Oklahoma Crops and Soils, 1946

Research Reported at the First Annual
Oklahoma Crops and Soils Conference

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
Bulletin B-295 April, 1946

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Cooperative Studies at the Stillwater Outdoor Hydraulic Laboratory

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INTRODUCTION

The Stillwater outdoor hydraulic laboratory of the Soil Conservation Service was first initiated in 1939. In that year the Service determined that its laboratory near Spartanburg, South Carolina, was neither adequate in water capacity nor suitable in location for extended studies in the use of vegetation as a channel lining. Lake Carl Blackwell near Stillwater, Oklahoma, offered an unlimited water supply. The central geographical location of Stillwater was excellent in that a great many different types of grasses and legumes could be grown. The Agricultural Experiment Station of the Oklahoma A. and M. College offered a cooperative arrangement in the use of the site, in furnishing welcome technical assistance, and in loaning equipment. In 1940 actual construction of the laboratory began.

The main purpose of the laboratory is to study the stability of vegetal lined channels and the retardance offered to water flow. Kind of cover, condition of cover, soil, bed slope, channel shape, and bed roughness are important variables. Studies are made of the hydraulic behavior of flows through vegetation as well as of flows over a bent and completely submerged cover. A complete hydraulic behavior picture is desired. For the field technician stability is expressed in terms of a maximum permissible velocity to use in design, and the hydraulic behavior in coefficients representing the resistance to flow. The latter is generally n in the Manning open channel flow formula commonly used to estimate velocity.

DESCRIPTION OF LABORATORY

Water for testing experimental channels is drawn from Lake Carl Blackwell through 5 siphons 20 inches in diameter.* With the reservoir at spillway elevation, the maximum rate of flow is about 200 cubic feet per second. Canals lined with vegetation convey the desired flows to test channels. Small flows to channels are conveyed in a 12-inch diameter pipe line directly to the site.

* Mr. Palmer's paper was illustrated by slides showing the laboratory and some details of its operation. These could not be reproduced here.—Editor.

The laboratory features two types of vegetal-lined test channels. One type includes field-size trapezoidal, trianguluar or parabolic shaped channels, many capable of carrying the full capacity of the five siphons. The other type of channel, termed "unit channel," is strictly a laboratory test channel. It is rectangular in shape, with smooth vertical walls of plywood or metal in place only during the testing period. Previous results have shown that this type of channel may be considered to represent a narrow section in the cross-section of a large field-size channel. The unit channels are 3 feet in width. The unit channel is used extensively because it yields more precise data than large channels and the data lend themselves more readily to scour and retardance analysis. An additional advantage is the ability to view the flow and vegetation behavior in profile through a glass panel.

The rates of flow are measured by previously calibrated flumes such as the Parshall or by smaller, more sensitive devices that have been developed by the Soil Conservation Service.

Testing Technique

The standard test procedure is to allow a steady flow to course down a test channel for 40 minutes. During this period, water surface observations are taken with point gages. Before and after a flow, point-gage measurements are made of the bed. A difference is considered scour or deposition.

Cross-sectional areas are computed from the point-gage measurements of bed and water surface, and mean velocities are determined from the measured discharges. Values of Manning's n and Kutter's n are computed from the respective formulas. These coefficients are not interchangeable as is commonly stated, for they are equal only for a hydraulic radius of 3.28 feet. As the depth decreases, Kutter's n becomes increasingly less than Manning's. The opposite is true for values greater than 3.28 feet.

Some Results of Tests

Bermuda grass has been subjected to extensive testing under conditions of long, short, green, and dormant. A uniform stand of long, green, second-year Bermuda offers probably the optimum protection to the channel bed. A unit channel with such a cover on a silt loam soil was subjected to over 13 hours of flow with a mean velocity of 8 feet per second, and the cover and bed remained essentially intact. Less than ¼ inch of soil was lost from the bed. A highly important item is the uniformity of cover. A single weak area in the cover would have prohibited such exhausive testing. The desirability of maintenance and timely repair cannot be stressed too highly.

As a contrast to a sod-forming grass like Bermuda, weeping lovegrass, a bunch grass, has been tested both long and in a cut state. The channels were established from broadcasted seed and at the end of the first season had attained a good growth. Being a definite bunch grass, there was considerable bare area on the channel bed. These channels suffered severe scour at discharges less than one-fourth those carried safely over Bermuda grass. At velocities of about 5 feet per second, severe scour occurred on the upstream side of clumps. Roots were exposed. Higher velocities would have resulted in actual uprooting of clumps and failure of the lining. Since experiments have shown that permissible velocity tends to decrease in slope, the value for weeping lovegrass on slopes steeper than 3 percent should probably not exceed 4 feet per second.

An excellent stand of *ischaemum* (King's Ranch strain) was obtained the first season on a silt loam soil well fertilized with barnyard manure and having plentiful moisture. Under these optimum conditions a growth of ischaemum more dense and luxuriant than could probably be expected in the field was obtained. This mass of foliage did not obscure its main weakness as a channel cover—it is a bunch grass by nature. At a velocity of 3.6 feet per second the roots of some of the plants were exposed. On the heavier soils on slopes steeper than 3 percent, the permissible velocity for ischaemum should probably not exceed 3.5 feet per second. For lighter soils the velocity should be still lower.

The difference in hydraulic behavior between a sod and a bunch grass cover is shown in these tests of Bermuda grass and *ischaemum*. For the samé discharge of 21 cubic feet per second the following results were obtained.

	Bermuda	**ischaemum**
Average depth	1.2 feet	1.4 feet
Mean velocity	6.2 feet per second	5.4 feet per second
Manning's **n**	.055	.072

Ischaemum with its greater bulk of vegetation and less uniformity in cover resulted in greater depth and considerably rougher flow. The net effect is reflected in a higher retardance coefficient. The *ischaemum* channel required 17 percent more depth to carry the same flow.

The completeness of flow retardance data obtained is illustrated by the data for Bermuda in Figure 1. The analysis and application is divided into three parts as determined by the behavior of the vegetation. *Low flows* course slowly between the stems and foliage without bending and submerging

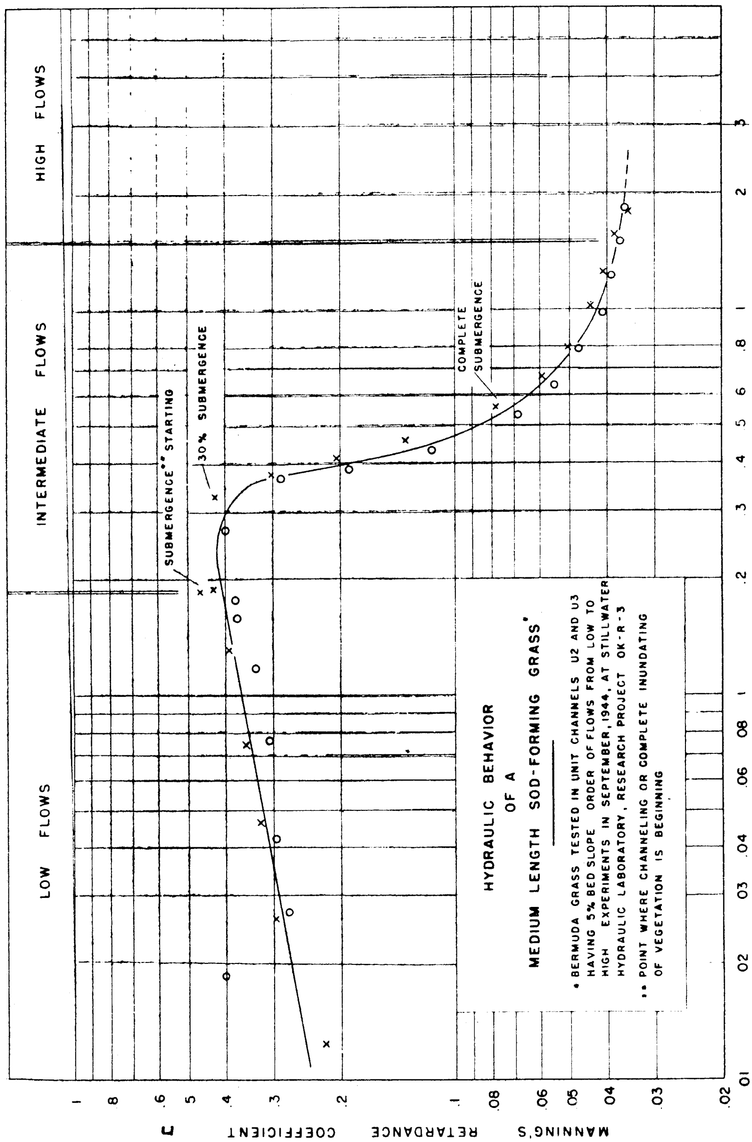

Figure 1.

them. A high, often constant level of retardance coefficient prevails. *Intermediate flows* are those that produce bending and complete submergence. The retardance coefficient, *n*, changes very rapidly with small changes in depth and velocity. *High flows* force the vegetation in or near a prone position. Even though the vegetation may be whipping vigorously in the flow, the retardance has reached a sensibly constant value that will not change greatly unless scour and loss of vegetation modify the bed.

The *low flow* results have application in surface runoff studies and shallow flows in irrigation, terrace, and drainage channels. Deeper, swifter flows in terrace channels, terrace outlets, and other vegetal-lined channels will often be in the intermediate flow range. The general application of a constant value of *n* is specially erroneous for estimating velocity in this range.

Terrace outlets are usually relatively steep and must carry a considerable discharge for short periods. With dense, uniform covers like Bermuda grass, the design flows might readily extend into the *high-flow* range where *n* would be sensibly constant. However, with most bunch grasses and covers like alfalfa, *Lespedeza sericea,* and weeping lovegrass the permissible velocities are exceeded before the *high-flow* range is entered. The consideration of a variable *n* is highly important.

A satisfactory criterion for estimating *n* has been developed as the product of velocity and hydraulic radius. This product, termed VR, expresses the bending movement which largely determines the behavior of the vegetation in the flow. A rapid graphical method solving Manning's flow formula has been developed so that VR and *n* will be compatible in the final design without resorting to laborious cut-and-dry methods. The design curves shown here are for long green Bermuda grass (Figure 2) and *Lespedeza sericea* (Figure 3). Experiments have shown that this solution for Bermuda grass is generally applicable to other medium length, uniform, close-growing covers such as common lespedeza, centipede grass, and crab grass. That for *Lespedeza sericea* has been determined to serve also for long, green covers of weeping lovegrass, *ischaemum,* alfalfa, and kudzu. When covers not yet studied in the laboratory are to be used, the appropriate design curve may be selected on the basis of a careful consideration of physical characteristics.

The use of these design curves is as follows: A velocity is selected with consideration of the type and maintenance of the cover and the bed slope of the channel. In this example,

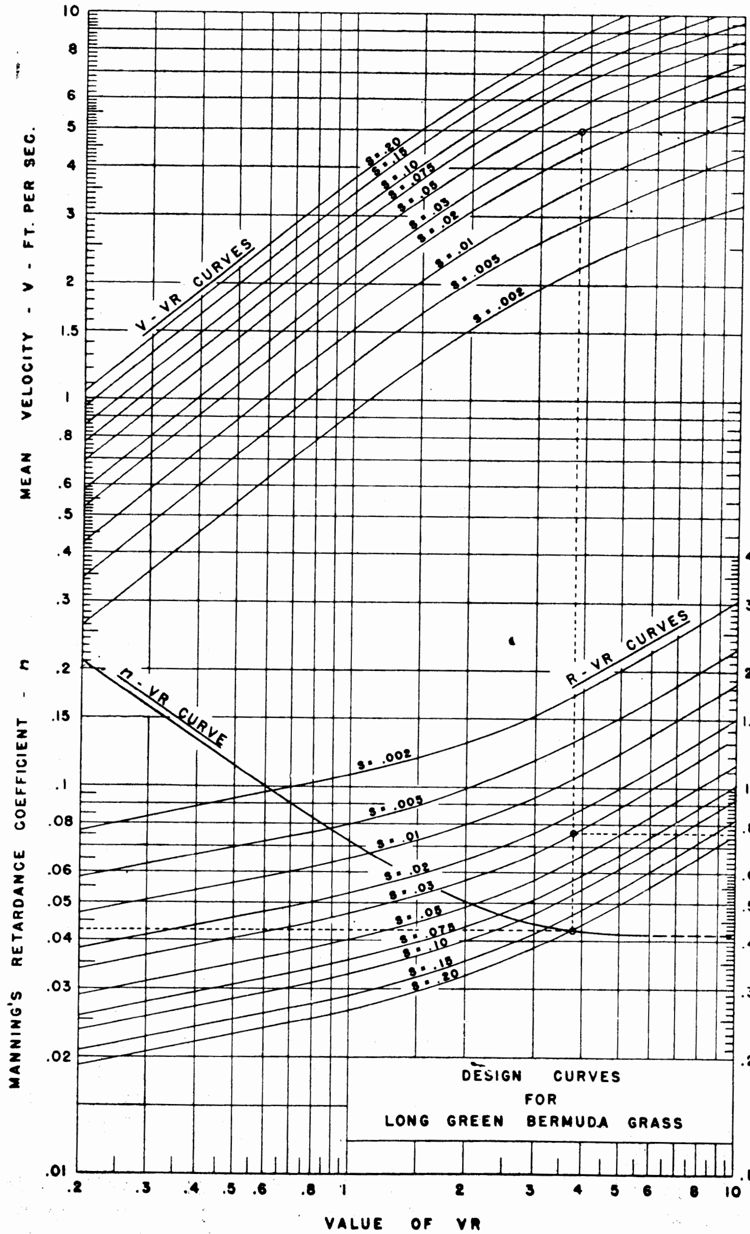
MEAN VELOCITY - V - FT. PER SEC.
MANNING'S RETARDANCE COEFFICIENT - n
HYDRAULIC RADIUS - R - FT.
VALUE OF VR
V - VR CURVES
n - VR CURVE
R - VR CURVES
S = .20
S = .15
S = .10
S = .075
S = .05
S = .03
S = .02
S = .01
S = .005
S = .002
DESIGN CURVES
FOR
LONG GREEN BERMUDA GRASS

Fig. 2.

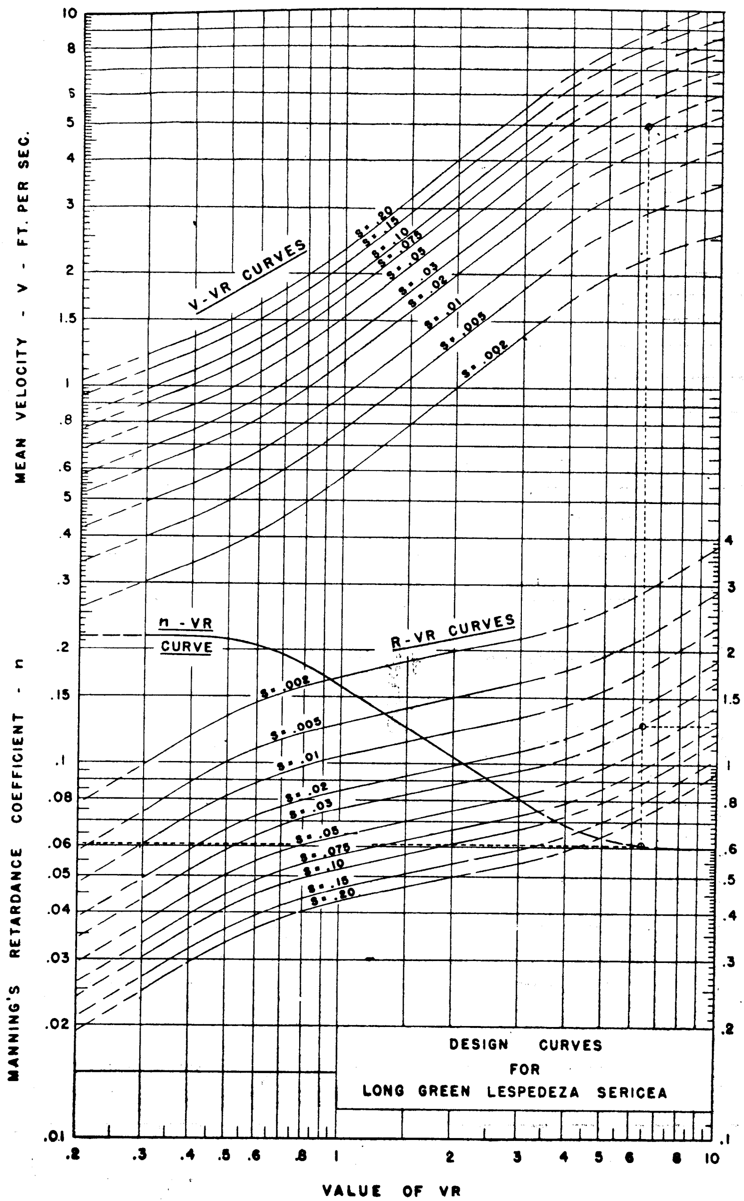
MEAN VELOCITY - V - FT. PER SEC.
MANNING'S RETARDANCE COEFFICIENT - n
HYDRAULIC RADIUS - R - FT.
VALUE OF VR
V-VR CURVES
n - VR CURVE
R-VR CURVES
S = .20
S = .15
S = .10
S = .075
S = .05
S = .03
S = .02
S = .01
S = .005
S = .002
DESIGN CURVES
FOR
LONG GREEN LESPEDEZA SERICEA

Fig. 3.

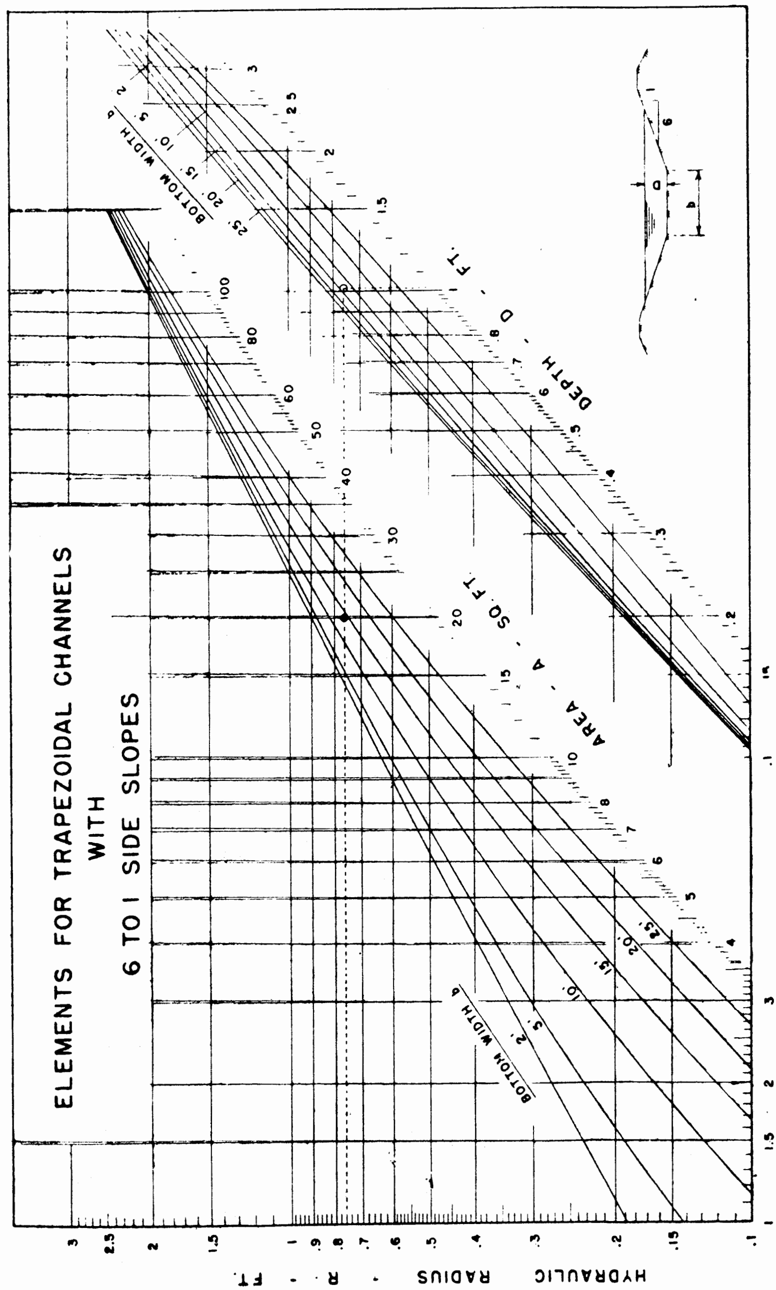
ELEMENTS FOR TRAPEZOIDAL CHANNELS
WITH
6 TO 1 SIDE SLOPES
HYDRAULIC RADIUS - R - FT.
AREA - A - SQ. FT.
DEPTH - D - FT.
BOTTOM WIDTH b
BOTTOM WIDTH b

Fig. 4.

where a discharge of 100 cubic feet per second is to be conducted down a 3 percent slope lined with long Bermuda grass, a velocity of 5 feet per second is tried. The initial step is to proceed to the right from 5 feet per second on the velocity scale to an intersection with the 3 percent slope curve. Then move downward to the lower 3 percent curve and right to the *R* ordinate scale. For long, green Bermuda grass, *R* equals 0.76 foot, a value for the hydraulic radius that must obtain for any channel section selected if the velocity is to be 5 feet per second. It is not necessary to know *n* since the value is considered in the design curve placement. It can be obtained by proceeding left from the intersection of the vertical dashed line with the *n*-VR curve to the *n* ordinate scale. In this example the value is .042.

Next, determine the channel section. Since the discharge is known and the velocity has been selected, compute the cross-sectional area required. For a discharge of 100 cubic feet per second and a velocity of 5 feet per second the cross-sectional area needed is 20 square feet. Entering the channel-element graph (Figure 4) with an *R* of 0.76 foot results in a bottom width of 14 feet and a center depth of 1.01 feet for a trapezoidal channel with 6 to 1 side slopes. The channel design has been completed unless the section is not satisfactory. If so, change the velocity slightly and proceed again through the graphical solution. Graphs solving trapezoidal channels with other common side slopes and for triangular and parabolic shapes have also been developed.

It has been possible to present herein only a brief description of the laboratory, to outline the objectives, and to illustrate the method of applying the results. We will welcome your continued interest and a visit to our outdoor hydraulic laboratory.

The Value and Interpretation of Chemical Tests for Available Plant Nutrients in Soil

By HORACE J. HARPER
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The quantity of easily soluble plant nutrients in soil as determined by chemical tests is only one of several factors which may affect the economic use of fertilizer or legume crops for soil improvement. Plant growth depends upon root expansion as well as root absorption; consequently, the physical condition of the soil may restrict plant development under many conditions.

The more important factors which should be considered in the interpretation of information obtained from chemical soil tests include kind and value of crops which will be grown, previous cropping systems, climatic hazards which may affect plant development, character and depth of surface soil as it may affect absorption and retention of water, disease and insect problems, subsoil conditions as they may influence internal drainage in humid areas, and the possibility of sub-irrigation or flood hazards which may be benefical or harmful to plant development.

Climate and Crops

In Oklahoma, the average climatic possibilities for maximum crop production are frequently lower than soil potentialities. When the natural fertility in the soil is capable of producing yields which approach the average climatic possibilities for a particular crop, the use of limestone or fertilizer should not be recommended unless the cropping system can be changed to take advantage of increased soil fertility. Wheat will respond to phosphate fertilization and legume rotations on soil where little response is obtained from cotton. Legume residues plowed under will produce a large increase in the yield of oats and barley on soils where little benefit will be obtained from similar treatments applied to corn or sorghum. Alfalfa and sweet clover are more responsive to phosphate fertilization and limestone treatments than cowpeas or soybeans. Hairy vetch yields can be increased by soil improving practices when lespedeza will show no effect from similar treatment. Usually crops which mature during the spring or fall are more responsive to soil improving practices than crops which grow and mature during the summer. Crop responses in some instances may be due to differences in nutrient requirements or the ability of different plants to absorb essential elements from relatively unavailable compounds in the soil.

INORGANIC ELEMENTS ESSENTIAL FOR PLANT GROWTH

The most important basic elements in the soil are potassium, calcium and magnesium. Other bases include manganese, iron, copper and zinc. Non-metallic elements include nitrogen, phosphorus, sulfur, and boron. The basic elements usually occur in chemical combination with the clay minerals, commonly called the exchange complex. They are readily dissolved by water containing carbon dioxide, or replaced by sodium or ammonium ions.

Easily soluble forms of phosphorus are present in the soil principally as calcium phosphate. Boron occurs as relatively insoluble borates. Nitrates and sulfates normally occur in the soil solution and are easily removed by leaching.

TOXIC SUBSTANCES

To solve some of the soil problems in certain areas, it may be necessary to test for toxic elements such as aluminum, for alkali salts (especially chloride), or for the quantity of replaceable sodium.

DECAY OF SOIL ORGANIC MATTER LIBERATES PLANT NUTRIENTS

Soil organic matter contains nitrogen, sulphur, and phosphorus in considerable quantities. When organic matter decays, these elements are changed to inorganic salts which can be absorbed by plant roots. Soils low in available phosphorus may not respond to phosphorus or nitrogen fertilization when legume residues are returned to the soil. This type of organic matter decomposes rapidly in moist, warm soil, releasing nitrates, sulfates, and phosphates. Since the nitrogen, phosphorus and sulfur in soil organic matter is not measured by chemical tests for inorganic elements, soils which contain a limited supply of available plant nutrients when the tests are made may supply an adequate quantity of nutrients for growth when weather conditions are favorable for the decomposition of the organic matter in the soil. Decomposition occurs at a slower rate in acid soils. Certain forms of organic phosphate are very resistant to decomposition by soil organisms; consequently, crop response to phosphate fertilization will correlate more closely with the results of chemical tests in acid than in non-acid soils high in organic matter.

SOIL REACTION AND LIME REQUIREMENT

A knowledge of soil reaction should reveal much more than the quantity of lime which may be needed to correct an acid condition. Such factors as the availability of phosphorus, probability of calcium and potash deficiency in sandy soils and soluble aluminum in fine-textured soils are assocated with high acidity.

Indicators for the determination of hydrogen ion concentration in contact with the soil measure absorptive capacity for basis in acid soil and the rate of mineral hydrolysis in alkaline soil. The potassium thiocyanate reaction, which is the basis of the Comber test for soil acidity, measures replaceable ferric iron, normally associated with acid soil. This test is convenient to use in the determination of lime requirement and is reasonably accurate except in sandy soils which may be acid but are very low in replaceable iron. The lime requirement of soils varying in surface texture and degree of acidity are given in Table 1.

Exchangeable Calcium and Soil Reaction

Calcium makes up a high percentage of the total bases in the exchange complex. Since this element is readily replaced by potassium and magnesium when salts of these elements are present in the soil solution, more calcium is leached into the subsoil during periods of abundant rainfall than any other base. The quantity of exchangeable calcium in a soil will depend to a very great extent upon the quantity of clay present and the soil reaction. High acidity alone cannot be used to indicate a calcium deficiency for acid tolerant crops. Only 1.5% of 1390 basic soils, 4.9% of 472 slightly acid soils, 7.4% of 485 moderately acid soils and 12.7% of 756 strongly acid soils collcted from different localities in Oklahoma were very low in exchangeable calcium according to Morgan's test. (Connecticut Agri. Exp. Sta. Bul. 450)

Soils which have the same pH value will have a similar ratio between total exchangeable bases and hydrogen in the clay complex but the quantity will vary with texture. Ex-

*TABLE 1.—Quantity of Agricultural Limestone Required to Neutralize the Acidity in Soils of Varying Surface Texture.**

		Soil Texture and Lime Requirements in Tons per Acre				
Degree of Acidity	Approximate pH	Sand	Sandy Loam	Loam and silt loam	Clay loam	Clay
Slightly Acid	6.1 to 6.7	.5	.8	1.0	1.5	2.0
Moderately acid	5.5 to 6.1	1.0	1.5	2.0	2.5	3.0
Strongly acid	4.9 to 5.5	1.5	2.0	3.0	3.5	4.0
Very strongly acid	Less than 4.9	2.0	3.0	4.0	4.5	5.0

* Recommendations based on limestone containing 30 to 40 percent of material passing through a 60-mesh sieve.

TABLE 2.—Classification of Field Crops According to Acid Tolerance.

Very sensitive to acidity	Tolerant of Slight Acidity	Tolerant of Moderate Acidity		Tolerant of Strong Acidity
Sweet clover	White clover	Soybeans	Cotton	Rye
Alfalfa	Bur clover	Hairy vetch	Lespedeza	Crimson clover
	Winter peas	Barley*	Sudan grass	Cowpeas
	Black medic	Wheat	Mungbeans	Flax
		Corn	Hop clover	Rye grass
		Oats	Sorghums	Peanut

* Very sensitive to aluminum toxicity.

changeable calcium and hydrogen will be lower in sandy soils than in medium or fine-textured soils which contain a higher percentage of clay. When acid tolerant crops are grown on fine-textured, strongly acid soils, they will be able to obtain sufficient calcium for optimum growth, whereas the same crops may respond to an application of agricultural limestone because of a calcium deficiency in coarse-textured, strongly acid soils when other plant nutrients are not limiting factors in plant development. A few crops and their degree of tolerance to soil acidity are given in Table 2.

Climatic conditions affect the absorption of calcium by some crops. Prairie hay will be low in calcium content during seasons of abundant rainfall and very high in calcium on the same plots during seasons when rainfall is limited; consequently, the availability of plant nutrients in a soil as indicated by chemical tests may not always be the determining factor in their utilization.

EASILY SOLUBLE PHOSPHORUS AND SOIL REACTION

In a region where phosphorus is the first limiting factor in plant development and accurate information is needed concerning the quantity of available phosphorus in the soil, an ideal solvent would dissolve soil phosphorus inversely proportional to field responses obtained when fertilizers are applied to crops grown on soils of varying natural productivity.

The quantity of easily soluble phosphorus extracted from a soil usually depends upon the ratio of liquid to soil and the kind and concentration of acid in the extracting solution. The amount of phosphorus extracted from soils which are low, medium or high in easily soluble phosphorus will be similar when a narrow ratio of liquid to soil is used. When a wide ratio of soil to water is used, soils high in easily soluble phosphorus will continue to supply phosphorus to the extracting solution. When soils are low in easily soluble phosphorus, the phosphorus which is dissolved will be highly diluted in a large volume of solution. The wide variation in phosphate concentration in solutions from different soils makes it possible to separate soils into five groups depending upon whether they are very low, low, medium, high or very high in easily soluble phosphorus. Re-absorption of phosphorus by iron compounds or clay minerals may affect the accurate interpretation of a chemical analysis for some soils. When plant roots absorb a soluble phosphate from the surface of a soil particle, there is no opportunity for re-absorption of the phosphate by other minerals in the soil. When soil is dispersed in an extracting solution, opportunity for re-absorption occurs because dissolved phosphorus will be exposed to many particles that would not have an opportunity to absorb the phosphate under field conditions; consequently, in many soils an extracting solution must be sufficiently acid to prevent re-absorption of extracted phosphate or inaccurate results will be obtained.

Fifth normal sulfuric acid (pH .88) will extract about 1 or 2% of the total phosphorus from strongly acid soils using 1 part of soil to 10 parts of liquid. Crop growth will be very poor on soils which contain practically no phosphorus soluble in fifth normal sulfuric acid. From 20 to 40% of the total phosphorus in neutral or basic soils will be dissolved by similar treatment. Hydrated iron phosphate will dissolve in fifth normal sulfuric acid, but it is insoluble in 0.1 normal acetic acid (pH 2.65). Some crops can utilize the phosphorus in hydrated iron phosphate whereas other crops will respond to phosphorus fertilization on these soils. Since one solvent will not give accurate information for all crops on all soils, the limitations of the extracting solution should be known and carefully considered in the interpretation of chemical analysis.

More easily soluble phosphorus is removed from the average soil by leaching with 0.1 normal acetic acid than will be obtained by extraction. As leaching continues, the quantity of phosphorus in the leaching solution may decline below the solubility product of freshly precipitated phosphates; consequently, they re-dissolve which increases the total quantity of phosphorus removed from the soil. Weakly acid extracting solutions with a pH about 5.0 may give good results on sandy soils but will not prevent re-absorption of dissolved phosphate on fine-textured soils; consequently, a method which gives good results under some conditions may be very unsatisfactory when soils with different physical or chemical characteristics are encountered. Since plants differ in their ability to utilize the relatively insoluble phosphates in soil, it is quite logical to suggest that a stronger solvent should be used to determine the availability of soil phosphates for crops like lespedeza, cowpeas, and hop clover, as compared with alfalfa, small grain and many vegetable crops.

Available Phosphorus and Crop Response to Fertilization

Phosphate fertilization will produce a profitable increase in the production of alfalfa when the easily soluble phosphorus by chemical tests is medium, low, or very low and other plant nutrients including soil moisture are not limiting factors in plant development. Corn, cotton, bur clover, Austrian winter peas, hairy vetch, barley, oats, wheat, soybeans, and sweet clover will respond to phosphorus fertilization when soil tests are low or very low. Cowpeas, peanuts, lespedeza, hop clover, rye, and grain sorghums are not as responsive to phosphate fertilization as the crops previously mentioned but usually respond to phosphate fertilizers when soil tests are very low and climatic conditions do not restrict production. Liberation of phosphorus from soil organic matter is one of the reasons for limited response from phosphate fertilizer applied for summer crops.

Usually soils which have a pH below 6 are low to very low in available phosphorus content. From pH 6 to pH 8, phosphorus availability is relatively high in soils which are well supplied with organic matter although low phosphate soils may occur in this pH range because of the nature or quantity of phosphorus in the material on which soil development occured. As the pH increases above 8, large quantities of calcium salts may reduce the availability of phosphorus for some crops.

The availability of phosphorus in calcareous soils cannot be correlated with crop response when determinations are made by leaching or extracting a soil with an acid solution, since phosphorus utilization by plants depends upon the solubility of calcium phosphates which is decreased in the presence of calcium bicarbonate or other calcium salts.

Exchangeable Potassium

The quantity of exchangeable potassium makes up a very small percentage of the total potassium in the average soil. One of the important problems in potash availability studies is to know how rapidly the potassium removed from the exchange complex by plant roots will be replaced as a result of weathering processes. This factor may result in a potash deficiency under certain conditions which would not occur if more time elapsed between the harvesting of one crop and the planting of another. A soil test made at the time a crop is to be planted will help to answer this problem.

Legumes have a higher requirement for potassium than grass crops. Wheat will make a good growth on soils where a potassium defiency occurs when alfalfa and many of the clovers are planted. Oats is a very strong feeder on potash feldspar; consequently, this crop does not necessarily obtain its potassium from the exchange complex to grow satisfactorily. Sweet clover does not contain as much potassium as alfalfa and it can feed strongly on relatively insoluable potassium compounds. Alfalfa grows rapidly; consequently, it must absorb a large quantity of potassium in a short period of time. Normally good alfalfa soils are very high in replaceable potassium. Cotton leaf rust is a good indication of potassium deficiency; however, the production of seed cotton may be as high on plots where early defoliation occurs because little or no potash was present in the fertilizer as on adjacent plots where normal leaf development and later maturity occurs as a result of heavier potash fertilization.

When grain is harvested, the loss of potash from the soil will not be so great as will occur when forage is removed; consequently, the quantity of potash which should be applied to a potash deficient soil will depend upon the crop to be planted and subsequent utilization.

Most of the potash deficiency in Oklahoma occurs in strongly acid sandy soils with strongly acid sandy subsoils. Many of the surface soils in Oklahoma which are low in available potash have an abundant supply of potash in the B horizon where the clay minerals have accumulated as a result of profile development and absorb soluble potassium salts as they are leached from the surface soil.

Available Magnesium

Tests which have been made on the availability of magnesium in Oklahoma soils indicate that only a very small percentage of the soils are deficient in this element. Plants utilize only one-half to one-fifth as much magnesium as calcium. Magnesium is also more strongly absorbed by the exchange complex than calcium; consequently, it is not removed rapidly by leaching. Loss of magnesium occurs principally when forage crops are harvested. Magnesium defiency is more likely to occur in strongly acid sandy soils with sandy subsoils than in fine-textured soils. Application of dolomitic limestone is the least expensive method to use in increasing the quantity of available magnesium in soil.

SULPHUR DEFICIENCY

Chemical tests for sulfate have little value because sulfur in soil occurs principally in the organic matter. Organic sulfur is changed to sulfate as a result of oxidation by soil organisms. Some gypsum or sodium sulfate may be present in the soils of low rainfall areas or in alkali soils.

About 6 to 12 pounds of sulfur is present in the rain falling on an acre of land; consequently, where runoff is not too great, the sulfur requirements for most crops will be satisfied in one year from this source. Where fertilizers containing ammonium sulfate or ordinary superphosphate (which is approximately one-half gypsum, are applied) the problem of sulfur defiency for crop production is not likely to be very important under average conditions.

NITRATE AND AMMONIUM NITROGEN

A chemical test for nitrate or ammonia in soil is of little value under average conditions. The ammonia content of soil is always low unless the soil is very acid, has been sterilized with steam which kills the nitrifying bacteria and permits ammonia to accumulate, or a fertilizer containing a high percentage of ammonia has been applied.

Nitrates are formed by the decomposition of protein material in the soil. If they are not absorbed by plant roots, they may be carried into the subsoil during periods of abundant rainfall. Plant tissue tests for nitrate nitrogen at frequent intervals during the growing season or a test for soil organic matter will provide more information concerning the probable need for nitrogen than a soil test for nitrate or ammonia.

IRON AND MANGANESE DEFICIENCY CAUSES CHLOROSIS

Plants use iron in the ferrous form. Soils which contain a good supply of organic matter and a considerable quantity of total iron will supply sufficient quantities of ferrous iron for optimum plant growth under normal conditions. Manganese is also absorbed by plants in the manganous form. Carbon dioxide plays an important role in the solubility of these elements. Chemical tests indicate that a very small percentage of Oklahoma soils are deficient in available manganese or iron. Manganese is more likely to be deficient in strongly acid sandy soils with sandy subsoils. Since these elements are used in relatively small amounts and occur principally in the vegetative portion of the plant (manganese occurs in the seed coat), the most rapid loss from the soil would occur when forage crops are grown and removed from the land.

Iron and manganese chlorosis usually occurs in soils low in organic matter and which have a high pH value due to the presence of considerable quantities of calcium carbonate. Severe chlorosis of certain varieties of grain sorghums frequently occurs on eroded areas or on land where cultivation has reduced the organic matter to a point where it will not maintain a reducing environment sufficient to form ferrous iron from the ferric compounds in the soil.

Spraying plants with a solution of iron sulphate will provide the iron needed for chlorphyll development. Adding this chemical to holes which have been dug near the base of affected perennial plants tends to acidify localized zones from which a sufficient quantity of ferrous iron for normal leaf development can be absorbed by plant roots. Increasing the organic matter content of cultivated land is the best method to use in correcting chlorosis but may be difficult to accomplish in a region of limited ranfall.

Minor Elements in Soil

The term minor element refers to the quantity of that element occuring in the plant. A minor element is just as essential for plant growth as calcium or potassium and characteristic physiological symptoms have been observed on many plants when severe starvation occurs.

Boron, copper, zinc, nickel, and manganese salts have been applied to several soils in eastern Oklahoma in addition to limestone, phosphorus and potash. No increase in the yield of oats, corn, lespedeza, cotton, barley or peanuts has been obtained from the minor elements applied.

Recent studies indicate that native grasses contain large quantities of zinc. Where hay is removed, zinc may soon become a limiting factor in plant development where the quantity of easily soluble zinc in the soil is low.

Boron deficiency may be responsible for the poor growth of alfalfa on some eastern Oklahoma soils. Bronze-colored or yellow leaves near the top of the plant, short internodes and failure to bloom profusely or set seed are symptoms of severe boron starvation on alfalfa. More boron occurs in legumes than in grasses. Plants growing on soils containing 1 or 2 parts per million of boron will not suffer from a deficiency of this element.

Summary of Chlorosis Experiments With Grapes at the Southern Great Plains Field Station, Woodward, Okla.

By L. F. LOCKE

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For the past 25 years yellowing and mottling of the leaves of numerous trees, shrubs, vines, and field crops during the summer months have been widely observed in this section of the country. The soil areas where plants become chlorotic, often localized in character, occur quite generally, especially where the lime content of the soil is high. The chlorosis areas vary in size from a few square feet to several acres. A wide range of plants, including trees (both fruit and ornamental), shrubs, vines, and field crops, are affected.

In 1915 a vineyard consisting of about 75 varieties was planted on a very light, sandy soil classified as Pratt loamy fine sand on the Southern Great Plains Field Station, Woodward, Oklahoma. On this type of soil many of the varieties did very well. In 1928 at a point only about one-fourth mile from this vineyard, an attempt was made to establish 20 of the more outstanding varieties of grapes on a site known to produce a chlorotic condition in sorghums. The soil at this site was classified as Quinlan very fine sandy loam. Many of the vines became chlorotic, and it was soon found that grapes were not going to do so well here as in the original vineyard. A few preliminary treatments, principally injections of iron salts and soil treatments, were made. Some of these treatments showed promise, but there were insufficient vines of any variety for detailed experiments.

In the spring of 1932 all the original vines were removed, and the vineyard replanted with four varieties: Beacon, Catawba, and Extra, which seem to be susceptible in about the order named, and America, which is very resistant to chlorosis on this soil. The vines were planted in solid rows of America, Beacon, Catawba, and Extra, systematically repeated three times, and with a fourth row of America as the last row.

The rows run north and south and were planted 10 feet apart with the vines 5 feet apart in the rows. This spacing is too close for best fruit production, but gave a large number of experimental plants per acre. The vineyard was kept clean culitvated, and the vines were allowed to grow naturally without trellising during the first season.

In the fall of 1932 the vines were examined carefully, and notes were made on the amount of chlorosis. During the winter of 1932-33 plans were made for chlorosis control experiments in this planting.

In the spring of 1933 the vineyard was divided into 18 plots. In the original arrangement 15 of the plots contained 18 vines, 6 each of Beacon, Catawba, and Extra. The other three plots were only half size and contained 3 vines of each of the three varieties. The America was not included in the treatments. The 18 plots were divided into three series of treatments: (1) mulches, (2) sprays, and (3) soil treatments. During the summer of 1933 the vines were trained up on the trellis. The single-trunk four-arm Kniffen system was used.

Mulches

Four materials were used as mulches. These were sorghum, wheat straw, alfalfa, and manure. There were two plots each of the sorghum and wheat straw, and one each of the others. Ammonium sulfate was used on the second plot of the sorghum and the wheat straw mulches. The mulching materials were applied in the spring of 1933 and were maintained 6 to 12 inches deep by annual additions of mulching materials until discontinued.

Sprays

The second series of experimental treatments consisted of various sprays. Those used in 1933 were commercial and chemically pure iron sulfate (copperas), zinc sulfate, zinc sulfate and lime, and lime alone. The iron and zinc sprays were used at the rate of 2 pounds to 50 gallons of water.

Spraying with commercial iron sulfate at 20- and 40-day intervals has controlled chlorosis to a certain degree. There may be some cumulative effect, and continued spraying over a period of years apparently makes the treatment rather effective.

Chemical Soil Treatments

Two methods were used in applying the chemicals to the soil. In part of the test four holes were made around each vine. The holes were approximately 1 foot deep and 1 foot from the base of the vines. In 1933 and 1934 the holes were made with the regular soil sampling tube which takes out a core 20 mm. in diameter and leaves a hole about one and one-quarter inches. One-fourth of the chemical dosage was placed in each hole, and the holes refilled with soil. In the second method of application the chemicals were broadcast over the plots and disked in.

The treatments used in 1933 were aluminum sulfate, ammonium sulfate, iron sulfate, magnesium sulfate, manganese sulfate, zinc sulfate, and sulfur, at the rate of one-fourth pound per vine. These were applied early in May. The ammonium, magnesium, manganese, and zinc sulfate treatments were applied in holes. The iron sulfate was applied by both methods, and the aluminum sulfate and the sulfur were broadcast and disked in. None of these treatments showed any benefit. Chemically pure iron and zinc sulfates were used; the other chemicals were commercial grade.

As the very light soil treatments applied in 1933 were of no benefit the same chemicals were used in 1934 in increased amounts. An application of 1 pound of each of these chemicals per vine was made May 5 and repeated July 5. None of these 1934 treatments showed any benefit.

The same chemicals were used again in 1935, but the rate of application was increased to 5 pounds to the vine, and commercial grade of all chemicals used. Iron and zinc sulfates were applied in solution as well as in dry state. An application of a combination of 5 pounds each of iron sulfate and sulfur, broadcast, was also included.

In applying the heavier chemical treatments it was necessary to make larger holes. These were dug with a posthole digger in the same pattern as previously, that is, four holes around each vine, about 1 foot deep and 1 foot from the trunk of the vine. Iron sulfate was dissolved at the rate of 1.25 pounds per gallon of water. After the one gallon of solution applied in each hole had soaked into the soil, the hole was filled twice more with water and then filled with dirt.

The iron sulfate in solution gave very marked results in controlling chlorosis in 1935. Applied dry in holes this chemical also reduced the chlorosis somewhat, but only slightly below that of the untreated check. The combined iron sulfate and sulfur broadcast reduced the chlorosis about the same as the iron sulfate alone, applied dry in holes. Zinc sulfate in solution gave the first indication of zinc being of any value; the chlorosis on the plot was considerably less than where the zinc sulfate was applied in a dry state, but it was not so low as in the dry iron sulfate treatment, and not nearly so low as where the iron sulfate was applied in solution. None of the other treatments were of any apparent benefit.

Owing to the excellent results obtained with iron sulfate in solution in 1935, most of the other soil treatments were discontinued. Beginning in 1936 work was concentrated on iron sulfate treatments. The treatment with 5 pounds of iron sulfate in solution was repeated and plots with 10 and 15-pound rates were added. As 5 pounds applied dry was of much less benefit than the same amount applied in solution, this rate was not repeated, but 10 and 15-pound dry treatments were added to the test. Combination iron sulfate and sulfur treatments and the 1935 iron sulfate and zinc sulfate treatments were left without additional applications for further observation. Treatments with aluminum sulfate ammonium sulfate, magnesium, manganese sulfate, and sulfur were discontinued, and iron sulfate treatments substituted. The results with iron sulfate in solution were outstanding. The treatment with 5 pounds of iron sulfate in solution in 1935, without further treatment, gave even better results in 1936 than the first year. The 5 pounds of dry iron sulfate in holes and the combination of iron sulfate and sulfur broadcast also had carry-over effects, but these treatments were not nearly so immediately beneficial as iron sulfate in solution. The treatments in 1936 with iron sulfate in solution were even more satisfactory than those made in 1935. The 15-pound rate reduced chlorosis practically to the vanishing point. This treatment was applied on a plot where for three previous years with other treatments the chlorosis had averaged nearly 50 percent. The 10- and 15-pound applications of dry iron sulfate reduced the chlorosis some, but neither treatment was nearly so effective as 5 pounds in solution.

No new soil treatments were made after 1937 and all previous soil treatments were left for further observation. The treatments in which the iron sulfate was applied dry continued to give results inferior to those where it was applied in solution. After five years the treatments applied in solution in 1935 were beginning to show indications that they might be losing some of their effectiveness. The increase in the amount of chlorosis, particularly in the case of the most effective treatment made in 1935, that is, 5 pounds of iron sulfate in solution, was somewhat more than the seasonal increase in the untreated check.

The results from iron sulfate treatments were in most cases satisfactory; only in the case of the plot treated with 15 pounds to the vine dry was the amount of chlorosis consistently higher than in the check. Chlorosis on both plots treated with zinc sulfate was slightly below the check. By the end of the 1940 season the original 1935 treatment of five pounds of iron sulfate in solution was beginning to be less effective. On the adjoining plot which received five pounds dry, the improvement was not so immediate, but the benefit is lasting longer. The treatment with 15 pounds of iron sulfate dry remained relatively less effective than that with smaller amounts, either dry or in solution.

To check these results and determine the practibility of treatment, the more successful treatments were duplicated on Vanhoutti spirea. In general results have been very similar to those on grapes; however, some caution must be used to avoid injury on spirea.

Treatments have also been made on about 120 species or varieties of other plants. Where the plants have not been previously too badly injured by chlorosis and treatments have been moderately heavy, results have, almost without exception, been beneficial.

Summary

Results with mulches looked promising for chlorosis control the first two years of the tests, 1933 and 1934. Vine growth of grapes was increased, and chlorosis decreased. Drought after heavy rains caused severe defoliation and drying up of the fruit on most mulched plots in 1935 and 1936. Chlorsis was not decreased by mulches in 1936, 1937, or 1940, but was to some extent in 1938 and 1939. Manure mulch has been very harmful. By the end of 1940 results were such that none of the mulches could be recommended.

Only iron sulfate (copperas) sprays were effective. Frequent spraying on both grape and spirea reduced chlorosis most. Zinc and lime sprays, alone or in combination, were of no benefit.

All chemical treatments of grape vines in amounts of 0.25 to 2 pounds of the chemical applied to the soil failed.

Aluminum sulfate, ammonium sulfate, magnesium sulfate, and manganese sulfate treatments were of no benefit to grape vines.

Commercial zinc sulfate at 5 pounds to the vine, applied in solution to the soil, gave only very slight indications of benefit.

Iron sulfate gave definite benefit when treatments were increased to 5 pounds to the vine.

Iron sulfate applied in solution gave markedly quicker results than the same or larger amounts applied dry, but the effect lasted a shorter time.

Iron sulfate applied in solution to the soil in single treatments in amounts of 5 to 60 pounds per vine controlled chlorosis and was not injurious to grape vines. Five-pound treatment was still quite effective after 6 seasons, and partially so after 8 or more seasons.

Iron sulfate applied to the soil in solution was effective for Vanhoutti spirea, but apparently must be used with more caution than on grapes.

Soil treatments with iron sulfate have also shown beneficial results in the case of 120 species and varieties of trees and shrubs and numerous annual and perennial flowers.

Wide Row Spacing of Small Grain as a Nurse Crop for Sweet Clover and Lespedeza

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ABSTRACT*

Sweet clover and lespedeza frequently fail when seeded in February or March on land where winter small grain or spring oats has been planted in drill rows seven or eight inches apart. Legume seedlings cannot survive a long summer drought when they have a shallow root system due to early season competition from small grain roots for available moisture and plant nutrients.

Many experiments conducted in different parts of the state have shown that sweet clover will make a good growth when planted alone and weed competition is not severe, on non-acid soils containing a good supply of available phosphorus and other plant nutrients. At Lawton and Woodward, Oklahoma, a better growth was obtained when sweet clover was planted in rows and cultivated.

Since most of the income derived from first-year sweet clover when planted alone is usually limited to a small amount of grazing during the fall and winter months, crop rotations with this legume have not been established on many farms. Experiments were started in 1929 to determine how much reduction in yield would occur if small grain was planted in wider rows to provide a better opportunity for the survival of the legume seedlings. The first experiments were conducted with winter wheat. The average yield of plots planted in rows 14 inches apart was not reduced more than one or two bushels per acre as compared with wheat drilled in 7-inch rows. The average yield of oats in two experiments conducted in 1936 was 30.5 bushels from 7-inch rows and 29.8 bushels from 14-inch rows. A smaller number of plants in the wider rows were taller and more vigorous, producing nearly as much grain because of increased tillering and larger heads. In 1937, the average oat yield from 36 cooperative studies was 25.6 bushels from 7-inch spacings and 23.3 bushels per acre from 14-inch spacings. In 1938 the average yield from 18 cooperative tests was

* A bulletin covering this subject is now being prepared for publication.

15.6 bushels in 7-inch rows and 14.6 bushels per acre in 14-inch rows. In all cases, one-half as much grain was planted in the 14-inch rows.

A row spacing study with winter barley was conducted for nine years on the Perkins Farm near Stillwater. Excellent stands of sweet clover have been obtained on all plots where the 14-inch spacing was used. The average yield of the barley was 29.2 bushels per acre in 7-inch rows and 25.3 bushels in 14-inch rows. A 10-year study at Stillwater, comparing spring oats planted in (1) 7-inch rows, (2) 14-inch rows, and (3) two 7-inch rows of oats alternating with two rows left vacant, has given the following results: 34.3 bushels, 34.6 bushels, and 29.9 bushels per acre.

A three-year study at the Perkins Farm to compare the effect of spacing on the growth of winter wheat, rye, winter barley, and spring oats supports previous data already obtained. The average yield of wheat from 10 comparisons over a three-year period has been 13.9 bushels per acre in 7-inch rows and 13.7 bushels per acre in 14-inch rows. Four comparisons of winter barley in 7-inch rows have averaged 20.3 bushels per acre, and 17.4 bushels from 14-inch rows. Four comparisons of rye for the three-year period have been 11.8 bushels per acre in 7-inch rows and 12.3 bushels in 14-inch rows. Twelve comparisons of spring oats in 7-inch rows have produced 21.7 bushels and in 14-inch rows, 21.3 bushels per acre.

Very little advantage in the stand of legume seedlings will be secured from wide row spacing of small grain when summer rainfall is abundant and summer temperatures are below average. When summer drought is severe, as the small grain approaches maturity and continues for two or three weeks after harvest, a good stand of sweet clover will be obtained on plots where the small grain is drilled in 14-inch rows, whereas a complete failure will frequently occur on plots where the drill rows are spaced seven inches apart.

Results obtained in this study indicate that a wide row spacing of small grain will provide a method whereby farmers can establish a legume rotation to maintain or increase future yields without greatly reducing the immediate farm income. Winter barley is probably a better nurse crop than spring oats, unless the oat land is rolled to prepare a firm seed bed for the legumes after the oats are seeded. Wheat and rye provide more shade and root competition than oats or barley; consequently, the percentage of legume failures will be higher when these small grains are planted as nurse crops even though a 14-inch row spacing is used.

New Developments and Interpretation of Conservation Surveys

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The success of soil conservation and proper soil management requires that the land be used for the purpose for which it is best suited, along with the application of soil management and conservation practices needed for each kind of land. To obtain basic information, a physical inventory must be made of the land. This physical inventory, called a "Detailed Soil Conservation Survey," shows in detail the soil series and types, erosion classes, slope conditions, and present land use. This type of survey was developed in 1934 and used until 1942. During this period many improvements were made in procedures, in interpretation of the surveys, and in classifying the land according to its use capability.

Beginning in 1942 a combination of circumstances made it necessary to re-examine all phases of conservation survey techniques and procedures. The number of soil conservation districts was increasing. Conservation survey personnel were taken into the armed forces without adequate replacements being available. It was also becoming evident that the old survey procedures were not adequate in some instances in showing the actual physical condition of the land. Also, many soil and erosion conditions were shown that did not have practical application in soil conservation planning. With this realization that some important land feature had been missed and many other features shown that were not needed, greater stress was placed on developing procedures that would meet the necessary requirements in giving only basic physical information of the land needed for conservation planning without showing a lot of unnecessary detail. This led to the development of the "Farm Planning Soil Conservation Survey" procedure (originally called the "Utilitarian Soil Conservation Survey").

The farm planning soil conservation survey attempts to eliminate information that has no value in conservation planning. It stresses those physical characteristics that affect soil management practices, crop adaptation, mechanical erosion control measures, and other conservation practices. Mapping of the physical features of a soil makes it easier for a person not trained as a soil scientist to understand and interpret soil conditions.

The new soil conservation survey procedure permits the mapping of a soil unit based upon similar profile characteristics such as depth of the soil profile, broad textural variations, permeability, and inhibitory factors. All soils that have the same profile characteristics such as depth, texture, permeability, and structure will be mapped as a soil unit. This should give each soil within the same physiographic area about the same productivity, crop adaptation, and response to soil management and conservation practices, even though the soil unit may include several soil series and types formerly mapped.

Each soil unit has been given a short descriptive name and number.

Soil Depth

Soil depth is the first factor to appear in the descriptive title, and three divisions are recognized: Very Shallow, Shallow, and Deep. Soil depth refers to the weathered zone in which plant roots may develop and obtain the necessary nutrients and water, which means the total depth of the profile to bedrock, or to a dense caliche layer, unweathered clay and shale layer, gravel beds, or a dense hardpan. This affects crop adaptation, crop yields, use of the land, and type of conservation practices and management.

The *very shallow* soils are those that have less than 10 inches of soil over bedrock or other restrictive layers. The *shallow* soils are those that are more than 10 inches deep and less than 20 inches deep to a restrictive zone for root development. The *deep* soils are those that have a solum more than 20 inches deep that can be readily penetrated by plant roots.

Textural Classes

Soil texture is the second factor used in the descriptive soil title. The texture of the surface soil has an outstanding influence on crop adaptation, fertilizer recommendations, permeability, tillage operations, time of planting, organic matter content, and soil-plant moisture relationship.

Five textural classes are mapped at the present time: Coarse, Moderately coarse, Medium, Fine, and Very Fine.

The *coarse* textures include the sands, coarse sands, fine sands, and loamy sands. A soil made up principally of sand has very little agricultural value. This type of land is referred to as "sand dunes," "deep sands," or soil with very little or no soil development. The soils that are classed as coarse textures permit water to pass downward very rapidly, which usually leaches plant food below the zone of root development. They allow rapid aeration of the soil which permits a rapid destruction of organic matter and loss of soil moisture.

The *moderately coarse* textured unit includes the sandy loam and fine sandy loam which are considered to be intermediate between the coarse and the medium textural classes. This textural class is adapted to a larger selection of crops than the coarse textured soils, but has a more limited crop adaptation than the *medium* textured soils. This textural unit requires more complex soil management and conservation practices for wind erosion control than the medium textured unit. This is especially true in the part of the state receiving limited rainfall.

The *Fine* textured unit contains the textural classes of silty clay loam, sandy clay loam, and clay loam. These fine textured soils are not adapted to as wide a selection of crops as the medium textured soils, take up water more slowly, and the surface bakes or crusts quickly after a rain.

The *very fine* textured unit contains the textural classes of clays and silty clays. This textural class has a very limited selection of adapted crops, has poor soil-plant moisture relationship, compacts easily, puddles when worked too wet, bakes and crusts easily, and in dry seasons cracks deeply which allows rapid evaporation of soil moisture.

Soil Permeability

Permeability is the third factor used in the descriptive soil title. The term "permeability" as used in this procedure refers to the rate moisture and plant roots penetrate the various soil layers and how the moisture is released to the plants. The rate of permeability is affected by texture, consistency, organic matter content, compactness, depth of soil profile, slope and erosion conditions. The ideal soil for the growth of most plants from the permeability standpoint is one which allows the excess water to drain away during periods of excessive rainfall and retains enough water for proper plant growth.

In field mapping, permeability is determined by observing texture of surface and subsoil, structure and consistency of subsoil, and presence and thickness of any zone which restricts the free movement of water or root development. Four permeability classes are used: Very Slowly Permeable, Slowly Permeable, Moderately Permeable, and Rapidly Permeable.

Permeability is also an index to the degree of soil aeration which has an important infuence on root development of plants and bacterial life in the soil.

When fertilizers are added to rapidly permeable soils, much of it is lost by leaching. In planning drainage systems, permeability is extremely important in determining type of drainage and cropping systems to use with the same amount of vegetative cover. Run-off is usually greater on very slowly permeable soils than on those more permeable, thus requiring more intensive erosion control practices. In general, rapid or very slowly permeable soils are less desirable than moderately permeable soils.

Inhibitory Factors

Special factors which have been set up and are used in conjunction with the standard soil number recognize such characteristics as salinity, stoniness, frequency of overflow, drainage condition, and cherty or gravelly conditions. While these factors do not necessarily affect the soil depth, permeability or texture of the soil, they are very important in conservation planning, soil management, and determining proper land use.

Slope Classification

The topography or slope on which a soil has developed definitely affects the complexity of the soil management and erosion control problem. Slope percent varies in different regions because of type of rainfall and soil in relation to erosion.

The following slope class limits have been established for the Farm Planning Soil Conservation Survey:

A—Less than 1%.
B—1% to 3%.
C—3% to 5%.
D—5% to 8%.
E—8% to 12%.
F—12% and over.

Land Use or Cover

The mapping of land use or cover is confined to four classifications, indicated by the following symbols: L—Cultivated; F—Woodland; P—Grass Land; H—Farmsteads, golf courses, urban areas, etc.

Erosion Classes

The mapping of erosion is confined to five classes indicated by the use of numbers: 1—none to slight; 2—moderate; 3—moderately severe; 4—severe; and 5—very severe.

Physiographic Areas

The state has been divided into 13 physiographic areas, each of which has characteristics which distinguish it from the others, and each has been assigned a standard number.

Some of the more important factors used in determining the physiographic areas are soil development, climatic differences, geological material, general topography, and influence of vegetative cover.

The securing of physical information of the soil by a uniform method nad placing it on a 4 inches equal one mile aerial photograph facilitates the interpretation of land conditions so that every acre of land can be treated according to its needs and capabilities.

REFERENCE

U. S. D. A. Miscl. Pub. No. 352, *Soil Conservation Survey Handbook.*

Competition Between Alfalfa and Pecan Trees for Available Moisture

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Pecans and alfalfa are adapted to the same kind of soil,—one which is fertile, friable, and well drained.

Farmers often attempt to produce both alfalfa and pecans on the same area, thinking that the pecan trees do not occupy all of a field and that it is possible to secure additional revenue by planting the area between the trees to alfalfa. Many even go so far as to think that alfalfa, by improving the soil, will increase the pecan crop. Unfortunately, observation and experience show that both of these crops cannot be satisfactorily grown on the same area of land at the same time.

The pecan is a deep rooted tree. Alfalfa is a deep rooted perennial. Both are hardy and adapted to live through a short period of dry weather, because the deep penetration of the root system permits the plant to draw moisture from the lower layers of the soil when the moisture from the upper strata is exhausted. Since both are deep rooted plants, there is rather severe competition between them when an effort is made to grow both upon the same field. Neither will do so well as would be the case if they were in separate fields. Alfalfa is found to be much shorter and makes considerably less hay. Pecans produce fewer nuts and the nuts are smaller and apt to be poorly filled.

The harmful effect of alfalfa is particularly evident when planted in the young or developing pecan grove. There are many instances when alfalfa planted between young pecan trees has caused a serious dwarfing effect among the young trees. It is much better to plant some annual, more shallow rooted crop, such as corn, cotton, or any cultivated crop, than to plant alfalfa in the pecan grove or orchard.

It is a fallacy to think that pecan trees occupy only the portion of the orchard covered by the branches. The roots of the trees usually extend two to three times farther outward from the trunk than do the branches. Therefore the area underneath the ground is usually pretty well occupied by pecan tree roots if the trees are large, even though the trees may be spread sixty to one hundred feet apart. Since the soil is well occupied by the root system and at some time during every season moisture is deficient, manifestly nothing is gained by attempting to produce more plants or a combination of plant products than the available moisture in the soil is able to support. If the owner of the land is interested primarily in pecans, then he should plant the area in pecans and handle it in the best possible manner for their growth and production. This usually will involve cultivation and annual cover cropping with rye or vetch or some other adapted cover crop.

In areas where cultivated land may be washed away by overflow currents, probably the best method is to seed the area to some permanent grass or perhaps to rye grass and lespedeza. Any kind of a grass (except Bermuda) which will make a good cover and prevent current erosion will be satisfactory. (Bermuda grass should never be planted in a pecan grove.) The grove thus planted may be pastured or mowed. Pecan production will probably be less in a grove in such a case than if the area were cultivated and an annual cover crop of vetch grown.

If the owner of the land is primarily interested in the growing of alfalfa, then all pecan trees should be removed to eliminate the losses incident to competition between alfalfa and pecans.

Pecans alone or alfalfa alone will most certainly result in greater profit than an attempted combination of these two plants. Although adapted to the same type of soil and requiring the same soil conditions, they will not succeed well when planted in the same area.

Fertilizer in Relation to Oklahoma Agriculture

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Considerable comment has been made on the original fertility of Oklahoma soils when they were in the virgin state. We hae heard of the great expanse of tall grasses and the wonderful growth that occured before the land was brought under cultivation. These accounts have been used to impress upon us the high fertility level of our virgin soils. In reality not all soils that produced such luxuriant growth in their virgin state were as well supplied with plant nutrients as these accounts would lead one to believe. Not many soil areas in this state are blessed with a large potential supply of nutrients. In fact, few of our soils have such a supply. Many of the soil areas of the state never had a high level of fertility even under virgin conditions. They were fairly productive of native grasses because of the rapid turnover of available plant food; and, since erosion was controlled by the vegetation, the soil continued to produce. A glance at the data in Table 1 will show what I have just expressed. Figure 1 shows the soil areas listed in the table.

The native grasses are good feeds but they have limited nutrient value. Their content of such nutrients as phosphorus and calcium is not high compared with many cultivated crops;

TABLE 1—Fertility Data on Oklahoma Soils, by Areas.[1]

Soil Area	Total Nitrogen[2]	Total Phosphorus[2]	pH Value	Soil Reaction	Percent low Phosphorus[4]
1. Black waxy soils	4,001	904	7.05	Neutral	28.1
2. Alluvial soils	2,756	864	7.19	Neutral	10.6
3. Eastern prairie	2,712	561	6.00	Slight[3]	67.8
4. Central prairie	2,176	489	6.56	Slight[3]	40.0
5. Western prairie	2,072	598	7.33	Neutral	3.6
6. Northern Ozarks	1,954	444	5.81	Medium[3]	83.3
7. High Plains	1,709	735	7.80	Basic	0.0
8. Interior Coastal plains	1,718	534	6.61	Neutral	59.3
9. Southern Ozarks	1,484	442	6.37	Slight[3]	75.0
10. Central cross timbers	1,386	411	7.03	Neutral	54.1
11. Sand hills and sandy land	962	337	7.16	Neutral	24.7
12. Granite soils	965	320	7.04	Neutral	40.0
13. Southern cross timbers	796	231	7.13	Neutral	78.9

[1] Data from Soil Survey—H. J. Harper, Leader.
[2] Pounds per acre to a depth of 6⅔ inches.
[3] Indicates average acidity.
[4] Percent of the soils in the area which are low to very low in available phosphorus.

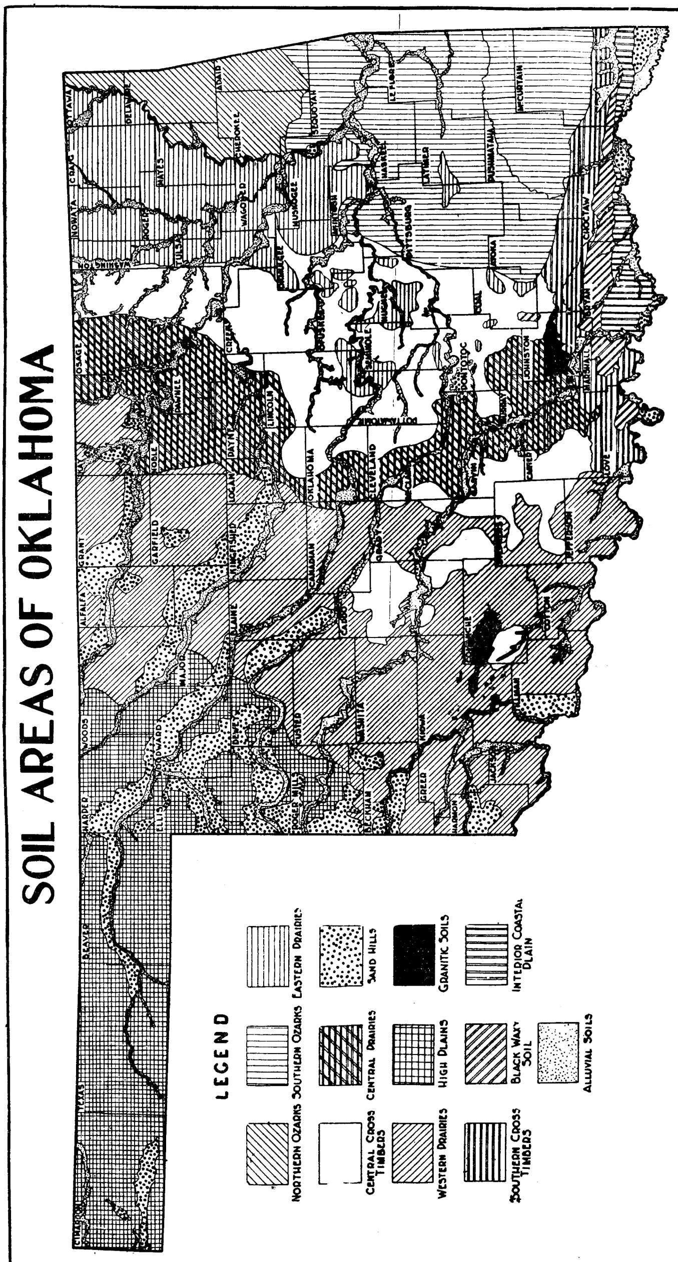
SOIL AREAS OF OKLAHOMA
LEGEND
NORTHERN OZARKS
SOUTHERN OZARKS
EASTERN PRAIRIES
CENTRAL CROSS TIMBERS
CENTRAL PRAIRIES
SAND HILLS
WESTERN PRAIRIES
HIGH PLAINS
GRANITIC SOILS
SOUTHERN CROSS TIMBERS
BLACK WAXY SOIL
INTERIOR COASTAL PLAIN
ALLUVIAL SOILS

Fig. 1.

whatever mechanical repair may be necessary—fertilizers to replenish their producing power. It is not too late to correct these conditions, but it may be too late in some cases for the owner to do it without outside help because of financial reasons. Poverty contributes nothing to the welfare of the soil, except more starvation.

We are carrying out tradition to the *N*th degree. We change crops, substituting those with lesser nutrient requirements until all cultivated crops fail and finally the land is "put back to pasture." To grow what? Only a little tickle grass and some other unpalatable plants which contain no nutrients to speak of for the support of animal life, let alone maintenance and growth. These areas must have some fertilizers if they are ever to be a factor in our agriculture and to pay taxes.

A survey of the use of commercial fertilizers in this state shows that the tonnage has been low. The average annual tonnage by five-year periods has been:

1931-35	3,588 tons
1936-40	4,303 tons
1941-45	11,048 tons

To increase crop yields, the yearly fertilizer tonnage should be much higher.

We have done little to help ailing pasture land. Land that has always been in pasture in areas where the rainfall is over 35 inches* needs consideration. These pastures could produce a better feed than is at present being produced. Legumes should be introduced, but to grow these legumes fertilizers are often necessary. To get results, a heavy rate of application is necessary. We need to realize, more than we have in the past, the value of a good pasture. The average farm pasture in eastern Oklahoma is not much more than an exercising ground. By fertilization we can increase the yield and nutrient content of species now present, and can greatly increase the pasture value through the introduction of suitable legumes. Legumes will not grow without a good supply of minerals in the soil; therefore the necessity for fertilizers on these soils. Legumes are good feed because they contain lots of nutrients—protein from the nitrogen they collect from the air, and minerals which they secure from the soil. A glimpse at some average analysis will suffice to show why they are good and why we have to fertilize the soil in order to get them to grow:

Average Percentage of:

	Nitrogen	Phosphorus	Potassium	Calcium
Legume Hay	1.2 to 2.3	.24	1.69	1.37
Prairie Hay	.5 to .6	.08	.5	.28

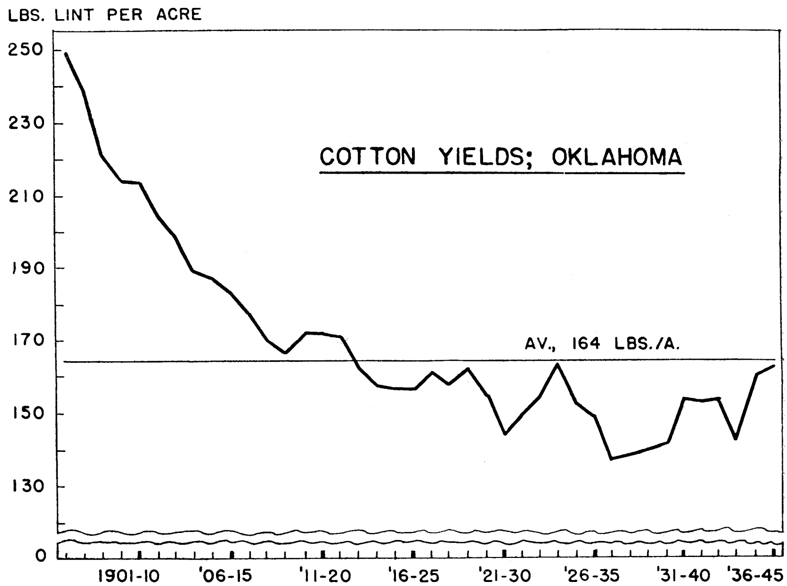

Fig. 2.—Ten-year Average Cotton Yields in Oklahoma, by Years.

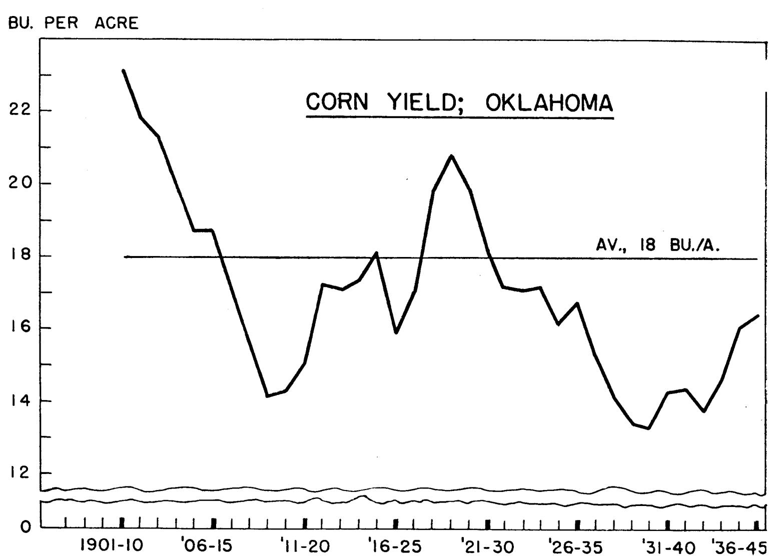

Fig. 3.—Ten-Year Average Corn Yields in Oklahoma, by Years.

and organic matter have disappeared. A large acreage has been abandoned from cultivation because of lack of fertility due to cropping and erosion. These acres will need—besides qualified men, and especially from certain soil areas. Of course there were many contributing factors, but soil fertility is no doubt of great importance. Strong, healthy men cannot be grown from products produced on poor soils. The health of the individual is reflected by the fertility of the soil on which his food is grown.

Finally, the soil is not dumb—it speaks a language we can understand if we only will. We need to learn the ABC's of the soil alphabet—and the sign language it expresses. The soil runs together, packs and crusts, stating, "Give me organic matter." It erodes and exclaims, "Tie me down." Water stands on it, and it crys, "Change my underclothes, and give me drainage." It rusts the cotton crop, and speaks for potash. It produces spindly stalks and asks for phosphorus. It slows down growth and yields only some spindly yellow plants, saying, "Oh, that I had some nitrogen."

"My sign language is complete, but how dumb are my listeners," the soil exclaims. "I wish they would do something while they can. I struggle for existence; I want to produce good crops; I want to live and let live but if I don't get help soon, I'll vanish and so will you. You can't get along without me. Give me fertilizers and proper care."

In considering our needs for nutrients it would be well to consider what we are now removing from our soils each year through cropping, as shown in Table 2. *These data do not include other sources of removal such as soil erosion.*

To supply the nutrients taken annually by only the crops listed in Table 2 would require approximately 443,000 tons of ammonium sulfate, 183,000 tons of superphosphate (20% P_2O_5), and 88,000 tons of muriate of potash (50% K_2O). In terms of a high grade commercial fertilizer containing 20 units of plant food per ton, it would require nearly 850,000 tons. Sooner or later we are going to realize this tremendous nutrient removal.

The soils are already giving us the "go sign" for fertilizer application in many areas, as I have already pointed out. The need could be further substantiated by the many tests which the Experiment Station has conducted in various sections of the state. Recently the Station has secured some very interesting and important data on the plowing under of nitrogen fertilizers, and it is safe to project that the use of nitrogen may become quite important on many soils, not only in eastern Oklahoma but in the major wheat area as well. The problem of the return of straw may be a matter of supplying nitrogen in this manner so as to facilitate decomposition and furnish humus for better moisture conditions and physical relationships.

The use of legumes in a soil fertility program as well as a livestock program calls for the use of more mineral fertilizers and lime. It has been estimated that 10,000,000 tons of limestone are needed in the state in order to correct soil acidity sufficiently to grow those legumes having high lime requirements and which are most valuable in adding nitrogen to the

TABLE 2—Plant Nutrients Removed from Soil Annually by Oklahoma crops.[1]

(Not including removal by other means, such as erosion,)

Crop	Av. Acres	Nitrogen (lbs.)	Phosphorus (lbs.)	Potassium (lbs.)
Wheat (grain only)	4,026,000	69,448,500	11,876,700	12,883,000
Corn (grain only)	1,903,000	28,107,310	4,776,530	5,347,430
Oats (grain only)	1,360,000	17,408,000	2,896,800	4,216,000
Sorghum (grain only)	760,000	8,519,600	1,170,400	1,406,000
Barley (grain only)	280,000	3,780,000	747,600	915,600
Sorghum (grown only for silage and forage)	1,119,000	28,758,300	3,950,070	36,658,440
Cotton (seed cotton)	2,012,000	16,324,880	6,217,080	7,887,040
Wild Hay	418,000	4,915,680	451,440	4,012,800
TOTAL	11,878,000	177,262,270	32,086,620	73,326,510

TABLE 3—Percent of Men Physically Disqualified by Selective Service; Oklahoma, by Soil Areas.[1]

Soil Area	Percent of Men Disqualified[2]
Northern Ozarks	31.0
Southern Ozarks	28.4
Southern Cross Timbers	31.0
Eastern Prairies	21.7
Central Cross Timbers	23.3
Central Prairies	21.3
High Plains and Western Prairies	19.8

[1] Due to overlapping within counties data could not be isolated for the other soil areas.
[2] Ages 18 to 25.

soil.* Many of these legumes also require the application of phosphate as well as lime to get the best results. Legumes increase crop yields and furnish a good protein and mineral feed for livestock. Their acreage should be greatly increased; but to accomplish this we will have to use fertilizers. It is pathetic to think that only about 1 acre in 20 now in cultivation is used for growing this important group of crops. Protein feed is at a premium and we should grow more legumes to provide that, if for no other purpose.

Recently I was furnished some important and enlightening data by the State Headquarters of the Selective Service. It is a well known fact that much of the population of this country was not physically fit for war service. Examine and consider the data given in Table 3. Note the high percentage of dis-hence the removal of these nutrients from the soil under virgin conditions is not as high as when cultivated crops are grown. Cultivated crops remove more nutrients from the soil; and as plant breeders increase the yielding ability of these crops the removal of nutrients becomes greater. Improved cultural practices in producing larger yields are also significant in this respect. These are all legitimate factors, but it is also legitimate and essential that the land operator consider what is taking place in the soil, and place in action some soil maintaining and building practices.

The accompanying charts (Figures 1 and 2) show what is happening to our yields of corn and cotton. Plant breeders and cultural practices are not able to stem the tide. These breeders and practices are holding up the yield as best they can, but it takes more. Data show that since the land in this state was brought under cultivation our soils have lost considerable fertility. About 36 percent of the original nitrogen

* Mimeographed report prepared by H. J. Harper (1943).

Effect of Dates and Depth of Tillage on Wheat Yields

By W. M. OSBORN
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The time and the method of tillage in the production of wheat was theoretically well and definitely established by scientists and actual wheat growers before the writer and most of those now engaged in such work were conscious of such problems. Experimental plots were established to prove the value of certain well defined practices. Men with fertile minds and vivid imaginations widely advertised the surest methods of production, with careful attention to the delivery of such advertisements into the hands of home seekers who sought cheap land. The results of such experiments did not substantiate the preconceived theories. Educators, research men, and growers became conscious of apparent mistakes and the startling lack of knowledge of the problems involved.

Soil moisture has been and is the No. 1 problem in most of the western wheat producing area in the United States. Maintenance of fertility has been important and its future importance increases. The preparation of a seed bed that will store and retain a maximum of the rainfall, control wind and water erosion, and permit profitable production is a concise statement of the wheat grower's primary objective.

Wheat growers with mechanical ingenuity, machinery manufacturers, soil scientists, and others have produced and put into use their conceptions of the tillage implements that were most effecient in the preparation of satisfactory seed beds. This deluge of equipment was usually designed to accomplish specific purposes on localized types of soil. Naturally, there has been an overlapping in the use of such equipment under widely varying soil and climatic conditions, and the various degrees of success attained have often led to confusion and contradiction.

The decision of when and how a field should be tilled may depend upon the moisture already in the soil and the subsequent loss of this moisture by weed growth, the possibilities of increased water storage by holding winter snows, or the retention of stubble necessary to prevent soil blowing. The protection of the soil by crop residues against such hazards has led to revolutionary cultural practices that necessarily involve a wide array of tillage implements.

Our modern harvest with the combine in the years of heavy production of straw brings up the question of the best methods of handling heavy crop residues. Shall we moldboard plow, list, disk, one-way, basin list, chisel, or burn the stubble? Naturally, the practice to be followed will be governed by the method or combination of methods best suited to the soil and climatic conditions, the equipment available, and an economic distribution of labor.

The effort to solve these problems has led, in recent years, to the establishment of extensive experiments in the wheat growing states. These experiments have been designed to throw some light and provide information on such practices as may prove to be the most suitable and valuable. It is impossible to cover all of the experimental information available in Oklahoma in this short paper and discussion. Emphasis on the data and results presented from the Southern Great Plains Field Station at Woodward and the U. S. Field Station at Lawton will stress the results from the timeliness of tillage rather than from the type of tillage used.

Woodward Results

At Woodward, 13- and 24-year results may be compared from early, midseason, and late preparation of seed beds (Table 1). In these comparisons the moldboard plow, the one-way, the disk harrow, the lister, and the basin lister have been used. In one additional experiment the wheat has been stubbled in.

The average yield of wheat for 13 years on ground that was moldboarded 8 inches deep early in the season was 17.4 bushels per acre. The same kind of mid-season preparation produced 2.1 bushels per acre less for the same period, and the loss on late plowing to the same depth was 6.5 bushels per acre.

Over a period of 24 years, 4-inch plowing early in the season produced an average yield of 20.3 bushels per acre, but the same kind of tillage late in the season produced only 10.9 bushels per acre. That is a loss of 9.4 bushels. Mid-season and late plowing produced average yields of 16.2 and 11.5 bushels per acre respectively for 13 years.

Where tillage was performed with the one-way to a depth of 8 inches for 13 years, the average yield on early tillage was only 0.3 bushels less than early plowing; but it was 1.9 bushels better than one-way midseason tillage and 4.3 bushels better than late one-waying.

For a period of 24 years, late one-way tillage produced 7.3 bushels per acre less than similar early season tillage. The differences between late moldboarding and the use of the one-way late in the season were very insignificant.

In the next comparison the only preparation of the seed bed was the disk harrow. When done early in the season and continued as needed previous to planting, the 13-year average yield of 16.9 bushels per acre is only 0.5 bushel less than early deep plowing. In fact, it was very slightly better than mid-season shallow plowing.

Where the crop had been stubbled in without any preparation, the average yield of 9.1 bushels was 7.8 bushels less than after disking. This method of production yielded less than any other method tested.

Wheat grown on early listed land for 13 years produced an average yield of 17.8 bushels per acre or 0.4 bushels more than early deep plowing. Where the listing was not done until mid-season, a loss of 1.7 bushels per acre was incurred.

Early basin listing for 13 years produced 1.1 bushels per acre less than ordinary listing. As compared with early deep plowing it was 0.7 bushel less. In a 24-year comparison, early basin listing yielded 1.0 bushel per acre less than early deep plowing, 3.0 bushels per acre less than early one-way tillage. Notwithstanding the great surge of popularity that basin listing received only a few short years ago, it produced the lowest average yield of the four methods of early preparation tested. Midseason and late tillage data for basin liting ar not available.

The 24-year averages presented in this discussion and in the table were obtained from fine sandy soil types. The 13-year averages were obtained from appreciably heavier sandy types of soil. Early seed bed preparation refers to early July tillage, mid-season tillage was done August 15, and late season preparation was performed in late September or early October.

Summary.—The data from the Woodward station emphasize the fact that there is but little difference in the yields obtained from the different methods of tillage employed. But, regardless of the method of tillage used, yields were decreased as the operations were delayed. On the appreciably heavier sandy types of soil where wheat was grown for 13 years, the average yield of all early methods of tillage, 17.2 bushels per acre, was 1.5 bushels greater than mid-season tillage and 5.0 bushels per acre more than the average for all late methods of tillage. The information presented warrants the assumption that the wheat grower in northwestern Oklahoma who does a good, workmanlike job of preparing a seedbed early in the season, regardless of the method used, stands to gain much more than the man who delays such work.

LAWTON RESULTS

The results from the Lawton station are confined to the production of wheat under continuous cropping on a heavy, tight soil designated as Kiowa Silty Clay Loam. Wind erosion is not too important or comparable with the sandy soils. Water erosion does occur rapidly and destructively. The annual average rainfall of 30.28 inches is frequently torrential and subject to erratic distribution. The results cover a period of 22 years, 1922-45, and seven methods of tillage: Late shallow plowing, 4 inches deep; early shallow plowing, 4 inches deep; early 8-inch plowing; early listing; disking as needed; disking at seeding time; and alternate summer fallow. Late shallow plowing was done during the latter half of September, and early tillage was performed as early in July as possible.

Late shallow plowing produced an average yield of 13.0 bushels per acre, which was 1.7 bushels per acre less than early plowing the same depth. Land plowed early to a depth of 8 inches averaged 15.8 bushels per acre, an increase of 2.8 bushels over late shallow plowing and 1.1 bushels over 4-inch plowing done early in the season.

The next comparison includes land that was prepared with the disk harrow or field cultivator or a combination of both implements, whichever appeared to be the most feasible and practical at the time the operation was required. The object has been to perform such operations with sufficient frequency to prevent weed growth and keep the surface soil receptive to rainfall. The 22-year average yield, 12 bushels per acre, is 3.8 bushels per acre less than on early deep plowing and 1.0 bushel less than on late shallow plowing. Yields in 9 of the 22 years were less than 10.0 bushels per acre.

In one other comparison, where the land has been disked at seeding time only, the 22-year average yield has been depressed to 8.9 bushels per acre. The annual yields were below 10 bushels per acre 15 times, and in 10 of 22 years they were approximately 5 bushels per acre or less.

In this continuous cropping experiment on different seed bed preparation, listing has always been done early in the season. From 1924 to 1938 inclusive, ordinary listing was practiced. Beginning with the 1939 crop, basin listing has been practiced to date. The average yield obtained for the 22 years of listing was 14.5 bushels per acre, only 0.2 bushel less than on early deep plowing. The average yield of basin listing for 7 years, 1939 to 1945, was 1.9 bushels per acre less than early deep plowing for the same period.

Wheat grown on alternate summer fallow produced the highest average yield of any method tested. However, the 20.1 bushel yield was only 4.3 bushels per acre more than continuous cropping on land that was plowed early and deep, and 5.4 bushels per acre better than early shallow plowing.

Summary.—On the heavy tight soils, as on the sandy soils, early tillage has paid a greater profit than late tillage. The differences in yield between plowing and listing have been negligible, but the yields were definitely depressed by disking only.

Conclusion

The economic employment of tillage machinery becomes an important factor. The principal and most profitable objective is to perform the operations, whatever they are, early in the season.

TABLE 1.—Wheat Yields on Different Methods of Tillage at Woodward, Oklahoma, 1922-45.

Tillage	Number of Plots	Average Yield (bu. per acre)
Field B; 13-year average 1932-44		
Early Preparation		
Plow 8 in.	7 to 10	17.4
One-way 8 in.	4 to 11	17.1
Disk	2	16.9
Basin List*	2 to 3	16.7
List	2	17.8
Average		17.2
Midseason Preparation (August 15)		
Plow 8 in.	2	15.3
Plow 4 in.	2	16.2
One-way 4 in.	2	15.2
List	2	16.1
Average		15.7
Late Preparation		
Plow 4 in.	3	11.5
One-way 4 in.	3	12.8
Average		12.2
No Preparation		
Stubble in	3	9.1
Field A; 24-year average 1922-45		
Early Preparation		
Plow 4 in.	1	20.3
Plow 8 in.	1	18.3
One-way 8 in.	1	18.6
Basin List	1	17.3
Average	--	18.6
Late Preparation		
Plow 4 in.	1	10.9
One-way 4 in.	1	11.3
Average		11.1

* Ordinary lister used in years prior to 1937.

TABLE 2.—Average Yield of Wheat Continuously Cropped on Different Methods of Seedbed Preparation at Lawton, Okla.; 22 Years, 1924-1945.

Method of Seedbed Preparation	Yield (Bushels per Acre)
Late plowing, shallow (4 in.)	13.0
Early plowing, shallow (4 in.)	14.7
Early plowing, deep (8 in.)	15.8
Early listing	14.5
Disking as needed	12.0
Disking at seeding time	8.9
Alternate summer fallow	20.1

Moisture Conservation and Wheat Production

By HARLEY A. DANIEL
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Soil Conservation Service and Oklahoma Agricultural Experiment Station.

Different methods of moisture conservation for wheat production are being studied on the Wheatland Conservation Experiment Station in Alfalfa County near Cherokee, Okla. This station is part of a cooperative research project of the Soil Conservation Service and the Oklahoma Agricultural Experiment Station. The station occupies 320 acres of rolling, deep, permeable soil and is typical of a large amount of the wheat land of Oklahoma and Kansas. Although it was established in July, 1939, this experimental area was not completed until the beginning of the 1941-42 crop season.

Experimental Procedure

The study is designed to compare the effectiveness of plowing, listing, basin listing and leaving a stubble mulch for the conservation of moisture and wheat production. The experiments are being conducted on 48 plots and 9 water-sheds. The plots and water-sheds are equipped for measuring rainfall and runoff. In addition, crop yields (grain and straw) are determined on these areas.

The effectiveness of different methods of continual tillage is studied on the plots. The different tillage treatments or main plots are divided into sub-plots, two of which are unterraced and the others terraced. The respective plot treatments were assigned by random selection and each treatment is triplicated. One-half of the unterraced plots are cultivated up and down the slope and the other on the contour, while the terraced areas are cultivated on the contour. Each plot was designed and located according to land slope and configuration and varies in size from three-fourths to over 4.3 acres. They are located on uniform soil, but the land slope ranges from 1.25 to 5.00 percent. Two-thirds of these plots are on slopes of less than 3.00 percent. The vertical interval between the terraces on this slope is 3 feet and that for the plots on the steeper slopes 4 feet. On the unterraced plots the run-off water is taken to the flume by converging earth dykes. These dykes have a grade of 0.3 feet per 100 feet. All terraces are built approximately level. One-half of the terraced plots have closed end terraces and the other has one end open. No run-off records are recorded for the series with the closed ends, but a flume is located in the channel at the open end of the other terraces and the run-off is measured at this point.

The effect of a rotation of tillage is being studied on 9 small natural watersheds. They are divided into three groups according to size, with 3 watersheds to the group. The first group contains approximately 2 acres each, the second 4.5 acres and the third 8 acres. The watersheds are all cultivated and seeded to wheat continuously on the contour, but the method of seedbed preparation includes one-way plowing, basin listing, and leaving a stubble mulch. These tillage methods are rotated on each watershed annually, with all treatments appearing each year in each group.

RESULTS

Effectiveness of the Different Methods of Tillage.

The amount of runoff and crop yields from the plots (Table 1) have been recorded annually during the last four years. To date the highest amount of runoff occurred on the plowed land and the lowest on the basin listed. The runoff from the stubble mulch and listed areas was also slightly less than that from the plowed land. The crop yields, however, were considerably lower on the stubble mulch land. These plots

TABLE 1.—Effect of Different Methods of Continuous Tillage on Runoff and Crop Yields on the Plots at Cherokee, Okla.[1]

Method of Tillage	Yield of Wheat per Acre				Percent Runoff	
	1945		Average[2]			
	Grain Bu.	Straw Bu.	Grain Bu.	Straw Bu.	1945	Average[2]
Stubble mulch	18.0	1.44	14.4	1.26	13.1	10.7
Plowed	26.3	1.90	17.8	1.59	15.1	11.0
Listed	26.2	1.88	17.8	1.51	13.2	10.5
Basin listed	26.2	1.87	17.4	1.50	10.5	9.7

[1] For crop year (July 1 to June 30).
[2] Four years, 1942-45. Precipitation 1945, 34.35 inches; average 26.2 inches.

TABLE 2.—Effect of Different Methods of Rotated Tillage on Runoff and Crop Yields on the Watersheds at Cherokee, Okla.[1]

Method of Tillage	Yield of Wheat per Acre				Percent Runoff	
	1945		Average[2]			
	Grain Bu.	Straw Tons	Grain Bu.	Straw Tons	1945	Average[3]
Basin listed	28.3	2.07	17.0	1.47	8.2	8.2
One-way plowed	27.1	1.73	18.2	1.52	16.5	11.1
Stubble mulch	23.8	1.62	15.8	1.30	15.2	9.9

[1] For crop year (July 1 to June 30).
[2] Four years, 1942-45.
[3] Three years, 1943-45.

contained a heavy growth of cheat and weeds in 1945 and 12 percent of the wheat plants were also attacked by an infestation of foot-rot. The tillage methods are rotated annually on the watersheds. These results (Table 2) show that the highest average yield to date has been produced on the one-way plowed land.

Effect of Direction of Cultivation and Terraces.

The effect of direction of cultivation and level terraces on the conservation of runoff water and crop yields (Table 3) are also being measured. Contour cultivation reduced runoff water loss an average of 19 percent. Even though this is an outstanding saving of moisture, observations on the watersheds, with land slopes of 1.5 to 3.0 percent, show that contour cultivation alone is not sufficient to control erosion. During the same period, however, a combination of terraces and contour cultivation conserved 40 percent more water than land cultivated with the slope.

Although the rainfall for the 1945 crop year was well distributed and over 8.5 inches above normal, terraces and contour cultivation greatly reduced runoff and also increased crop yields. The yield of wheat per acre was increased 1.3 bushels in 1945 and 2.0 bushels in 1944 by terraces and contour cultivation.

COMBINATION OF PRACTICES NEEDED

These results, as well as those obtained at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma, show that many combinations of conservation practices are necessary to control erosion, conserve rainfall and maintain fertility. Lands differ in soil characteristics, slope and degree of erosion. They also differ in capability and adaptability. To get the most from each piece of land year after year, it must be used correctly. That is why sound land use heads the list of factors

TABLE 3.—Effect of Direction of Cultivation and Level Terraces on Runoff Water and Crop Yields at Cherokee, Okla.[1]

Direction of Cultivation	Wheat Yield (bu. per Acre)		Runoff Water (percent)[2]			
	1945	Average	1945	Difference	Average	Difference
With slope	23.2	16.5	17.4		13.1	
Contour	24.6	17.3	12.7	27	10.6	19
Terrace-Contour	24.5	16.6	9.1	49	7.8	40

[1] For crop year (July 1 to June 30).

[2] Four years, 1942-45, total inches of precipitation 30.03, 20.28, 22.33 and 34.35, respectively. The average annual rainfall compiled by the Weather Bureau in Cherokee since 1915 is 25.68 inches.

involved in a somplete soil conservation program. Once the land has been properly classified, there remains the important problem of selecting the crop it will grow to the best advantage and determining what soil conservation and improvement practices are necessary to keep it producing. Soil conservation research findings on crop and pasture lands of Oklahoma show that by this process of wise land use and practical conservation farming, severe erosion can be controlled, runoff materially reduced and crop and food production maintained at about one-third higher level.

Grass in Crop Rotations

By V. C. HUBBARD
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In a report of the subcommittee on grass-crop rotations presented at a meeting of the Southern Great Plains Revegetation and Stubble Mulch Committee held at Amarillo on January 10, 11, and 12, 1944, it was ascertained from reports of interested workers in eight states that some phase of grass-crop rotation work was being carried on in nearly every state of the Great Plains. At some stations work of this nature has been under way since 1906. Of course, grass-crop rotations have been carried on for many years in states outside of the Great Plains, and in many foreign countries such as South Africa, Great Britain, Sweden, Germany, USSR, Africa, India and Australia

The early rotations in the Plains were mostly conventional in that alfalfa and adapted tame grasses were used and the tenure of grass was relatively short, often only one to three years. This is definitely too short, partcularly for native grasses in the drier Plains areas.

Deferred rotations in which native prairie grasses are left in for four to twelve years or longer are relatively new, probably dating back not earlier than 1935.

The general subjects upon which it is hoped that such rotations will furnish information include the following:

1. Whether land in cultivated crops for many years will be improved by introducing grass into a rotation with crops.

2. The effect of periods of one to twelve years of grass on the production of subsequent field crops.

3. The relative effect of various grasses on the soil when they are grown in pure and in mixed stands with and without legumes.

4. The effect of grass on the structure of the soil, particularly in regard to resistance to wind and water erosion, change in organic matter content, physical conditions, water absorption capacity, pH value, etc.

5. The possibility of obtaining stands of grass annually or periodically in rotations.

6. The stablizing effect of various grasses in pure and mixed stands on a variety of soil types.

7. Which grasses can be readily killed by cultivation after they have become established.

8. How long effects of grass will presist after the sod of various ages is plowed.

9. Whether flat grass terraces will control erosion on fairly sharp slopes.

10. The annual and average cured forage yields of pure and mixed stands of grass of various ages when grown in rotations with crops.

A deferred-grass rotation involves establishing a stand of grass (usually a native grass) and leaving the land in grass long enough to permit it to make maximum root growth and come into full production of pasture, seed or forage. The cropped portions of a farm would probably be planted to such cash crops as wheat, sorghum or cotton, depending on the area of production in the Southern Great Plains. These crops might be continuous or they might rotate with each other until such time as all or a portion of the grass was plowed up and replaced with cash crops, at which time all or a portion of the cropped land might be reseeded to grass.

Due largely to the time element involved and variability of climatic conditions, reliable evaluation of such rotations is slow; and, as may be readily understood, preliminary data may not always be a true index of the long time value of such rotations.

Early data, comments and observations gleaned from workers in the Great Plains who have reported on grass-crop rotations are summarized briefly as follows:

A. It has been relatively easy to obtain stands of native grass if good seed and recommended seeding practices are followed. In the grass-crop rotations at Woodward there have been no failures and only one poor stand in the past six years.

B. First year stands are usually weedy enough to justify mowing one or more times to reduce setting of weed seed. Good stands are usually fairly free of weeds by the second year. In about three to four years, seeded stands of native grass may normally be expected to equal or exceed those of good native pastures. Annual yields from 5-year old seedings in field C at Woodward indicate that it may take five years or longer for the slower growing species to come into full forage production.

C. The rate of development of roots varies appreciably in different species. It probably requires three to five years or longer, depending on location and climatic conditons, for the root systems of the common native grasses to develop fully. Stevenson and White in 1941 concluded from observations of brome grass, crested wheat grass and slender wheatgrass that the old and tough roots were more efficient in promoting good soil structure than the slender easily decomposed roots. In three to four years, brome grass and crested wheatgrass produced about twice as much root fibre of about twice the tensile strength of that of slender wheatgrass. When plowed, sods of the two former grasses formed unbroken slices, whereas that of slender wheatgrass crumbled readily. With all three grasses about 44 percent of the roots occured in the top 3 inches of the soil and 88 percent in the first foot.

D. Detailed soil samples taken of 1 to 5-year (1940-45) old grass sod and from continuously cropped land for organic analysis have shown very little change to date and Dr. L. T. Alexander of the Division of Soils, Fertilizers and Irrigation, Beltsville, Maryland, writes, "There are no differences in organic carbon or nitrogen between the plots sampled in 1940 and in any later year. This is true of plots coming out of and going into grass."

Visual observations, however, indicate that 3-year or older native grass plowed under leaves the land definitely more resistant to water erosion than continuously cropped land.

Several workers in the Great Plains have stated that the plowed grass land will not necessarily make soil drifting easier to control. Under some conditions sod land is more susceptible to wind erosion for the first few years after breaking than is land continuously cropped to small grains.

Wet sieve analysis of four grass plots (each a different species or mixture) and adjoining wheat plots at Woodward, made by Dr. L. B. Olmstead, Soil Physicist of the Division of Soils, Fertilizers and Irrigation, at Manhattan, Kansas, might aid in explaining the above statement n that the analysis indicated the samples from the 4-year-old grass plots had more fine material than those from wheat land. These preliminary data further seem to indicate that samples from grass land, particularly the upper six inches, showed more resistance to breaking down in wet sieving than soil from plots continuously cropped to wheat, perhaps explaining partially the added ability of grass land to absorb moisture and to resist water erosion.

Relative to the wet sieve analysis, Dr. Olmstead writes, "It seems quite clear that the grass plots have more water-stable aggregates than the wheat plots."

E. The relative production of grass species varies appreciably as is evidenced by the following 3-year (1942-44) average yields of cured forage obtained from the grass-crop rotations in field B at Woodward: *E. curvula,* 5748 pounds; grass-legume mixture, 2662 pounds; *A. smithii,* 2385 pounds; and native-grass mixture, 1329 pounds per acre.

Harry M. Elwell, Soil Conservation Service, Guthrie, Oklahoma, gives a 5-year average yield for *E. curvula* of 6854 pounds per acre, indicating that grass yields will vary greatly from one locality to another just as grain or row crops do.

Undoubtedly grass will yield better on good land than on poor. Well established new stands of a given species or mixture of species will generally yield more than comparable old stands.

Some species take appreciably longer than others to reach maximum production. For example, at Woodward 20 grass plots, most of them seeded in 1940 and composed primarily of side oats grama and blue grama, produced the following cured forage yields:

Year	No. Plots Involved	Average Yield per acre (lbs).
1942	20	411
1943	18	691
1944	18	777
1945	18	1000

In contrast, weeping love grass (Ecv) seeded in 1941 in field B at Woodward made its highest yields in 1942. Since then, yields have fallen off slightly each year though in 1945 (the fifth year) it still averaged nearly two tons cured forage per acre.

Western wheatgrass (Asm) also seeded in 1941 in field B made its highest forage yields in 1944 and fell off slightly in 1945 the fifth year.

F. It is generally conceded that grass will reduce water erosion and will improve the structure of cropped soils, but whether or not grass builds up fertility is questioned. Dr. B. T. Shaw says, "It is rather difficult to see how a grass crop if harvested for hay can bring about an increase in fertility as it is generally observed that grass is one of the first crops to respond to fertilization. Legumes usually add nitrogen to the soil but also cause depletion of many other plant nutrients."

R. Bradfield states, "Few forage crops can be soil improving and not soil exhausting. Forage species may improve the soil in respect to organic matter, nitrogen or soil structure, but will normally lower or deplete mineral nutrients. It is only in soils where these elements are not brought below the optimum level where the beneficial effect on soil conditions outweight such nutrient depletion that the grass can be considered as soil improving."

In general grass might better be thought of as a soil saving crop since erosion is appreciably less from grass land than from cultivated land.

G. The returns from grass or yields of grass are normally lower than the return or yields of crops as is evident from the following data from field C at Woodward, Oklahoma:

Crop	No. years	No. plots	Average Yield, Pounds per acre
Native grass mixture	3* (1942-44)	18	626
Wheat grain	5 (1940-44)	21	1122
Kafir grain	5 (1940-44)	5	1242
Kafir (fodder and grain)	5 (1940-44)	5	5292

* Grass seeded mostly in 1940 and no yields taken in 1941.

H. O. R. Mathews, J. F. Brandon, D. W. Robertson and A. L. Hallsted report that the yields of small grains immediately following the breaking of sod in the Great Plains are generally low, probably largely due to a depletion of soil moisture. At Woodward where sod has been plowed in January, providing 8 to 9 months of fallow, wheat yields have been intermediate, i.e., better than continuous wheat, but not as good as wheat after fallow. Wheat after wheat on land that has been in grass, has yielded similar to wheat on continuously cropped land. A. L. Hallsted of Hays, Kansas, suggests that "probably a sorghum row crop would follow immedately after sod better than small grains."

I. Most grasses such as blue and side-oats grama, Buffalo, weeping and love grasses and probably most summer growing grasses, in solid or in mixed stands, will kill readily when the sod is broken for winter cereals. However, winter growing grasses such as Western wheat may volunteer and cause some competition if plowed in the spring for a winter wheat crop. Plowing such winter grasses under in January or February and cultivating to prevent further growth until planting time for either sorghums or wheat should prevent appreciable volunteer growth.

Progress in Corn Improvement

By JAMES S. BROOKS
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ABSTRACT*

The corn improvement program of the Oklahoma Agricultural Experiment Station is aimed at testing available hybrids to determine their adaptation to Oklahoma conditions and at breeding hybrids more nearly adapted than any now available.

Adaptation is a matter of degree; a *perfectly* adapted hybrid corn is a practical impossibility. Factors being given consideration in breeding hybrid strains for Oklahoma, in addition to ability to produce a good yield of good quality corn, include resistance to excessive rainfall, drought, hot dry winds, chinch bug attack, Southwestern corn borer attack, corn ear worm damage, corn smut, stalk rots, and ear rots.

* Dr. Brooks' talk was concerned chiefly with 1945 results of the Oklahoma Corn Performance Tests. These are reported in Okla. Agri. Exp. Sta. Bul. No. B-292.

Progress in Sorghum Improvement

By JOHN B. SEIGLINGER
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in Charge of Sorghum Improvement Work
for Oklahoma

To tell of the progress in sorghum improvement I shall outline what we are attempting to do in sorghum improvement or breeding, and indicate what has been accomplished.

Because of the limitations of travel during the war and realizing that one person can be at only one place at any specified time, sorghum improvement in Oklahoma has been speciconfined in location to Stillwater and Woodward. Even when the work was limited to these two places there have been many times when I should have been at the place where I was not.

Most of you know that new varieties or even superior selections do not just happen, nor are they plucked in number from thin air as are rabbits or full-blooming plants from a magician's hat. Improvement of crop plants takes planning, time, work—and luck.

Progress in crop improvement generally starts when the problem is recognized, and some of our improvement work with sorghums has only reached the stage where we realize something should be done to remedy a condition. Much of the so-called improvement in which progress has allegedly been made is based on research and findings of men working in other states or even other countries. In attempting to improve sorghums we use any likely ideas or materials available, irrespective of where or by whom they were originated or propagated. I certainly do not wish to imply that the progress we may have made and expect to make is peculiar to my work, as sorghum breeders are all using facts established by others, and using breeding material from many sources.

Grain Sorghums

Starting with grain sorghums, the desires of the growers are recognized by developing varieties suitable for harvesting with the combine harvester. At present several selections of Dwarf kafir for machine harvesting are ready for increase and wider trial. The best appearing Dwarf kafir has been 16 years in development (the original cross was made in 1929) and has been satisfactory in yield and appearance at both Stillwater and Woodward. Another selection from this cross appeared to be well adapted to Woodward conditions more than six years ago, but when it was grown at Stillwater and Lawton under severe disease infestations it failed to stand up and it was necessary to select a line apparently more resistant to the charcoal disease. While the Dwarf kafir as developed appears to be a good combine variety, we are working with many other lines of Dwarf kafir, some of which may prove better than the variety to be released. We are also still working for a better combine milo.

One of the objectives in our sorghum breeding program was to develop a non-bitter seeded darso. Apparently this end should be accomplished by either a white or yellow-seeded variety of darso. Quite a number of white and yellow-seeded darsos have been obtained by crossing darso with white-seeded kafir, or later by crossing white-seeded darso. Kafir segregates back to darso. This procedure has worked out according to theory, but it has been found that in the darso area of Oklahoma the white- and yellow-seeded varieties have been so badly discolored by weathering that the original brown-seeded variety is brighter and more attractive. This severe weathering has occurred in 4 of the 5 years, 1941 to 1945, at Stillwater. For this same period weather discoloration has been bad only one year at Woodward. The progress made in developing a non-bitter seeded darso resolves into a new problem of possible resistance to weather discoloration. That problem is now recognized and two possible solutions are under way to remedy the condition. While this weather and fungi discoloration has delayed the release of non-bitter seeded darsos, the same problem is present in milos for Central Oklahoma and must be considered in their breeding and development.

To keep abreast of other states, we have started to develop grain sorghums with the so-called waxy endosperm for possible industrial uses. The needs in waxy varieties seem to be for types suitable for harvesting with combine, also grain without spotting and with a very thin mesocarp. The waxy material will be in third generation in 1946. Selections are made and grown at both Stillwater and Woodward.

Varieties of sorghums for harvesting with the combine should have certain characters which are often difficult to obtain in the right degree in one plant. The combine variety must be dwarf enough to harvest with an ordinary combine; also, a short plant will be less inclined to blow down or "lodge". It should be of vigorous growth to insure a yield comparable with standard varieties. The combine variety must not shatter but must be threshable. When the combine sorghums were confined to the milo area, it was sufficient that they mature by frost and stand in the field until harvested. The freeze which stopped growth also insured rapid drying or curing of the grain. With the expansion of combine sorghums into the pest (insect and disease) dominated district, harvesting difficulties are certain. The sorghums will have to be planted earlier to get well started before the bugs, and this will throw their ripening in late summer (during September). Harvesting will be done before freezing weather and there will be the problem of too much moisture in the grain. In the southwestern part of the state, I understand the combined grain is piled on the ground and soon dries sufficiently to be bulked. Artificial drying is an answer if a drier is available. One possibility of meeting the damp grain problem is from the breeding angle. For the last two years I have noticed that in some sorghum heads the center stem ripens and dries with the grain. The drying of the stem may extend only an inch or two below the head, the main part of the stalk remaining green and alive. This condition seems too good to be true; but I understand other sorghum breeders have observed this combination of ripe head and green, live, standing stalk, so we have another factor to incorporate in combine sorghums for their eastern extension.

Forage Sorghums

Improvement of forage sorghums has been directed to obtain types of different maturities, with a more palatable seed, better standing ability, and better leaf retention. Crosses of African millet, Sumac, Collier, and Leoti sorgos have been made with white- and yellow-seeded sorghums for combinations with different maturities and with yellow or white seed. Sumac sorgo contributes standing ability to its crosses, while crosses of Collier or Leoti give segregates which retain their leaves better than the present crop of forage sorghums. These forage sorghum crosses are in the second to fifth generations and naturally require further observation and selection.

Progress has been made by increasing and making available for growers seed of Sumac No. 1712 and African Millet.

Sirup Sorghums

Progress in the improvement of sirup sorghums is in the stage of learning how the varieties may or should be improved. During the last three years, 1943-45, we have made sirup from eight or more of the common sirup sorghum varieties. In this period varieties with different maturing dates have been tried and their yield and quality of sirup and ease of making sirup have been studied. It was observed that tillering is an undesirable character for a sirup sorghum but desirable for a forage variety. Collier sorgo, while one of the sweetest sorghums and carrying a high percentage of sugar, has too high a ratio of sucrose to other (reducing) sugars and it is difficult to make good sirup from this variety. In spite of not knowing many of the answers, sorgo crosses have been and are being made to obtain better sirup sorgos. Several selections of these crosses will be tested for sirup making in 1946.

Broom Corn

Improvement of broomcorn has been to obtain a brush which will not weather stain, to eliminate or lessen the hardiness of the glumes and fibers, and to obtain heads generally free of center stems. Crosses have been made to accomplish these improvements and the progress made in each instance has been to obtain parents for final combinations. By crossing broomcorn and Leoti sorgo, fair broomcorn types have been obtained which do not stain red; however, they do stain brown, but this color is not so objectionable as red. Also, one selection from the broomcorn-Leoti sorgo cross appears to be genetically free of center stems, but in this case the brush often becomes crinkly when heading is difficult. Crossing broomcorn and a broom kaoliang produced segregates with smoother glumes than regular broomcorn but these selections must be back crossed to broomcorn for satisfactory brush.

Insect and Disease Resistance

When working for a specific improvement there is the additional requirement that the plant be resistant to insect and disease damage. Each of these requirements is a full-time problem and neither has been solved. It is apparent that there are degrees of resistance to chinch bug damage in sorghums, but at present the method of determining resistance is to expose the plants to bug attack and watch the results. As yet no indicator of chinch bug resistance has been discovered other than chinch bugs. For the last five years, our station plant pathologists have been noting and studying the occurrence of charcoal rot, or lodging disease, in the sorghum nurseries (of 150 to 180 varieties) at both Woodward and Perkins and under two conditions of stand at each place. There have been definite indications that resistance to the charcoal disease is genetic, but at the same time it is influenced by seasonal or environmental conditions. Of the many varieties of sorghums grown in the two nurseries since 1941, a few varieties have been free of charcoal disease. It is hoped that these varieties may be resistant to the disease and that this resistance can be transferred by crossing to the commercially grown sorghums.

A Year-'round Pasture Program

By HI W. STATEN
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Every farmer or rancher knows that the ideal feed for livestock is fresh, lush green grass and legumes in either permanent or supplementary pastures. The closer we can come to duplicating spring pasture conditions the year 'round, the better our cows will do at the milk pail or in pounds of beef and the larger the margin between feed costs and take-home profits. Such amazing results are being accomplished in various sections of the country that today virtually all states do not speak of just permanent pastures and a grazing season from May to October.

Once upon a time we in Oklahoma generally thought pasture in terms of native or so-called permanent pastures. That was only natural because the native pasture on most farms was the only pasture cows had access to throughout the growing season. Today, sole reliance upon native pasture, however improved, is rapidly vanishing. We now think of pastures in terms of new grassland crops and practices upon which a new and more efficient livestock industry can be built. We are thinking of pastures today in terms of grass farming. Grass farming has three main objectives: (1) the production of many times more pasture, because we realize the cow of today needs it and is not getting it; (2) good pasture, either native or tame, as the cheapest feed one can give to livestock; and (3) grass farming as a sane and safe land-use policy.

Less than 50 years ago the broad prairies of Oklahoma were covered with a dense growth of native grasses. During the past four to five decades we have plowed up practically all the plowable pasture land in Oklahoma and planted it to cotton, corn, wheat, sorghums, and other clean-cultivated crops. In general, the native pastures now existing on farms in Oklahoma are crowded to the woodlands, rocky slopes, and low fertility soil areas. These pastures are now badly overgrazed, weedy, and seriously eroded. It is difficult to believe that the rich climax grass species could have been so badly misused in this short period.

The position which pastures occupy in the agriculture of Oklahoma is changing as our state grows older. In the pioneer stage when there was an abundance of land, much of it was not utilized and pastures existed as an open range without regard to the quality of land producing that pasture. As the state became more settled and divided into farms, each operator was confronted with the necessity of deciding whether the various acres within his farm should be regarded as arable land or pasture and woodland. These judgements are always exercised, sometimes well and sometimes badly. As time passed and new generations came, much of the best land was planted to clean-cultivated crops and the process of soil depletion began. Sometimes management revealed a very complete regard for the factor of depletion, but more often crops were harvested and fed or sold without regard for the maintenance of the productivity of the land. Thus, year after year, yields of our cultivated acres have declined and now we find in the state of Oklahoma approximately 2½ million acres of our onetime fertile soil have been worn out and are in the stage of abandonment. Three to four million additional acres are in a state of dangerous submarginal condition. One county in central Oklahoma twenty years ago produced forty thousand bales of cotton annually but now produces only seven to eight thousand bales.

Now, it is hoped, we have come to the sane position in our thinking that the cost of soil fertility losses and declining yields are sufficiently great that we should conclude our interest lies in using more of our land for pasture. The present trends of the thinking in Oklahoma are toward a better land use, which, of course, must include soil fertility, erosion control, and more and better pastures.

A year-'round pasture program for Oklahoma is no dreamed-of Utopia which is impossible to attain. Many farmers, particularly in the central and eastern sections of Oklahoma, have accepted and adopted the "year-'round pasture" slogan and have actually put it into practice. Several large ranchers in northeastern and eastern Oklahoma have established a program of pasture development which will give them a maximum of green lush pasture days through the calendar year.

In planning a year-'round pasture schedule to provide the maximum low-cost forage, it is very essential that thought be given to the section of the country and the crops adapted to that section. Oklahoma is widely variable from east to west. Many pasture crops suited to central and eastern Oklahoma cannot be used in the western sections. This is particularly true of many of the pasture legumes and ryegrass.

Schedules of adapted pasture plants for eastern, central, and western Oklahoma have been worked out and are presented in Okla. Exp. Sta. Cir. C-116. These schedules and the accompanying explanation give suggestions for developing a pasture program which will provide maximum grazing throughout the year. No one farm will use all the crops listed, but the calendars picture the grazing season of the crop year so that any farmer may select the combinations which most nearly meet his conditions and needs.

Results of Sagebrush Control Studies at Woodward, Okla.

By D. A. SAVAGE

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TIME TO MOW

June is the ideal time to mow sagebrush for best control of brush and maximum improvement of grass, according to the results of extensive date-of-mowing tests conducted at the U. S. Southern Great Plains Field Station, Woodward, Okla., since 1937. June is the optimum month for control because the sagebrush roots contain less stored food at that time than any other season in the year, as shown by the results of comprehensive chemical analyses made through a five-year period by Dr. J. E. Webster, Department of Agricultural Chemistry Research, Oklahoma Agricultral Experiment Station. The mowing period may be extended, however, to include the latter part of May and the forepart of July with satisfactory results. Mowing at other times in the year reduces the vigor of the brush to some extent but eliminates very few of the plants.

ADVANTAGES OF MOWING BRUSH

The Woodward Station tests showed that mowing in June for two successive years, when combined with deferred grazing during the growing season, has the following distinct advantages:

1. It eradicates most of the brush.

2. Controls many other weeds.

3. Greatly reduces the vigor of the surviving brush and makes it more palatable as winter browse.

4. Doubles the stand, vigor, and production of grass.

5. Reduces grazing pressure on individual grasses by making all plants in a pasture available to grazing.

6. Increases the carrying capacity of a pasture to the extent of 80.8 percent, the actual increase being from 99 to 179 yearlings per section.

7. Increases gain per head of yearling steers by a margin of 16.3 percent. The average gain was 356.6 pounds per head on the mowed pastures as compared with 306.6 on nonmowed areas.

8. Improves the feeder grade of cattle produced.

9. And more than doubles the beef production per acre, the actual increase being from 48.2 to 98.6 pounds per acre.

DEFER GRAZING

It is extremely important to defer grazing—exclude livestock from a pasture—from June to September of the mowed years. This protection enables the grass to recover, develop a deeper and more extensive root system, and compete to better advantage with the weakened sagebrush. All of the mowed brush should be left on the land to provide a protective mulch for natural reseeding. The cut brush soon deteriorates and does not interfere with the second mowing.

MOWING EQUIPMENT TO USE

Most any heavy duty power take off mower, when properly equipped, can be used satisfactorily in mowing heavy brush. The operation merely requires a series of special attachments on ordinary heavily-constructed power mowers. All of the necessary attachments are manufactured by most machine companies. Rubber-tired tractors have been used in heavy brush without evidence of damage to the rubber.

First Mowing of Heavy Brush:

For the first mowing of heavy brush, use a five-foot cutter bar equipped with (1) a complete set of snub-nosed pea guards having extra rear bracing and square bolt holes, (2) heavy under-serrated sections (they are about one-sixteenth of an inch thicker than ordinary sections), and (3) a double set of hold-down clips (one less than twice as many as are ordinarily supplied with a regular mower bar). Mow in low gear the first time to obtain maximum sickle speed, setting the mower to cut as close to the ground as possible. Insert an extra gear in the mower or power takeoff, if necessary, to obtain high sickle speed. Keep sickles sharp and all mowing equipment in snug working order at all times.

Second Mowing of Heavy Brush:

For the second mowing of heavy brush or the first mowing of light brush, use a six-foot cutter bar equipped with (1) a set of heavy pointed rock guards having extra rear bracing and square bolt holes, (2) heavy under-serrated section, and (3) a double set of hold-down clips. The snub-nosed guards will handle heavier brush than the rock guards, but the latter will do a cleaner job and should be used if the brush is not too heavy. In mowing the second year, cut the brush in a direction opposite that of the first cutting, using the same speed as in mowing hay. The opposite direction of the second mowing removes prostrate plants that escaped the first operation. These plants, if left uncut, will replenish the food in the roots and retard control.

WHERE TO MOW

Sagebrush has limited value as a winter browse plant for beef cattle but is seldom eaten extensively by cattle except when the supplies of grass are exhausted or wholly covered with snow. This value of the brush and its ability to control soil blowing on exposed areas of deep sand indicate the desirability of leaving some sagebrush unmowed on the higher dunes. However, it is extremely important to mow most of the brush in a pasture, because livestock usually concentrate on mowed areas and are likely to graze them excessively if they do not represent a considerable part of the entire pasture. Sufficient sagebrush will usually survive the mowing operations to provide browse for emergency use in severe winters. Furthermore, the second and third growth sagebrush is more palatable than the coarser growth of nonmowed plants.

ADVANTAGES SOON DEFRAY MOWING COSTS

The cost of the first mowing of sagebrush is estimated to range from $1.00 to $2.00 an acre, depending on the amount and size of brush plants, the type of machinery used, and the availability of labor. The second mowing may be conducted for about the same cost as in mowing hay. The advantages in favor of mowing during the first two winters following the treatment at Woodward were sufficient to defray all costs of the operations. After that the increased gains of beef cattle represented clear profit and amounted to 50.4 pounds per acre as an average for three years. In 1945 the grazing results were subjected to an economic analysis by Dr. Peter Nelson, Head, Department of Agricultural Economics of the Oklahoma Agricultural Experiment Station and W. F. Lagrone and D. W. Blackburn of the Bureau of Agricultural Economics, U. S. D. A., stationed at Stillwater. Their study showed that the mowed pastures made $2,165.10 more net returns per section of land than was obtained from similar land not mowed.

Machinery for Brush Removal and Control

By MAURICE B. COX
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The need for machinery for removing brush and controlling sprouts has been observed from results of the Red Plains Conservation Experiment Station, Guthrie, Okla., and other research centers. The work of the Red Plains station is typical of a large acreage of native grass intermingled with scrubby, woody vegetation. The growth of the grass, however, is definitely limited by the shade from the trees and brush (Table 1). The use of such land for pasture can be greatly improved by removing the shade. The average yield of grass on fully cleared virgin land was five times that found on land 90 percent shaded.

After the land is cleared of brush, the stand of grass quickly develops a sod equal to that of native grass, providing the sprouts are controlled. The sprouts remaining on various areas cleared of scrubby oak, after annual mowings, has been determined (Table 2). Consistent mowing gradually reduces sprout growth, and after ten years the small quantity left offers little competition to the grass.

TABLE 1.—Effect on Native Grass Production of Shade from Blackjack Trees and Brush.

Grass Densities[2]	Percent of Land Shaded
None[1]	15.5
20	12.0
60	6.3
90	3.0

[1] Fully cleared virgin land.
[2] Determined by line transect.

TABLE 2.—Percentage of Original Oak Sprouts Remaining on the Land After Clearing and Spring Mowing

Density of Brush	Year Land Cleared	Treatment or Number of Years Mowed	Percent Remaining in 1945
Light[1]	1935	10	8.5
Light	1935	8	11.1
Light	1943	2	44.7
Light	1943	Unmowed	58.3

[1] Light density brush before clearing approximately 22,200 shrubs per acre, 2 inches or less in diameter at 1 foot above ground level.

Kinds of Machinery Used

Several kinds of machines have been used to remove the brush. Many of them have given satisfactory results under conditions favorable to their particular design. The machines that have been used most extensively in Oklahoma and Texas include the brush mower, mobile power saws (tractor mounted and small hand operated), bulldozers, tree dozers, brush beaters, giant stalk cutters, and steel cables attached to heavy crawler tractors.

Brush Mowers.—Power mowers, equipped with stub guards and heavy sections, can be operated without stopping through fairly dense growth where the stems are less than 1½ inches in diameter. It is possible for a good operator to handle stems up to 2 inches in diameter if only one is encountered at a time. The most efficient method where many of the plants exceed 1½ inches in diameter is to have these stems removed with an axe ahead of the mowing.

Mobile Saws.—Two types of mobile saws have been used with good results reported. The tractor mounted saw is excellent on scattered trees. It is also good for mowing large brush with the tractor in motion. It is difficult to operate this machine to cut at a uniform distance above the surface of the ground. This condition interferes with the use of a cutter-bar type mower for succeeding mowings. The other is a standard cord-wood saw blade powered by a small motor mounted on a two-wheel frame for hand operation. It will cut practically any type material that can be cut with the larger saw. It is excellent for thinning stands of trees such as pecan or removing undesirable trees.

Dozers.—Bull and tree dozers, mounted on large crawler tractors, readily uproot and remove heavy growths of large trees. For a blade of this kind to remove trees and brush, it must be operated at the ground surface or slightly below. This is necessary to prevent the small stems from bending without being uprooted and the larger material breaking off above the ground. Under such operations, the ground surface is usually stripped of all vegetation, left very rough and subject to erosion. For this reason, these machines should not be used on shallow soils but confined to land that is to be seeded to legumes or quick-growing grasses. Under certain conditions, the dozer can be used for uprooting scattered large trees and the resulting holes filled without extensive damage to the grass.

Brush Beaters.—Two types of brush beaters have been developed. One consists of a series of weighted chains fastened to a horizontal revolving shaft which acts much the same as a hammer mill. The other has a number of discs, each mounted on the end of vertical shafts with lugs projecting from the edges of the discs. The chain beater is driven from the power take-off of a tractor and the disc beater by an automobile motor mounted on the machine. Both of these machines do good work in sage brush and shinnery oak.

Giant Stalk Cutters.—Extravagant claims have been made for heavy stalk cutters in killing and controlling brush. These machines consist of 8 to 12 grader blades, 4 to 10 feet long, mounted on large spider hubs or on large steel cylinders. They are much like common stalk cutters except much larger and weighing from 1,000 to 8,000 pounds per section. Two benefits are claimed for their use, the killing of brush and weeds and light cultivation of the ground, which improves grass development and moisture conservation.

Giant Sweep.—This machine consists of a very large sweep made of grader blade stock and mounted under a heavy frame supported by two wheels. The sweep is V-shaped and supported by three shanks, one at the point and one near the end of each wing. In operation, this sweep cuts a swath 8 to 10 feet wide to a depth of 6 to 18 inches, which requires a large crawler type tractor. This implement should operate satisfactorily in clay soils but will probably give much trouble by dragging and pulling up roots when used on sandy soils.

Heavy Rooter Blade.—This implement consists of a heavy cutter blade 3 to 4 feet long mounted on a bulldozer frame. The blade is run under the main roots of small trees or stumps individually. It is very good for scattered stands of small trees.

Steel Cable Attached to Two Tractors.—Dragging down trees with a steel cable attached to two heavy crawler type tractors has proven satisfactory for dense cedar growths. The tractors move parallel to each other with the steel cable attached between them, thus dragging down and uprooting all the trees between the tractors. This type of action leaves the brush more or less windrowed.

Discussion

Machines for removing brush from farm lands must satisfy two general requirements: Sturdiness; and economy of operation. A machine that requires excessive maintenance or covers too small an area per day is certain to be unsatisfactory.

It appears unlikely that a machine or clearing method will be developed that will satisfy the above requirements for all conditions or types of brush. The requirements of a machine to handle brittle or brashy material such as sage or creosote brush will be quite different from that for tough, taller growing material like blackjack or persimmon. The brush problem areas may be divided into climatic zones, such as arid or semi-desert, sub-humid and humid. The plant types may range through sage, creosote brush, buck brush, cedar, mesquite, blackjack and live oak thickets, persimmon and sassafras, to large trees such as elm, honey locust, hickory and hackberry.

The value and productiveness of land cleared will limit the amount of work that can be expended. The first effort in removing brush should be directed toward land that is occupied by light brush and scattered trees with a desirable cover of native grass in the open areas. From present land values, it appears that only land with this type of growth can be economically cleared for pasture purposes.

Poisons for Eradicating Brush
(Progress Report)

By HARRY M. ELWELL
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Some of the new poisons recently tried at the Red Plains Conservation Experiment Station, Guthrie, Okla., and in field trial studies of the various Soil Conservation Districts in the state were ammonium sulfamate (trade name Ammate) and the 2, 4-D compounds such as Weedone and two that have not been named. In some of the studies, the effect of these materials was compared with sodium arsenite, sodium and calcium chlorate, and zinc chloride.

Method of Procedure

Ammonium sulfamate was dissolved in water and the solution injected into trees and sprayed onto the foliage of oak and persimmon. The injection solution contained 2½ pounds per gallon, while only 1 pound was used in the spray. The ratio for the sodium arsenite mixture was 1 pound per gallon water. These materials were applied in punched holes, and in axe incisions completely circling the tree, made near the root collar. An application was also made on the stumps of freshly cut trees. The 2,4-D compounds were also dissolved in water in accordance with the manufacturers' recommendations. These solutions were sprayed on the leaves of green brush. The new chemicals were also compared with water solutions of sodium and calcium chlorates and zinc chlorides.

The leaves and foliage should be saturated, which requires a strong and uniform spray. The addition of a small quantity of soap to the solution seemed to make the poison adhere more readily to the foliage. Approximately 250 gallons of solution will usually completely saturate brush with an average height of about four feet and a density of 20,000 shrubs per acre.

Discussion of Results

The studies with the new chemicals were started in 1945, and only a little information has been obtained. The use of chemicals in eradicating undesirable plants will require further study and should proceed with caution. Sodium arsenite applied in axe incisions killed the trees within a week. The ammonium sulfamate was much slower; in some cases three weeks time elasped before the leaves turned brown. The chemicals did not function satisfactorily when applied on the stumps or in holes punched in the tree.

Ammonium sulfamate spray completely defoliated oak and persimmon brush. It appears to have killed all terminal shoots and much of the older wood. In a few cases, however, new leaves appeared on the lower trunks of the plants. Occasionally a few sickly sprouts appeared near the root crown. Some of the material was carried into the root system because the root wood was discolored. Ammonium sulfamate is poisonous to most all plants but harmless to the soil and animals. However, by a careful job of spraying ammonium sulfamate on the leaves of brush, little damage was done to the native grasses intermingled in a woody vegetation. This compound appears to be desirable for use on undercover in valuable timber land and orchards.

The 2,4-D compounds reacted slowly on leaves of oak brush and trees. However, there was a rapid growth development of the cambium layer along the main stems, and this abnormal growth caused considerable cracking and splitting of the wood. The roots were also discolored and did not show any signs of sprouting. The plants did not put out any new leaves. The 2,4-D compounds, therefore, might be more desirable for brush eradication in pastures.

The sodium and calcium chlorates and zinc chloride sprays readily burned the leaves, but new growth occurred immediately. Several applications of these sprays would probably be required to kill oak brush.

The prices of these chemicals may be a limiting factor in their use at the present time, but there will probably be a reduction in prices as the demand increases. Another factor entering into this problem is the removing of the dead trees and brush after they have been killed by the poisons. Attempts are now being made to find new machines that will break and crush this material into a mulch for soil improvement and erosion control.

Chemicals for Eradicating Weeds
(Progress Report)

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Most of the chemical weed control trials made at the Oklahoma Agricultural Experiment Station in 1945 were with 2,4-D (dichlorophenoxiacetic acid). With perennial plants that are difficult to kill, at least two years of work will be necessary for reliable information. Other chemicals have been used in preceding years and fairly accurate recommendations can be made regarding their use.

Since 2,4-D is new, a number of tests were made on a large variety of weeds and plants; but it is with the weeds that are difficult to control, such as bindweed, that the chemicals must prove their killing ability.

Several commercial brands of 2,4-D were used in the tests. All chemicals were used at the rate of 1000 ppm. in water, and plants were sprayed until all leaves were well covered with water. About 1½ gallons per square rod is required for bindweed.

Applications made on bindweed on April 13, followed by damp cold weather, gave a 90% kill. The weed was growing rapidly at that time.

Bindweed in full bloom was sprayed on May 24 when temperatures were 85 to 90 degrees. The soil was very dry at the time of application and for several days afterwards. Less than a 25% kill was secured by this application.

2,4-D was applied on June 7 to bindweeds that had been kept down by a cultivator, then allowed to grow again to the pre-bud stage. This application was followed by a rain the second day. An 80% kill or better was made from this application.

The summer dormant applications on bindweed gave little better than a 50% kill.

No one application of 2,4-D killed all bindweeds in any trial.

The percentages of kill were determined by plant counts at the time of application and again in the fall before frost. Counts must be made the second year to get final results.

Several applications were made on spurge nettle at different times of the growing season. Best results were obtained at the full bloom stage. At this stage all plants having a root system of 2½ inches or less in diameter were killed, but large roots, 3 to 5 inches in diameter, were not all killed. The 2,4-D killed the leaves of this plant in one to two days, which was much faster than on other plants observed.

2,4-D stopped the growth and fruiting on the horse or bull nettle but did not kill the plant. On the silverleaf horse nettle the root system was killed down 12 inches or more and it seems the control will be 100%.

2,4-D did not kill climbing milkweed.

We found no harmful effects from spraying 2,4-D on field crops belonging to the grass family, at the rate of 1000 ppm. in 1½ gallons of water per square rod. It did not kill Johnson or Bermuda grass.

Cotton seemed to be the easiest field crop to kill with 2,4-D and caution must be used in applying the chemical near cotton fields.

No harmful effect was noticed on crops planted in soil treated with 1000 ppm. 2,4-D in 1½ gallon of water per square rod.

2,4-D killed almost all broad-leafed annuals with the exception of a very few.

It would seem that the stage of growth and weather conditions before and after treatment have much to do with the effectiveness of 2,4-D. More work must be done before we can determine the best way to use 2 ,4-D on perennial plants.

Other chemicals used for weed control were sulphamic acid, Ammate and sodium chlorate.

Sulphamic acid and Ammate applied as a spray quickly burned all vegetation to the ground, but the perennials quickly recovered and produced more growth.

Trials with sodium chlorate on bindweed show that best results were secured on a dry application made in October, at the rate of 4 pounds per square rod. Spraying, at the rate of 4 pounds per square rod, during the growing season did not always give complete control.

Spraying Bermuda grass and Johnson grass with sodium chlorate, at the rate of 3 to 4 pounds per square rod, gave good kills. Dry applications can be made on these grasses.

Sodium chlorate will cost $40 to $50 per acre to use, therefore is practical only on small areas. It also kills all vegetation on the treated soil for two or more years.

Revegetation of Eroded Land

By HARRY M. ELWELL
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Many additional cattle could be supplied with pasturage if the millions of acres of idle, eroded and unused land were revegetated and developed. Grass, as a whole, reestablishes itself slowly under natural conditions on eroded land (*1*) *, but this process can be greatly accelerated by working with nature. At the Red Plains Conservation Experiment Station, grass and other permanent vegetation greatly reduce runoff water (Table 1), even from eroded, shallow, regrassed land. The amount of

TABLE 1.—Runoff Water from Different Kinds of Plant Cover.[1]

Watershed Treatment	Average[2]
	Runoff Percent
Cultivated terraced land	20.45
Eroded regrassed land	12.31
Native grass and woodland	1.36
	Precipitation[3] Inches
Total Rainfall	32.60

[1] On watersheds located on rolling, mainly shallow land.
[2] Average of 6 years.
[3] Average annual precipitation compiled by Weather Bureau in Guthrie, Oklahoma, since 1898 is 32.50 inches.

runoff from such land was 40 percent less than that from cultivated terraced land. The native vegetation, however, reduced the runoff water loss 93 percent. There are several methods of establishment, but the kind of vegetation and method of establishment varies with soil and climatic conditions.

MAJOR FACTORS

The major factors involved in regrassing of eroded land are low fertility, poor physical condition of the soil, low available moisture, and poor biological activity. If the law fertility is due to mineral deficiences, the lacking minerals must be supplied by the addition of limestone and commercial fertilizers. The nitrogen may be obtained by growing legumes or by supplying commercial fertilizers. In fertilizing, it sometimes may be desirable to make an application sufficient to take care of the plant needs for several years However, in a study on severely sheet-eroded soils at Guthrie, light row fertilization of sweet clover (Table 2) gave good results.

* Italic figures in parentheses refer to literature cited at end of article.

TABLE 2.—Effect of Phosphate, Lime and Contour Tillage on the Yield of Sweet Clover Planted in Standard Rows on Eroded Land

Fertilizer		Pounds of Sweet Clover per Acre[1]	
Kind	Pounds per Acre	Listed[2] on Contour	Smooth Seedbed
None		668	105
Superphosphate and limestone	40 80	1790	555
Rock phosphate and limestone	40 80	2150	590

[1] This particular yield was produced in 1935.
[2] Furrows 3 to 4 inches deep.

Where the seed was planted in shallow furrows on the contour, the light application of rock phosphate and lime increased the yield of the second year's growth of the clover over three times. The yield was also increased by superphosphate. The higher production on the contour listed area definitely shows the value of moisture conservation. The full value of the fertilizer application is not obtained unless it is applied in combination with the best possible soil and water saving practices. The sweet clover reseeded and produced a good forage growth on the fertilized area for several years.

Under maximum growth of native vegetation, there is always considerable biological activity. This may be observed from the decay of residue and also from the presence of insects, worms and other forms of life. Eroded, abandoned land has lost most of its organic matter. As a result, there is little or no biological life to start rebuilding fertility and improving the physical condition. Some of the first plants to appear on poor, shallow eroded soil (2) are lichens, algae and moss crusts. Therefore sweet clover and other plants supply organic matter or food for a new life of soil organisms. This is essential for a good seedbed for native grass.

In addition to these factors, grasses are greatly influenced by climatic conditions. Studies made in Nebraska (4) show that blue grama (*Bouteloua gracilis*) was the most drouth-resistant native grass. Other grasses occur in the following order of drouth resistance: buffalo (*Buchloe dactyloides*), black grama (*Bouteloua hirsuta*), drop seed (*Sporobolus asper*), side-oats grama (*Bouteloua curtipendula*), little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon fureatus*), switch (*Panicum virgatum*), and Indian grass (*Sorghastrum nutans*). Due to the frequent drouths that occur in Oklahoma, a mixture of both tall and short grasses is usually recommended for reseeding eroded land.

METHOD OF REVEGETATION

If the land to be revegetated is seriously gullied or sheet eroded, special treatment will be necessary. In some areas it may be necessary to divert the runoff water from the original channels by installing low-cost contour furrows or ridges between and above the sources of gullies. Satisfactory results (Table 3) have been obtained at Guthrie by installing vegetative barriers of brush and crop residue, plowing down the gully bank, applying a light application of fertilizer and lime when needed and introducing legumes. After the legumes are established, grasses may be introduced. Where such procedure had been followed, the density of the vegetation in the treated gullies was over three times greater than that of the untreated.

Bermuda grass and other introduced grasses do quite well on most soil conditions in the more humid areas. But revegetation can be greatly accelerated by the use of legumes and light applications of lime and mineral fertilizer. Results from field trials in the soil conservation districts show that proper fertilization and pasture treatment have doubled and, in some cases, increased up to four times the yields of pastures in eastern Oklahoma. One of the most common methods of establishing Bermuda grass is the planting of the root sprigs. There are other grasses, however, that are giving good results and, if found desirable, may also be established.

Due to the arid conditions prevailing in much of central and western Oklahoma, native grass in general seems to be best adapted to this area. There are also several methods of establishing these grasses, but satisfactory results have been obtained by applying mulches of mature hay containing seed or by planting in a dead stubble.

TABLE 3.—Density of Vegetation on Treated and Untreated Gullies.

Treatment of Gullies	Percent Density of Vegetation		
	Perennial Grasses	Annual Weeds and Grasses	Total
Untreated	2.29	0.16	2.45
Treated[1]	5.95	2.04	7.99

[1] Gully banks plowed down, light application of lime and superphosphate applied and sweet clover planted, which was followed the third year by a seed-hay planting of native grass.

TABLE 4.—Effect of Different Methods of Seeding on Density of Little Bluestem Grass.

Treatment	Density of Stand		
	1943	1944	Average
	Percent	Percent	Percent
Method of seeding[1]			
Seed-Hay[2]	7.38	9.44	8.41
Threshed seed	2.92	3.70	3.31
Virgin native grass[3]	8.13	7.08	7.61

[1] Amount of seed applied per acre was the same for both methods.
[2] The hay and other mulch used amounted to 1,500 pounds per acre.
[3] Includes all palatable perennial native grasses.

Seed-Hay Method.—The seed-hay method has given better stands and sod development than other method of seeding native grasses on badly-eroded land at Guthrie (Table 4). This method of seeding produced a density of grass 2.5 times as great as that from threshed seed. By the end of the second growing season, the density on the seed-hay area was about the same as that of virgin native grass. Although the seed-hay method of regrassing land is proving to be very satisfactory, it is probably best adapted for severely-eroded and gullied land and for seeding bare areas in pastures. Usually 1,500 to 2,000 pounds of hay or straw per acre will give satisfactory results.

Stubble and Hay Mulches.—The most consistently successful method to use in regrassing cultivated lands in the drier portion of Oklahoma (*3*) consists of drilling a mixture of adapted grasses, principally native species, in the spring in the protective stubble and hay residue left by a previous crop of cane (sorgo), Sudan grass or other sorghum. June is usually the safest month to drill the preparatory crop and insure maximum production. Earlier plantings are necessary, however, in chinch bug infested areas; and later plantings are desirable elsewhere when moisture conditions are favorable. Whenever the cover crop begins to produce seed stalks, it should be mowed at a stubble height of about 6 to 10 inches and most of the hay left on the land to insure maximum protection to the seedbed the following spring. The cover crop, if allowed to mature seed, often volunteers the following year and competes seriously with grass seedlings for moisture and plant food.

The second most successful method consists of drilling the grasses in a high, dense stubble of cane, Sudan or sorghum from which the hay has been removed. This method provides less protection to the seedling grasses but affords some return from the preparatory crop. It is, therefore, a practical and satisfactory method to use in special sites where soil blowing is less serious or where the slope of the land is such that severe washing is not a problem.

MANAGEMENT

After the grass has been established, the most logical approach for improving and conserving it is intelligent management. One of the essential practices that should be observed is fire prevention. Results at the Guthrie station (2) show that the forage yield of native grass was decreased 50 percent by continuous fall burning.

Fall and winter mowing of poor stands develops a mulch, saves seed, supplies organic matter, and also affords protection to the young seedlings. Spring mowing for weed control has also been quite beneficial in maintaining a good stand. An ideal period for this mowing is about the time the weeds begin to bloom. Light to moderate grazing, depending upon moisture conditions, aids in increasing the stand on reclaimed eroded pastures. Adjustment of grazing periods to permit the grass to produce seed is also helpful in improving and maintaining a cover. Pastures sometimes become sod bound and occasional light disking is beneficial. The yield of Bermuda grass hay was increased 26 percent and that of native grass 6 percent by disking the sod lightly every other year in March at the Guthrie station (Table 5).

Much of the establishment and improvement of pastures on unused land is practical for the average landowner or occupier. Pastures on idle, eroded or scrubby woodland may be maintained by keeping out fires, conservative use, and eliminating undesirable species with the mowing machine. These practices will assist in developing a mulch cover for erosion and flood control. Thus, through proper management, much of the shallow eroded and unused land can be converted into useful pastures and meadows and, if grazed conservatively, satisfactory returns obtained.

TABLE 5.—Yield of Hay From Cultivated Grass.[1]

Method of Cultivation	Pounds of Hay per Acre	
	Bermuda Grass	Native Grass[2]
Untreated	971	2274
Disked[3]	1224	2419
Difference of gain	253	145

[1] Average of 4 years of results, 1941-44.
[2] Mixture of little and big bluestem and Indian grass.
[3] Disked lightly every other year in March.

TABLE 6.—Use of Shallow Soil for Livestock Production.

Kind of Soil	Beef Produced per Acre (pounds)	Yield of Hay per Acre (tons)
Regrassed—eroded (1944-45)	40	.60
Cleared virgin (1944-45)	60	1.00
Regrassed, eroded and virgin (5-year average)	40	

During the last five years, summer grazing experiments with yearling steers on such land at the Guthrie station produced on average of 40 pounds of beef per acre (Table 6). The amount of beef obtained compared favorably to that produced on the range land of the area.

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Establishing Bermuda Grass From Seed

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The materials for this paper has been obtained entirely from experience as a technician in the Gaines Creek Soil Conservation District, located in the southeast part of Oklahoma.

The need for better pastures has been realized by the farmers and ranchers of this district for a number of years, and a number of Bermuda grass pastures have been established from roots in the past years. With the starting of the war, and the prospects of acute labor shortage, the farmers and technicians felt that the pasture program, which is very important in the district, must continue, but that a faster and more economical method of establishment should be found.

Development of the Method

One farmer and cooperator in the district had been planting Bermuda seed for two years with varying degrees of success. He planted Bermuda seed in 1940 and lost approximately 70% by winter killing. In 1941 he planted another field and that winter lost approximately 40%. After studing this cooperator's methods and results, and realizing the necessity of continuing the pasture program, it was planned to attempt a district-wide seeding program.

In November, 1942, the district supervisors ordered 1200 pounds of unhulled Bermuda grass seed. This seed was hulled with a borrowed home-made scarifier. Six cooperators planted the seed in 1943. It was agreed by the cooperators planting the seed, and the technicians assisting the district, to follow certain methods on all fields: 1st, a well prepared and firm seed-bed obtained by plowing, discing, harrowing and cultipacking; 2nd, planting hulled scarified seed; 3rd, broadcasting seed with either cyclone or wheelbarrow seeders at the rate of approximately 3 pounds per acre; and, 4th, mowing weeds as often as necessary to prevent shading. Due to inability to keep the seeders at a consistent rate, the seed was planted at rates ranging from 1 pound to 8 pounds per acre. On one 30-acre field the rate was varied purposely from approximately 2 pounds per acre to 8 pounds per acre. From observation of these different rates of seeding, it was determined that from 1 pound to 2 pounds per acre would be the proper rate of seeding.

In spite of torrential rains and floods in May, 1943, and the drouth that summer, a complete coverage was obtained on approximately 90% of the fields. The following winter of 1943-44, fields on the uplands and prairies lost 95% of their grass, while those in the creek bottoms, protected by the trees, lost very little of their grass by freezing.

It was observed in 1943 on one field with shallow soil that rows of grass about every two feet was all that survived the drouth. It was finally determined that these rows were left as small furrows by the tractor wheels in the second rolling with the cultipacker. This caused us to observe other fields where the soil was shallow, and it was decided that planting grass seed in small furrows or rows would probably be the best method.

Encouraged by the success of seeding in 1943, the district supervisors purchased 3000 pounds of seed for planting in 1944. Of this amount 300 pounds were sold to neighboring districts and 2700 pounds were planted by the Gaines Creek District cooperators.

Only one cooperator in 1944 planted his grass in rows. He seeded 32 acres in 18-inch rows the last of May and the first week in June. This field had a complete cover by August. Most farmers, observing this field and the broadcast fields, expressed their opinion in favor of row planting. In the fall of 1944 approximately 95% of all grass seeded that spring was covered or bedded for winter protection and approximately 95% of the grass came through the winter in good shape.

All of the farmers who have followed the original plan of planting on a well prepared, firm seedbed, and who have kept the weeds mowed, have reported excellent results. Most of the fields have had complete coverage the first summer and some grazing has been started by the middle of July.

It has been observed that by planting hulled seed the farmers have gained several weeks in obtaining a stand, which is very important due to the soil moisture. By planting hulled seed, the farmers have been getting a stand in from seven to twelve days, while some farmers seeding unhulled seed report that it requires from three to six weeks to get a stand.

Neither commercial fertilizer nor legume green manure crops have been used by the farmers in the Gaines Creek Soil Conservation District in connection with seeding Bermuda grass, but it is felt that it is a practice that should be used. One district cooperator who seeded a few acres broadcast on bottomland in 1944 did broadcast approximately 25 pounds of

4-12-4 fertilizer on a fraction of an acre about a month after seeding. The fertilized grass was much better in every way than that not fertilized. The stolon development and forage growth were doubled, which showed the results of the fertilizer.

Since most of the cooperators are planning on row seeding in the future, it is felt that they will use a mixed fertilizer. It is the opinion that legume green manure crops, plowed under at least two weeks prior to seeding Bermuda grass, especially on their cultivated fields, would aid materially in establishing the young grass as the land is low in nitrogen and organic matter.

Precautions and Practices

From observation, Bermuda grass can be successfully and economically established from seed in the Gaines Creek Conservation District when proper precautions and practices are used. A discussion of these precautions and practices follows:

1. *Soil Adaptation.*—The medium textured soils, such as the fine sandy loams, very fine sandy loams and silt loams, are best adapted for Bermuda grass as they retain moisture, are deeper and friable. The farmers have found that Bermuda grass can be planted successfully on most of the soils in the district except the shallow and seriously eroded upland soils. As one farmer, who seeded 150 acres in 1945, stated last fall, "Where I had the soil I had the grass."

2. *Seedbed Preparation.*—Bermuda grass is a very delicate plant while young and responds to a well prepared seedbed, free from other plant competition. The farmers from the start have attempted to prepare the best seedbed possible. Some few have attempted to plant on a poorly prepared seedbed and failed completely. Several farmers have purchased cultipackers to aid in properly preparing the seedbed and to cover the seed after broadcast planting. The district supervisors purchased two cultipackers for use by the cooperators.

On the tighter soils, the seedbed is best prepared by flat breaking, discing, harrowing and cultipacking if prepared immediately prior to seeding. If prepared early, the rains will firm the soil; then the field should be scratched by harrowing or light discing before seeding. On the sandy soils, tandem discing, harrowing and cultipacking will usually prepare a good seedbed. A well prepared, clean, firm seedbed is very essential in establishing Bermuda grass from seed.

3. *Time of Seeding.*—It has been determined in the Gaines Creek District, that the proper seeding time is from May 1 (if the soil is warm) to about June 10 or 16. Bermuda grass likes warm, moist weather.

4. *Methods of Seeding.*—Bermuda grass seed may be planted by several methods. The main thing is to get as uniform seeding as possible. The farmers in the Gaines Creek District have used the cyclone hand seeder, wheelbarrow seeder, grain drill with grass seed attachment, Planet Jr. and the regular one- and two-row planters with a small grass-seed attachment. From observation, it is felt that on the uplands and prairies it is best when planted in two- to three-foot rows. This method gives the young grass some protection from hot winds, shifting soil, collects summer moisture, reduces the amount of seed necessary, and is easier to bed in the fall. One of the district cooperators, Lee Hopper, seeded approximately 150 acres in rows in the spring of 1945 using a two-row tractor with planter attachments. No plow openers were used. Instead a 2-inch rubber hose was attached to each seed hopper, extending down and in front of each rear wheel. The weight of the tractor pressed the seed into the ground, leaving it in a shallow furrow. This method proved very successful and Mr. Hopper obtained a perfect stand where the soil was good.

The majority of seed has been broadcast in the past, using the 14-foot wheelbarrow seeder and covered by rolling with a cultipacker; but the farmers are expressing their intention of planting in rows in the future because it requires less seed, is faster, and the stands are as good. Bedding for winter protection is easier and they do not destroy much grass during bedding. The small seed attachment with regular one- or two-row planter (developed by the Soil Conservation Service Nursery in San Antonio, Texas) has been found to be ideal for row planting of Bermuda grass.

5. *Rates of Seeding.*—As stated before, the farmers in the Gaines Creek Soil Conservation District have planted at rates varying from ½ pound to 1 pound per acre in rows and from 1 pound to 8 pounds per acre broadcast. From observation, ½ pound to ¾ pound per acre in rows, and from 1 pound to 2 pounds of seed per acre broadcast, give the best results. Larger amounts of seed have proved detrimental, as the young plants are crowded and tend to grow erect with little or no stolon development; while with a smaller amount of seed, evenly distributed, the young grass wil start developing runners within a week or ten days after it gets above ground.

6. *Management after Seeding.*—The young Bermuda grass plant is very sensitive to shade, therefore the farmers attempt to keep weeds and other vegetations mowed and grazed to prevent shading. The farmers believe that regulated grazing is beneficial in the newly seeded Bermuda grass pastures. The

stock aid in eliminating competition. Their hooves press the stolons and crowns into the soil, which assists the grass in getting established. It has been determined that the farmers will not seed any pasture legumes with Bermuda grass the first year because of the detrimental effect of the competition.

7. *Care Through First Winter.*—From study and observation of winter killing on the first fields planted from 1940 through 1943, and from finding that first year Bermuda grass does not develop underground rhizomes, it was decided to try covering or bedding in October or November of the first year to give the young grass protection the first winter. This practice was put into effect in the fall of 1944 on approximately 95% of the grass seeded that spring. The implements used were listers, cultivator shovels and turning plows. With the broadcast seeding, it was necessary to destroy approximately 50% of the grass to cover the other 50% . In the one 32-acre field seeded in 18-inch rows (which were too close), the farmer plowed up one row and covered two rows. All bedding was done on the contour to prevent winter erosion and conserve moisture. In the spring of 1945, in March and April, the grass was uncovered by discing and harrowing, which leveled the ridges, filled the furrows and made mowing easier. Of the grass bedded in the fall of 1944, at least 95% came through the winter in perfect shape and the fields made solid sod during the summer of 1945.

8. *Management the Second Year.*—The second spring after the grass has been uncovered and leveled for mowing, the farmers are seeding lespedeza (Kobe and Korean), and grazing is started as soon as the grass and lespedeza have made sufficient growth. The second fall they are seeding winter legumes —Yellow Hop and White Dutch clover. The better soils are furnishing grazing the second year at about 1½ acres per animal unit.

STATEMENTS FROM FARMERS AND RANCHERS

The following statements were obtained from farmers in the Gaines Creek Soil Conservation District who have successfully established Bermuda grass pastures from seeding:

Harry Stiers, Supervisor of the Gaines Creek Soil Conservation District: "I planted 22 acres of Bermuda grass with seed in 1944 and 11 acres in 1945. This grass was seeded at the rate of about 1½ pounds per acre broadcast and planted the last of May and the first week in June. By September the entire field was sodded. The new grass furnished about three months of grazing and carried one cow per 3 acres. The best seed bed possible is essential and I have found that the better the soil the better the grass."

Lee Hopper, Rancher, Pittsburg, Okla. "I have seeded Bermuda grass for three years but did not pay much attention to seedbed preparation the first two years and failed. In the spring of 1945 I seeded 150 acres on a well prepared seedbed and planted in 2½ foot rows with a two-row tractor, using about ¾ pound of hulled seed per acre. I have a good stand and where the soil is good the sod is solid, but where the soil is thin and eroded it is not so good. I started pasturing in August and grazed it the remainder of the summer and fall. I could not have planted roots on over 10 or 15 acres for the same cost that I seeded 150 acres. I plan to seed several hundred acres more."

Freddie Browne, Rancher, McAlester: "In the past three years, 1943 through 1945, I have seeded close to 400 acres to Bermuda grass and plan on seeding around 1000 acres more. It is possible that I would not have planted any grass by the root system during this time. Under present conditions, seeding Bermuda pasture is quicker, cheaper and a sure way of establishing a good pasture. My advice is, do not spare effort in preparing the best seedbed possible, as it will pay. I have found that from 1½ pounds to 2 pounds of seed per acre is about the correct rate for seeding broadcast. In the future I plan to plant in rows as I believe it has advantages over broadcasting; 1st, it can be seeded on the contour; 2nd, it requires less seed; and, 3rd, it is easier to bed for winter protection. The newly seeded Bermuda grass has furnished me about three months grazing the first year. I think winter covering is very essential the first year. It is good insurance and saves a lot of worry. Uncovering in the spring is very simple and fast."

J. D. Bogard, Farmer, Indianola: "In May and June, 1944, I seeded 32 acres to Bermuda grass in 18-inch rows with a Planet Jr., two-row seeder. I used about ¾ pound per acre. The field was solid by August 15 and furnished grazing for seven head of stock for four months. I prepared a good seedbed, which is necessary. In the fall I bedded the grass to protect it from winter killing. All of the grass came through the winter and gave me an excellent pasture throughout the summer and fall of 1945. In the spring of 1945, after uncovering with a disc and harrow, I seeded 500 pounds of Kobe lespedeza. During July and August, this field grazed 30 head of cows and calves."

Kobe and Sericea Lespedeza in East-central Oklahoma

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The transition from a productive cultivated crop area to an unproductive one has come about in East-central Oklahoma within a very short time. The acuteness of agricultural problems has been in keeping with the rapidity of this change. It has been easy to misinterpret crop adaptation in much of East-central Oklahoma. For example, evidence of inadequate drainage may not show up in the soil profile or be evident from observation during certain periods, yet the water table may be near the surface for as much as six months some years. Wet lands interfere with seedbed preparation, distribution of barnyard manure, retard decomposition of crop residues, and limit adaptable plants.

Winter legumes have not succeeded comparable to other areas. In fact the average farm has grown no legumes of any consequence. Seed have simply been wasted in too high a percent of cases where used.

A major farm problem in East-central Oklahoma is to get soil-holding and soil-improving crops capable of producing pasture and hay on idle and non-paying cropland that farmers can afford to establish. Kobe and sericea lespedezas have come from efforts to find crops and legumes in particular that would fit these requirements.

Kobe lespedeza is a variation of Common lespedeza, being larger, principally in size of leaf, stem and seed. It is an annual, maturing seed in October, which is a month later than Korean lespedeza. It makes upright growth which permits easy harvesting for hay, seed or pasturing. It is the most drouth resistant of the annual lespedezas.

Kobe grows well on prairie soils, more fertile timber soils, and poorer drained timber soils. Kobe utilizes efficiently soils too wet to row crop. On mound phase prairie soils where the height of corn is uneven, Kobe grows taller where corn is poorest.

Kobe is not sensitive to the usual soil reactions of the area, consequently the addition of lime is not a requirement for its successful growth. Samples of plants tested have shown more than adequate calcium content for nutritional requirements even though some tests were below a pH of 5.0, which is classed as strongly acid. On the other hand, the phosphorus content has been low even though the soil tested adequate where the plants had grown. Excellent response has been observed from application of phosphate fertilizers. This experience with the use of lime and phosphate is supported in part by Progress Report No. 953, recently published by Texas Agricultural Experiment Station, which deals with soils and crops not greatly different from those of East-central Oklahoma.

Kobe has been easy to establish, requiring little seedbed preparation. The matter of smooth land to permit efficient harvesting of hay and seed, however, should not be overlooked. Seed germinate about the last week in March, which is considered proper time of seeding. As Kobe seed are larger than other lespedezas, 25 pounds per acre should be seeded if stand is expected first year.

Kobe is perhaps two weeks later than Korean. When used for pasture it dovetails well with winter legumes as they carry the grazing load easily until Kobe and Bermuda grass make sufficient growth. In using Kobe with Bermuda for hay they should not be seeded with winter legumes as they would offer too much competition for Kobe. Under pasture conditions, grazing the winter annuals gives sufficient openings in the sward for Kobe.

Kobe is a very palatable pasture plant. Farmers who use it have been well pleased with the extra grazing furnished in the latter part of grazing season when every pound of fat makes a cow that much easier to winter.

Kobe and the other annual lespedezas are of sufficient quality for hay that a farmer can do about anything with them that can be done with alfalfa hay. Not much local information on hay yields is available as most plantings have been used for seed production. One ten-acre planting on good Kobe land produced 1½ tons of hay in 1944 and 1945 per acre. This field was opened for grazing soon after haying and perhaps as much vegetation was obtained in this manner as from haying. Only one hay crop or seed crop should be expected from Kobe annually.

Kobe is not so prolific a seeder as Korean. The seed shatter to a greater extent than Korean. This accounts in part for the high price of seed. Another reason is that Korean is adapted to a part of the country that has more machinery for harvesting. Yields of seed on Kobe have run from 100 to 300 pounds per acre.

Sericea lespedeza is a long lived perennial legume. The first plantings of any consequence in East-central Oklahoma were made in 1939. Considerable acreage had been planted some five years earlier in Okmulgee County. These plantings were visited and evaluated. Their growth was quite satisfactory but no effort had been made to utilize the crop for hay or pasture, consequently there was little on which to base an opinion of the potential use of the crop.

Since sericea is deep rooted, much of the root system is in the subsoil, even on good land, and satisfactory growth can be expected even on land too eroded to row crop. It is rarely affected more than temporarily from drouth unless growing in shallow clay pan soils or in soil underlaid with rock near the surface. Its greatest value lies in its ability to produce productively on many soils where most other crops fail.

Kobe and sericea complement each other. Where one does not work well the other may approach its best production. There are very few sites where one or the other is not adapted. Sericea grows on most well drained timber soils and deeper prairie soils.

The following recommendations on establishing sericea are based on some nine years of local experience of Soil Conservation Service technicians' working with farmers:

1. Prepare seedbed by breaking and one or more of the following treatments to secure a smooth, firm seedbed: Discing, harrowing, dragging, logging, or cultipacking. If seedbed is rough, small seed may be covered too deeply by rain.

2. Sow 20 pounds of scarified seed per acre from April 1 to May 25. May 10 to 20 have been optimum dates. Do not cover seed. If land is sloping, harrowing and breaking should be on the contour.

3. It is not desirable to sow with other crops such as small grains and especially sudan, unless an exception be made for sandy soils.

4. The first year's growth is disappointing. If grass or weeds overtop sericea plants, it may be desirable to mow in June or July.

Sericea is ready to hay between May 20 and June 1 when it reaches 12 to 15 inches in height. Woody cells begin to develop at the base of the stems when they reach 12 inches in height and work up to the top of the stems by the time they are around two feet in height. Quality of hay is very dependent on the plant being cut in the proper stage. Sericea cures fast enough to cut, rake, and haul in the same day. The stems and leaves cure evenly. The leaves will shatter badly if the hay is left in the field too long.

Some difficulty has been encountered in getting sericea cut at the right time because farmers are busiest with other farm work at the season sericea is ready for harvest. Farmers often resort to grinding late cuttings. Two hay crops or one hay crop and one seed crop may be obtained annually.

The quality of sericea hay has been challenged frequently. I believe that an unbiased appraisal would reveal that the principal criticism has come from experiences where the cutting was not done early enough, and from individuals who had not fed it. Getting stock to eat it is not a problem in East-central Oklahoma. It is difficult to tell where sericea hay is being fed around the farm by what stock leave.

Local analyses of sericea have shown a protein content of 11 to 15%. Kobe has analyzed about 3% under sericea in protein.

Sericea as an erosion control cover has few equals either on upland or bottomlands. In the 1943 floods, in several instances sericea was under water as much as five days or more without the stands being impaired. On one particular field no damage was done to the part in sericea, whereas elsewhere $1750 of dozer labor was required to fill potholes and level the land so it could be planted to crops.

Sericea is a prolific seed producer. However, efficient harvesting is somewhat hindered by winds causing seed to shatter as they mature. Seed production has been almost adequate for local needs for three or four years. The seed have a hard outer coat and should be scarified before planting. A homemade abrasive wheel scarifier has been used. It has a capacity of about one hundred pounds of seed per hour.

The potential possibilities of sericea are well illustrated by a planting made near Stigler, in Haskell County, in 1940. Seventy pounds of seed, costing at that time $10.50, were planted on 4 acres of sandy soil without treatment, capable of producing 15 bushels of corn per acre in normal years. In the five years following, 25 tons of hay and 3400 pounds of cleaned seed have been obtained from this 4-acre planting. This hay has supplied all the roughage for approximately four milk cows on the farm.

Kobe and sericea are wild-growing plants. They enable a farmer to pay for his land, make a living, and improve his soil, all at the same time. Their requirements are few and simple. They do not require the best land on the farm. They are planted only once. They do not have to be cultivated and hoed. They have few insect enemies. They serve as hosts for few plant diseases. They eat the simpler plant foods, and support nitrogen fixing bacteria that work when it is hot. They do not require limed soils. They hold the soil and enable it to drink much of the water that falls. They produce hay that has an average of six sacks of cottonseed meal (protein) in each ton. They yield seed to sell to neighbors. They add valuable humus to the soil. They furnish nutritious grazing to the farmer's stock when grasses become fibrous. Their annual production of feed units per acre is equal to 30 to 60 bushels of corn. They have sufficient merit that farmers increase trial plantings on their own initiative and expense. They are green until frost. Their residues protect the earth in winter from washing and form a mulch to protect the young plants as they begin to grow after the last frost.

Grass Seed Harvesting, Cleaning, and Processing
A Summary of Techniques Developed by the Soil Conservation Service, U. S. Department of Agriculture

By JAMES E. SMITH Jr.
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It has been adequately demonstrated by the Nursery Division of the Soil Conservation Service, during the past 10 years, that good quality seed of all the grasses employed in attaining proper land use can be readily harvested with ordinary farm harvesting machinery. For all of these grasses except buffalo grass, necessary machine adjustments to permit good work are few and minor in nature. Although binders, headers, mowers, and even hand-stripping have been found desirable for seed harvest in special instances, the combined harvester-thresher is ordinarily the best machine for the job. This discussion deals in the main with that method only.

HARVESTING

Choice of the Combine.

In general, combines having tooth-and-concave cylinders are less satisfactory for grass seed harvest than combines having angle- or rasp-bar cylinders. It is possible to vary the number of teeth in the former type and effectively reduce the amount of straw chopping, but such adjustment seldom results in the quality of seed material more readily obtainable in the latter type.

Cutting width of the combine is not important in itself, but the ratio between separating capacity and width of cut is usually greater in small combines than in larger ones. In harvesting grass seed of such species as the gramas, Canada wild-rye, western wheatgrass, and bluestems, the seed separates from the straw slowly and with considerable difficulty, and care must be exercised to insure that the combine separator does not receive, from a wide sicklecut, more material than can be handled without undue loss of seed in the tailings. This can usually be accomplished for a wide range in combine sickle widths by adjustment of the rate of forward travel to the capacity of the separator and type of seed being harvested.

Major changes in cylinder speed are usually necessary between different grass fields, and sometimes during the day in the same field. It follows that the operator of a combine which has a simple speed change device will normally harvest better seed than one using a machine on which the desired speed changes are difficult to accomplish.

Combine Adjustments.

Regardless of the size or make of combine used, the following initial adjustments are necessary before starting grass seed harvest:

1. Render the fan inoperative either by removal of the blades or by disconnecting the fan drive mechanism.
2. Set the cylinder concave clearance at about—
   ½-inch for bluestem.
   ⅜-inch for gramas, western wheatgrass, and Canada wildrye.
   ¼-inch for switchgrass.
   ⅛ to 3/16-inch for the lovegrasses.
3. Set the cylinder speed at about—
   800-1000 RPM for bluestem.
   1100-1200 RPM for gramas, western wheatgrass, and Canada wildrye.
   1400-1600 RPM for switchgrass and the lovegrasses.
4. Remove the perforated sieve if there is one in the cleaning shoe. Its use in any event will not eliminate recleaning, and may cause trouble by becoming plugged.
5. Equip the reel bats with brushes or belting flaps which will sweep the sickle clean at each revolution.
6. Make certain that the flanging on the clean-grain auger extends full-length into the bin elevator boot.
7. For most chaffy grass seed, the lower adjustable sieve should be removed, and the tailings rake at the outer end of the upper adjustable sieve should be covered with a solid piece of tin or stiff carboard.
8. When using a combine with bin and unloading auger, place a post or 4x4 inside the bin with one end resting in the auger opening. Removal of the timber when the bin is full provides a starting opening for the unloading process.
9. For combine harvest of buffalo grass seed, the sickle must be moved forward and placed to run flat on the ground. Following this, the gap between the new sickle position and the header canvas must be bridged with a sheet of tin, the sickle driver lengthened, and the reel re-set over the sickle. Cylinder speed and cylinder concave spacing should be about the same as for grama grasses.

Since switchgrass, the lovegrasses, and similar seeds are easily re-cleaned in ordinary fanning mills, it is best to use fast cylinder speed and close cylinder concave spacing to completely thresh all seed possible without regard for the amount of trash also taken with the seed. Seed of such grasses as the bluestems, Canada wildrye, western wheatgrass, and the gramas are difficult to re-clean. Therefore, when combining them every effort should be made to avoid short pieces of stems and like trash. This is accomplished by slow cylinder speed, wide cylinder concave spacing, and by cutting fairly long straws instead of short-heading.

CLEANING AND PROCESSING

Freshly-harvested seed of all grasses must be spread and dried, before final cleaning and storage, to prevent spoilage by heating and molding.

A valuable adjunct to any cleaning operation, large or small, is a simple screening device called a scalper which is used to remove coarse trash from combine-run seed material. It consists essentially of an inclined screen held in supporting framework and caused to shuttle back and forth by the action of an eccentric drive connected to a small engine or motor. The screens are usually constructed from hardware cloth. Two sizes, 8-mesh and 4-mesh, are satisfactory for rough cleaning most combine-run grass seed material. This scalper, used in conjunction with fanning mills and other cleaning equipment, greatly speeds the cleaning of all grass seed, and can be used alone to produce good quality seed from combine-run bluestem, grama, and western wheatgrass material.

Ordinary 2-screen fanning mills are used to clean such seed as the lovegrasses and switchgrass, as well as highly refined seed of other species. A wide range in screen sizes is essential if best quality seed is expected. Openings in the top screen in each case should be just large enough to allow the largest seeds to fall through, and openings in the botton screen small enough to hold the small, good seed units, and at the same time allow sand, small weed seeds, and other such impurities to fall through.

For weeping and sand lovegrass, a 1/23-inch perforated zinc top screen and a 36x36-mesh wire screen for the bottom are satisfactory. In cleaning switchgrass, a size 7 or 8 top screen and a size 1/23 bottom screen will usually be found suitable. In cleaning western wheatgrass, slotted screens sizes A, B, and C are proper for the top, with a size 1/18 or 1/20 for the bottom. Canada wildrye is difficult to clean using either a scalper or a fanning mill without processing to remove the awn.

Many of the grasses produce seed having hairs, awns, and other undesirable appendages which make them difficult to clean and to plant in any but special drills. Hammermills having free-swinging hammers of straight strap steel, a large screen surface, a minimum clearance between hammers and screen of about ¼-inch, driven at speeds between 800 and 1300 RPM, have been employed to remove these seed appendages and even to completely hull some species.

With experience, it is possibe by this hammermill processing treatment to "trim" such seed as that of bluestems, gramas, Canada wildrye, and western wheatgrass so that it can be seeded with ordinary grain drills. More vigorous hammermilling produces free grain of all grasses except the last two mentioned in this discussion. After hammermilling seed, a fanning mill is usually required to remove the dust and broken hulls. Seed breakage is not excessive if proper care is taken in choice of the mill screen size, speed of operation, and rate of feed.

Reduction of seed material to clean grain permits more accurate planting, a more accurate evaluation of the seed quality, and more dependable laboratory analysis than is true for unhulled grass seed. The prinicpal objection to this treatment at present is that no commercial planting equipment is available for field seeding at the low per-acre rates required if the full value of the hulled seed is to be realized.

A Preliminary Study of the Distribution of Roots of *Ulmus pumila* in a Sand Dune

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For a number of years many windbreak plantings of *Ulmus pumila,* Chinese elm, on sandy sites in eastern New Mexico have been building up sand dunes within and adjacent to the plantings. Some of the plantings bordering cultivated fields or roads often accumulated soil to a depth of more than six feet. This buildup was especially noticeable during the drought years experienced during the 1930's. In spite of this accumulated soil over the original planting level, a large percentage of the plantings of *Ulmus pumila* managed to survive. The relatively scant precipitation was available for plant life during the drought years is shown by the weather data at the U. S. Field Station near Tucumcari, New Mexico. The average annual precipitation from 1931 through 1940 was 13.70 inches. During the driest year of the drought, only 6.13 inches was recorded in 1934. The seasonal precipitation, from April to September, inclusive, amounted to only 4.65 inches that year, as compared to the average seasonal precipitation of 10.63 inches.[2]

Examination of many of these plantings showed that if a brisk reverse "blow" occurred after a relatively long "quiet" period, the wind would remove several top inches of the sandy soil and expose a multitude of small fibrous roots of *Ulmus pumila.* The presence of these small feeder roots indicated that the species depended rather strongly upon securing moisture in the upper portion of the dunes. In order to ascertain the distribution of the roots of *Ulmus pumila* on dunes that had accumulated after establishment of the species, the present preliminary study was made.

The planting which was selected for the study is located in Quay County at the U. S. Field Station near Tucumcari, New Mexico. The planting consists of two rows of *Ulmus pumila* planted in a north-south direction with a spacing of 15 feet between the rows. The planting was made in the spring of 1931. The windbreak is located along the west boundary of the

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[1] Acknowledgment is made of the assistance given by Mr. D. R. Burnham, superintendent, U. S. Field Station, Tucumcari, New Mexico.

[2] Summarized from monthly data furnished by Mr. Burnham. This data, submitted by Mr. Johnson, was omitted to conserve space, but is available upon request.—Editor.

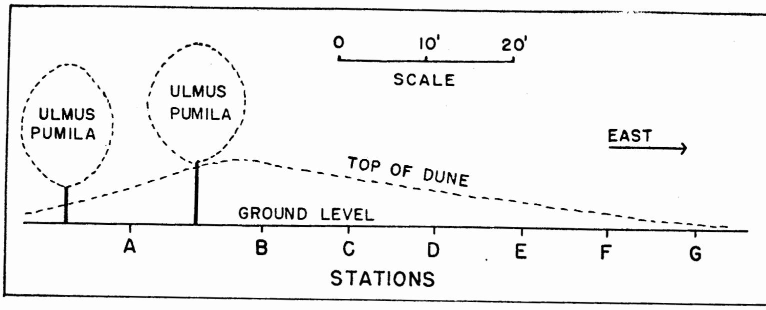

Fig. 1.

Station and the accumulation has resulted from sandy soil blown in from an adjoining cultivated field to the west. The relative size of the dune as of November, 1940, when the study was made, is shown in Figure 1.

Method Used

Two trenches were dug across the entire width of the dune. These were made with a horse and "slip" and facilitated the work of removing cubic foot sections of soil at regular intervals along one wall of each trench. The first series of cubic foot samples was started midway between the two rows of trees at point A; the second series was started at point B, equi-distant from the trees, namely, 7½ feet east of the east tree row. The other points C, D, E, F and G were taken at 10-foot intervals as shown in Figure 1. As each cubic foot sample was taken at the various levels from the top of the dune, the roots from each section were carefully separated from the soil. The root samples were uniformly air-dried and carefully weighed. The total weights of all of the roots found at each cross-section were recorded and the roots were then separated into two groups according to size. A separate weighing was made of all the small feeder roots in order to get a comparative reading of the distribution of the feeder roots as related to the distribution of all roots. The readings made at station A were disregarded inasmuch as the roots found there were from both tree rows and were in a limited zone of intense competition.

Results and Summary

The actual weights of all roots and of the feeder roots of *Ulmus pumila* in cross-sections at the various levels below the top of the dune were converted to percentages. These results are illustrated graphically in Figures 2 and 3.[3]

[3] Tables showing the percentage of all roots and of feeder roots for the various levels at each of the stations indicated in Fig. 1 (except Station A; see text) for both trenches were presented by Mr. Johnson but are omitted here to conserve space. The tables are available upon request.—Editor.

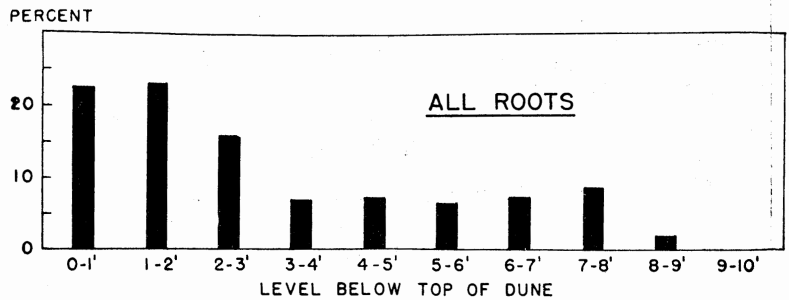

Fig. 2.

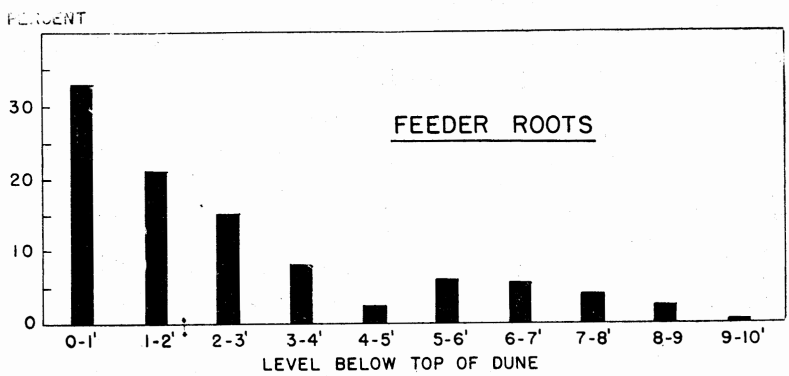

Fig. 3.

More than 60 percent of all of the roots in the east side of the dune were found in the upper 3 feet of the dune. More than 50 percent of all of the roots were in the upper 3 feet of the dune from the base of the east row of trees to a point 37½ feet away from the trees.

The percentages of small feeder roots found in the upper 3-foot level of the dune was even greater, being 69 percent. Approximately one-third of all of the feeder roots were found in the upper one-foot level of the dune. More than 52 percent of all of the feeder roots were found in the upper 3-foot level extending 37½ feet away from the base of the trees.

Photographs made of the root system of the trees show that as new roots developed along the stem of the tree near its base, they turn upward instead of extending downward into the original ground level or laterally from the stem. After the roots turn upward in the dune, they then roughly parallel the top of the dune. Visual examination showed that the primary roots that were developed at the original planting level had died and were decayed.

This preliminary study of the distribution of roots of *Ulmus pumila* in this particular sand dune indicates that the major portion of all of the roots and particularly the small feeder roots, are located in the upper soil levels. The development of a multitude of small feeder roots near the surface of the dune partially accounts for the ability of the *Ulmus pumila* to take advantage of even small amounts of precipitation when soil moisture penetration is comparatively shallow.

The Status and Use of Shelterbelts in Western Oklahoma

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Tree planting was begun in what now is Oklahoma even before the date of the first legal settlement in th spring of 1889. Where factors of site, selection of species, protection and maintenance were sufficiently correlated, some of these plantings still exist in varying degrees of vigor. Immediately following settlement, the planting of forest trees was mainly for shade or for aesthetic values. Before long, however, many plantings for protection from both summer and winter winds as well as for fuel and posts were being attempted on both suitable and prohibitive soil types in western Oklahoma. Sporadic planting of farmstead windbreaks and of ornamental trees continued through the first half of this century, but it was not until President Roosevelt took a personal interest in the Shelterbelt Project in 1933 that any exceptional impetus was given the use of trees for soil stabilization and crop protection. In the past ten years nearly three thousand miles of tree shelterbelts have been planted in western Oklahoma in the 21- to 30-inch rainfall zone.

Because of the previously indifferent success or complete failure of extensive field plantings in many instances, the large scale tree planting programs launched in the middle 30's brought on a wave of controversy over the feasibility of trees in the Plains region. Many persons stated their belief that trees in close stands could not be expected to thrive in a region where they had originally grown only along creeks or rivers. They pointed to the many early-day failures in field plantings on the upland. With the development of the program and the successful establishment of many millions of trees in windbreak plantings, this view has given way, for the most part, to an increasingly high regard for the field shelterbelt as a practical measure to help prevent wind erosion on the lighter soils.

Of the three thousand miles of shelterbelt planted in Oklahoma, the majority are already fulfilling their planned role, or they can be made into desirable belts by correcting relatively minor mistakes. These belts are very largely the wide, multiple-use type of plantings. They are intended as the basic foundation for extensions by the landowner into complete protective patterns. The development of such patterns was slow prior to 1942 because many farmers hoped direct federal assistance might be broadened sufficiently to cooperate in this task and because, during the war, the lack of labor made extensive planting out of the question. Even so, some farmers in almost every locality have increased their protection by adding narrow belts. Quite a number of miles of shelterbelt patterns have been planned in connection with coordinated soil and moisture conservation measures which the state's soil conservation districts are carrying on with the farmers of western Oklahoma. The districts have the help of Soil Conservation Service technicians in this work.

This slack period in extensive shelterbelt planting was not without value. Farmers are able to see, from looking at the older belts, what they might expect in completing the pattern begun. Technicians have not only had this same opportunity, but a further one for analyzing the many factors affecting the planning and use of shelterbelts. Some forty million forest trees have been planted in western Oklahoma under some degree of technical guidance, and additional millions have been used as ornamentals or in farmstead windbreaks and utility plantings according to the individual's needs and tastes on all types and conditions of soil. These trees, in their many combinations and associations, provide the technician a rich heritage in sign posts for practical planting in the future.

The known factors now enable (1) the designing of shelterbelts composed of tree and shrub species proved to be adapted to the environment and tolerant of each other, (2) the selection of species most resistant to disease and insect damage, (3) the evaluation of sites in terms of soils, topography and erosion conditions which can support the desired shelterbelt structure, and finally, (4) the grouping of shelterbelts into effective patterns for maximum benefits.

An effective shelterbelt can be designed from relatively few trees and shrub species. These are desert willow, Russian mulberry, red cedar, shortleaf, loblolly and Austrian pines, cottonwood, sycamore, honey locust and Chinese elm. These species are able to remain thrifty in close association with each other, and to achieve a height and form contributing to the desired type of structure. Such a structure is one providing the maximum height possible with an unbroken face of foliage extending upward from the ground level.

Within limits, the width of the shelterbelt has relatively little influence on its effectiveness. Land use considerations and the economics of the average farm, considered together with possibly slight variations in effectiveness of shelterbelts of various widths, are restricting present planning almost wholly to belts of three to five rows. Attempts at fostering unusual longevity for the planting as have been carried out in the wider belts through using extra rows of slow growing, relatively long lived trees in combination with the fast growing, shorter lived species, are now being undertaken in the narrower belts, for the most part by the use of conifers rather than of decidous species. The mounting disfavor for inclusion of post species in the composition is another reason for the increasing use of narrow shelterbelts. Utility post species planted in pure stands on good sites, often in out-of-the-way field or creek corners, produce better products at a faster rate. The object and hence the methods for managing a post planting or a shelterbelt are not compatible.

At the present, the greatest weakness among the tested shelterbelt species lies in the tall tree group. Cottonwood and sycamore are restricted to relatively few sites. Thornless honey locust seldom develops an effective type of crown until it approaches full stature, and Chinese elm suffers considerable breakage from wind and ice. However, these represent the most suitable of any species tested to date, and unless some of the exotics being tried give better promise, it will be necessary to continue their use or employ trees attaining less height and decrease the interval between belts in the farm pattern.

Another problem receiving detailed attention for the past eight years and at present only partially solved is the use of shelterbelts in localities infested with cotton root rot [*Phymatotrichum omnivorum* Shear (Dugger)]. This area in Oklahoma within the shelterbelt zone is confined to parts of Cotton, Tillman, Kiowa, and Comanche Counties. Investigations have been restricted to deep, medium to coarse textured, permeable to freely permeable soils as those suited to shelterbelt planting within the 21- to 30-inch rainfall zone. As far as is known, any dicotyledonous tree or shrub may be infested by the *ozonium* fungus, but there is wide variance in their ability to withstand the attacks. Even so, the present number of species known to be highly resistant to cotton root rot is small. Some of them make little contribution to the shelterbelt structure. The species are desert willow, cedar, soapberry, hackberry, and ailanthus. Sycamore is usable and desirable when alternated in the row with ailanthus. If a higher loss from root rot is accepted and additional rows are used in the shelterbelt, green ash, apricot and eastern black walnut may be used within the limits of the rainfall zone and soil types mentioned above.

One development of particular interest in connection with the shelterbelt species now employed is the excellent showing being made by shortleaf and loblolly pine in the southern half of the state on deep, medium textured, freely permeable soils. Both species have been growing at the average rate of 3½ feet per year over a six-year period on the more favorable sites. Some shortleaf has grown as much as five feet per year over the same period. Even on very poor sites the growth rate has averaged about two feet annually. Based only on the ten years experience to date, it would be unwise to predict the final outcome of these plantings, but it may be that these trees, in combination with cedar or Arizona cypress, will make it possible to have highly effective belts of coniferous species alone. The great advantage of conifers in providing all-season protection is accepted by all.

The tree species mentioned above are all well adapted to one or more of the three upland soil groups now recognized as suitable for and responding to the use of shelterbelts. The conservation survey soil units that are in general suitable are (1) the deep, medium textured, permeable soils; (2) the deep, medium textured, freely permeable soils; and (3) the deep, coarse textured, permeable soils. The permeability of all these soils must extend for a depth of at least six feet. Further qualifications are that these soil units occur within Land Capability Classes I, II, and III; i. e., with slopes not exceeding 4 percent and with erosion conditions less than severe. Oklahoma has thousands of acres now in cultivation within the shelterbelt zone conforming to the above standard. Theoretically, especially designed shelterbelts with wide row spacing may be established on heavier or shallower soils, but there is a question of their economic feasibility, and it is certain that so far it has not been possible to prescribe the cultural treatment necessary for their perpetuation in complete patterns.

The shelterbelt pattern is all-important in arriving at any appreciable soil and crop protection. In fact, it is doubtful whether the isolated one-half mile belt so commonly planted pays for the ground it occupies. Investigations have shown that four-or-five-row shelterbelts in patterns pay their way in increased crop yields alone. The soil stabilization benefits, our major concern, may be counted as clear profit. Present shelterbelt planning is largely on the basis of shelterbelt intervals of eighteen to twenty times the expected height of the tall trees, realizing other soil stabilization measures such as strip cropping or sound crop residue management may be needed. Shelterbelt intervals equal to twelve to fifteen times the height of the tall trees would be needed for satisfactory wind control with trees alone.

Shelterbelts are an effective conservation measure in the control of wind erosion. Some factors are still imperfectly known, but it is now possible to plan and plant shelterbelts with assurance of success. The Soil Conservation Service, through the soil conservation districts, is giving increasing emphasis to the use of this conservation tool.

Urgent Agronomic Problems

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We appreciate the opportunity so kindly provided for me to appear before this group of agricultural workers to present what the Soil Conservation Service operations personnel consider to be the most urgent agronomic and soils research needs pertaining to soil and moisture conservation.

It is realized that some research work is already under way on some of the subjects which will be mentioned. The results to date of some of this work have been reported previously during this conference. However, as a matter of emphasis they have been included in this paper.

In order to obtain the thinking of those closely associated with field operations, all district conservationists and survey supervisors in the state of Oklahoma were asked to submit suggestions. State office representatives and regional office technicians who work in Oklahoma were also requested to present their ideas on this subject. It is rather interesting to note the uniformity of thinking as to what research is needed in the various sections of the state. It is difficult to list in priority those problems which are the most urgent, and no attempt has been made to do so. Where the need for a particular type of research is confined to a specific section of the state, it is so indicated:

1. Grass-cropland rotations. It is believed that information on this subject is needed throughout the state. We are very hopeful that the work under way at Woodward will supply much of the information needed with reference to the Rolling Plains area. The value of legumes for soil improvement purposes in the central and eastern portions of the state is well recognized. However, the question is constantly arising as to the advisability of including grass in a soil-conserving and soil-improving rotaton. We need to know:

a. Species of grass to use. (Should be one which can be readily established.)

b. Length of rotation.

c. Desirability of including a legume in the mixture in the western portion of the state.

d. Effects of such rotations on the physical condition of the soil and yield of crops as compared with those in use at the present time.

2. The value of legumes in a cropping system in the western portion of the state; namely, the Rolling Plains and the High Plains. Specifically, the problem is primarily that of the advisability of including sweet clover, vetch, Austrian winter peas, or other legumes in a cropping system on the wheat, grain sorghum, and cotton areas.

3. On the sandy lands in western Oklahoma research is needed to develop a means of land preparation prior to planting and cultivating that will leave all or most of the crop residue on the surface to prevent wind erosion. This type of soil is best adapted to row-crop farming and it is often necessary to replant from two to four times as a result of losing the stand because of wind erosion.

4. In western Oklahoma there is need for a grass which can be readily established (one growing season), and which wil afford adequate cover in terrace outlet channels and waterways for the disposal of terrace runoff water.

5. Additional information is needed as to the results that can be secured by applying barnyard manure to various crops in the 15- to 25-inch rainfall area in western Oklahoma.

6. Information is needed on irrigated land in the High Plains and Rolling Plains. The development of the Altus irrigation project, along with other smaller irrigation projects in western Oklahoma, has focused attention on this need. Practices and crops on which further information is needed are:

a. Irrigated pastures: (1) Adapted legumes; (2) adapted grasses; (3) mixtures; (4) management.

b. Use of fertilizers for soil conserving and improving crops.

c. Cropping systems to control erosion and to increase soil productivity.

7. Establishment of Bermuda grass by seeding in that portion of the state where it is adapted.

8. Methods of establishing native and introduced grasses on the eroded soils of the West Cross Timbers and Reddish Prairies, with particular reference to the old cultivated and idle fields.

9. The value of Lespedeza sericea in the eastern portion of the state, for use as hay, grazing, and soil improvement.

10. Continud emphasis on studies to determine the most practical and effective methods of performing stubble mulch tillage.

As pointed out in the beginning of this discussion, there is some research work already initiated on some of the subjects mentioned, which should be continued. It is entirely possible that research work has been completed on some of the problems; if so, it is requested that this information be assembled and made available for field use as soon as possible.

There is a need for information with reference to various treatment and management practices in specific areas on different soil groups. Since these are somwhat of a local nature it is believed that this type of information can best be secured through the extension of research field trials, many of which are being conducted at the present time.

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