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A Soil Improvement Program for Oklahoma

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A SOIL IMPROVEMENT PROGRAM IN OKLAHOMA

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A fertile soil is the basis of a prosperous farming industry and the foundation upon which any permanent system of agriculture must rest. The ability to produce large quantities of feed, grain, and forage economically is a prerequisite to the development of a profitable dairy or livestock enterprise. The successful production of cotton, wheat, and other cash crops is dependent, to a large extent, upon the fertility of the soil and its relation to yield per acre. The permanence of agriculture depends upon the control of soil loss and the maintenance of fertility. Since the beginning of time, history is replete with accounts of civilizations that prospered for a time, only to pass from decadence to complete oblivion as the soil resources were exhausted.

EVIDENCES OF SOIL DEPLETION

The potential fertility of Oklahoma soils has rapidly declined during the brief period in which these soils have been in cultivation. The organic matter, nitrogen, and mineral content of the cultivated soils have decreased as a result of the combined effects of soil erosion, leaching, and crop production. In less than half century, the soils have lost 30 to 35 percent of their nitrogen and 35 to 40 percent of their organic matter. The greatest losses have occurred in the central and eastern sections. The extent to which organic matter and nitrogen have decreased in different sections of the State is shown in Table 1.

Phosphorus deficiency has become a limiting factor in crop production on many soils in central and eastern Oklahoma. Laboratory tests show that 41 percent of the soils in central

Table 1.—Decreases in Organic Matter and Nitrogen in Cultivated Soils in Different Sections of Oklahoma.

Section of State*	Losses of Nitrogen	Losses of Organic Matter
Northeast	36	34
Southeast	38	43
North Central	29	33
South Central	34	38
Northwest	25	28
Southwest	26	30

* See Fig.9, page 33.

Oklahoma are low to very low in available phosphorus, and 59 percent of the soils in the eastern section are deficient in this mineral. Phosphorus deficiencies tend to decrease as rainfall decreases. Only 12 percent of the soils in the western section are low to very low in available phosphorus. None of the soils tested in Ellis, Texas, and Cimarron counties show phosphorus deficiencies. A graphic picture of phosphorus deficiencies in Oklahoma soils is shown in Fig. 3, page 13.

The soils in central and eastern Oklahoma have been severely leached of their calcium. Consequently, soil acidity has become a serious problem on many farms in those areas. The degree of acidity varies from very strongly acid to slightly acid, and the percentage of cropland which is acid bears a very close relation to rainfall intensity. In the eastern section where the average annual rainfall is 36 inches or higher, 72.6 percent of the soils are acid. In the central area, the average annual rainfall varies from 28 to 36 inches, and 44.8 percent of the soils are acid. In the western section where the rainfall average is less than 28 inches, only 14.3 percent of the soils are acid. As the degree of acidity increases, environmental conditions in the soil become less favorable for plant development; the rate of decay of organic matter is decreased, and the availability of nitrogen, phosphorus, calcium, and other essential plant nutrients is reduced.

Losses of soil and organic matter have greatly reduced the moisture-holding capacity of many soils in Oklahoma. In studies of cropped and virgin soils, H. F. Murphy[1] found that, on the average, the cropped soils actually had only 76 percent as much water available for crop use as the virgin soils.

The rapid decline of soil fertility has been accompanied by a corresponding reduction in crop yields. In the decade 1900-'09, the average yield of corn in Oklahoma was 24.2 bushels per acre. The average yield of corn for the 5 years 1921-25 was only 16.2 bushels, and the yield further declined to 13.2 bushels per acre for the 10-year period, 1930-39. This represents a decrease of 11 bushels per acre and a reduction of 45 percent in the productivity of the land as measured in terms of corn production. The situation with respect to cotton is similar. Between 1900 and 1909, the average yield per acre was 216 pounds; for the 5 years, 1921-25, the average yield was 169 pounds per acre; and, for the period 1930-39, the average was only 147 pounds per acre. This represents a decline of 69 pounds per acre, or a reduction of 32 percent in productivity. The average yield of oats for 1900-09 was 29.4 bushels; for 1921-25, 21.6

[1] Murphy, H. F., Aspects of Western Soil Improvement. (Mimeograph.)

bushels; and for 1930-39, the yield dropped to 20.2 bushels. This represents a reduction in yield of 9.2 bushels per acre and a decline of 31.5 percent in productivity.

HOW SOILS LOSE FERTILITY

When virgin soils are put in cultivation, losses of soil, organic matter, and plant nutrients usually begin to occur at a rapid rate. These losses are due to (1) removal of plant nutrients by crops, (2) losses of soil by water erosion, (3) removal of soluble material through leaching, and (4) losses of particles by wind erosion.

Loss Through Crops

When crops or livestock are sold from the farm, large quantities of plant nutrients are taken from the soil. This is one of the most important ways by which the fertility of soils is reduced. The approximate amounts of plant nutrients contained in the important crops produced in Oklahoma are shown in Table 2.

It will be seen from the table that grains and seeds are relatively high in nitrogen and phosphorus, while the straw or

Table 2.—Average Plant Nutrient Content of Oklahoma Crops.[1]

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	3000 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.
[1] Harper, H. J., Okla. Exp. Sta. Bul. No. B-279, "Commercial Fertilizers for Oklahoma Crops," 1944.

stover is relatively high in pattasium and calcium. Legume hays contain large quantities of all the plant nutrients.

Erosion by Water

The greatest losses of soil fertility occur on sloping lands in the humid section of the state where erosion is most severe. The topsoil, which is gradually washed away by erosion, contains most of the organic matter, nitrogen, and soluble minerals which are essential for plant growth. Erosion is removing fertility on many farms more than 20 times as fast as it is being removed by crop production. More than 2,000,000 acres of cropland in Oklahoma have already been abandoned as a result of erosion and at least 8,000,000 additional acres are subject to moderate or severe erosion.

Leaching

When water passes down through the soil it dissolves some of the plant nutrients and carries them away in drainage water. Leaching is a slow process, but since it is continuous in regions of high rainfall, it may cause enormous losses.

Soil Blowing

In areas where soils are subject to blowing, the wind may transport dust and fine soil particles for long distances. Under such conditions, soils may suffer losses of organic matter and nitrogen. The losses are most severe when the land has little or no protective covering of vegetation or crop residues during periods of heavy winds. When severe storms occur, small plants may be blown out as the surface soil is removed by wind action.

LAND USE

When soil is lost by erosion more rapidly than it is being formed, the problem of land use becomes important from the standpoint of a permanent agriculture. The most important soil features which affect land use are fertility, slope, depth of surface soil, character of the soil profile, texture, and susceptibility to erosion.

Experiments conducted since 1929 by the Red Plains Conservation Experiment Station at Guthrie show that soil loss occurs at a rapid rate on terraced land in a rotation in which cotton, oats, and darso have been grown. One of these experiments was located on land which had a slope of 2.8 percent. The land was protected by a terrace 2,536 feet long with an interval between terraces of 4 feet, and a channel gradient of 0 to 4 inches. The rate of soil loss during the 8-year period from 1931 to 1938 was 8.5 tons per acre annually. This rate of soil loss would require only about 20 years to remove one inch of surface soil as compared to 500 to 1,000 years required for natural agencies to build one inch of soil from partially weathered rock. Another experiment on the same station was located on a slope of 4.7 percent. The terrace was only 1,500 feet long, the vertical fall was 3.4 feet, and the channel gradient was 2 inches. The rate of soil loss, which was only one inch in 55 years, is still much greater than the rate of soil formation. It is quite evident that row crops cannot be grown continuously on steep slopes, even when the land is protected by terraces, without eventually destroying the soil.

Proper soil management may be of even greater importance than land use in properly utilizing and conserving the soil on many farms. Experiments show that improved cropping systems which include erosion-resisting and soil improvement crops such as sweet clover, alfalfa, and grasses, along with terraces, will greatly reduce the rate of soil loss on sloping soils. It has also been shown that soils protected by perennial grasses will not be removed faster than one inch in two or three thousand years.

The type of farming or cropping system should be suited to the conditions of the land and the physical environment. Consideration must be given to conserving the soil, and to securing a living for the operator. The aim should be to determine the most profitable utilization of the land which will also conserve the soil and maintain its fertility.

HOW SOILS MAY BE IMPROVED BY MECHANICAL METHODS

Terracing

The first step in a complete soil improvement program on crop land is the construction of terraces to control run-off water on sloping lands where erosion cannot be controlled by tillage and agronomic practices. Properly constructed terraces convert running water into slow moving water and materially reduce soil losses. Each terrace collects the water from its drainage area and carries it around the slope at a rate which reduces erosion to a minimum. Terraces also hold the water longer on the slope where it falls and more of it is absorbed into the soil.

The importance of proper maintenance of terraces cannot be emphasized too strongly. No system of terraces, however well planned or constructed, can be successful over a period of years unless kept in good repair.

The terrace system should be supplemented by crop rotation and contour tillage to increase the efficiency of rainfall, control inter-terrace erosion, and prevent the silting of terrace channels.

Wind Erosion Control

The effective control of wind erosion is to prevent the soil from reaching a condition which permits soil blowing. Under normal conditions this can be accomplished by the use of proper tillage and cropping parctices. Soils which are covered with well established vegetation, or with crop residues such as sorghum or Sudan, are in condition to resist wind action. A protective cover of raw organic matter on the surface of the soil is especially important, since it may prevent injury to young plants from drifting sand. Listing on the contour or at right angles to the direction of the prevailing winds or tillage with other implements which will leave a rough, uneven surface, will also check soil blowing.

Strip cropping with sorghums on row crop land is effective under average conditions in low rarinfall areas, if the sorghum stalks are left standing during the winter and early spring when severe soil blowing is likely to occur. When large fields with southern slopes are seeded to small grain, interplanting with strips of sorghums will reduce the hazards of soil blowing.

The choice of crops to be grown on land which is susceptible to wind erosion is an important factor in preventing soil blowing. Some sandy soils which are not suitable for small grain may be planted to sorghums if the stalks are left on the land. In areas where peanuts are grown, sorghums may be planted in alternate strips with peanuts to reduce both wind and water erosion. In southern Oklahoma, a crop such as rye or vetch may be planted following peanuts for winter cover. If peanuts are harvested too late for planting a winter cover crop, the land should be contour listed to conserve moisture and to prevent wind and water erosion during the winter.

Contour Tillage

Contour tillage refers to plowing, planting, and cultivating approximately parallel with terraces or established contour lines. The small furrows and ridges resulting from these operations retain more of the water where it falls and facilitate its entrance into the soil. This gives a more even distribution of rainfall and increases the amount of moisture available for crop use. Contour tillage is necessary to control inter-terrace erosion, which, in turn, prevents the silting of terrace channels. When used in connection with terracing, contour tillage is one of the most effective methods of conserving moisture and preventing soil loss.

By conserving soil and moisture, contour farming increases crop yields. At Goodwell, Oklahoma,[3] on a deep silt loam soil with a slope of less than one percent the average annual grain yield of wheat and milo for a 10-year period was increased 3.1 bushels per acre by terracing and contour tillage to conserve moisture. The yield of tepary bean hay was increased an average of 273 pounds per acre for a 4-year period by the same cultural practices. Harper[4] reports that moisture saved by contour cultivation increased the yields of kafir and seed cotton at Granite, Oklahoma, in 1935. At the Wheatland Conservation Experiment Station,[5] Cherokee, Oklahoma, run-off water was reduced 40 percent, and the yield of wheat was increased 2 bushels per acre in 1944 by terracing and contour cultivation. Soil loss was reduced from 38.24 tons to 16.57 tons annually, and the average yield of seed cotton was increased from 404 pounds to 432 pounds per acre, by contour cultivation on a 6.75 percent slope at the Red Plains Conservation Experiment Station at Guthrie.[6] It is evident, however, that contour tillage alone does not provide adequate conservation of soil and moisture on steep slopes of soils which are highly susceptible to erosion.

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[3] Oklahoma Panhandle Experiment Station Bulletin No. 58, 1935.

[4] Harper, H. J., Prof. of Soils, Okla. Agri. Exp. Sta., Greer County Soil Survey, 1937.

[5] Unpublished Data, Wheatland Conservation Experiment Station, Cherokee, Oklahoma.

[6] Oklahoma Experiment Station Bulletin No. B-257, May 1942.

ORGANIC MATTER

1. Importance of Organic Matter in the Soil

Organic matter is one of the most important constituents of the soil, and an adequate supply of this material is essential in maintaining high levels of crop production. Organic matter provides food for the soil bacteria, and increases their activity. It is the source of energy for these organisms, without which the plant food elements could not be made available for crop use. Organic matter improves the tilth of the soil and provides a more favorable condition for the absorption of water.

Organic matter is the source of nitrogen in the soil. When organic matter is decomposed by soil organisms, nitrogen is liberated as ammonia, and, subsequently, converted into the nitrate form. In this form it is readily available for crop use. The decay of organic matter also releases soluble phosphorus, calcium, potassium, magnesium, sulphur, and other minerals essential for plant growth. In soils well supplied with active organic matter, growing crops get most of their nutrients from this source.

In a cultivated soil, the organic matter is constantly undergoing decomposition or change in form as a result of bacterial activity, and the productivity of the soil is dependent upon this change. From the standpoint of plant nutrition, organic matter is beneficial only as it is active. The activity of this material is of even greater importance than the total amount in the soil. It is important that the soil be managed in such a way as to have a steady supply of organic matter undergoing this process for the benefit of growing crops.

Organic matter releases plant nutrients in the soil only as it decays. The time required for decay is not the same for all kinds of plant material. Legumes such as cowpeas, soybeans, vetch, or winter peas turned under as green manure may decay in two to three weeks. If the plants are allowed to mature and become dry, a somewhat longer period of time will be required for decay. Legume residues will decay more rapidly than non-legume residues, and will leave more active humus in the soil. The nitrogen in legumes will become available for crop use much more quickly than the nitrogen in non-legumes when these materials are plowed or disced into the soil. The residues from corn, cotton, sorghums, small grains, weeds, and other coarse non-legume plant material will require two to three months under average conditions to decay. It is important that crop residues be plowed under early enough to allow time for decay and the release of plant nutrients before crops are planted on the land.

Fig. 1.—Effect of lime and phosphorus on the growth of Sweet Clover on upland soils. Left: 3 tons limestone and 400 pounds rock phosphate per acre. Right: 500 lbs. rock phosphate per acre. (Mae Sumner's Farm, Vinita, Craig County.)

A systematic plan for replenishing and maintaining the reserves of organic matter in the soil is an essential part of good soil management. Organic matter and nitrogen accumulate most rapidly in undisturbed soils which are planted to deep-rooted and sod-forming crops such as alfalfa, sweet clover, or grass mixtures containing legumes. Crop residues, barnyard manure, and green manure crops are also important sources of organic matter.

2. How Organic Matter May be Maintained in the Soil

SWEET CLOVER: Sweet clover is one of the best legumes that can be grown for soil improvement in Oklahoma. The sweet clover plants develop deep root systems and produce high yields of vegetative material which add considerable amounts of organic matter to the soil. Sweet clover also adds more nitrogen to the soil than most other legumes. This is because the plants make much of their growth in the fall and early spring when conditions for nodule development are most favorable. Sweet clover will grow only in soils which are not acid and which are well supplied with available phosphorus. If the soil is acid, a sufficient amount of finely ground limestone must be added to neutralize the acidity. If the soil is deficient in phosphorus, a phosphate fertilizer must be applied. An application of 200 pounds of 20 percent superphosphate or 400 pounds of finely ground rock phosphate may be applied and mixed with the surface soil efore planting the sweet clover. Sweet clover may be planted with oats, barley, or wheat as a nurse crop. Drilling the small grain in 14- to 16-inch rows provides a more favorable condition for the development of the young seedling sweet clover plants. A dense growth of sweet clover is one of the best crops for the prevention of soil loss. The crop

Fig. 2.—Sweet clover roots penetrate compact clay subsoils. Experiment Station Farm, Stillwater, Okla.

will provide some pasture during the fall of the first year. The second-year growth of sweet clover may be used for pasture or for the production of a seed crop. Many farmers have found that a sweet clover seed crop will have a cash value equal to or greater than a wheat crop produced on the same land. The sweet clover residues may be utilized for soil improvement.

LESPEDEZA: Korean lespedeza is an excellent crop to grow for soil improvement in eastern Oklahoma. It will make a fair growth on soils of medium to low fertility where sweet clover will not grow without the use of mineral treatments. On acid, phosphorus-deficient soils the addition of lime and phosphate will stimulate the growth of lespedeza and increase the mineral content of the plants. Lespedeza grows in thick stands and provides protection against soil erosion throughout the summer and fall. When a full growth of lespedeza is plowed or disced into the soil, it adds large amounts of organic matter and nitrogen, which will greatly increase the yields of succeeding crops.

Lespedeza may be planted with oats, wheat, barley, flax, or ryegrass. It may also be planted alone or with Bermuda grass in a permanent pasture. Lespedeza is perhaps most valuable when planted with one of the small grain crops in a one-year rotation. After the grain crop is harvested, the lespedeza may be pastured or a seed crop may be harvested and the residues utilized for soil improvement.

HAIRY VETCH AND AUSTRIAN WINTER PEAS: Hairy vetch and Austrian winter peas are valuable crops for soil improvement in central and eastern Oklahoma. These crops, however, will not make satisfactory growth without fertilizer treatments when planted on soils which are low in available plant nutrients.

On phosphorus-deficient soils, vetch may be fertilized with superphosphate or rock phosphate at the rate of 100 to 200 pounds per acre. Vetch is especially adapted in the easteren part of the State and on sandy soils in the central area. It has a lower lime requirement than sweet clover.

Austrian winter peas can be used in rotation with winter wheat in the central area to increase the organic matter and nitrogen content of the soil. On soils which are low in available phosphorus, this legume will respond to an application of 150 pounds of superphosphate drilled in the row with the seed at the time of planting. If the soil is acid, an application of finely ground limestone should be made.

Vetch and winter peas may be turned under as green manure, or the seed crops may be harvested and the residues utilized for soil improvement.

OTHER LEGUMES: Cowpeas, soybeans, mung beans, and crotalaria are all sources of organic matter and nitrogen when the residues of these crops are plowed or disced into the soil.

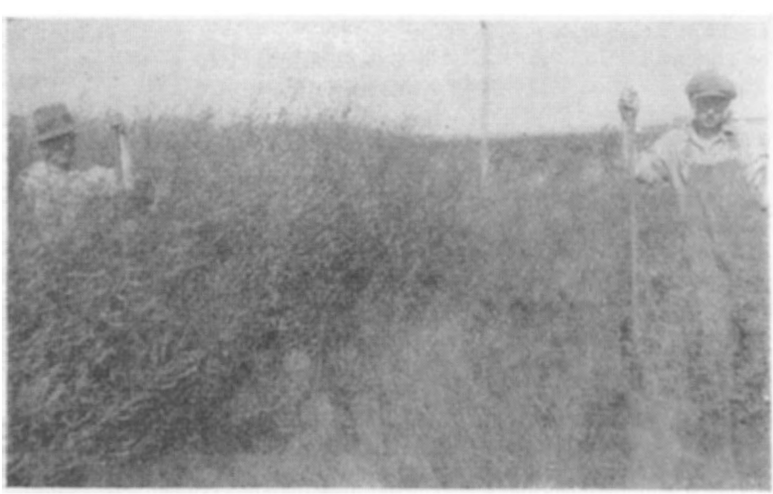

Fig. 3.—Effect of lime and phosphate on the growth of lespedeza.

When the crops are harvested for hay, very little organic matter and nitrogen are added to the soil. Cowpeas and Golden mung beans produce about the same forage yields and are, therefore, about equal in value for soil improvement. Cowpeas produce somewhat higher yields of forage than soybeans. Green mung beans are grown extensively for grain, and the residues are used for soil improvement. Preliminary studies indicate that adapted strains of crotalaria may prove to be more valuable than cowpeas for use in rotations with corn, cotton, sorghums, or oats on sandy soils in southeast Oklahoma. Cowpeas, mung beans, and crotalaria are acid tolerant and are vigorous feeders on relatively insoluble plant nutrients. These crops will frequently make good growth on soils which are low in available minerals.

NITROGEN

1. Importance of Nitrogen in the Soil

Nitrogen is one of the most important limiting factors in crop production on many soils in Oklahoma. This condition commonly occurs on land where soil depleting crops have been grown for a long period of time, and legume crops have not been included in the cropping systems. The soil nitrogen was absorbed originally from the air, while the mineral nutrients such as calcium, phosphorus, and potassium came from the weathered rock material from which the soil was formed. Virgin soils, which were formed under grass, generally contain more nitrogen than soils which were formed under timber. Medium and fine-textured soils usually contain more nitrogen than sandy soils. Many shallow, sloping soils which have been subjected to severe erosion are very low in nitrogen.

Nitrogen stimulates a rapid, vigorous, early growth of plants. It also imparts to the leaves and stems a dark green color and a thrifty appearance. When soils are low in available nitrogen, plant growth is stunted and root development is restricted. Nitrogen in plants governs to some extent the utilization of phosphorus, potassium, and other minerals. This element is also a constituent of all plant and animal proteins and is found especially in tissues that are concerned with growth and reproduction.

Losses of nitrogen from the soil are constantly taking place. These losses occur mainly as a result of removal by crops, erosion, and leaching. Crops remove large amounts of nitrogen from the soil each year. One bushel of wheat removes one and one-fourth pounds of nitrogen, and a bushel of corn or barley removes approximately one pound of nitrogen. The 12 principal crops grown in Oklahoma remove an estimated 213,-

558,000 pounds of nitrogen annually. Replacement of this nitrogen would require 530,000 tons of ammonium sulphate at a cost of more than $20,000,000.[7]

The amount of nitrogen lost from cultivated soils each year as a result of erosion probably exceeds the amount removed by crops on sloping land. Leaching accounts for the loss of large amounts of nitrate nitrogen in high rainfall areas because this form of nitrogen is soluble, and heavy rainfall tends to wash it into the subsoil, below the feeding zone of most plant roots. Leaching is more pronounced in sandy soils than in fine textured soils.

2. Fixation of Nitrogen by Legumes

It has long been recognized that legumes improve the soil and make it possible to grow larger grain crops. This is due to the fixation of nitrogen by certain organisms commonly called nodule bacteria which live in association with the roots of legume plants. The organisms in the root nodules take free nitrogen from the air, and synthesize it into forms in which it becomes available for crops. They, in turn, receive sugar from the plant; consequently, both the bacteria and the legume benefit by this association. Some of the nitrogen is released directly into the soil by the decay of the nodules, but most of it is absorbed into the roots, stems, leaves, and seeds of the legume plants. If the plants are plowed or disced into the soil, the nitrogen becomes available for succeeding crops.

Other groups of soil bacteria fix nitrogen from the air, using soil organic matter as energy. The quantity of nitrogen fixed by these organisms depends upon soil and climatic conditions. Some investigators believe that, under favorable conditions, it may amount to as much as 10 to 15 pounds per acre annually. This non-symbiotic fixation of nitrogen, even though small in amount, is important in maintaining the supply of soil nitrogen, especially in areas of low rainfall where it may be difficult to grow legume crops. Still smaller amounts —five to seven pounds per acre—are brought down each year in rain water.

The amount of nitrogen fixed by legume bacteria depends upon several factors. The condition of the soil with respect to tilth, aeration, drainage, and moisture, the presence of the proper strain of bacteria, the supply of active calcium (lime), and the kind of legume are all of prime importance in nitrogen fixation. Legumes which grow during the fall and early spring when conditions are more favorable for nodule development, will add more nitrogen than summer legumes. Forma-

[7] Harper, Horace J., Okla. Exp. Sta. Bul. No. B-279, "Commercial Fertilizers for Oklahoma Crops."

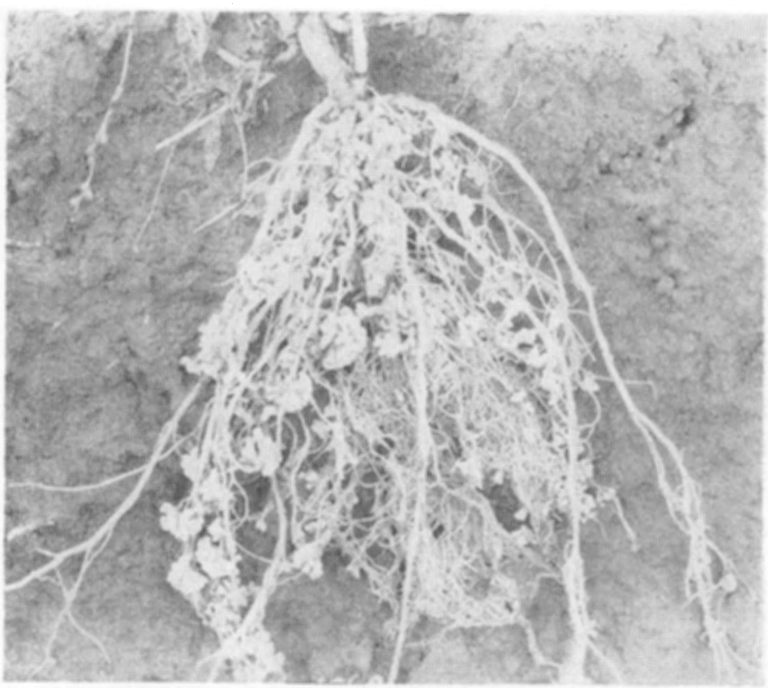

Fig. 4.—Nodules on the roots of Austrian winter peas. The organisms in the root nodules take free nitrogen from the air and synthesize it into forms in which it becomes available for crops.

tion of nodules on the roots of legumes may not occur during dry, hot, summer weather. In soils which are acid and deficient in phosphorus, the supply of nitrogen cannot be built up rapidly without the use of lime and phosphate fertilizer to increase the growth of legume crops. All legume seeds should be inoculated before planting.

Under favorable conditions, land planted to alfalfa may acquire 200 to 250 pounds of symbiotic nitrogen each year for the first three or four years, after which the amount fixed will be very small. A good crop of sweet clover may acquire 130 to 180 pounds of nitrogen by fixation. A growth of sweet clover equivalent to 2 tons of dry matter, if plowed under, will add 75 to 100 pounds of nitrogen to the soil and the roots will add appromixately the same amount. A crop of vetch equivalent to one ton of dry matter contains 60 to 70 pounds of nitrogen. A crop of cowpeas equivalent to one ton of dry matter contains 25 to 35 pounds of nitrogen, and other summer legumes have a similar nitrogen content. Non-leguminous residues, such as corn stalks or straw, add very little nitrogen to the soil. A ton of wheat straw contains only about 10 pounds of nitrogen.

Maximum additions of nitrogen to the soil will occur only when the entire plant growth is utilized for soil improvement. When annual legumes are cut and removed for hay, very little nitrogen is added to the soil. If the crops are pastured, a large part of the nitrogen and much of the organic matter will be returned to the soil in the manure.

3. Farm Manures

Farm manure, when properly utilized, is an excellent source of nitrogen. The composition of manure varies widely, depending upon the kind and age of livestock, the kind of feeds consumed by the animals, and the method of handling. An average ton of manure contains approximately 10 pounds of nitrogen, 2 pounds of phosphorus, and 8 pounds of potassium. It also contains calcium, magnesium, sulphur, and all of the trace elements.

4. Nitrogen Fertilizers

In high rainfall areas where the nitrogen content of the soil is not maintained by growing legume crops and by utilizing barnyard manures and crop residues, nitrogenous fertilizers are frequently used as an additional source of nitrogen. If a high percentage of the land is planted to soil depleting crops, it may be economical and desirable to supply part of the nitrogen in commercial form. This is especially true on farms where crops having a high cash value are grown, or where legume crops cannot be utilized as feed for livestock. The nitrogenous fertilizers most commonly used in Oklahoma are nitrate of soda, ammonium sulphate, and ammonium nitrate. Fertilizer grades, such as 4-12-4 or 5-10-5, also contain nitrogen. The first figure in the formula indicates the number of pounds of nitrogen contained in 100 pounds of the fertilizer.

WINTER COVER CROPS

Cover crops protect the land during the winter and early spring when it would otherwise be exposed to the harmful effects of wind or water erosion. They are especially valuable to plant following peanuts, or other crops which leave the land virtually bare or unprotected in the fall. Cover crops provide a convenient and effective means of supplying organic matter and nitrogen to the soil. They also take up soluble nitrogen which might otherwise be lost in drainage and conserve it for succeeding crops.

Hairy vetch, Austrian winter peas, crimson clover, rye, and rye grass are all used to some extent for winter cover crops. Vetch is well adapted in eastern Oklahoma and on sandy soils in the central section. Austrian winter peas can be used in the central part of the state to provide winter cover and to increase the organic matter content of the soil. Rye and rye grass are grown extensively becaause they will grow on soils relatively low in fertility and because of their value as pasture crops. Rye is especially well adapted to sandy soils.

The management practices on the farm will determine how the winter cover crops are to be used. In humid areas, the crops are sometimes plowed or disced into the soil for soil improvement. If the crop turned under is a legume and if the plants are well inoculated, the supply of both organic matter and nitrogen in the soil is increased. Non-legumes, such as rye and rye grass, when incorporated into the soil, add organic matter but do not increase the nitrogen content of the soil. Cover crops are frequently used for pasture, or for the production of seed after which the residues are utilized for soil improvement.

SOIL STRUCTURE

Soil structure refers to the arrangement or grouping of the soil particles. In soils possessing a desirable structure, the particles are held together in aggregates of different sizes and shapes. The aggregates are called granules, and the soil is said to have a granular or crumb structure. Structure is important in determining the tilth and mellowness of soils, the rate of absorption of water, the ease with which roots penetrate, and the resistance to erosion.

Under the influence of grass, prairie soils develop a desirable granular structure which is gradually destroyed as a result of tillage. In a study of 28 paired samples of virgin and cultivated soils, Harper[8] found that 51 percent of the weight of the virgin soils was in the form of granules which were stable in water, whereas the cultivated soils contained only 24.2 percent of stable granules. The cultivated soils were capable of absorbing only 85 percent as much water as the virgin soils. As the granular structure is destroyed, the soil particles are packed more closely together, pore space is reduced, and the capacity of the soil to absorb water is greatly diminished. Lime and organic matter improve the physical condition of the soil, but only under grass or sod forming crops do soils develop the desirable granular structure.

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[8] Harper, H. J., Unpublished Data, Oklahoma Agricultural Experiment Station.

LIME AND FERTILIZERS IN SOIL IMPROVEMENT

1. The Need for Lime in Soil Improvement

Soil improvement on many farms in central and eastern Oklahoma will require the use of agricultural limestone to neutralize soil acidity, supply calcium, and provide more favorable conditions for the growth of legume crops.

The lime requirement of soils is affected by several factors. Upland soils are usually more acid than bottom land soils. Land that has been in cultivation for a long time will be more acid than a similar area used for pasture or meadow. Soils in high rainfall areas, where severe leaching occurs, have a much higher lime requirement than soils in low rainfall areas where little or no leaching has taken place. Under the same climatic conditions, sandy soils develop acidity more quickly than the fine-textured soils because of greater leaching. Fine-textured soils have a higher lime requirement for the same degree of acidity than sandy soils. Lime should be applied only on soils which are acid. Carefully collected samples of soils should be tested to determine lime needs, and the rate of application should be the amount required to neutralize the acidity as indicated by the test.

Lime should be thoroughly mixed with the surface soil for immediate benefits. It may be applied on plowed land and mixed with the soil by deep discing. When lime is applied on stubble or unplowed land, a disc or field cultivator should be used to mix it with the surface soil before the land is plowed. When lime is applied on pasture land, it should be disced into the soil.

Proper use of agricultural limestone in a soil improvement program is necessary in order to obtain the greatest benefit from an application of this material. Lime is a corrective and a soil conditioner. It is not regarded primarily as a fertilizer. It supplies only one of the 11 elements which are essential for plant growth and which plants must obtain from the soil. Lime applied on land where legumes are not included in the rotation will have very little effect on the yields of grain crops. Lime has increased the yield of wheat only one-half bushel per acre over a period of 15 years on the Oklahoma Experiment Station farm at Stillwater. The effect of liming on the yield of barley has been similar. Lime should be used primarily to increase the growth of sweet clover and other legumes which will add organic matter and nitrogen to the soil. This system of management will increase the yields of succeeding crops. Many soils which are acid are also deficient in phosphorus, and it may be necessary to apply phosphate

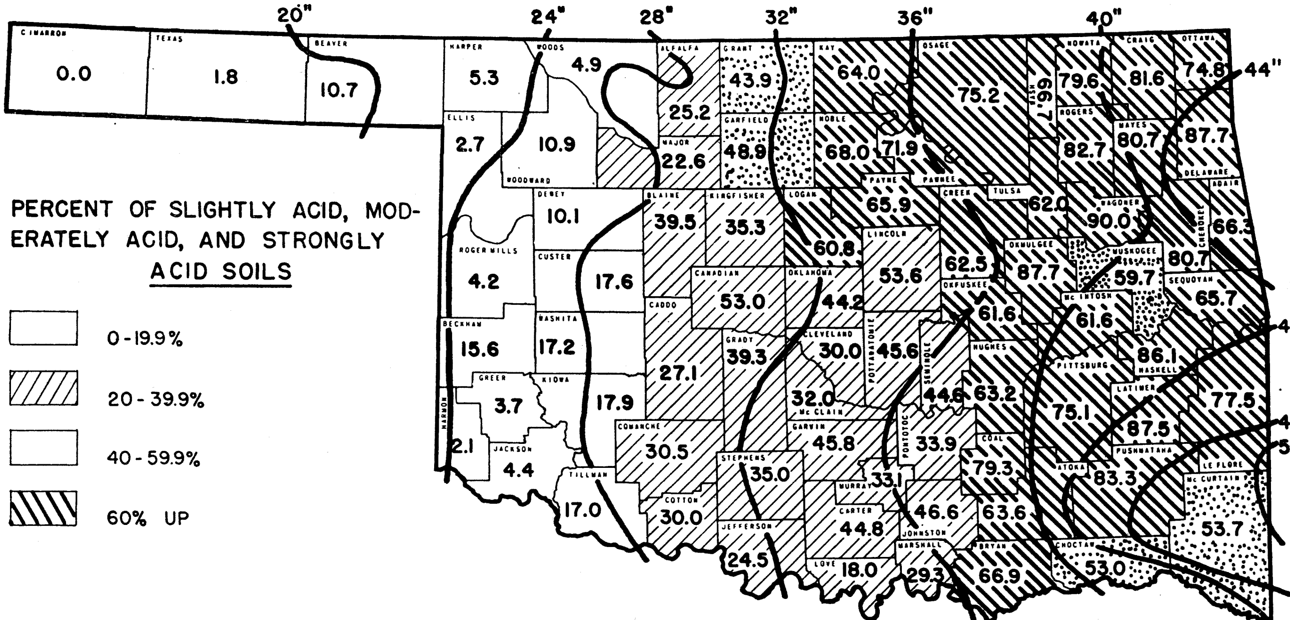

Fig. 5. Lime Needs of Oklahoma Soils

The needs for agricultural limestone to neutralize soil acidity increases from west to east in Oklahoma, along with rainfall. The map is based on analysis of nearly 20,000 soil samples made by the Oklahoma Experiment Station soils laboratory. The lines divide rainfall areas. Soils should be tested for lime requirement before applying lime. Most county agents are equipped to make these tests.

fertilizer, in addition to lime, in order to grow the legumes which are most valuable in soil improvement.

2. Importance of Phosphorus

Phosphorus is one of the first limiting factors in crop production on many soils in central and eastern Oklahoma, and phosphate fertilizer must necessarily form an important part of the soil improvement program in those areas. Phosphorus is one of the most essential elements in the growth and development of plants. It stimulates root development, enabling plants to absorb larger quantities of plant nutrients, and, thus, to make more rapid growth. It is also necessary in flowering and fruiting and in the development of grains and seeds. Phosphorus hastens the maturity of plants and increases grain yields. It also improves the quality of grains and forages and increases their feeding value for livestock. When pasture soils are well supplied with available phosphorus, better bone development of the grazing animals will result.

The forms of phosphate most commonly used at the present time are rock phosphate and superphosphate. Phosphate rock is ground to a high degree of fineness and sold as rock phosphate. It usually contains 30 to 34 percent of phosphoric acid. Rock phosphate has a relatively low solubility in water, but it may be used in connection with the growth of alfalfa, sweet clover, winter legumes, and pastures containing legume mixtures. The usual rate of application is 300 to 400 pounds per acre. The material should be thoroughly mixed with the soil before the crops are planted.

Ordinarily, superphosphate is prepared by mixing sulphuric acid with finely ground rock phosphate to make the phosphorus more readily available. It usually contains 18 to 20 percent phosphoric acid (P_2O_5). Superphosphate containing 45 to 50 percent of phosphoric acid (P_2O_5) is produced by mixing phosphoric acid with rock phosphate. This fertilizer is commonly designated as treble superphosphate. Since the phosphorus in superphosphate is immediately available for crop use, it may be used in connection with the growth of legumes, small grains, corn, cotton, and other crops which respond to phosphate fertilization. Superphosphate is usually applied with a fertilizer drill at the time the crop is planted. The rate of application varies from 100 pounds to as high as 300 pounds per acre, depending upon the kind of crop and the fertility of the soil.

When legume crops are grown, phosphorus increases the fixation of nitrogen by increasing the total yield of the crop. Sweep clover will make satisfactory growth only in soils which

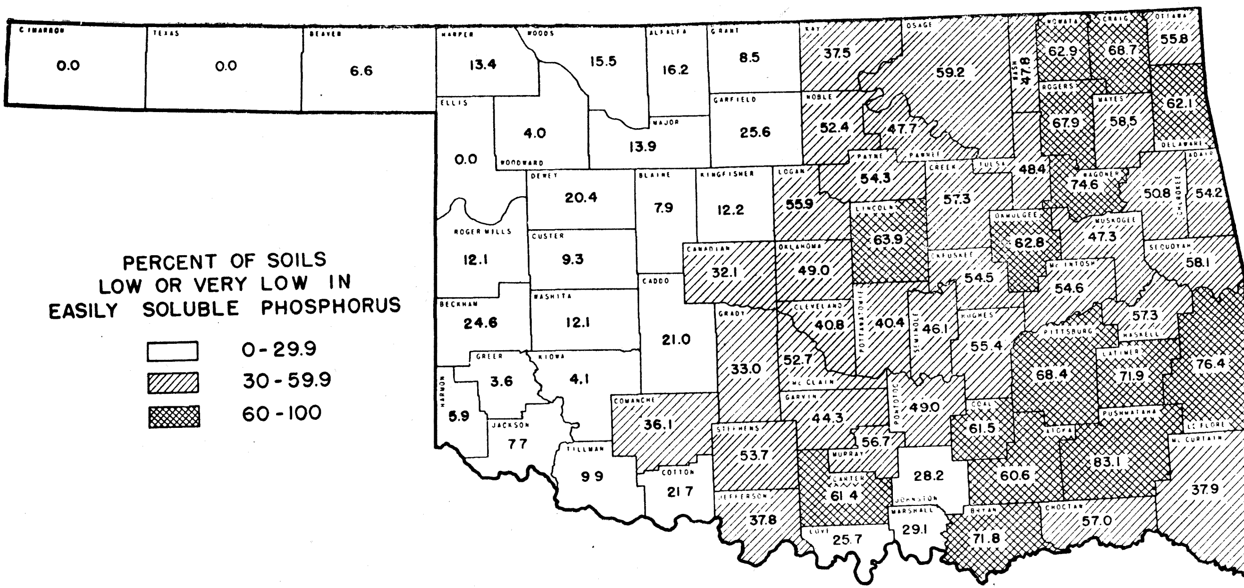

Fig. 6. Phosphorus Needs of Oklahoma Soils

This map shows the percentage of cropland soils in each county which need phosphate fertilizer. The map is based on the analysis of more than 1600 samples of soils by the Oklahoma Experiment Station soils laboratory. Soil tests to determine phosphorus needs should be made before applying phosphate fertilizer. Most county agents are equipped to make these tests.

are well supplied with available phosphorus. Consequently, the application of phosphate fertilizer on phosphorus-deficient soils to increase the yield of sweet clover and other legume crops is an important factor in increasing the nitrogen and organic matter content of the soil.

3. Commercial Fertilizers

It has already been pointed out that large quantities of plant nutrients are being removed from Oklahoma soils each year by the continued production of soil depleting crops. Some of the nitrogen can be returned to the soil by growing legume crops, but phosphorus, potassium, and other minerals can be replaced only by the use of commercial fertilizers containing these elements. Fertilizers should be used in connection with other improved practices including crop rotation, liming of acid soils, conservation of soil and moisture, and proper tillage methods, all of which contribute to soil improvement and increased crop production.

Fertilizer recommendations apply only to land which is in good physical condition, and where experiments or chemical tests indicate that a profitable response from fertilization should be obtained under average weather conditions.

ALFALFA: Alfalfa may be grown on many farms in central and eastern Oklahoma by selecting deep, well drained soils and providing proper soil treatments. The use of limestone to neutralize soil acidity and an application of commercial fertilizer or barnyard manure will usually provide favorable conditions for the growth of alfalfa.

Agricultural limestone should be applied on acid soils at the rate indicated by soil tests. The application should be made at least six months before the alfalfa is planted, and the lime should be thoroughly mixed with the surface soil.

Either superphosphate or rock phosphate may be used to increase the yield of alfalfa on soils which are deficient in phosphorus. The phosphate should be applied at the rate of 200 to 300 pounds per acre, and the rock phosphate at the rate of 400 pounds per acre. The fertilizer should be drilled or applied broadcast and disced into the surface soil before the alfalfa is planted. Established stands of alfalfa may be top dressed with barnyard manure at the rate of six to eight loads an acre or with a combination of manure and superphosphate about February 1 each year. If manure is not available, a 2-12-6 fertilizer should be drilled or broadcast at the rate of 200 pounds per acre. On soils which are deficient in potassium 50 to 100 pounds of potash fertilizer an acre should be applied in order to produce maximum yields of alfalfa.

Fig. 7. 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, 5,820 pounds per acre. At right, unfertilized; yield, 3,400 pounds an acre. Five year average. (Experiment Station's Agronomy Farm. Stillwater, Okla.)

CORN: Medium and early maturing varieties of corn will respond to phosphorus fertilization on soils which are well supplied with nitrogen but low in available phosphorus. Superphosphate should be drilled in the row with the seed at the rate of 100 to 150 pounds per acre. Corn should be grown in rotation with alfalfa, sweet clover, or other suitable legumes to maintain a good supply of nitrogen in the soil.

COTTON: When soils contain sufficient quantities of nitrogen to produce good cotton stalks but are low in available phosphorus, 100 to 150 pounds of superphosphate an acre drilled in the row at the time of planting will produce a profitable increase in yield under average weather conditions on deep, sandy soils in central and eastern Oklahoma. If cotton does not produce a vigorous plant growth, a mixed fertilizer containing nitrogen should be used. A 4-12-4 fertilizer applied at the rate of 150 to 200 pounds per acre is recommended on medium and fine-textured soils in southeastern Oklahoma. For sandy soils in this area, an application of 150 to 200 pounds an acre of 5-10-5 or a 4-12-6 fertilizer is recommended. On soils which are not deficient in potassium and where cotton rust is not injurious, 150 to 200 pounds an acre of 4-12-0 fertilizer may be applied.

Fig. 8. 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. (Okla. Exp. Sta. Bul. No. B-279, "Commercial Fertilizers for Oklahoma Crops.")

WHEAT: Applications of 100 to 200 pounds of superphosphate an acre have given profitable increase of yields of wheat on prairie soils in central and eastern Oklahoma. If the wheat is to be used for winter and spring pasture, a 2-12-6 or 4-12-4 fertilizer is recommended since a fertilizer containing nitrogen will produce a more vigorous early growth and provide more pasture.

BARLEY: On soils which are high in nitrogen but low in available phosphorus, an application of 100 to 150 pounds per acre of superphosphate will increase the yield of winter barley. On low nitrogen soils barley should be grown in a rotation with alfalfa, sweet clover, or lespedeza.

PEANUTS: When peanuts are grown as a cash crop and the vines are removed from the soil, 200 pounds an acre of 2-12-6 fertilizer should be applied. An application of 150 to 200 pounds an acre of rock or superphosphate will increase the yield of peanuts on soils which are low in available phosphorus but not deficient in potassium.

LESPEDEZA: Lespedeza can utilize forms of soil phosphorus which are not readily available to most crops. Consequently, this crop will usually not respond to fertilization except on soils which are very low in available phosphorus. On such soils an application of 100 pounds of superphosphate per acre may increase the growth of lespedeza.

FLAX: Flax is best adapted on soils which are well supplied with organic matter and are not acid. An application of 150 pounds of superphosphate an acre on phosphorus deficient soils will usually increase the yield of flax.

HAIRY VETCH: Hairy vetch will respond to either superphosphate or rock phosphate when planted on phosphorus deficient soils. The fertilizer should be drilled in the row with the seed at the rate of 100 to 200 pounds an acre.

AUSTRIAN WINTER PEAS: Austrian winter peas will respond to phosphorus fertilization on soils which are low in available phosphorus. The fertilizer should be drilled in the row with the seed at the rate of 150 pounds per acre.

OATS: Oats will usually respond to phosphorus fertilization when grown on soils which are well supplied with organic matter but deficient in available phosphorus. Superphosphate drilled in the row with the seed at the rate of 150 pounds per acre is perhaps the best fertilizer for this crop. A greater total benefit will be obtained from the fertilizer when lespedeza is planted with the oats for pasture or for soil improvement.

RYEGRASS: Ryegrass does not respond to phosphate fertilization except on soils which are very low in available phosphorus. Superphosphate applied at the rate of 100 to 200 pounds per acre when the seed is planted is a good fertilizer for this crop.

SOYBEANS: When soybeans are cut for hay they remove large amounts of nitrogen, phosphorus, and potash from the soil, and fertilizer treatment will eventually be needed to replace 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 forage yields of soybeans in several tests.

SWEET CLOVER: Sweet clover can be successfully grown only on soils which are well supplied with available prohphorus and are not acid. Usually rock phosphate or superphosphate can be effectively used to increase the production of sweet clover when applied on soils which are deficient in phosphorus. 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. If sweet clover is planted in wide rows, fertilizer should be drilled in the rows at the rate of 30 to 50 pounds per acre. If the fertilizers are broadcast, apply 200 pounds of superphosphate or 400 pounds of rock phosphate per acre and disc into the soil several weeks before the sweet clover seed is planted. Acid soils must be neutralized by the addition of limestone before sweet clover can be successfully grown.

NOTE: For complete recommendations on the use of fertilizers see Oklahoma Experiment Station Bulletin No. B-279, "Commercial Fertilizers for Oklahoma Crops," 1944.

IMPROVED CROPPING SYSTEMS

1. Crop Rotations

A good system of crop rotation is a fundamental principle of proper soil management. In contrast to the continuous growing of one or more soil depleting crops on the same land or to irregular cropping of the land without a definite plan, the systematic rotation has many advantages, most important of which is the provision for maintaining or improving the fertility of the soil. A good rotation system provides several sources of income and gives some protection against crop failure and low market prices. It also distributes labor requirements throughout the year, and permits better use of farm machinery in diversified farming areas.

Setting up a rotation plan may necessitate a reorganization of the farm layout. Fields should be divided as nearly as possible according to soil type and topography. Each field should be large enough to cultivate conveniently and economically.

In determining the crop rotations to be used on the farm, many factors should be considered. The fertility of the soil, its texture, reaction, tilth, drainage, topography, and the average annual rainfall place certain limitations on the kinds of crops which can be grown. Adaptation to soil types is an important factor in determining what crops should be included in the rotation. Such crops as peanuts, cotton, sorghums, sweet clover, and rye may be grown on sandy soils whereas alfalfa, corn, oats, and wheat are best adapted on medium and fine-textured soils.

The crops which should be grown and their sequence in the rotation are frequently dependent upon topography. Rotations suited to level lands may be entirely unsuited to sloping lands on the same farm. On lands which are not subject to erosion, row crops may occupy a prominent place in the rotation. On steep slopes, erosion resisting crops such as small grains, sweet clover, lespedeza, and grass mixtures may well occupy the land a greater portion of the time.

2. Rotation Aids in Erosion Control

Crop rotation aids in the control of erosion on sloping soils. In experiments conducted at the Red Plains Conservation Experiment Station at Guthrie from 1930 to 1941, inclusive, the soil loss on land farmed to cotton continuously was 4.4 times greater than from land in a 3-year rotation of cotton, wheat, and sweet clover. Crops differ widely in erosion resistance. Land in wheat lost only 1.59 tons of soil annually, and sweet clover reduced the loss to less than one-

Table 3.—Average Effect of a Crop Rotation on Run-off and Soil Loss[1]

Crop[2]	Run-off in per-cent of rain-fall	Soil loss per acre-tons
Rotation:		
Cotton	10.74	8.81
Wheat	11.08	1.59
Sweet Clover	5.95	0.49
Average	9.26	3.64
Continuous Cotton	12.03	16.06

half ton of soil a year. Land grown to cotton continuously lost 16.06 tons of soil annually compared to an average loss of 3.64 tons for the rotation.

Experiments to determine the effect of cropping systems on erosion control have been conducted by the Missouri Experiment Station. On land planted to corn continuously the soil loss has averaged 19.7 tons per acre, and on land planted to wheat each year the soil loss has been 10.1 tons per acre. A 3-year rotation of corn, wheat, and clover reduced the average annual soil loss of 2.7 tons per acre.

Table 4.—Effect of Different Cropping Systems on Erosion Control, Mo. Exp. Sta. (14-year average)*

Cropping Practice	Average Annual Soil Loss in Tons per Acre	Percent Run-off
Bare, cultivated soil—no crop	41.0	30
Corn (Continuous)	19.7	29
Wheat (Continuous)	10.1	23
Rotation—corn, wheat, clover	2.7	14
Bluegrass	0.3	12

* Mo. Exp. Sta. Bul. No. 366.

3. Rotations and Crop Yields

Crop rotations including sweet clover and other adapted legumes have given substantial increases in crop yields in central and eastern Oklahoma. In Nowata county the yield of oats was increased from 32 bushels to more than 61 bushels per acre by including sweet clover in the rotation. In Rogers county the yield of oats was increased from 16 bushels to 56 bushels per acre following sweet clover. In each case, it was necessary to apply lime and phosphate fertilizer to the soils in order to grow sweet clover.

[1] Daniel, Elwell, and Murphy, Okla. Exp. Sta. Bul. No. B-257, "Conservation and Better Land Use for Oklahoma," 1942.

[2] Plot 1/100 acre in size; all cultivation with the slope; land slope 7.70 percent; soil Stephensville fine sandy loam.

Table 5.—Oats Following Sweet Clover—L. H. Demaree Farm, Talala, Oklahoma*

Treatment	Oats following oats (Bu. per Acre)	Oats following Sweet Clover (Bu. per Acre)
No treatment	16.0	40.9
Lime, superphosphate	28.7	55.9
Lime, rock phosphate	21.8	54.1

At the Lone Grove Experiment Station, the yield of corn was increased from 11.5 bushels to 29.7 bushels following sweet clover. In Lincoln county corn alone produced only 12 bushels per acre, whereas corn planted after sweet clover produced 21 bushels per acre.

Table 6.—Effect of Sweet Clover on Yield of Corn, Lone Grove and Chandler*

Treatment	CORN YIELD IN BUSHELS PER ACRE	
	Lone Grove	Chandler
Corn (Continuous)	11.5	12.0
Corn following Sweet Clover (with lime and phosphate)	29.7	21.0

* Unpublished Data, Oklahoma Agricultural Experiment Station.

At the Oklahoma Experiment Station at Stillwater, the yield of barley has been increased from 16.9 bushels to 28.4 bushels per acre by including sweet clover in the rotation.

Table 7.—Effect of Sweet Clover on Yield of Barley, Oklahoma Agricultural Experiment Station, Stillwater*

Barley (Continuous)	16.9
Barley following sweet clover (with lime and phosphate)	28.4

Wheat grown in rotation with sweet clover has averaged more than 20 bushels per acre over a period of 14 years. Wheat grown on the same land each year has yielded less than 14 bushels per acre. Austrian winter peas have increased wheat yields on low nitrogen soils in the wheat section. The Oklahoma Experiment Station reports that wheat yields at Stillwater were increased from 16.6 bushels to 24.4 bushels per acre by including Austrian winter peas in the rotation. In Garfield county the yield of wheat was increased from 20 bushels to 42 bushels per acre following Austrian winter peas.

Table 8.—Effect of Austrian Winter Peas on Yield of Wheat*

Treatment	YIELD IN BUSHELS PER ACRE	
	Stillwater	Carrier
Wheat (Continuous)	16.6	20.0
Wheat following Austrian winter peas	24.4	42.0

* Unpublished Data, Oklahoma Agricultural Experiment Station.

The influence of crop rotations in maintaining crop yields is also clearly shown in studies conducted by the Missouri Experiment Station over a period of more than 50 years. The results of these studies are shown in Table 9. Corn in the rotation has produced an average of 38 bushels per acre. On land where corn has been planted continuously each year the average yield has been only 18 bushels per acre. Oats grown continuously on the land each year have produced 20 bushels per acre, whereas oats in the rotation have averaged 30 bushels per acre. Wheat grown on the same land each year has averaged only 10 bushels per acre. Wheat grown in the rotation has averaged 16 bushels per acre.

Table 9.—Effect of Rotation on Yields of Corn, Oats, Wheat, Mo. Exp. Sta. (Average of 50 years)*

Crop	AVERAGE YIELD IN BUSHELS PER ACRE	
	Continuous	Rotation
Corn	18	38
Oats	20	30
Wheat	10	18

* Smith, G. E., "Cropping Systems and Soil Fertility," Mo. Exp. Sta. Cir. No. 247, 1942.

4. Management of Wheat Following Sweet Clover

In regions of medium or low rainfall, excessive amounts of readily available nitrogen in the soil may cause injury to wheat by stimulating a growth that the moisture is incapable of maintaining to maturity. In central and western Oklahoma wheat following sweet clover will require careful management to avoid injury from the large amount of nitrogen which the sweet clover adds to the soil. Tillage methods which leave part of the sweet clover residues on the surface of the soil will reduce the amount of nitrogen which would otherwise be available the first year. In some cases, heavy vegetative growth may be controlled by late planting. Drilling the wheat in 14- to 16-inch rows will bring about a better balance of the number of plants per acre and the available moisture.

* Unpublished Data, Oklahoma Agricultural Experiment Station.

and experiments* show that this method of seeding will not reduce the yield of wheat under normal conditions. If excessive growth develops, fall and spring pasturing may be advisable.

5. Suggested Cropping Systems

Because of the differences in soils, climatic conditions, crop adaptations, and types of farming the state has been divided into six regions for convenience in developing suggested cropping systems. These regions are shown in Figure 9.

Region 1—Great Plains

The soils in the Great Plains were formed under conditions of low rainfall, and very little leaching has taken place. Consequently, most of the soils in this area are well supplied with minerals containing available plant nutrients. The average annual rainfall is only 17 inches in the Panhandle and approximately 25 inches in the other counties comprising the high plains area.

The most important problems in the area are the conservation of moisture, the control of run-off water, the prevention of soil blowing, and the addition of a maximum amount of crop residues to the soil.

Wheat and grain sorghums are the most important crops grown in this region. A regular rotation system including legumes cannot be followed because of the low average annual rainfall. In the western part of the region, a three-year rotation of wheat, sorghums, and fallow may be used on medium and fine-textured soils where wind erosion is not a serious problem. The sorghums are relatively more dependable than wheat and they supply feed for livestock. If a four-year rotation is preferred, wheat may be grown two years instead of one year, provided moisture conditions are favorable for seeding wheat. If the grower wishes to take full advantage of soil wheat. If the grower wishes to take full advantage of soil moisture for wheat production, a flexible cropping system may be used. Wheat may be planted each year when there is sufficient moisture in the soil and an adequate amount of crop residues to prevent soil blowing. If conditions are unfavorable for seeding wheat or if wheat fails, the land should be contour listed or cultivated with some other implement which will leave a rough, uneven surface to prevent soil blowing. Sorghums should be planted the following season, after which the land may be fallowed one year and again seeded to wheat.

Sandy soils which are highly susceptible to wind erosion

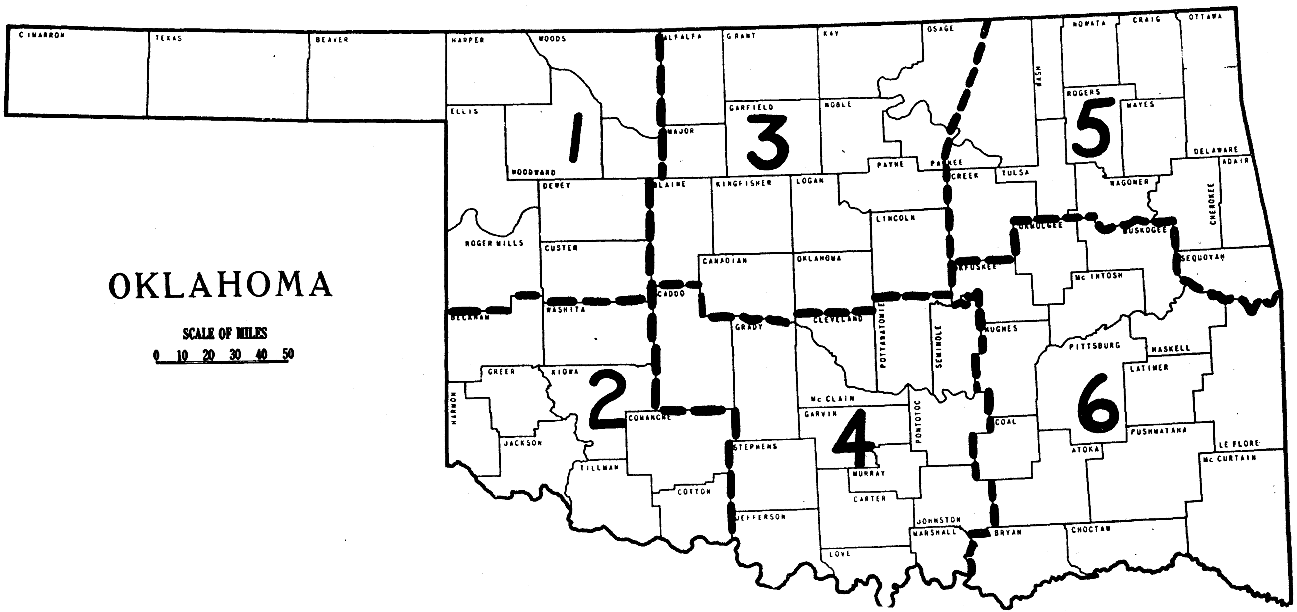

Fig. 9.—For purposes of developing suitable cropping systems the state has been divided into six regions, as shown above. These divisions are based primarily upon climatic factors and crop adaptations. Since climatic changes from one region to another are very gradual, the division lines merely indicate transitional zones. In some instances cropping systems adapted to certain soils in one region may also be used on similar soil in an adjoining region.

should usually be planted to sorghums and the stalks left on the land during the winter to prevent soil blowing. The land should be prepared for planting after the major windy season has passed. Planting on the contour or at right angles to the direction of the prevailing winds will reduce soil blowing.

Cropping systems which include fallow are not recommended in the eastern part of this area, since the yields of wheat following a year of fallow have been only slightly higher than when wheat is grown continuously. Furthermore, a year of fallow does not necessarily insure a crop of wheat the following year. On medium and fine-textured soils, wheat may follow wheat when there is sufficient moisture in the soil at planting time. If conditions are unfavorable for seeding wheat, oats or spring barley may be planted in the spring; or, if a summer crop is preferred, sorghum, mung beans, or tepary beans may be planted.

The supply of available moisture in the soil at planting time is of very great importance in the production of wheat and other winter and small grains. The close correlation between the yield of wheat and the depth of soil moisture at planting time is shown in extensive studies conducted by the Kansas Experiment Station. In these studies, wheat planted in dry or nearly dry soil failed 71 percent of the time. When planted in soil with one foot of moisture, the crop failed 34 percent of the time, or about one year in three. Wheat planted in soil with two feet of moisture failed only one year in seven. When the moisture had penetrated to a depth of three feet at planting time, the wheat crop failed only one year in ten.

Table 10.—Effect of Depth of Moisture at Seeding Time on the Yield of Winter Wheat at Hays, Colby, and Garden City, Kansas, 1909-1936, Inclusive[1]

Depth of Moisture at Planting Time	Percentage of Years the Crop Failed
Dry or nearly dry	71% (7 years in 10)
One foot of moisture	34% (1 year in 3)
Two feet of moisture	14% (1 year in 7)
Three feet of moisture	10% (1 year in 10)

Since water is the greatest limiting factor in crop production in the Great Plains region, every drop should be conserved where it falls. Under average farming conditions, only about 20% of the total annual rainfall in the Panhandle enters the subsoil and becomes available for plant growth. Tillage

[1] Kansas Experiment Station Bulletin No. 273, "Soil Moisture and Winter Wheat Production."

of small grain stubble immediately after harvest increases the absorption of water into the soil. Summer tillage to control weed growth, keep crusts broken, and the surface roughened is also important in conserving moisture and preventing wind erosion. At the Southern Great Plains Field Station, Woodward,[2] land plowed in June has produced an average of 4.5 bushels more wheat than land plowed August 15, and 8.8 bushels more than land plowed in October.

Table 11.—Effect of Early Tillage on Wheat Yields, Southern Great Plains, Woodward, Oklahoma, 1922-1940

Date of Plowing	YIELD OF WHEAT IN BUSHELS PER ACRE	
	Plowed	One-Way
Early preparation (June)	16.7	15.5
Intermediate (August 15)	12.2	13.0
Late (October)	7.9	9.5

REGION 2—SOUTHWEST

The soils in the Southwest have been formed under conditions of low rainfall and beneath a cover of native grasses. Most of the soils in this area are well supplied with minerals. Only about 15 percent of the cultivated land is low in available phosphorus, and this deficiency appears mainly in the sandy areas. The availability of the phosphorus in most of the soils is high. Less than 15 percent of the soils are acid.

The average annual rainfall is 24 to 30 inches, and moisture is the first limiting factor in crop production in most of the area. The distribution of rainfall during the growing season is frequently poor, and crops suffer during periods when the temperature is high and rainfall is light. Terracing, contour tillage, and planting should be practiced more extensively on cultivated land in order to increase the penetration of water and reduce the loss of surface soil by erosion.

An experiment to determine the effect of time of plowing on the yield of winter wheat and barley was conducted on the reformatory farm at Granite for a period of five years. The results of this experiment are shown in Table 12.[1]

Early plowing produces a favorable condition for the absorption of summer rainfall and increases the rate of decay of soil organic matter, which results in the accumulation of larger quantities of available plant nutrients in the soil when weed growth is controlled by summer tillage.

[2] Methods of Tillage for Winter Wheat, Southern Great Plains Field Station, Woodward, 1941.

Table 12.—Effect of Time of Plowing on the Yield of Winter Wheat and Barley, on the Reformatory Farm at Granite, Oklahoma[1]

Time of Plowing	ACRE YIELD*	
	Wheat	Barley
	Bushels	Bushels
July	16.8	22.9
August	14.0	20.7
September	11.9	13.7

[1] Soil Survey of Greer County, Oklahoma, 1937.
* 5-year average.

Another experiment conducted at Granite in 1935 shows the importance of contour planting as a means of conserving moisture. The results of this experiment are shown in Table 13. Marked increases in yields of cotton and kafir were obtained on plots planted on the contour, compared with those planted parallel with the slope.

Table 13.—Comparison of Acre Yields of Cotton and Kafir Planted on Contour and Parallel with the Slope

Experiment No.	Method of Planting	KAFIR FOR		Seed Cotton
		Forage	Grain	
		Pounds	Pounds	Pounds
1	Rows parallel with slope*	2,124	318	392
2	Rows planted on contour	3,456	1,250	595

The principal crops grown in the area are cotton, small grain, and sorghums. Alfalfa is also an important crop on bottom land soils in several counties. The finer textured soils are adapted to the production of wheat and other small grains because these crops grow during that part of the season when drouth is not likely to be a limiting factor in plant development. The sandy soils are better adapted to cotton and sorghums. On many medium textured soils all three of these crops may be grown. Cotton and sorghums have lower fertility requirements than wheat and will often make good growth on soils where wheat yields are low.

Many of the upland soils are low in organic matter, and nitrogen is a limiting factor in crop production. Cropping systems which include legumes that can be grown under the prevailing climatic conditions should be used. Legumes that grow during the spring and fall when conditions are favorable for nodule development will add more nitrogen and organic matter to the soil than summer legumes. Alfalfa, sweet clover, Austrian winter peas, and vetch are important crops in this group.

Adapted summer legumes include cowpeas, annual sweet clover, mung beans, and peanuts. Cowpeas frequently produce an abundance of nodules in moist, sandy soils, and experiments conducted on the reformatory farm at Granite* show that this crop will produce a greater yield of forage than any other summer legume. Consequently, it is the most important summer legume that can be grown for soil improvement in rotation with cotton and grain sorghums on the sandy soils in this area.

Bottom Soils:

On deep, well drained bottom soils a rotation of alfalfa and cotton is quite satisfactory. The alfalfa will usually produce profitable yields for several years after which it may be followed by cotton three or four years. The alfalfa serves as a cash crop and provides legume hay for feed. It also adds organic matter and nitrogen to the soil.

On bottom land where alfalfa is not grown, a rotation consisting of oats or barley and sweet clover the first year, sweet clover the second year, and cotton two years would make an excellent cropping plan for maintaining soil fertility. If annual sweet clover is used, the rotation might consist of sweet clover one year and cotton two years. When cotton follows alfalfa or sweet clover, more cultivation may be necessary because of the increased growth of grass and weeds which is likely to occur.

Sandy Soils:

On sandy soils a three-year rotation of cotton, sorghums, and cowpeas is suggested. Cotton is the main cash crop for sandy soils, the sorghums provide feed, and cowpeas will add organic matter and nitrogen to the soil. Golden mung beans may be substituted for cowpeas in this rotation if desired.

On sandy soils which are well supplied with lime and phosphorus a three-year rotation consisting of cotton, sorghums, and annual sweet clover may be used.

When sorghums are grown on soils susceptible to wind erosion, the stalks may be left on the land during the winter to prevent soil blowing. In years when crops other than sorghums are grown, strips of sorghum or Sudan may be planted to control wind erosion.

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* Slope of less than 1 percent.

Permeable Upland Soils:

On deep, permeable upland soils a rotation consisting of oats or barley and sweet clover the first year, sweet clover the second year, and wheat two years is recommended. In drilling the oats or barley it may be necessary to leave three holes in the drill box open and close two in order to provide more moisture and sunlight for the development and growth of the young sweet clover plants.

A rotation consisting of Austrian winter peas or hairy vetch one year and wheat three years may be used on these soils if desired.

Fine-Textured Soils:

Many of the fine-textured soils in southwestern Oklahoma are shallow in depth and have dense clay subsoils. These soils are used largely for the production of wheat and oats. Because of the unfavorable physical soil structure, the erratic rainfall, and the high summer temperatures, it is difficult to obtain a satisfactory growth of legumes for soil improvement. Planting small grain on the same land year after year may not be objectionable so long as the supply of plant nutrients in the soil is sufficient to maintain production at a level as high as climatic conditions will permit, if plant diseases or insect pests do not interfere with the growth of the crops. The use of grasses in rotations on these soils may eventually become necessary.

REGION 3—NORTH CENTRAL

Approximately 30 percent of the nitrogen and 35 percent of the organic matter which was contained in the virgin soils in this region have been lost as a result of cultivation and erosion. Forty percent of the soils are medium to strongly acid and 54 percent of these soils are deficient in phosphorus. The principal crops grown in the area are wheat, barley, oats, sorghums, and corn. Sweet clover is perhaps the best soil improvement crop that can be grown because of the large amounts of organic matter and nitrogen which it adds to the soil. Other legumes which can be grown for soil improvement are alfalfa, Austrian winter peas, vetch, lespedeza, cowpeas, and mung beans.

Early tillage and contour planting are important factors in small grain production. The results of an experiment conducted at Carrier to determine the effect of time of tillage on the yield of winter wheat are shown in Table 14.

Table 14.—Effect of Time and Method of Tillage on Yield of Winter Wheat, Carrier, Garfield County, Oklahoma*

Time	Plowed	One-Way	Listed
Early Preparation	17.7	12.8	12.8
Late Preparation	14.7	8.9	8.3

* Unpublished Data, Oklahoma Agricultural Experiment Station.

Early tillage conserves moisture and increases the rate of decay of organic matter which makes possible a larger accumulation of plant nutrients in the soil when weed growth is controlled by summer tillage.

The yield of wheat was increased two bushels per acre at the Wheatland Conservation Experiment Station* in 1944 by contour planting on terraced land, compared to seeding parallel with the slope. The loss of run-off water was also reduced 40 percent by these cultural practices.

On soils which yield less than 15 bushels of wheat per acre under average conditions, rotations which include legumes should be followed.

Rotations for Medium and Fine-Textured Soils

1. Wheat or Barley (3 years)
   Oats or Barley, Sweet Clover
   Sweet Clover
2. Alfalfa (3 to 5 years)
   Corn or Wheat (3 to 5 years)
3. Alfalfa (4 years)
   Corn (1 year)
   Oats (1 year)
   Wheat (3 years)
4. Oats—Wheat seeded in fall
   Wheat, Sweet Clover
   Sweet Clover
   Corn
5. Wheat (3 years)

   Austrian Winter Peas (1 year)

The Austrian winter peas may be harvested for seed and the residues used for soil improvement.

The sweet clover should be planted with winter barley or oats as a nurse crop. The small grain should be drilled in 14- or 16-inch rows to provide more favorable conditions for the development of the young seedling sweet clover plants the first year. Lime and phosphate fertilizer must be ap-

* Unpublished Data, Oklahoma Agricultural Experiment Station.

plied in order to grow sweet clover successfully on many soils in this area.

Wheat following alfalfa or sweet clover may make excessive vegetative growth because of the large amount of available nitrogen in the soil. This can be controlled to some extent by delaying planting and by planting the wheat in 14- or 16-inch rows. In some cases, heavy fall and spring grazing may be necessary to help remove heavy vegetative growth.

Rotations for Sandy Soils

1. Cowpeas, Vetch
   Vetch, Sorghums, including Sudan
2. Vetch
   Rye

On sandy soils which are not suitable for wheat production, the rotation consisting of cowpeas, vetch, and sorghums is suggested. The cowpeas may be used for pasture or for seed. The vetch provides winter cover and will add organic matter and nitrogen to the soil. On deep, coarse, sandy soils which occur along the larger streams vetch and rye grown in alternate years will provide winter cover and the crops may be harvested for seed or used for pasture.

Rotation for Cotton Area

Cotton is an important crop on many farms in the southern part of the north central region and rotations which include cotton are important in this area.

1. Oats, Sweet Clover
   Sweet Clover
   Corn or Sorghums
   Cotton or Peanuts

The above rotation which includes sweet clover for soil improvement is considered an excellent one. It is very flexible, permitting a choice of corn or sorghum the third year and cotton or peanuts the fourth year. It is not advisable to follow sweet clover with cotton because of the excessive growth of weeds and grass which may occur. If additional pasture is needed, some corn may be harvested early and the land planted to rye for winter grazing.

Region 4—South Central

Many of the soils in the south central region are highly susceptible to erosion and the control of soil losses constitutes a major problem in this region. The soils have lost an average of 34 percent of their nitrogen and 38 percent of their organic matter. Thirty-six percent of the cultivated soils are acid and 43 percent of these soils are deficient in available phosphorus. A soil improvement program for Region 6 must include terracing and other practices to control erosion, the application of lime and phosphate fertilizer on mineral deficient soils, and the use of crop rotations including legume crops to increase the organic matter and nitrogen content of the soils. Following are suggested rotations for sandy soils and for medium and fine-textured soils:

Sandy Soils

1. Oats, Sweet Clover
   Sweet Clover
   Corn or Sorghum
   Cotton or Peanuts
2. Peanuts—(Rye seeded in Fall)
   Rye—Sorghum
   Cowpeas—Vetch
   Vetch—Cotton(Vetch)
3. Cotton—Vetch seeded in Fall
   Vetch, Peanuts (Rye)
   Rye, Cotton

In rotation No. 1 sweet clover is used for soil improvement. The sweet clover may also be utilized for pasture. Rotation No. 2 includes rye and vetch for winter cover and grazing, cowpeas and vetch for soil improvement, peanuts, cotton, and rye for cash crops, and sorghum for grain. Rotation No. 3, rye and vetch are again included for winter cover, grazing, and for soil improvement. Winter cover crops used for soil improvement should usually be turned under about April 15 in order to allow sufficient time for the decay of vegetative material and for seedbed preparation.

Medium and Fine-Textured Soils

1. Oats, Sweet Clover
   Sweet Clover
   Corn
   Corn or Cotton
2. Cotton
   Oats—Alfalfa seeded in Fall
   Alfalfa (3-4 years)
   Corn (2 years)

In the rotations for medium and fine-textured soils, sweet clover and alfalfa are included as the soil improvement crops. In rotation No. 1 wheat or other small grains may be substituted for corn if the land is not well suited to corn.

REGION 5—NORTHEAST

Region No. 5 includes northeast Oklahoma. The principal crops in this area are corn, wheat, oats, grain sorghums, and flax. Approximately 75 percent of the cultivated soils in this region are acid, and 60 percent of these soils are deficient in available phosphorus. Consequently, limestone and phosphate fertilizer must be applied on most soils in order to grow sweet clover and other suitable legumes for soil improvement. On soils in this area which are suitable for corn, one or more of the following rotations may be used:

1. Small grain, Sweet Clover
   Sweet Clover
   Corn
   Corn
2. Small Grain, Sweet Clover
   Sweet Clover
   Corn
3. Corn
   Soybeans
   Small Grain, Sweet Clover
   Sweet Clover
4. Alfalfa (3-4 years)
   Corn (2 years)
   Small grain
5. Soybeans—Winter Barley
   Barley, Lespedeza

In rotation No. 1 sweet clover is planted in the spring with small grain. The sweet clover may be used for pasture from October to December the first year and from April to July the second year. The only difference between rotations 1 and 2 is that in No. 1 corn is grown two years. This rotation is especially adapted on the better corn soils. In rotation No. 3, sweet clover is again included in soil improvement and for pasture. If pasture is not needed, the sweet clover may be used for the production of a seed crop. Sweet clover is followed by corn, and soybeans for hay are grown one year.

On soils which are not well adapted to corn, suggested rotations include primarily small grain crops and adapted legumes.

1. Oats, Lespedeza—Mung Beans or Cowpeas
2. Soybeans or Mung Beans—Wheat in Fall
   Wheat, Sweet Clover

Sweet Clover
Darso or other sorghums

3. Oats or Barley, Sweet Clover
   Sweet Clover
   Wheat
   Wheat

In rotation No. 1, oats and lespedeza may be used indefinitely unless it becomes necessary to summer fallow the land to control weeds, in which case wheat should be seeded in the fall. Mung beans or cowpeas may be used occasionally instead of lespedeza if desired. Rotation No. 3 is especially suited to shallow, claypan soils and sloping soils which are highly susceptible to erosion.

If soils are acid and if limestone cannot be applied, rotations using acid tolerant legumes, such as cowpeas, lespedeza, and vetch should be used.

REGION 6—SOUTHEAST

Region 6 includes the counties in southeastern Oklahoma. The average annual rainfall is 45 inches, which in normal seasons is sufficient for the growth of most crops. The soils are highly eroded and are low in available minerals, particularly phosphorus and calcium. These soils are also low in organic matter and soluble nitrogen. Lime and prosphate fertilizer will be needed on many soils to grow sweet clover, vetch, and other legumes which should be included in the rotations to add organic matter and nitrogen to the soil. Since corn, cotton, peanuts, and oats are grown most extensively in this area the rotations should naturally include these crops. The cropping systems suggested are examples of good rotations which may be used. Most of these rotations are flexible and can be changed to some extent if desired. For example, grain sorghums, cotton, and corn may be used interchangeably. Peanuts may also be substituted for either of these crops on sandy soils.

On well drained bottom lands and stream terraces where the soils are deep and permeable, a rotation consisting of oats, alfalfa, corn, and cotton may be used. The oats will be harvested in May or early June, and the land can be plowed immediately for fall seeding of alfalfa. The alfalfa will be left on the land as long as it maintains a good stand and produces profitable yields. Following the alfalfa, two crops of corn may be grown. The corn may be followed by cotton for two years if desired, after which it may again be planted to oats and seeded to alfalfa in the fall. Other suggested rotations are as follows:

1. Cotton (to be fertilized)
   Oats with lespedeza, cowpeas, or mung beans
   Corn with cowpeas (alternate row effect)
2. Oats, Sweet Clover
   Sweet Clover—Fall Spinach or Beans
   Corn or Cotton
3. Cotton
   Kafir with cowpeas (alternate row effect)
   (recommended on poorly drained, fine-textured soils not suitable for early planted crops.)

Most of the upland soils in Region 6 will require the use of mineral treatments including lime and phosphate for the successful growth of sweet clover and other lime loving legumes. The following rotations are suggested for these soils:

1. Oats with lespedeza, cowpeas, or mung beans
   Corn interplanted with cowpeas
   Cotton (or peanuts on sandy soils)
2. Oats, Sweet Clover
   Sweet Clover
   Corn
   Cotton (Peanuts may be substituted on sandy soils)
3. Small grain—vetch seeded in Fall
   Vetch, Sorghum
   Soybeans, Mung beans, or Cowpeas with winter small grain
4. Peanuts (Rye planted in Fall)
   Rye (pastured or harvested for grain), cowpeas or mung beans
   Cotton(Vetch seeded in Fall)

In rotation No. 1 the lespedeza, cowpeas, and mung beans may be used for pasture or for the production of seed, and the residues utilized for soil improvement. Rotation No. 2 includes sweet clover to increase the organic matter and nitrogen content of the soil. This is an excellent rotation since it provides cash crops, pasture, feed grain, and soil improvement. Rotation No. 3 includes vetch and small grains for winter cover and winter pasture. The vetch and mung beans may be used for soil improvement. Rotation No. 4 is suitable for sandy soils on which peanuts are grown. Rye is seeded in the fall following peanuts to provide winter cover and to control wind and water erosion. Vetch following cotton will serve the same purpose. The residues of the legume crops used in all of these rotations should be used for soil improvement.

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