizer on Cowpeas.
At left, no fertilizer, yield 1170 pounds an acre. At right, residual effect of 200 pounds of 12-24-12 fertilizer, yield 2420 pounds an acre. (George Caldwell farm, Stillwater.) Fertilizers for cowpeas should be applied to some other crop in the rotation, rather than directly to the cowpeas (See page 20).

maintain a supply of available nitrogen, and superphosphate at the rate of 150 pounds an acre on phosphorus deficient soil are procedures which should be followed to increase the yield of flax. A firm seed bed is also a very important factor in the successful production of this crop.

HAIRY VETCH and AUSTRIAN WINTER PEAS.—Winter legumes are valuable crops for soil improvement, but they will not produce a high yield of forage when planted without fertilizer on soils low in available plant nutrients.

On soils low to very low in available phosphorus, hairy vetch will respond to either superphosphate or rock phosphate drilled in the row with the seed. The rate of fertilization should be from 100 to 200 pounds an acre, depending upon the distance between the drill rows. This crop will produce very little growth without fertilizer on soils that contain sufficient fertility to produce a fair growth of cowpeas when summer moisture is not a serious limiting factor for plant development. It can be planted in rows 21 inches apart by going over the land twice, using a two-row corn planter with fertilizer attachment. A grain drill with fertilizer distributor is more convenient to use if it is available.

In the central part of the state, Austrian winter peas can be used in a rotation with winter wheat to increase the nitrogen content of the soil. This legume responds to phosphorus fertilization on soils which are low in available phosphorus and have not been seriously damaged by accelerated erosion. One hundred and fifty pounds of superphosphate an acre should be drilled in the row with the seed at the time of planting.

Hairy vetch is better adapted than Austrian winter peas to sandy soils or areas receiving abundant rainfall. The winter peas are also damaged more frequently than the vetch by disease and plant lice during cool, moist weather in early spring. The seed of these crops should be inoculated with the proper legume bacteria before planting, since natural inoculation is absent in a high percentage of Oklahoma soils.

LESPEDEZA.—See "Cowpeas," page 20.

OATS.—Oats usually respond to phosphorus fertilization when grown on soils deficient in available phosphorus but containing a good supply of organic matter. One hundred pounds of superphosphate drilled in the row with the seed at time of planting is a good fertilizer for this crop on upland prairie soils.

Potash fertilizers are not important in the production of oats on many potash deficient soils because this crop can obtain an adequate supply of potassium for normal growth from the relatively insoluble potash minerals in a soil.

Top-dressing oats with a soluble nitrogen fertilizer such as nitrate of soda applied at the rate of 100 to 200 pounds an acre when the crop is six to eight inches high is a common practice in humid regions where the supply of available nitrogen is limited by wet weather during the early part of the growing season. Only a limited amount of information on the top-dressing of oats with nitrogen fertilizers has been obtained under Oklahoma conditions. An increase in the grazing value or hay production can be obtained by this procedure.

The low market value of oats will restrict the use of fertilizer on this crop unless it is raised to supply grain or pasture needed on the farm. If the increase in oat yield obtained as a result of fertilization will be less expensive than the cost of purchasing a similar quantity of grain or forage, it will be profitable to apply fertilizer.

Effect of Cowpeas on Yield of Oats.

At left, oats following weeds every third year, yield 10.4 bushels per acre. At right, oats following cowpeas every third year, yield 33.6 bushels per acre. (Experiment Station's Perkins Farm, 9 miles south of Stillwater.)

Oats should be grown in a four- or five-year rotation with sweet clover in central Oklahoma, or in a continuous cropping system with Korean lespedeza in the eastern part of the state. A legume crop will maintain a good supply of available nitrogen in the soil for the continued production of this crop and eliminate the use of a nitrogen fertilizer as a top-dressing except during those seasons when the decomposition of soil organic matter is retarded by cold wet weather in April and May.

PEANUTS.—See "Cowpeas," page 20.

RYE and RYE GRASS.—Both rye and rye grass have a low fertility requirement. They will make a good growth on relatively poor soil if the organic matter content is not too low. Rye is ordinarily planted on sandy land because it will make a better growth on that kind of soil than other small grain. Any cropping system which will increase the organic matter content of the soil will be of more value in maintaining the yield of this crop on sandy land than the annual application of some commercial fertilizer at the time the crop is planted.

Rye grass does not respond to phosphate and potash fertilization unless the availability of soil phosphorus and potassium is very low. On dark prairie soils in eastern Oklahoma, rye grass will respond to superphosphate applied at the rate of 100 to 200 pounds an acre when the seed is planted, using a grain drill equipped with a fertilizer distributor. If the drill with fertilizer attachment is not available, the fertilizer can be broadcast and disked into the soil before the rye grass is planted.

Legumes should be grown with rye grass both to maintain the nitrogen content of the soil and to increase the calcium and phosphorus content of the forage. Winter legumes should be planted with the rye grass and Korean lespedeza should be seeded in the spring if rainfall is favorable for the growth of legume crops.

SORGHUMS and SUDAN GRASS.—Sorghums grown for grain are not responsive to fertilizer treatment on a high percentage of the cultivated soils in Oklahoma. The most extensive acreage of these crops occurs in the western part of the state where moisture is frequently an important limiting factor in their production. Fertilizers are not recommended for direct application to these crops.

Forage yields of many sorghum crops can be increased appreciably on poor sandy soil by growing them in a cropping system with a legume such as cowpeas. Farmyard manure is an excellent fertilizer which will increase the forage yield of sorghum and Sudan grass when these crops are planted on soils low in organic matter.

Where soil and climatic conditions are favorable for growth of sweet clover, this legume should be grown in a four-year rotation with oats, Sudan grass and a row crop of sorghum for forage or grain production. Chinch bugs may limit the production of Sudan grass and late planted sorghum crops in south central Oklahoma.

SOYBEANS.—There is some indication that soybeans should be grown more extensively in eastern Oklahoma to provide an additional source of protein feed for livestock in that area.

When soybeans are cut for hay they remove a large quantity of plant nutrients from the soil, and fertilizer treatment will eventually be required to compensate for this loss. Superphosphate or rock phosphate applied in the row with the seed at the rate of 100 to 150 pounds an acre have increased the yield of soybean forage in several tests. On strongly acid land, limestone will also be needed to produce maximum yields.

Early maturing soybeans planted during the latter part of April are more likely to respond to fertilizer treatment than late maturing varieties or varieties planted late so that they mature during the hot, dry summer weather.

Effect of Fertilizer on Soybeans.

At left, 200 pounds of superphosphate, yield 5,350 pounds an acre. Center, no fertilizer, yield 2030 pounds an acre. At right, 266 pounds of 4-12-4 fertilizer, yield 7,370 pounds an acre. (J. O. Kimbro farm, Checotah.)

When a complete fertilizer, such as a 4-12-4, is used, it must be applied so that the fertilizer will not come in direct contact with the seed or serious injury to germination may occur.

SUDAN GRASS.—See "Sorghums," page 24.

SWEET CLOVER.*—Rock phosphate or superphosphate is most effective in the production of sweet clover when it is applied in drill rows on nonacid, phosphorus deficient soil. The sweet clover seed should be scattered on the surface of the ground above the band of fertilizer, which should be drilled about 3 inches deep. The rate of application per acre will depend upon the width between the rows. From 30 to 50 pounds an acre should be applied when the distance between rows is 42 inches. This spacing is not recommended except for very poor soils where low-cost methods for soil improvement must be used to improve the grazing value of the land. Planting sweet clover in drill rows 14 to 16 inches apart between alternate rows of oats will require from 100 to 150 pounds of rock phosphate or superphosphate an acre.

On slightly acid or moderately acid soils, one part of phosphate mixed with two parts of finely ground limestone should be drilled at least three inches deep. Drilling places the fertilizer and limestone in the soil where it will not dry out easily

* See Oklahoma Agricultural Experiment Station Bulletin B-248 and Circular C-94 for further information on the use of sweet clover for soil improvement.

and will provide sweet clover seedlings growing above the fertilized zone with calcium and phosphorus needed for optimum plant growth.

If broadcast applications are used, apply 200 pounds of superphosphate or 400 pounds of rock phosphate and disk these fertilizers into the soil several weeks before the sweet clover seed is planted.

Acid soils must be neutralized by the addition of limestone to provide a more favorable condition for the growth of sweet clover.

WHEAT.—Profitable increases in the production of winter wheat have been obtained by applying 100 to 200 pounds of superphosphate an acre in the drill row with wheat planted on the prairie soils in central and eastern Oklahoma. Mixed fertilizers containing nitrogen will increase the growth rate of wheat, which may be important when this crop is used for winter and early spring pasture. Experiments indicate that phosphorus and/or nitrogen are the important limiting factors for wheat production in that part of Oklahoma which receives an average annual rainfall of 30 to 40 inches.

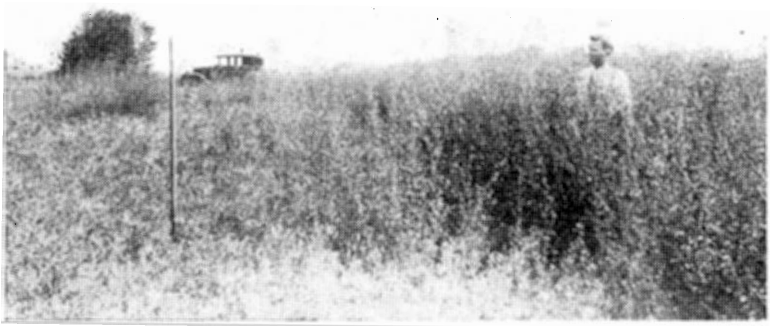
The use of superphosphate to increase wheat production is a temporary practice so far as a permanent system of soil fertility is concerned. Phosphorus fertilization may utilize the soil nitrogen more efficiently but yields will eventually decrease unless some method other than the application of commercial fertilizer is used to improve the productive capacity of the soil. Each bushel of wheat contains approximately 1¼ pounds of nitrogen which came from the soil. The use of a fertilizer such as a 2-12-6 will stimulate an early growth of the crop, but the nitrogen in 200 pounds of this fertilizer is not sufficient to produce the straw and grain required to make three bushels of wheat. Most of the nitrogen in a wheat crop will be obtained from the soil unless a high nitrogen fertilizer is applied. Korean lespedeza should be grown in a rotation with soft winter wheat in the eastern part of the state to assist in maintaining the nitrogen content of the soil. In central Oklahoma, production can be maintained by growing sweet clover every four or five years in a rotation with wheat and oats, if agricultural limestone and a phosphate fertilizer are used where necessary to grow the sweet clover.

Vegetable and Garden Crops

Vegetable crops require a more fertile soil than ordinary field crops because many of these crops have a relatively short growing period and must obtain a large quantity of plant nu-

Effect of Drilling Phosphate and Limestone in Rows on Sweet Clover Production.

Unfertilized plot, right, no yield At left, plot fertilized with 200 pounds of rock phosphate mixed with 400 pounds of limestone and drilled in row at time of planting. Yield, 3660 pounds per acre. (Bob Stokes farm, Glencoe.)



Rock Phosphate vs. Rock Phosphate and Limestone on Sweet Clover. Rock phosphate, 1,000 pounds per acre produced 577 pounds of sweet clover (left). The same amount of rock phosphate plus limestone produced 5,180 pounds per acre (right). (Stanley Dugan farm, Pawnee.)

trients in a short time. They also have a higher acre value than field crops and a higher percentage of the total income can therefore be spent to increase production and improve the quality of the crop.

A tentative classification of several vegetable crops according to soil fertility requirements, prepared by H. B. Cordner of the Horticulture Department of the experiment station, is presented in Table II. Special fertilizer requirements or soil adaptations are indicated in the footnotes to this table. When the soil is medium to low in natural fertility and fertilizer cannot be obtained, crops listed under "Medium" or "Low" in the table will make a better growth than those having a high fertility requirement.

When a garden soil has been fertilized rather heavily with farmyard manure, rate and character of plant development will depend to a great extent on weather conditions. If animal manures cannot be secured and chemical tests indicate that one or more elements are deficient in a soil, the use of commercial fertilizer can be recommended in regions where lack of rainfall does not seriously limit plant development.

For most vegetable crops the rate of fertilization should be from 400 to 600 pounds an acre. The rate will vary for different vegetable crops, depending upon soil requirements and the distance between rows. For instance, a lower rate of application would be recommended for sweet potatoes, which have a low fertility requirement.

Crops such as watermelon, cantaloupe, and cucumber, which are planted in hills, should be fertilized with one-half to one pound of fertilizer applied over a circular area 12 to 18 inches in diameter and mixed thoroughly into the soil to a depth of six to eight inches.

For small gardens, three to five pounds of fertilizer for each 100 feet of row should be applied in a furrow about three or four inches deep and thoroughly mixed with the soil before the crop is planted. In high rainfall areas, where drainage will be an important factor in the growth of early spring crops, this furrow should be opened in the top of a bed or ridge.

Some of the more desirable fertilizer grades for vegetable crops are 5-10-5 and 4-12-4. Leafy vegetables usually require more nitrogen. Root crops require a higher percentage of phosphoric acid and potash. The ratio between these three plant nutrients in a fertilizer will usually depend upon the available supply of each element in the soil. Potash can be omitted from a fertilizer grade applied to crops grown on non-acid bottomland soils. Tomatoes, sweet corn, and sweet potatoes need a fertilizer containing a higher ratio of phosphoric acid to nitrogen and potash. A 1-3-1 ratio between the nitrogen, phosphoric acid and potash in the fertilizer is recom-

TABLE II.—Tentative Classification of Vegetable Crops According to Soil Fertility Requirement.

High soil fertility level	Footnote	Medium soil fertility level	Footnote	Low soil fertility level	Footnote
Beet	3	Asparagus	1	Radish	3, 4
Cabbage	2	Bean	2	Turnip	2
Chard		Carrot	3	Sweet potato	6
Eggplant		Cantaloupe	1, 5		
Lettuce		Cucumber	1, 5		
Onion	3, 4	Kale	4		
Pepper		Parsnip			
Rhubarb	1	Pea	3, 4		
Spinach	3, 4	Potato	1		
Tomato	1, 2	Squash	1, 5		
		Sweet corn	2		
		Watermelon	1, 5, 6		

1. Crops favored by an abundance of organic matter or barnyard manure.
2. Crops generally favored by a large application of superphosphate.
3. Crops usually planted in narrow rows, which increases the rate of fertilizer application on an acre basis.
4. Crops usually planted early in the spring and requiring readily available form of nitrogen at time of planting.
5. Crops planted in wide rows, so rate of fertilizer application on an acre basis is low.
6. Crops requiring sandy soil, which may be low in organic matter.

Effect of Fertilizer on Irish Potatoes.

At left, 100 pounds of 21-53-0, yield 99.6 bushels an acre. Center, no fertilizer, yield 68.0 bushels an acre. At right, 500 pounds of 4-12-4 fertilizer, yield 103.2 bushels an acre. (Frank French farm, Stillwater.)

mended for most vegetable crops when they are planted on loam, silt loam, or clay loam soils.

Orchards and Small Fruits

Available nitrogen and soil moisture are two important limiting factors in the growth and production of orchard trees and small fruits under average Oklahoma conditions. Tree roots penetrate into the subsoil and obtain a sufficient quantity of mineral elements for plant development on land where annual crops need fertilization. Fertilizer is recommended only when young trees or bushes show a lack of vigor as indicated by short terminal growth and sparse leaf development.

Young fruit trees may be fertilized late in March or early in April with one-fourth to one pound of ammonium sulfate, ammonium nitrate, or nitrate of soda. The quantity will depend upon the size and age of the tree. The fertilizer should be broadcast evenly over the surface of the ground and outward from the tree trunk as far as the branches extend.

After the trees begin to bear fruit, the following fertilizer treatments are recommended when legume crops* are not used to increase the nitrogen content of the soil.

APPLES.—Mature apple trees should be fertilized with three to five pounds of ammonium sulfate three weeks before the blossoms open.

CHERRIES.—One pound of ammonium sulfate should be applied around each tree two to three weeks before the blossoms open.

GRAPES AND SMALL FRUITS.—Farmyard manure should be applied every three or four years and thoroughly mixed with the surface soil. On very sandy soils or soils low in available phosphate and organic matter, 180 pounds of a fertilizer mixture containing 60 pounds of ammonium sulfate and 120 pounds of ordinary superphosphate applied in early spring will materially increase the production and quality of the fruit. This fertilizer is similar to a 4-12-0.

PEACHES.—One pound of ammonium sulfate or ammonium nitrate per tree should be applied two or three weeks be-

* An economical method of renewing the organic material and supplying nitrogen to orchard soils has been worked out in the Oklahoma Agricultural Experiment Station orchards and is now being used successfully by commercial orchardists. It is a modified cover crop and cultivation system in which vetch is left to mature in the orchard on alternate years. Information can be obtained by writing: Department of Horticulture, Oklahoma A. and M. College, Stillwater, Oklahoma.

fore the blossoms open, and a second application of one pound per tree should be made about the first of June to aid in fruit development.

PEARS.—A pear tree should not be fertilized with nitrogen except when grown on a soil low in organic matter. A succulent growth of young wood is susceptible to a bacterial disease called pear blight. Light cultivation with a disk to control tall-growing vegetation is the only treatment recommended for a pear orchard on the average soil.

PLUMS.—Plums should be fertilized similarly to peaches except that the rate of fertilization per tree should be reduced.

STRAWBERRIES.—A good soil for strawberry culture should contain an abundant supply of organic matter and a sufficient quantity of available plant nutrients to produce a vigorous vegetative growth the first season after the plants are set.

When strawberries are planted on soil low in natural fertility, three fertilizer applications should be made during the first two seasons, as follows:

1. A complete fertilizer should be applied in the row with a fertilizer distributor before the plants are set. (The fertilizer may be applied around the plant and worked into the soil, but this procedure greatly increases the cost of application and is recommended only for small areas.)

2. Ammonium sulfate should be applied as a side-dressing on each side of the strawberry rows or beds in September of the first year at the rate of 200 pounds an acre. This aids in the development of fruit buds, which determine to a very great extent the number of berries that will be produced the following spring.

3. A similar application of ammonium sulfate should be made in September of the second year.

Injury will occur to the leaves, and the crowns may be severely damaged, if ammonium sulfate is broadcast over the area.

BLACKBERRIES, DEWBERRIES, LOGANBRRIES, and BOYSENBERRIES.—These crops are adapted to soils of moderate to low productivity. Too much available nitrogen in a soil will increase vegetative growth and make the plants more susceptible to winter killing. Available moisture is an important factor in the successful production of these crops.

Planting hairy vetch with a drill between berry rows spaced about eight feet apart will supply nitrogen as the vetch residues decay. The vetch may need to be fertilized for optimum growth. Maintaining organic matter is more important on poor sandy soils than on fine-textured soils. The latter usually contain more organic matter.

Decorative Plantings

Lawns

Fertilizing a lawn will not overcome the harmful effects produced by close cutting (less than one and one-half inches), competition from tree roots, shade, or a deficiency of moisture in the subsurface soil.

Usually a vigorous growth of vegetation will be obtained the first two or three years after a lawn is planted. As the soil becomes more dense due to tramping or the packing effect of rain, the availability of nitrogen gradually decreases, especially on lawns from which the grass clippings are removed, and a decrease in the vigor of the grass often results.

Dark colored soils usually contain enough nitrogen to produce a good growth of vegetation without fertilization. Light colored soils frequently fail to produce a good growth of grass unless a nitrogen fertilizer is applied or white clover is planted to increase the available nitrogen supply in the soil.

An ideal soil for the growth of grass should not contain too much sand or too much clay and should be slightly acid to neutral in reaction. Very sandy soils dry out too quickly. Soils containing more than 25 to 30 percent of clay eventually become so compact that they are not favorable for root development and the absorption of moisture unless the organic matter content of the soil is high.

Grass clippings contain a considerable quantity of plant nutrients. If clippings are regularly removed from a lawn, the addition of fertilizer containing a large quantity of available nitrogen will materially improve the growth of vegetation.

Inorganic forms of nitrogen such as ammonium sulfate must be applied very carefully to obtain a uniform green color over the entire lawn.. Uneven spreading will cause a difference in color. Mixing fertilizer with sand or dry soil will aid in obtaining a more even distribution The rate of application may vary from one-half to one pound for each 100 square feet of lawn.

A complete fertilizer such a 12-6-4 or a fertilizer grade containing smaller quantities of nitrogen may be used on a new lawn or on soil which is low in available phosphorus or potash. The phosphorus and potash in a fertilizer grade is of little value so far as the growth of the grass is concerned after one or two applications have been made. They may be used, however, to provide a more favorable condition for the growth of white clover unless the soil is too sandy or the climate is too dry. A mixed fertilizer should be applied at the rate of two to three pounds per 100 square feet.

Fertilizer should not be applied when the grass is wet unless water is applied immediately to wash the fertilizer into the soil.

Cottonseed meal is an excellent fertilizer for grass, flowers, or shrubs, especially during the late spring and summer months.* As the cottonseed meal decays, nitrogen and phosphorus are made available to the plant roots. The slow liberation of these plant nutrients maintains a relatively uniform growth for a long period of time after the fertilizer is applied. Cottonseed meal should be applied at the rate of three to five pounds for each 100 square feet of lawn or cultivated area in March or early April.

A compost may be used to improve the physical structure and fertility of a clay soil where a slight change in grade is not objectionable. A compost pile may be prepared by placing three or four layers of organic material approximately 12 inches thick between three-inch layers of sandy loam topsoil. Water should be added when necessary to keep the soil and organic matter moist. The pile should be turned every two or three months to obtain a more uniform product and hasten the partial decay of the more active forms of organic matter. After a pile has been turned three times, it should be screened through hardware cloth having two wires per lineal inch. If cottonseed meal and superphosphate are mixed with the compost when it is turned the first or second time, the fertilizing value of the mixture will be materially improved. When composts are used as a mulch, enough material is applied to produce a surface cover about one-fourth inch thick. A favorable physical condition can gradually be produced on the surface of a clay soil which cannot be obtained with mineral fertilizers or light applications of organic materials.

Roses

Soil fertility is only one of many factors which may affect the successful production of roses. Diseases, dry weather, and

* Limitation on the sale of protein meal, cake or pellets requiring a signed statement that the purchase complies with the provisions of the War Production Board's Food Production Order 9, revision 3, was revoked on March 15, 1944.

winter injury cannot be controlled by fertilization. Too much clay or a deficiency of organic matter in the surface 18 inches of soil is more likely to limit plant development than is a deficiency of mineral elements. Roses do not usually respond to fertilizer treatment on soils which produce a vigorous growth of other forms of vegetation.

Well decomposed cow manure is an excellent fertilizer to mix with the soil in the bottom of a hole at the time roses are planted.

Cottonseed meal is one of the best fertilizers for a rose garden.* It is free from weed seed and the nitrogen is released slowly over a long period of time, which provides a favorable condition for uniform vegetative growth. The rate of application should be from three to five pounds for each 100 square feet of bed. The fertilizer should be spread evenly over the ground early in March and cultivated into the soil with a hoe. A second application of cottonseed meal may be made during the latter part of July or early in August. The rate of this application should be reduced to one-half of the spring treatment to prevent excessive stimulation of a succulent fall growth which might be severely injured by winter weather.

A complete commercial fertilizer containing from four to six percent of nitrogen is used by many rose growers to increase vegetative development. The quantity of phosphoric acid or potash in these fertilizers is not important. A 5-10-5 grade is a good fertilizer for the average rose garden. It should be applied about April 1 at the rate of two or three pounds for each 100 square feet of bed. Ammonium sulfate applied at the rate of one-half pound per 100 square feet about the time the first crop of blooms has developed will help produce a second crop of blooms if the soil is deficient in available nitrogen as a result of excessive rainfall.

Roses prefer a slightly acid to moderately acid soil. Many soils in Oklahoma contain too much lime for successful rose production unless adapted varieties are planted. A sandy soil which does not contain too much calcium carbonate can be changed from an alkaline to an acid reaction by sulfur or iron sulfate. Soil containing a high clay content will require a larger quantity of these materials than sandy soil. One pound of sulfur or four pounds of iron sulfate for each 100 square feet of bed is sufficient for a preliminary treatment. If the roses do not show any beneficial effects from the initial treatment, soil tests should be made after three or four months to determine whether successive treatments should be applied.

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* See footnote on page 34.

When a soil is moderately to strongly alkaline, it should be replaced with a more favorable soil at the time the roses are planted.

Additional information on the production of roses may be obtained from the following publications: Arkansas Agricultural Extension Circular 412; Texas Agricultural Experiment Station Circular 90; U. S. D. A. Farmers' Bulletin 1547; Michigan Agricultural Experiment Station Special Bulletin 222; and New York State College of Agriculture Special Bulletin 342.

SHADE TREES AND SHRUBS

Many Oklahoma shade trees and landscape plantings could be improved by proper fertilization. The cost of fertilizer is relatively insignificant as compared with the satisfaction obtained from the improved growth.

Nitrogen is the most important limiting element in the vigorous growth of trees and shrubs on the average soil where severe drouth does not interfere with plant development. To provide nitrogen, ammonium sulfate should be applied in late winter or early spring. It can be broadcast evenly over the surface of the ground from the trunk of a tree outward as far as the branches extend, or it can be placed in holes spaced about two feet apart in one or more circles around the tree beneath the tips of the branches. Holes aproximately three-fourth of an inch in diameter and 12 to 18 inches deep can be made with a soil auger or by driving an iron pipe into the earth. Two ounces of ammonium sulfate should be placed in each hole. Two to five pounds of fertilizer should be applied, depending upon the size of the tree. The value of a complete fertilizer for trees will depend upon the quantity of nitrogen which it contains. The average soil contains sufficient minerals such as potassium, calcium, magnesium, iron, phosphorus, and sulfur to support a good growth of vegetation if nitrogen is applied.

Trees growing in or adjacent to lawns that are fertilized with nitrogen fertilizers should absorb sufficient nitrogen from the fertilizer applied to the grass.

FACTORS AFFECTING RESPONSE TO FERTILIZATION

Important factors that should be considered in the development of a soil improvement program with fertilizers include the physical and chemical character of the soil, effect of drouth and excessive rainfall during critical periods of plant development, ability and opportunity of the plant to use water efficiently, and fertility requirement and feeding power of the plant for relatively insoluble forms of soil minerals.

Physical Character of the Soil

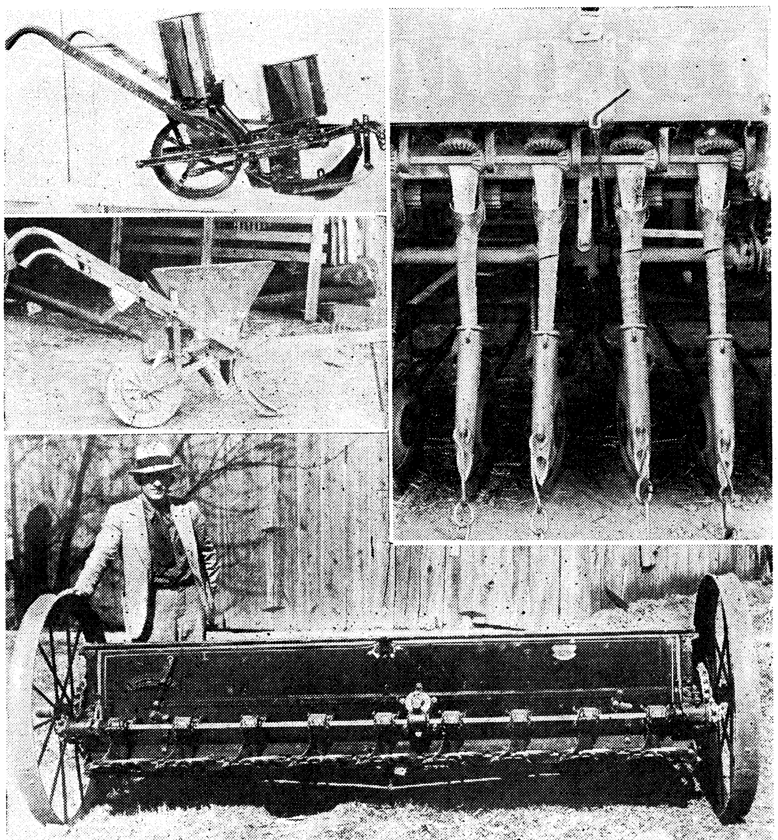
The physical character of a soil is an important factor in determining the rate of moisture absorption, water holding capacity, soil aeration, and opportunity for root development. Fertilizer applied to soils containing too much sand or clay frequently does not produce as great a return on the investment as a similar quantity of material applied to a medium textured soil.

Eroded land is normally lower in organic matter and higher in clay content than the original soil. Experiments indicate that it is more difficult to obtain a profitable response from fertilizer applied to the average eroded soil than to land which, because of a more favorable slope or better management, has not suffered from the destructive effect of runoff water. One of the big problems in Oklahoma at the present time is to determine how much money can be spent profitably to improve the productivity of moderately eroded land. The low waterholding capacity of an eroded soil may restrict crop production although a chemical test may show that the soil should respond to fertilization. The physical character of many soils has slowly changed while soil fertility has been exploited by the continued production of corn, cotton, and small grains. This condition applies to a large area of land in central and southern Oklahoma. Large quantities of nitrogen and organic matter must be added to these soils, along with other plant nutrients when needed, to improve crop production.

Climatic Hazards

In areas where too much or too little rainfall occurs during critical periods of plant development, low-cost methods of soil improvement must be used. On some soils, fertilization will increase forage yields but will not increase yields of grain. Under such conditions it is frequently more desirable to fertilize a legume crop for soil improvement rather than to fertilize a cash crop.

An application of limestone and a phosphate fertilizer to increase the growth of deep-roooted legume crops involves a lower financial risk than an application of a complete fertilizer to a crop of grain or cotton. When legume residues are



Four Types of Fertilizer Distributors.

Upper Left: A one-row combination fertilizer distributor and planter. Below it is a one-row distributor for use when fertilizer is placed in furrow before bed is made for cotton, corn, or sweet potatoes. Fertilizer for row crops should be applied at the side and below seed level for best results. **Upper Right:** Section of combination fertilizer distributor and grain drill. Fertilizer falls through galvanized iron spouts into grain spouts and is in contact with seed. Germination of seed is not injured because rate of application is usually low. **Bottom:** Box type fertilizer distributor with star feed wheels, for applying fertilizer broadcast. Rate of application can be varied from 100 to 2,000 pounds per acre.

returned to the soil, low crop yields during any one year will not reduce the beneficial effect obtained from succeeding crops. Another advantage of a crop rotation is that all crops do not mature at the same time, consequently a method which improves the fertility of the soil will benefit those crops which are not affected by unfavorable weather during critical periods of plant development.

Under conditions where the risk from fertilizer applied to increase the yield of a cash crop is not too great, a system can be developed in which the fertilizer can be applied to the crop having the highest fertility requirement or which matures when weather conditions are most favorable for crop production. Under such conditions other crops in the rotation will normally benefit from the residual effect of fertilizer applied if the nitrogen content of the soil is maintained.

Ability and Opportunity to Utilize Water

Water is not used with equal efficiency by all plants. Crops which grow during the spring and fall usually have more available moisture and respond to fertilizer treatment on mineral deficient soils when no increase in yield is obtained from crops which mature during hot, dry weather. Small grains are more responsive to soil-improving practices than corn or grain sorghums. Yields of wheat, sweet clover, alfalfa and hairy vetch will be increased by phosphate fertilization when no effect from the same fertilizer treatment will be obtained on cowpeas, peanuts or lespedeza.

Alfalfa requires three times as much water as a sorghum crop to produce one pound of dry hay. Legumes require more water than small grains for the same yield of dry matter. A crop planted on good soil also needs less water to produce a pound of dry matter than the same crop planted on poor land.

Fertility Requirements of Crops

Crops vary in their nutrient requirements and ability to obtain different elements from the relatively insoluble compounds in the soil. Plants with a strong feeding power and extensive root system or a lower need for plant nutrients will make better yields on poor soil than other plants having a lower ability to obtain nutrients from relatively insoluble forms of soil minerals, a greater fertility requirement, or a restricted root development. Common Oklahoma field crops can be classified according to their response to soil improving practices into the following groups:

High: Alfalfa, barley and Irish potatoes.

Intermediate: Wheat, Austrian winter peas, hairy vetch, sweet clover, oats, cotton, soy beans and corn.

Low: Lespedeza, cowpeas, rye, sorghums for grain, mung beans, peanuts and sweet potatoes.

Crops in the intermediate group will make a fair growth without fertilization on land where alfalfa and barley will not make a maximum yield unless fertilizers are applied. Crops in the low group will make a good growth on soils where crops in both the preceding groups need to be fertilized to produce satisfactory yields.

In interpreting the feeding power of plants, some consideration must be given to the effect of soil reaction, availability of minerals released by the decay of soil organic matter, and whether the crop is a legume or a non-legume. Legume crops will normally make a good growth on soils low in organic matter and nitrogen if they contain a good supply of available mineral elements. Small grain, cotton and corn must be supplied with both nitrogen and mineral elements when they are planted on mineral-deficient soils low in organic matter.

Where grain crops such as corn may be more important than legumes as a source of feed on limited areas of good soil, cheap, commercial nitrogen might be used to raise a larger acreage of grain on land especially suited for this purpose, by plowing under the nitrogen two or three weeks before the corn is planted.*

Experiments have been conducted at several agricultural experiment stations to obtain information on the fertilizer need of different crops planted on soils low in available nitrogen, phosphorus and/or potassium. Results compiled by Hartwell, formerly of the Rhode Island Agricultural Experiment Station, are given in Table III.** A few additions to this table have been made as indicated. Tomatoes respond favorably to phosphorus fertilization, consequently the tomato was changed from a low to a high response in this table. Although some crops are usually planted on sandy soil relatively low in natural fertility, these crops require fertilization for the production of maximum yields. A very good example of this condition is the watermelon; it is usually planted on sandy soil, but requires hill fertilization to insure a good crop.

* Applying fertilizer in the plow furrow increases the availability of plant nutrients during drought periods and does not stimulate early growth so much as row application at time of planting. See Indiana Agricultural Experiment Station Bulletin 482.

** For additional information see Conn. Agr. Exp. Sta. Bul. 450.

COMPOSITION OF FERTILIZER MATERIALS

A common inquiry concerning the composition of fertilizer is as follows, "If superphosphate contains phosphorus equiavlent to 20 percent of phosphoric acid, what is the remaining 80 percent of this material?" Superphosphate is a chemical mixture composed principally of monocalcium phosphate and calcium sulfate. It is produced by the action of sulfuric acid on finely ground rock phosphate. The monocalcium phosphate contains phosphorus chemically combined with calcium, hydrogen, oxygen and a small quantity of water. Superphosphate containing no gypsum can be pro-

*TABLE III.—Response of Field and Garden Crops to Different Fertilizers Applied to Soils Deficient in These Elements.**

High Response	Medium Response	Low Response
	NITROGEN FERTILIZATION	
High Response	**Medium Response**	**Low Response**
Barley	Alfalfa**	Beans
Lettuce	Beets	Cabbage
Millet	Carrots	Corn
Onions	Cotton**	Peas
Parsnips	Oats	Potatoes
Spinach**	Sorghum**	Rye
Squash	Tomatoes	Sweet Clover**
	Turnips	
	Wheat	
	PHOSPHORUS FERTILIZATION	
High Response	**Medium Response**	**Low Response**
Alfalfa**	Barley	Beans
Beets	Corn	Carrots
Cabbage	Cotton**	Millet
Onions	Lettuce	Oats
Parsnips	Potatoes	Peas
Squash	Rye	Sorghum**
Tomatoes†	Sweet Clover**	
Turnips	Wheat	
	POTASSIUM FERTILIZATION	
High Response	**Medium Response**	**Low Response**
Beets	Alfalfa**	Beans
Lettuce	Barley	Cabbage
Onions	Carrots	Corn
Parsnips	Cotton**	Oats
Squash	Millet	Peas
	Potatoes	Rye
	Tomatoes	Sorghum**
		Sweet Clover**
		Turnips
		Wheat

* Compiled by B. L. Hartwell, Rhode Island Agricultural Experiment Station. (Am. Soc. of Agronomy Jour., 13:458 (1922).

** Crops added to list prepared by Hartwell.

† Shifted from low to high response based on local observations

duced by treating finely ground rock phosphate with phosphoric acid. This material is frequently called treble, triple, or double superphosphate and the commercial product contains phosphorus equivalent to 45 percent of phosphoric acid.

Nitrogen and ammonia are gases which must be combined with other elements to form a solid or a liquid. Sodium nitrate contains 16 percent of nitrogen. It is impossible to incease the quantity of nitrogen in this compound because the nitrogen is combined in definite proportions with sodium and oxygen. Ammonium nitrate and urea contain a high percentage of nitrogen because the weight of other elements in these chemical compounds is low as compared with the total nitrogen present.

Muriate of potash contains potassium equivalent to 50 percent of potassium oxide. This compound contains no oxygen, consequently a fertilizer analysis expressed in terms of nitrogen, phosphoric acid and potash does not indicate the manner in which these substances are combined with other elements in their respective salts. The presence of impurities in fertilizer materials is responsible for reducing the quantity of nitrogen, phosphoric acid, and potash as compared with the percentage of these substances in chemically pure salts.

A few common fertilizer materials, their chemical formulas and the approximate percentages of the different elements in the pure salts are given in Table IV. It will be observed from these analysis that the most abundant element in all fertilizers except the muriate of potash is oxygen. Oxygen is present in the air as a gas but it will combine chemically with many elements to form solids. Sulfur and oxygen combine with water to form sulfuric acid. Ammonia gas will react with sulfuric acid to form ammonium sulfate which is a nitrogen fertilizer. Phosphorus and nitrogen also combine with oxygen and water to form acids which may be neutralized with ammonia, lime or other alkaline substances to form fertilizer materials. Cyanamide contains a considerable quantity of free carbon which reduces the nitrogen content of this fertilizer as compared with the pure salt.

Fertility Sold in Marketing

The potential fertlity in Oklahoma soils has gradually declined as a result of the continued production of soil depleting crops and the sale of livestock or livestock products. The average organic matter content of cultivated land has decreased approximately one percent each year from the combined effect of soil erosion, leaching and crop production. Some of the ni-

*TABLE IV.—Approximate Chemical Composition of Several Common Fertilizer Salts.**

Name and kind of fertilizer	Chemical formula of salt present	PERCENTAGE OF THE DIFFERENT ELEMENTS IN PURE SALTS									
		Nitrogen	Phosphorus**	Potassium†	Calcium	Sodium	Sulfur	Oxygen	Hydrogen	Chlorine	Carbon
Nitrogen fertilizers											
Ammonium nitrate	NH_4NO_3	35.0						60.0	5.0		
Ammonium sulfate	$(NH_4)_2SO_4$	21.2					24.2	48.4	6.1		
Cyanamide	$CaCN_2$	35.0			50.0						15.0
Sodium nitrate	$NaNO_3$	16.4				27.0		56.5			
Urea	$(NH_2)_2CO$	46.6						26.7	6.7		20.0
Phosphate fertilizers											
Rock phosphate	$Ca_3(PO_4)_2$††		20.2		38.7			41.3			
Superphosphate (18 to 20% P_2O_5)	$CaH_4(PO_4)_2\ H_2O$ $2CaSO_4\ 2H_2O$		10.4		20.2		10.7	56.5	2.2		
Superphosphate (45% P_2O_5)	$CaH_4(PO_4)_2\ H_2O$		24.6		15.8			57.2	2.4		
Potash fertilizers											
Muriate of potash	KCl			52.4							47.6
Sulfate of potash	K_2SO_4			44.8			18.4	36.8			

* Fertilizer materials contain impurities which reduce the percentage of nitrogen, phosphorus or potassium as compared with the pure salt.
** To change the percent of phosphorus to phosphoric acid (P_2O_5) multiply by 2.29.
† To change the percent of potassium to potash (K_2O) multiply by 1.23. †† This compound may frequently contain calcium floride and other impurities which reduce the total phosphorus content.

trogen can be returned to the soil by growing legume crops, but fertilization will eventually be required to replace the mineral losses.

The average quantities of nitrogen, phosphorus, potassium and calcium removed from an acre of land by 15 important Oklahoma crops are given in Table V. Forage crops remove large quantities of potassium and calcium. Grain crops contain large quantities of nitrogen and phosphorus. An estimate of the total quantity of these plant nutrients removed from Oklahoma soils each year by twelve crops is given in Table VI.

If Oklahoma farmers should be required to replace the nitrogen, phosphorus, potassium and calcium removed annually from Oklahoma soils by crops, it would be necessary to purchase approximately 530,000 tons of ammonium sulfate, 90,000 tons of superphosphate, 40,000 tons of muriate of potash and 35,000 tons of agricultural limestone. The cost of this material would be approximately $25,000,000, of which more than 80 percent would be for nitrogen.

Livestock farming does not require as much commercial fertilizer to maintain soil fertility as cash-crop farming. Table

TABLE V.—Average Plant Nutrient Content of Oklahoma Crops.

Crop	Portion Harvested	Yield per Acre*	TOTAL QUANTITY OF NUTRIENT (LB. PER A.)			
			Nitrogen	Phosphorus	Potassium	Calcium
Alfalfa	Hay	6000 lb.	151.0	12.6	121.2	85.8
Barley	Grain	30 bu.	27.2	5.5	7.5	.7
	Straw	1500 lb.	8.8	1.3	18.9	4.8
Corn	Grain	25 bu.	21.7	3.9	4.6	.2
	Stover	1500 lb.	14.1	1.3	25.1	6.8
Cotton	Lint	250 lb.	.8	.1	1.0	**
	Seed	500 lb.	16.8	2.7	4.7	1.0
Cowpeas	Hay	300 lb.	89.4	7.5	43.5	33.9
Kafir	Grain	20 bu.	20.2	3.3	3.9	.5
	Fodder	3000 lb.	36.0	5.1	46.2	14.1
Oats	Grain	40 bu.	24.6	4.2	5.1	1.2
	Straw	2000 lb.	12.6	2.6	33.2	7.2
Peanuts	Hay	3000 lb.	45.0	3.0	30.0	45.0
Potato, Irish		100 bu.	20.4	3.6	38.6	.6
Potato, sweet		100 bu.	13.4	2.8	28.5	1.1
Prairie hay		3000 lb.	30.0	2.4	24.0	6.0
Rye	Grain	10 bu.	10.0	2.0	3.2	.2
Soybeans	Hay	2500 lb.	55.0	6.5	31.0	28.0
Tame hay		4000 lb.	48.0	9.6	45.2	18.8
Wheat	Grain	20 bu.	25.2	5.2	5.3	.4
	Straw	2000 lb.	12.2	1.4	16.0	4.4

* These values may be lower or higher than normal production on many soils.
** One pound of calcium in 15 bales of cotton.

VII shows the loss of nitrogen from the sale of livestock and livestock products is about one-seventh as great as compared with the production of cash crops such as cotton, grain and forage. The average cost of returning the plant nutrients sold from Oklahoma farms each year in the form of livestock or livestock products has been calculated to be about $3,-500,000, or about one-seventh of the value of plant nutrients in crops marketed. It would not be correct, however, to say that cash-crop farming is seven times as destructive to soil fertility as livestock farming. Many of the cultivated fields on a livestock farm are planted to soil depleting crops every year and no fertility is returned to improve their productive capacity. Soil erosion is removing more fertility from many of these fields than the crops which are grown on them. Since the cost of supplying minerals lost under a livestock sysem of farming is lower than the cost of replacing soil fertility when cash crops are grown, the use of land for livestock farming should tend to increase as the fertility declines except on soils adapted to the production of horticultural crops, or on areas where soil erosion is not a serious problem and the physical character of the soil and climatic conditions are favorable for the production of cotton, grain or hay.

TABLE VI.—Estimated Quantity of Nitrogen, Phosphorus, Potassium, and Calcium Removed From Oklahoma Soils Each Year by 12 Crops.

Crop	Average Annual Production*		Nitrogen (Pounds)	Phosphorus (Pounds)	Potassium (Pounds)	Calcium (Pounds)
Barley	2,099,590	bu.	1,903,619	384,923	524,895	48,990
Corn	44,137,500	bu.	38.311,350	6,885,450	8,121,300	353,100
Cotton	944,681	bales	1,511,489	188,936	1,889,362	62,978
Cotton seed	472,340	tons	31,741,281	5,101,277	8,880,001	1,889,362
Hay, alfalfa**	412,800	tons	20,777,600	1,733,760	16,677,120	11,806,080
Hay, prairie	470,770	tons	9,415,380	753,230	7,532,300	1,883,076
Hay, tame†	775,272	tons	18,606,528	3,721,305	17,521,147	7,267,556
Oats	26,957,045	bu.	16,578,579	2,830,489	3,437,022	808,711
Potatoes, Irish	2,527,322	bu.	515,573	90,983	803,688	15,163
Potatoes, sweet	1,378,681	bu.	165,441	34,467	351,563	13,786
Rye	237,225	bu.	236,465	49,153	75,722	5,313
Sorghums, grain	11,005,500	bu.	11,115,555	1,815,907	2,146,072	275,137
Wheat	49,745,500	bu.	62,679,330	12,933,830	13,182,557	994,910
Totals			213,558,190	36,523,710	81,142,749	25,444,162

* 1919 to 1940, inclusive. Data from Agricultural Marketing Service, U S. Department of Agriculture.
** Average yield from 1924-1940, inclusive.
† Composed chiefly of Sudan grass, Johnson grass, and cane.

TABLE VII.—Estimated Nitrogen, Phosphorus, and Calcium Content of Livestock and Livestock Products Sold From Oklahoma Farms Each Year.

	Average Quantity Marketed	Estimated Total Weight (Tons)	Total Nitrogen (Pounds)	Total Phosphorus (Pounds)	**Total Calcium (Pounds)**
Cattle	806,880	363,096	20,478,614	5,373,820	9,658,353
Eggs	(doz.) 60,000,000	45,000	1,944,000	222,700	3,132,000
Hogs	613,530	64,420	2,602,568	502,476	837,460
Milk	(lbs.) 489,000,000	244,500	2,885,100	855,750	704,160
Chickens	17,000,000	34,000	2,380,000	326,400	444,000
Sheep	173,300	7,365	409,494	75,123	135,516
			30,591,776	7,356,269	14,911,489

SOURCE OF DATA: Average number and estimated weight of cattle, hogs, and sheep from Agricultural Marketing Service, U. S. D. A.; data on eggs and chickens from Poultry Department, Oklahoma A. and M. College; milk production based on records of the Dairy Department, Oklahoma A. and M. College; chemical composition of the different items from standard textbooks and technical publications.

APPENDIX I:

Collecting Soil Samples for Chemical Analysis

The following procedure should be used to obtain soil samples which will accurately represent each area. Collect six or seven samples of surface soil from each field or soil type and place them in a pail or sack. Accurate samples can be obtained from the immediate surface of a plowed field. Samples from pasture land and other uncultivated areas should be taken with a spade or soil auger from 0 to 6 inches deep. Thoroughly mix the surface samples from the different locations, remove approximately one pint of the composite sample and place it in a suitable container. Samples of subsurface soil should be obtained from three locations in each area. The depth of sampling should be from 15 to 18 inches. Mix the three subsurface samples thoroughly and save one pint for analysis. Number each surface and subsurface sample so that it can be easily identified. A suggested plan of numbering is: Surface No. 1, Subsurface No. 1, Surface No. 2, Subsurface No. 2, etc. The name and address of the landowner should be placed on each tag for identification. *Spread each sample on a sheet of paper and air dry before the soils are packed for shipment.*

Analyses will be made to determine the degree of acidity and available phosphorus content of each sample. Tests for available potash, organic matter and soluble salts will be made if it appears that additional information is needed to determine what treatment or treatments may be required to improve the productive capacity of the land. Results of a chemical analysis provide only a part of the information needed to make recommendations which should be followed to improve soil fertility and increase crop yields. Send a letter with the samples indicating the location of the land, the problem as it appears to the landowner or individual collecting the samples, the previous treatment, the crops to be grown, and the depth at which clay is encountered in the subsurface soil. The latter information is important because shallow surface soils are frequently responsible for a poor yield of crops, especially when limited rainfall or a poor distribution is unfavorable for plant development.