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SUDAN GRASS SILAGE

TECHNICAL BULLETIN

BY C. K. FRANCIS AND W. G. FRIEDEMANN

DEPARTMENT OF CHEMISTRY

A SINGLE STOOL OF
SUDAN GRASS

SUDAN GRASS SILAGE

BY C. K. FRANCIS AND W. G. FRIEDEMANN

The Department of Chemistry is engaged in investigating silage as prepared from the grain sorghums and closely related crops. A part of this experiment involves considerable work with sudan grass, and, owing to the apparent excellent quality of the silage, it has been deemed advisable to publish some of the results of this experiment at this time.

Sudan grass was introduced into the United States from the Sudan district, Northern Africa, by the United States Department of Agriculture and first grown at the United States Field Station, Chillicothe, Texas, in 1909. The Oklahoma Agricultural Experiment Station obtained a supply of the seed which was planted in the spring of 1912, and since then a crop has been grown each year; additional tests have been made in various parts of the State which have demonstrated the value of sudan grass as a forage crop for this section. The chemical composition indicates that it is a feed of good quality, comparing favorably with timothy and millet, and very much better than prairie hay. The comparative values are indicated in the analysis reported in Table I.

TABLE I

Chemical Composition of Sudan Grass as Compared With Other Hay

Hay	Water	Ash	Protein	Carbohydrates		Fat
				Fiber	Nitrogen-Free Extract	
Sudan grass	7.20	5.60	7.94	31.56	45.45	2.04
Prairie hay	8.12	7.67	4.34	35.06	42.66	2.25
Cane fodder	8.38	6.31	6.62	23.43	52.01	3.25
Kafir fodder	6.96	8.94	8.75	27.87	45.51	1.97
Alfalfa	8.40	7.40	14.30	25.00	42.70	2.20
Bermuda	6.52	8.03	11.91	24.85	46.60	2.09
Millet	7.70	6.00	7.50	27.70	49.00	2.10
Mimothy	13.20	14.40	5.90	29.00	45.00	2.50

A previous bulletin of this Station, by R. E. Karper,* describes sudan grass, the preparation of the ground, methods of planting, and time and method of harvesting. The crop which was used in the experimental work herein described was sown with an ordinary grain drill at the rate of eighteen pounds to the acre. The grass was cut with a grain binder and hauled almost immediately to the silo. At the time of cutting, about one-sixth of the plants had reached the milk stage. The plants made a rapid growth and the dense condition caused the development of the fine stalks. Experiments on the College farm have demonstrated that when the crop is seeded by means

*Sudan Grass, Bulletin No. 103, 1915.

of a drill the stalks are much larger than when the seed are broadcast.

A steel silo 25 feet high and 9 feet wide, approximate capacity seventy-five tons, fitted with doors and without a cover was used for curing the crop. As each door was put in place it was made airtight with the aid of cotton batting. About a week before filling, the interior of the silo was thoroughly covered with asphalt paint. The sudan grass was cut early in August, 1916, during a dry period, so that the plants did not contain as much moisture as desired. The cutter was adjusted so as to cut to a three-quarter-inch length and a small stream of water was kept flowing into the blower, thus distributing the added water throughout the material as it was placed in the silo.

During the filling of the silo the material was packed by three men tramping it into place as solidly as possible. The sudan grass, owing to its leafy nature and dry condition, did not pack readily. The day after the silo had been filled, water was added at the top until it ran out at the two-foot level. Three days later the contents of the silo had settled several inches, and this space was filled with additional wetted silage to serve as a cover. This material did not cure well, and was discarded when a strong, moldy condition developed, but the silage just beneath it cured nicely and retained its flavor throughout the feeding period.

The composition of sudan grass silage as compared with corn silage is shown in Table II. The length of time which the material remained in the silo is indicated in the first column as days.

TABLE II

Percentage Composition of Sudan Grass Silage and Corn Silage

(Water-free basis)

	Ash	Protein	Carbohydrates		Fat	Dry Matter
			Fiber	Nitrogen-Free Extract		
16-8-4 Sudan grass silage, fresh	7.21	9.38	30.55	50.53	2.33	40.47
16-7-18 Corn silage, fresh	6.58	8.39	23.39	59.48	2.16	30.49
16-12-1 Sudan grass silage, near top 122 days	5.60	8.20	33.53	50.50	2.17	27.74
16-12-29 Corn silage, near top, 148 days	6.81	9.56	23.62	57.41	2.60	27.75
16-12-28 Sudan grass silage from middle, 140 days	6.51	10.36	33.57	46.79	2.77	27.24
17-2-1 Corn silage from middle 182 days	6.20	8.85	22.84	59.15	2.96	27.44
17-1-36 Sudan grass silage, 2 feet above bottom, 281 days ...	5.15	8.33	34.69	49.11	2.72	24.29
17-2-8 Spoiled sudan grass silage, 2-foot level, 192 days	8.95	10.94	29.05	48.82	2.24	24.28

It is necessary when studying substances of this nature to reduce the analyses to a comparative basis by eliminating the water, because the quantity varies to a great degree in different samples. The total dry matter is reduced in the spoiled silage, whereas the protein is increased. The increase in the amount of protein may be accounted for by the fact that in decay of this nature objectionable proteid substances are produced. These may often be detected by the presence of bad odors.

It will be observed that on the whole there is but little difference in the analyses of the corn silage and the sudan grass silage at the several stages of curing, the principal difference being in the quantity of fiber.

The original analyses are shown in Table III. The data in the column under "as sampled" represent the material when it was brought to the laboratory and it is in this condition that it was used as a feed. The nitrogen-free extract includes the soluble carbohydrates, such as sugars and gums. Other substances may be included; for example, acids and compounds related to the alcohols. Probably this is the most important group of substances present because they produce the pleasant aroma and taste which cause many animals to relish silage.

TABLE III

Analyses of Sudan Grass Silage and Corn Silage

	As Sampled	As Analyzed	Water-Free
16-8-4 **Sudan Grass Silage as Put in Silo**			
Water	59.53	8.02	....
Ash	2.92	6.63	7.21
Protein	3.80	8.63	9.38
Fiber	12.36	28.10	30.55
Nitrogen-free extract	20.45	46.48	50.53
Fat	.94	2.14	2.33
	100.00	100.00	100.00
16-7-18 **Fresh Corn Silage as Put in Silo**			
Water	69.51	9.11	....
Ash	2.00	5.98	6.58
Protein	2.56	7.63	8.39
Fiber	7.13	21.26	23.39
Nitrogen-free extract	18.14	54.06	59.48
Fat	.66	1.96	2.16
	100.00	100.00	100.00
16-12-1 Sudan Grass Silage Below Spoiled Portion, 122 Days			
Water	72.26	7.83	....
Ash	1.55	5.16	5.60
Protein	2.28	7.56	8.20
Fiber	9.30	30.90	33.53
Nitrogen-free extract	14.01	46.55	50.50
Fat	.60	2.00	2.17
	100.00	100.00	100.00

16-12-29 Corn Silage Below Spoiled Portion, 148 Days	As Sampled	As Analyzed	Water-Free
Water	71.25	13.68	....
Ash	1.96	5.88	6.81
Protein	2.75	8.25	9.56
Fiber	6.79	20.39	23.62
Nitrogen-free extract	16.50	49.56	57.41
Fat	.75	2.24	2.60
	100.00	100.00	100.00
16-12-28 Sudan Grass Silage from Middle, 140 Days			
Water	72.76	8.90	....
Ash	1.77	5.93	6.51
Protein	2.82	9.44	10.36
Fiber	9.14	30.58	33.57
Nitrogen-free extract	12.75	42.63	46.79
Fat	.75	2.52	2.77
	100.00	100.00	100.00
17-2-1 Corn Silage from Middle, 182 Days			
Water	72.56	9.60	....
Ash	1.70	5.60	6.20
Protein	2.43	8.00	8.85
Fiber	6.27	20.65	22.84
Nitrogen-free extract	16.23	53.47	59.15
Fat	.81	2.68	2.96
	100.00	100.00	100.00
17-1-36 Sudan Grass Silage 2 Feet from Bottom, 281 Days			
Water	75.71	6.95	....
Ash	1.25	4.79	5.15
Protein	2.02	7.75	8.33
Fiber	8.43	32.28	34.69
Nitrogen-free extract	11.93	45.70	49.11
Fat	.66	2.53	2.72
	100.00	100.00	100.00
17-2-8 Spoiled Sudan Grass Silage, 2-Foot Level			
Water	75.72	2.86	....
Ash	2.17	8.69	8.95
Protein	2.66	10.63	10.94
Fiber	7.06	28.22	29.05
Nitrogen-free extract	11.86	47.42	48.82
Fat	.55	2.18	2.24
	100.00	100.00	100.00

The curing of the fresh crop so as to produce the material known as silage depends to a large degree on a process of fermentation. Recently it has been demonstrated that fermentation proceeds under the influence of certain complex substances known as enzymes, and these have the power to decompose and in other ways change the substances present so as to form acetic acid. If an extra large quantity of air should be present, together with an excess of water, the amount of acetic acid necessary to act as a preservative will not be produced, and then objectionable substances, such as mold, may develop. Experiments made by this department have shown that the fermentation or condition of the silage may be judged to a great extent by the temperature produced during the early stages. Usually the maximum temperature is reached within the first thirty-five to forty days, and should any great increase occur afterward it evidences abnormal chemical action.

TABLE IV

Temperatures Recorded

(Degrees Fahrenheit)

Observation Made		Location of Thermometer in the Silo			Atmospheric Temperature at the Same Time (Maximum)
Date	Days After Filling	Near Top	Middle	Near Bottom	
August					
5	0	95.0	89.6	89.6	99
7	2	109.4	93.2	93.2	95
8	3	107.6	95.0	95.0	99
9	4	109.4	95.0	96.8	96
10	5	109.4	95.0	95.0	98
11	6	107.6	96.8	96.8	96
12	7	113.0	96.8	96.8	97
14	9	113.0	96.8	96.8	102
16	11	113.0	98.6	96.8	99
18	13	111.2	98.6	96.8	96
19	14	111.2	100.4	98.6	96
21	16	111.2	100.4	98.6	99
23	18	114.8	102.2	96.8	89
25	20	116.6	104.0	96.8	96
26	21	120.2	98.6	96.8	98
28	23	113.0	100.4	96.8	69
30	25	114.8	100.4	96.8	89
September					
1	27	114.8	102.2	98.6	83
4	30	118.4	100.4	95.0	90
6	32	113.0	98.6	93.2	94
8	34	114.8	100.4	93.2	95
11	37	114.8	98.6	96.8	94
13	39	116.6	98.6	95.0	76
15	41	116.6	98.8	93.2	72
18	44	118.4	95.0	91.4	84
20	46	114.8	89.6	84.2	87
22	48	109.4	93.2	84.2	82
25	51	115.8	89.6	86.0	86
28	54	107.6	86.0	80.6	88

The temperature developed in the silo was noted at regular intervals until a decided fall was observed. These records were obtained by means of a registering maximum thermometer which las lowered into a two-inch pipe erected in the center of the silo. Each observation was made by lowering the thermometer to the proper level and allowing it to remain there for five minutes. The upper or top level was fixed at five feet from the top of the silo, the middle level at twelve feet, and the lower level at twenty feet, or five feet from the bottom. Observations of temperature were made from August 5 until

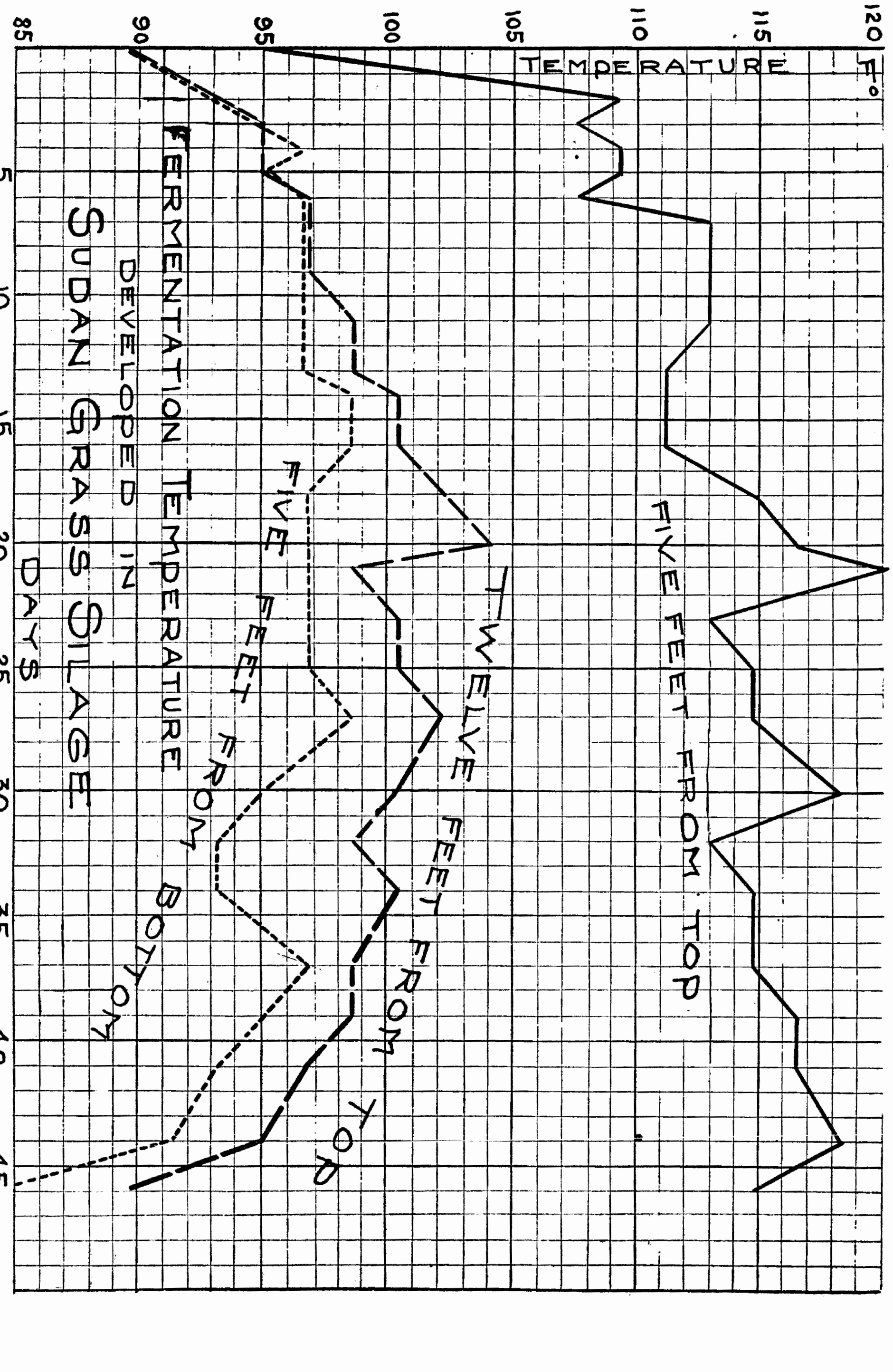


Figure I

Novmber 10. The record of the temperature readings covering the curing period is shown in Table IV, and illustrated in the curve, Figure 1.

It appears from the table and the illustration that the maximum temperature is reached in about twenty-one to thirty days, as indicated by the record of August 26 for the top portion, of August 25 for the middle portion, and September 1 for the bottom. A well defined reduction of temperature is indicated by the records for September 4 and 6. Therefore, any subsequent material rise must be due to a secondary fermentation which may develop from a number of abnormal conditions.

It must be remembered that a silo is similar to a can or jar used in the canning of vegetables and fruits, and many of the precautions observed in the canning process must be taken into account in curing and preserving silage. An excess of water is better than too little, but the most important thing is the exclusion of air. If the material is not cut into small pieces and not well packed (both conditions often exist), large amounts of air will be included, the presence of which will materially hasten spoiling.

The curve shown in Figure 1 illustrates the temperatures recorded for sudan grass in a metal silo for the period indicated. On August 26 (twenty-one days) it will be noted that the temperature was high in the top portion and had started to fall at the middle and at the bottom. Additional records show that on October 20 (seventy-six days) the temperature was a degree and a half higher, but it should be explained that on October 12 (seventy days) and 14th (seventy-two days) there was rain; and, as the silo was not covered no doubt this increased temperature resulted from a secondary fermentation caused by the additional moisture being introduced into the silo at that time. Some of the silage near the top was spoiled, and while a small quantity of silage is usually lost, any extensive formation of molds should not occur.

One of the causes of spoiling is that of rain falling into the silo and producing a temperature and moisture condition favorable for the development of enzymes which aid the growth of various molds. The temperatures recorded for October 17 and 20, top portion, show a considerable rise, which may be explained as being due to spoiling, which was assisted by warm, damp weather, followed by rains on October 12 and 14. The total quantity spoiled in this silo was approximately four feet, being the covering material.

It has been the common practice in Oklahoma not to cover silos because it has been thought that the rainfall was not enough to cause a serious damage to the silage. However, the cost of a roof is so small that no one should risk losing a large quantity of excellent feed for the lack of a watertight cover. The College is now covering all of its silos.

One of the objections which has been raised against sudan grass is the difficulty of curing it for fodder. The character of the plant is such that it has been known to heat and spoil in the stack after being cured in the sun for so long as a week to ten days. The crop is easily cured with practically no loss of silage, therefore the silo offers a means for handling and satisfactorily curing this crop, thereby overcoming the objection.

This sudan grass silage was somewhat bulkier than corn silage, was of a light brown color, and had a faint acid odor. No alcohols were detected by the usual laboratory methods. The silage was fed to the College sheep, and, while proving a good feed, it did not appear to be relished by the animals so well as the corn silage, but quite as well as that made from other grain sorghums, and was relished much more in this form than as cured hay.

In the establishment of terrace outlets or other conservation channels, stability is one of the main concerns. The channel must be protected from washing out and developing into a gully. Vegetation generally provides the most economical means of obtaining this protection. The measure of the protective ability of vegetation is the speed of flowing water to which it can be subjected and still prevent soil loss and failure of the channel which it lines. This velocity which should not be exceeded is generally termed the "permissible velocity." It is possible to control the speed with which a given rate of flow of water will pass down a given slope by proper selection of channel cross-section and lining. Before a rational design of a conservation channel can be atempted, an estimate must be made of the permissible velocity. This velocity will depend principally on the kind and condition of vegetation in the channel and on the texture of the soil. The experiment reported herein is concerned chiefly with the effect of the soil texture variable on the permissible velocity in grass-lined channels.

These experiments were conducted at the Stillwater Outdoor Hydraulic Laboratory of the Soil Conservation Service Research in cooperation with the Oklahoma Agricultural Experiment Station. A good description of this laboratory appears in the proceedings of the First Annual Oklahoma Crops and Soils Conference.* Suffice it to say here that facilities are available at this laboratory for constructing, planting, and maintaining various types of conservation channels. Water is available for testing any channel at any time.

THE EXPERIMENT

To determine the relative protection offered by a grass to channels in soils of different textures, an experiment was devised wherein channels identical in every respect except soil texture were subjected to identical flows of water. In this way the damage to the different channels could be compared readily and the relative protection offered by the grass evaluated.

Three soil textures were employed in this experiment. These were a silt loam, a sandy, and a fine sand. Two grasses were used, Bermuda grass and weeping lovegrass. The Bermuda grass was planted on all three soils. The lovegrass was planted only on the silt loam and the sandy loam. Table I shows the channel numbers of the combintions tested.

The cover in Bermuda grass channel U2-1 was established by sprigging. The covers in channels U2-4 and U3-7 were established from Bermuda grass roots left in the subsoil over which the topsoil had been placed. The topsoil was filled in to a depth of 3 inches. At the time of the tests (October) the covers were a dense, medium-long, uncut Bermuda grass. To the eye they appeared identical. Careful stand counts revealed higher density of cover in channel U2-1 than in U2-4 or U3-7. However, this difference in density was believed to be of minor importance.

The covers in the lovegrass channels, U5-1, U6-1, and U7-2, were established by seeding in April. At the time of testing (November) the stands were very similar in appearance. Measurements showed the grass to be a little longer in the first two channels than in the third.

The test procedure was to subject the channel to a measured flow for a 40-minute period. During the flow, measurements were made from which the mean velocity of the flow in the channel could be computed. After the flow had been stopped a careful examination of the channel bottom was made to see if any material had been moved or any plants torn out. Also, measurements of the bottom elevation at several cross-sections were

* Okla. Agri. Exp. Sta. Bul. B-295 (April, 1946).

TABLE I.—Channel Numbers of Combinations Tested.

Soil	Bermuda grass	Weeping Lovegrass
Silt Loam	U2-1	U5-1, U6-1
Sandy Loam	U2-4	U7-2
Fine Sand	U3-7	

Each of these channels had the following dimensions:
Shape: rectangular. Slope: 5 percent.
Bottom width: 3 feet. Length: 96 feet.
Sides: vertical plywood panels, in place only during flows.

made in an effort to determine the depth of scour. If little or no damage had occurred, the channel was subjected to a higher flow for another 40-minute period and the observations repeated. This was continued until the channel under test was judged to have been excessively damaged. Each channel was subjected to the same test schedule, from .01 c. f. s. to 70 c. f. s. Only channel U2-1 (Bermuda on silt loam) received all flows. The other channels showed evidence of failure at one of the smaller flows and testing was discontinued.

RESULTS OF THE EXPERIMENT

The results of this experiment are presented in Table II. It must be emphasized that the velocities given in Table II are not being recommended as "permissible velocities." Instead, they are, as indicated in the column heading, the mean velocity of flow in the channel during the test in which the permissible velocity was judged to have been exceeded. A recommended permissible velocity for a given soil-cover combination can be determined only after considerable testing in laboratory and observing in the field. E. g., in the silt loam Bermuda channel a flow velocity of 9.5 feet per second was reached before scour started to take place, yet the recommendation of this laboratory, based on many tests for a good channel of this soil and vegetation combination, would be 8 feet per second. Using this comparison as a basis, the permissible velocities tentatively recommended for good uniform covers in a uniform channel on slopes not exceeding the indicated maximum are as shown in Table III.

TABLE II.—Results of the Experiment.

Channel number	Cover	Soil texutre	Test flow during which permissible velocity was judged to have been exceeded		
			Flow No.	Discharge rate (c. f. s.)	Mean velocity (feet per sec.)
U2-1	Bermuda grass	Silt loam	15	35.7	9.5
U2-4	Bermuda grass	Sandy loam	13	11.0	5.9
U3-7	Bermuda grass	Fine sand	11	4.3	3.5
U5-1	weeping lovegrass	Silt loam	13	14.1	4.6
U6-1	weeping lovegrass	Silt loam	13	14.0	4.7
U7-2	weeping lovegrass	Sandy loam	12	6.8	2.7

TABLE III.—Tentative Permissible Velocities.

Grass	Soil texture	Permissible velocity (ft./sec.)	Maximum slope (ft./ft.)
Bermuda	Silt loam	8.0	.10
Bermuda	Sandy loam	5.0	.10
Bermuda	Fine sand	3.0	.05
Weeping lovegrass	Silt loam	3.5	.05
Weeping lovegrass	Sandy loam	2.0	.05

APPENDIX

Mechanical Analyses of Soils Used.—Mechanical analyses of the soils used in this experiment were made by Beuyouces method. The results are given in Table A-I.

Vegetation Density Measurements.—For the purpose of describing and comparing the stands, a stand count was made of the average number of stems of Bermuda grass per square foot. In the case of weeping lovegrass a line interception method was used instead. The results are presented in Tables A-II and A-III.

TABLE A-I.—Mechanical Analyses of Soils Used.*

Soil	Channels in which used	Analysis		
		% silt	% clay	% sand
Silt loam	U2-1, U5-1, U6-1	41	21	38
Sandy loam	U2-4, U7-2	8	28	64
Fine sand	U3-7	0	5	95

* By Soil Conservation Operations Soils Laboratory.

TABLE A-II.—Grass Density of Bermuda Grass by Stand Count Method.

Cover	Channel	Stems per square foot
Bermuda	U2-1	480
Bermuda	U2-4	375
Bermuda	U3-7	350

TABLE A-III.—Grass Density of Weeping Lovegrass by Line Interception Method.

Cover	Channel	% Interception
Weeping lovegrass	U5-1	23.2
Weeping lovegrass	U6-1	20.0
Weeping lovegrass	U7-2	19.3

Terrace Maintenance as a Normal Part of Farming Operations.

By J. J. COYLE
Chief, Regional Engineering Division
Soil Conservation Service
Fort Worth, Texas

The Soil Conservation Service of the U. S. Department of Agriculture, in cooperation with the boards of supervisors of the 77 soil conservation districts in Oklahoma, recently compiled an estimate of the total amounts of conservation practices needed in a coordinated soil conservation program for the farm and ranch lands of the state. Such a program consists of four essential points: (1) Proper land use; (2) the right combination of conservation practices; (3) maintenance or improvement of fertility; and (4) economically sound conservation farming or ranching. The estimate of the kinds and amounts of practices needed is based upon the district supervisors' knowledge of their districts and the knowledge gained by Soil Conservation Service technicians in helping and operators to develop farm and ranch plans.

According to the estimate, 730,305 miles of terraces will be required to protect lands to which this practice is adapted. Of this amount, 686,486 miles are needed on farm lands within organized soil conservation districts and 43,819 miles are needed on farms in areas where districts have not yet been organized.

At current charges for terrace construction by contractors, the cost of applying the needed amount of terracing for the state as a whole would be approximately $66,000,000. In addition to the cost of constructing the terraces, there is the further cost of providing protected outlets and waterways. Without them no terrace system can be considered complete or even satisfactory. The cost of providing the necessary outlets will probably amount to $16,000,000.

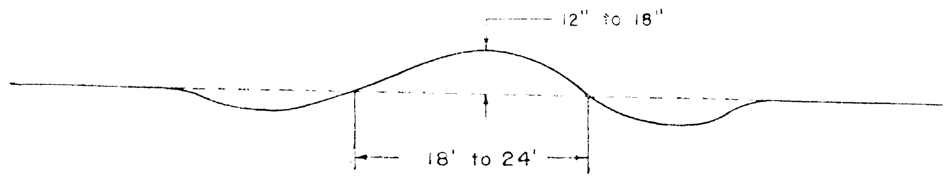
Much acceptable terracing with adequate outlets has already been applied. But unless these terraces and those yet to be constructed are properly maintained, there is every reason to predict that the entire investment of approximately $82,000,000 will be lost, or worse, may result in actual damage to the land.

The record of terrace maintenance has been anything but satisfactory. On many farms it would be difficult today to find traces of terraces which were at one time built up to adequate size. How do we explain this neglect of so costly a conservation practice? Is it because the average farm operator lacks the necessary equipment to maintain the terraces? We have ample proof that this is not the reason. We know that terraces have been maintained successfully with almost every type of plow. The fault probably lies in the fact that, in the past, the installation of terraces has been emphasized and promoted, with very little attention given to the need for maintenance. It is only during recent years that much thought has been given to systematic methods of terrace maintenance as a normal part of farm operations.

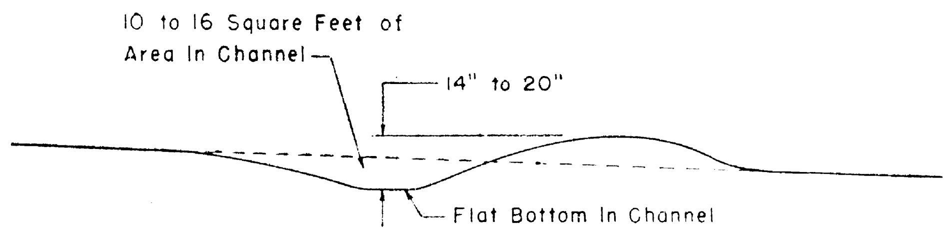
Before terrace maintenance can be emphasized properly, there must be a clear understanding of the different factors involved in a satisfactory maintenance program. The usual conception of terrace maintenance is limited to the plowing out of the channel for a channel-type terrace or plowing up the ridge of a ridge-type terrace.

Adequate terrace maintenance actually begins with proper use and care of the area between terraces. The operations involved in land preparation and crop cultivation should be performed parallel to the terraces. All gullies should be plowed in and planted to close-growing, fibrous-rooted crops wherever practical until the gullies have disappeared. As a further precaution against excessive silting of the terrace channel, the best conservation cropping system possible should be followed in cropping the terraced field. Such a system would include cover crops and soil improving crops as frequently as is practical. These crops not only act as an impediment to waterflow, but also, by the addition of organic matter, make the soil more absorptive and erosion resistant.

For the terraces themselves, one of the first steps should be the removal of all silt bars which have formed as a result of erosion in small gullies or rills between terraces that have been fully controlled. The removal of silt bars is usually done with a fresno or slip scraper. The



RIDGE TYPE TERRACE Recommended on Slopes of 3% or Less In Areas Where Conservation of Water Is A Major Factor In Terracing. Constructed By Moving An Equal or Nearly Equal Amount of Earth Into The Ridge From Each Side Maintenance Plowing Is Performed So As To Keep The Ridge Up To The Dimensions Shown.



CHANNEL ~~RIDGE~~ TYPE TERRACE: Recommended on All Terracable Slopes Where Primary Purpose of Terrace Is Erosion Control. Constructed By Moving All Earth Down Hill So As To Form Adequate Channel. Maintenance Plowing Is Performed So As To Keep Channel Open To Desired Dimensions And Blend Back Slope of Ridge Into Interval Below Terrace.

Fig. 1.—Types of Terraces in General Use.

material making up the bar is moved on to the terrace ridge or back up the slope to fill in a gully or rill.

Consideration should next be given to the need for building up any low areas in the terrace ridge which may have occurred as a result of excessive settling or from pulling equipment across the terraces in entering or leaving the field.

Plowing of the terraces as a part of the maintenance program is the next operation. The method of performing this operation depends upon the

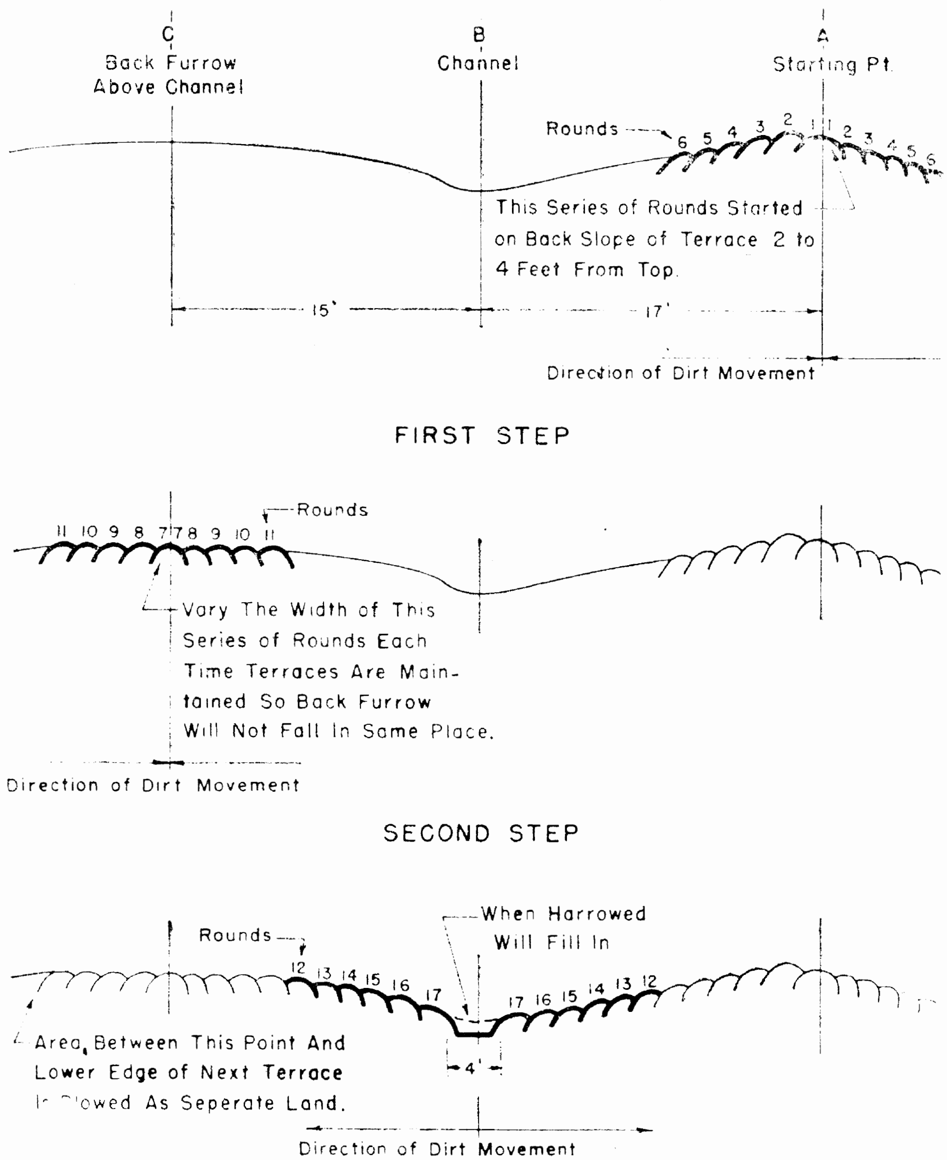


Fig. 2.—A Recommended Method of Maintaining Channel Type Terraces With Moldboard Plow.

type of terrace being maintained. The two types now in general use are known as the ridge type and the channel type. The ridge-type terrace is recommended for use on gentle slopes in areas where water conservation is of as much importance as erosion control. These terraces are often run level. The identifying characteristic is a ridge of earth 12 to 15 inches high and 18 to 24 feet wide as measured above natural ground elevation. Constructed in this manner, it is effective in backing water on to the area above the terrace. Maintenance plowing is performed by back-furrowing toward the ridge so that the desired height and width are maintained.

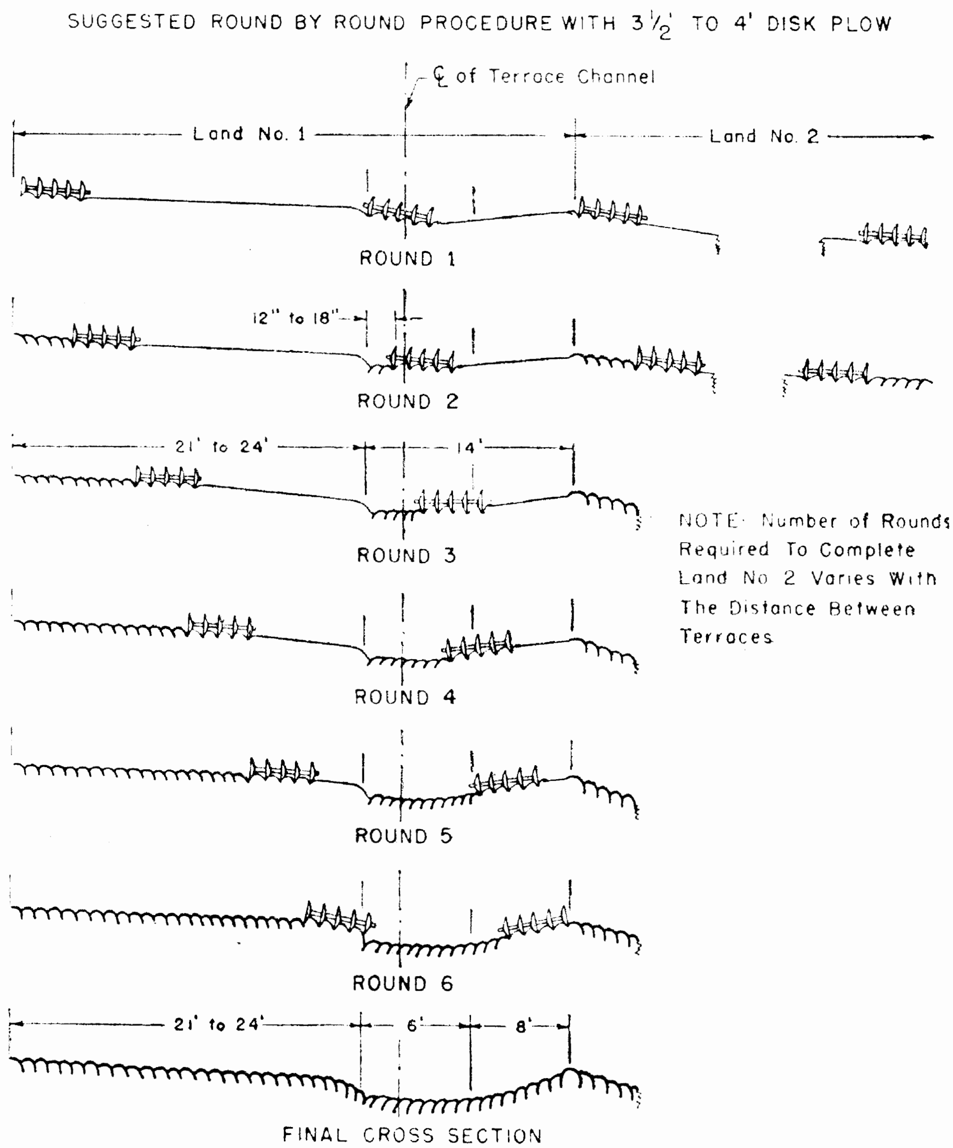
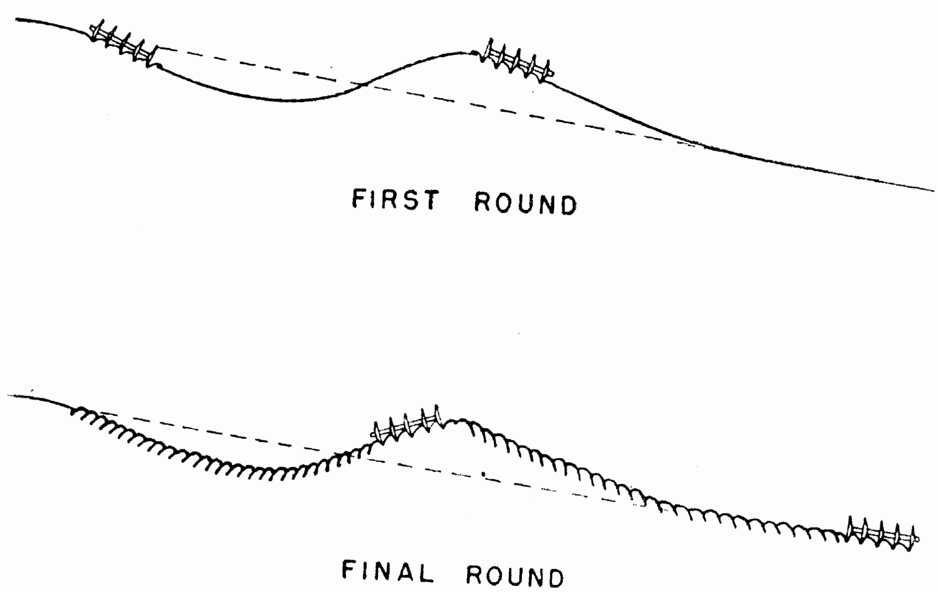


Fig. 3.—A Recommended Method of Maintaining Channel Type Terraces With Disk Plow.

The channel-type terrace is recommended for use on all terraceable slopes where the major problem is one of erosion control. This type of terrace consists of a water channel excavated to a depth of 6 to 10 inches below natural ground elevation, with the excavated material placed down slope in the form of a ridge. Maintenance plowing of a terrace of this type is performed in a manner that will maintain an effective cross-sectional area of 10 to 16 square feet in the water channel. The ridge below the channel is plowed so as to blend it in with the interval below the terrace as much as possible. Figure 1 shows the major differences between the two types of terraces.

There are many methods of plowing so as to obtain the desired results for each type of terrace. Typical methods are illustrated in Figures 2 through 6. An important point to remember in plowing the ridge-type terrace for maintenance is to vary the width of the plow land each year so



Rounds Should Be Spaced So That Width of Plowed Area Below Terrace Is 1/3 More Than Width of Plowed Area Above Terrace. This Calls For Overlapping The Rounds Above Terrace.

NOTE This Method Not Recommended For Continuous Use. May Be Used Occassionally In Rotation With Method Shown In Figure 3.

Fig. 4.—A Method of Maintaining Channel Type Terraces With Disk Plow.

that the dead furrow does not fall in the same place year after year. An important point to remember in connection with the channel-type terrace is to vary the method enough each year to prevent the formation of a secondary ridge above the water channel.

After the maintenance plowing is completed, the next step is to examine the ends of the terraces to make sure they are open where they should be open and closed where they should be closed. Many terraces, adequate in size from the standpoint of channel or ridge, have broken during periods of heavy runoff because the outlet ends were not open as they should be. A little work at the proper time with a fresno or slip scraper may save a large repair job later.

All of the effort put into terrace maintenance may be lost unless periodic inspection is made of the waterway or area which serves to dispose of the runoff from the terraces. Following each rain which produces heavy runoff, an inspection should be made and all necessary repairs made to the vegetative cover or structures. Mowing or controlled grazing should be practiced where the waterway or other outlet area is protected by vegetation,

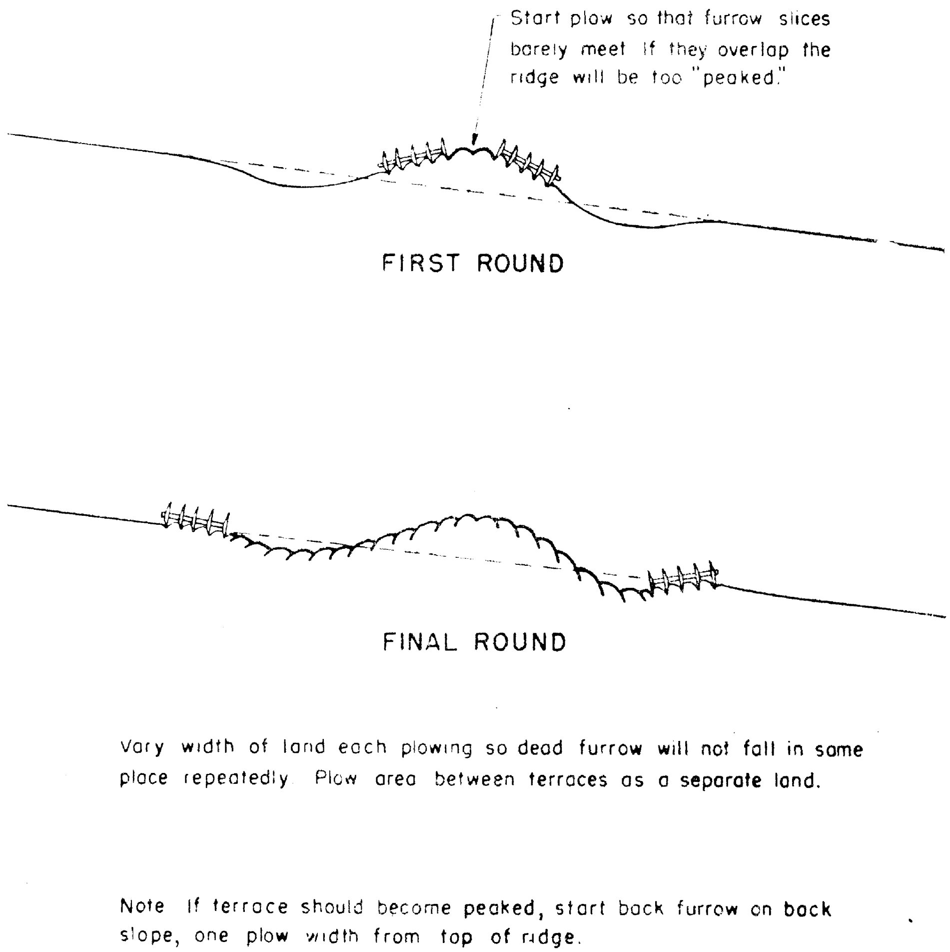


Fig. 5.—A Recommended Method of Maintaining Ridge Type Terraces With Disk Plow.

so that the desirable grasses will not be replaced by undesirable species or weeds.

It is nearly impossible to outline all of the factors involved in adequate terrace maintenance without leaving the impression that it is quite a large task. It is important to remember, however, that not all of the factors will involve actual work on every terraced field every year. For example, there will be little need for removal of silt bars after the first year or two if the intervals between terraces are handled properly. In fact, the entire job of terrace maintenance is simplified if we regard terracing as only one of many practices needed in a complete, coordinated erosion control propram. The success of terraces is entirely dependent upon control of erosion on the intervals between them. This control may be achieved by such measures as crop residue management, contour cultivation, and the fullest possible use of crops which give the maximum benefits in the form of cover and soil improvement. Also, there should be little need for repair to vege-

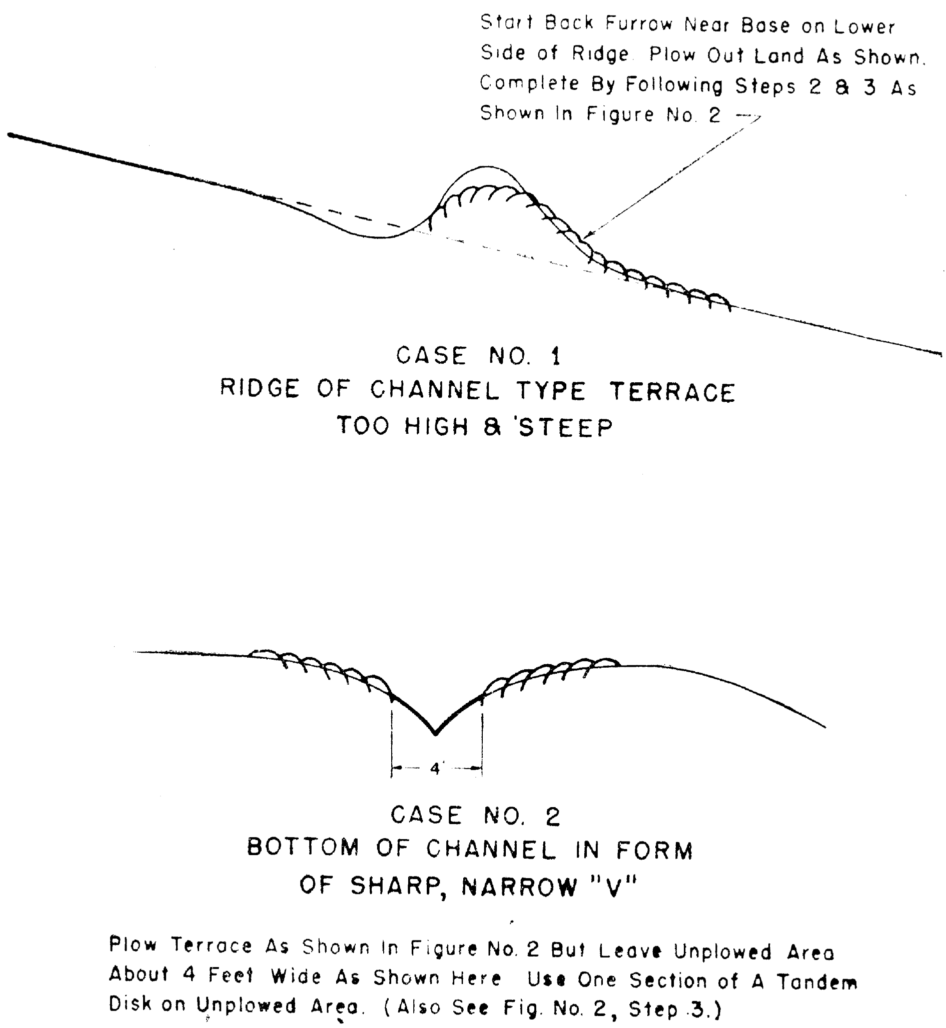


Fig. 6.—Special Problems in Channel Type Terrace Maintenance.

tative cover or structures in outlets if they are properly cared for during their first years of existence. The essential point is that the farmer be fully cognizant of the factors which need consideration and that he give them such thought and attention as needed to make his terrace system perform as it should, since it is the foundation of the coordinated erosion control program on his sloping, cultivated fields.

The supervisors of soil conservation districts have given considerable thought to the need for adequate terrace maintenance and are emphasizing this phase of a conservation program. They know from their own experiences as farm owners and operators that, if the terrace maintenance program is to be a success, the work needed to maintain a system of terraces must become just as much a habit with the farmer as any of his other farming operations. They realize, as should all of us, that the protection of an investment of approximately $82,000,000 justifies the best efforts of all concerned.

The Agronomic Phases of the Soil Conservation Program

By W. M. NIXON
Chief, Regional Agronomy Division
Soil Conservation Service
Fort Worth, Texas

In order to understand more clearly the place of agronomy in a coordinated soil conservation program, I believe that it would be helpful to review briefly what is involved in such a program:

Sound land use. Insofar as possible and practical, land should be put to the use for which it is best adapted. The major uses to which land is devoted are cropland, pasture land, woodland and wildlife.

The factors which determine sound land use are many. Kind of soil, slope of the land, degree of erosion, and economic needs of the operator are some of the most important considerations.

The right combination of conservation practices. After land use has been determined, at least three objectives must be considered in planning the application of conservation practices: (1) The measures must protect the land against erosion; (2) they must be adapted to the operator's type of operation; and (3) they must be economically feasible. In addition to these, in areas of low rainfall, water must be conserved and used wisely; in areas of high rainfall, land may need draining. Alluvial lands must be protected against flooding before it is feasible to apply extensive conservation practices.

Experience has proved that the use of a combination of several practices is essential to the achievement of all three objectives. A single practice, or too few practices, may seem to be a "short cut" to conservation; but a "short cut" usually results in conservation being "cut short."

As in our choice of land use, we should take a tip from Nature in the selection of conservation measures; vegetative control should be used to the fullest extent. Where soil, slope, or degre of erosion or intensity of use makes it impossible to get protection with vegetation alone, then supplementary mechanical measures should be employed.

The maintenance and improvement of soil productivity. When man fails to apply and maintain a conservation program on the land, he contributes to its deterioration. Every soil particle carried away by run-off water removes plant nutrients that are either a physical or chemical part of each soil particle. The loss of any part of the topsoil layer reduces the infiltration rate and absorptive capacity, increases run-off and accelerates erosion in direct relation to the amount of removal. In addition to erosion, poor drainage and excessive use of irrigation water affect the productive capacity of the soil.

When man uses land for production in accordance with its capabilities and applies all the needed conservation practices, erosion is controlled and the possibilities for maintaining or improving the productive capacity of the soil are increased.

Economically sound conservation farming. Since soil and water conservation is not an end within itself, but merely a means of bettering human welfare, then the very first consideraton in planning a conservation program should be the permanent welfare of the people who own and operate each individual farm or ranch. In fact, before a program of soil conservation and improvement will be accepted generally, the owners and operators of farm and ranch units must be shown the "whys" and "wherefore's" of such a program in dollars and cents. To determine whether or not a given farm or ranch unit can be continuously operated at a profit, a long-time as well as an annual plan of operations is essential. The long-time plan is to guide future production toward greater net returns without impairment of the land. The annual plan must give intelligent direction to the actual work of accomplishing the long-time objectives.

The agronomic phases of soil conservation have to do with two of the four land uses mentioned—those of cropland and pasture land.

CROPLAND PRACTICES

On cropland the agronomic practices used in a complete conservation program are conservation cropping systems, cover and soil-improving crops, strip cropping, proper residue management, and stubble mulch. The combination of use and the intensity of use of these practices depend upon the kind of soil, percent slope of land, degree of erosion, climatic conditions, and the economic needs of the operator.

A conservation crop rotation implies more than the regular succession of different crops. To be a "conservation cropping system" the crops used and the sequence in which they are used must be such that soil erosion is held to a minimum and the productivity of the soil is maintained or improved. Probably the most widely recommended conservation crop rotation consists of (1) a clean-tilled crop, (2) a small grain, and (3) a legume or grass crop. Legumes and grasses are generally recognized as soil-conserving and soil-improving crops.

A conservation cropping system which is very effective in conserving the soil and improving its productivity in the Forested Coastal Plain Area of Southeastern Oklahoma is:

First year—Corn and summer legume, with vetch or other winter legume planted in the fall, following corn harvest.

Second year: Cotton, with oats planted in the fall, following cotton harvest.

Third year: Cowpeas, or other summer legume.

The corn and peas are interplanted or planted in alternate rows. This provides a legume with the corn. Vetch or other winter legume provides a protective cover for the soil and is turned under in the spring for use as green manure. Oats planted in the fall, following cotton, serve as a cover crop for the prevention of soil erosion. This cropping system is an improvement over that of alternate cotton and corn or straight cotton, which is conducive to soil loss and soil depletion.

Farmers following such a conservation crop rotation in conjunction with other conservation practices have found that soil losses have been largely controlled and crop production has been increased from 20 percent to 100 percent.

A rotation of cotton, wheat and sweet clover over a 15-year period at the Soil Conservation Experiment Station at Guthrie, Oklahoma, reduced soil losses 75 percent and water losses 25 percent. Over a 5-year period in the same rotation, the yield of cotton was increased 87 pounds per acre. Also at Guthrie the effect of winter cover crops on yields of cotton was as follows:

Kind of cover	Percent yield increase
Wheat	17 (12-year average)
Vetch	31 (12-year average)
Winter peas	32 (8-year average)

Cotton in a rotation with hubam clover produced 44 percent more cotton as compared with cotton after cotton at the Blackland Experiment Station, Temple, Texas.

In any cropping system the order or sequence in which crops are grown is of particular importance. At the Tyler, Texas, Conservation Experiment Station the average soil loss from October through December, 1943, where vetch followed cotton, was 3.07 tons per acre, while on a comparable area where vetch followed corn the soil loss was only .31 ton per acre.

The results obtained on the Southern Piedmont Conservation Experiment Station, Watkinsville, Georgia, point out rather strikingly the importance of a conservation cropping system in conserving and improving soil. The area where these results were obtained is similar in many respects to southeastern Oklahoma. The results include:

Four years' records (1940-1943), obtained from comparable run-off plots representing normal terrace-interval slope lengths of 70 feet on a 7 percent slope, indicate for continuous cotton an average annual loss of 22 percent of the rainfall as run-off, 29 tons of soil loss per acre, and a yield of 0.45 of a bale of cotton per acre.

During the same four-year period two 3-year rotations begun in consisting of oats for grain and Kobe lespedeza for seed, then cotton, allowed an annual average of but 15.5 percent run-off and only 7.4 tons per acre of soil loss. The cotton yield was 0.63 of a bale per acre, or 54 percent increase over continuous cotton grown the same years.

During the same four-year period two 3-year rotations begun in 1940 and 1941, respectively, and consisting of oats for grain and first-year Kobe lespedeza for seed, volunteer second-year Kobe lespedeza for hay, then cotton, allowed an average loss of but 12.5 percent of the rainfall as run-off, 5.4 tons per acre soil loss, and the cotton yielded 0.81 of a bale of cotton per acre, or an increase of 74 percent over the continuous cotton grown the same year.

In explaining the significance of these results it is pointed out that the land in continuous cotton on terrace intervals of 7 percent slope will lose its present topsoil to the 6-inch depth in some 35 years; the 2-year rotation in 136 years; and the 3-year rotation in 189 years—on the basis of an extension of the four years' soil loss data. A prospective "topsoil life" of 200 years is assumed to indicate a satisfactory degree of erosion control for a successful rotation of crop lands.

I believe we can assume that the above results would be comparable to other conservation-type cropping systems which are being used or are applicable to Oklahoma.

Dr. H. F. Murphy, Head, Agronomy Department, Oklahoma Agricultural and Mechanical College, states "A well planned cropping system will save the soil more effectively than all other efforts at soil conservation." Quoting further from Dr. Murphy, "Terraces are necessary on the steeper slopes, but the soil between terraces will continue to wash unless the right type of crops are grown to pin it down. Erosion on many of the less sloping fields can be controlled by growing a combination of crops which require little or no cultivation, return considerable plant matter to the soil and keep the land covered in the winter by a growing crop or heavy stubble. The same rotation will control erosion between terraces on the steeper slopes." Some conservation crop rotations recommended by Dr. Murphy are:

For cotton-growing section of state:

Three-year Rotation

First year: Cotton—spring, summer and fall. Rye—fall and winter. Pasture.

Second year: Rye—winter and early spring. Pasture and plow under. Sorghum—spring, summer and fall. Leave stubble over winter.

Third year: Cowpeas—spring and summer. Pasture and plow under. Rye—fall and winter. Pasture. Plow under in time to plant cotton.

This rotation provides one cotton and one sorghum crop, one cowpea crop for soil building, and nine months of pasture, in three years.

Four-year Rotation

First year: Cotton—spring, summer and fall. Rye—fall and winter. Pasture.

Second year: Rye—winter and early spring. Pasture and plow under. Sorghum—spring, summer and fall. Leaave stubble over winter.

Third year: Oats and sweet clover—spring, summer and fall. Pasture or cut oats for hay or harvest for grain. Pasture sweet clover in fall.

Fourth year: Second year sweet clover—spring and summer. Pasture and harvest for seed. Rye—fall and winter. Pasture. Plow under in time to plant cotton.

This rotation provides one cotton and one sorghum crop, one oats crop for pasture, hay or grain, one sweet clover seed crop, and 13 months of pasture, in four years.

For Wheat section of state:

Three-year Rotation

First year: Wheat and sweet clover. Seed the sweet clover on top of the ground in winter. Pasture the wheat, then harvest grain. Pasture sweet clover in fall.

Second year: Second year sweet clover. Pasture and harvest seed. Plant wheat in fall and pasture.

Third year: Wheat, pasture and harvest grain. Plant wheat in the fall and pasture.

This rotation provides two wheat grain crops, one sweet clover seed crop, and 11 months of pasture, in three years.

Four-year Rotation

First year: Wheat and sweet clover. Seed the sweet clover on top of the ground in winter. Pasture the wheat, then harvest grain. Pasture sweet clover in fall.

Second year: Second year sweet clover. Pasture and harvest seed. Plant wheat in the fall and pasture.

Third year: Wheat. Pasture out early, plow under and plant sorghum for grain. Leave sorghum stubble over winter.

Fourth year: Oats or barley for grain. Plant wheat in the fall and pasture.

This rotation provides one wheat, one grain sorghum and one oat or barley crop for grain, one sweet clover seed crop, and 12 months of pasture, in four years.

For Eastern Oklahoma:

More favorable moisture conditions in eastern Oklahoma permit successful use of such an annual rotation as wheat and lespedeza, rye and lespedeza, rye grass and lespedeza, or wheat followed by cowpeas. These crops may best be utilized as pasture. The following two-year rotations also are practical in that section:

First year: Wheat and sweet clover. Second year: Second year sweet clover, followed by wheat in the fall.

First year: Oats and lespedeza, followed by wheat in the fall. Second year: Wheat for pasture, followed by sorghum (Leave stubble over winter).

First year: Wheat and lespedeza or wheat followed by cowpeas, with wheat again in fall. Second year: Wheat for pasture, followed by cotton. Plant wheat in the cotton in fall.

Rye can be substituted for wheat in any of these rotations.

I agree wholeheartedly with Dr. Murphy's thinking as to the value of a good cropping system in conserving and improving soil productivity.

Organic matter and soil nutrients are constantly being removed from the soil by erosion, leaching, or plant use. This applies to good, level land, as well as rolling land. An experiment at the Ohio Experiment Station showed one cubic foot of virgin sod weighed 65 pounds, contained 60 percent pore space, and 66 tons of organic matter per acre. One cubic foot of the same soil cultivated for 40 years weighed 82 pounds, contained 50 percent pore space, and 45 tons of organic matter per acre. When the organic matter in the soil is depleted, not only is production decreased but the soil erodes more rapidly. The use of conservation cropping systems such as those mentioned will aid greatly in protecting the soil from erosion and in maintaining and increasing soil productivity.

Cover crops, strip cropping and proper management of crop residues are important components of a conservation cropping system. These practices aid in both wind and water erosion control. Some data from Mississippi State College show very conclusively the value of cover and crop residues in reducing soil losses:

Description	Soil loss (tons per acre)	
	Feb. 12/13 2.41″	Feb. 16/22 4.28″
Bare land on a 9% slope	7.6	7.4
Land with a small amount of cotton crop trash and no cover crop	0.8	1.2
Land with a small amount of cotton crop trash and a poor stand of vetch	0.2	0.5

The following cropping systems were taken from conservation farm plans on two farms in the Texas County Soil Conservation District in the Oklahoma Panhandle. They illustrate the importance of strip cropping and crop residue management in the soil conservation program in that area:

"**Cropping System.**—The cropping system on Field No. 1 will consist of approximately 2/3 wheat and 1/3 summer fallow. The summer fallow land will be in strips approximately 290 feet wide extending in an east-west direction and will alternate with strips of growing wheat of approximately twice the width of the summer fallow strips. The cropping sequence will be two years wheat and one year summer fallow. In event of wheat failure all fallow strips will be planted to sorghums.

"**Cropping System, Field No. 9, 476 Acres.**—This field will be planted continuously to wheat as long as conditions are favorable. If small grains fail, the field will be planted to the first crop in season when favorable moisture conditions occur. If this crop is sorghum it may be grown in strips alternating with strips of summer fallow. The summer fallow strips will not exceed a width of 20 rods. Sorghum strips will not be less than 10 rods in width."

These farm plans also called for the following treatment with reference to crop residue management and tillage operations:

"**Crop Residue Management and Tillage Operations.**—In tillage operations the maximum amount of stubble will be left on the surface. As soon after the wheat is harvested as possible the land will be tilled. If summer rains are adequate to produce good fall soil moisture, wheat will be seeded. If moisture is scant, wheat will not be seeded. During dry years when stubble is light, an under-surface tillage implement with sweeps will be used to leave the maximum stubble on the surface. In years when stubble is heavy the one-way plow will be used. Fallow will be practiced only when there is adequate stubble to prevent development of a blow hazard.

"If, in spite of the above treatment, blowing develops, emergency tillage will be used. The stubble will be protected from burning."

Much has been said pro and con with reference to the practice of stubble mulching. Personally, I thing that it is a very important soil and moisture conserving measure. True, the practice does not always result in immedite large production increases; however, it insures continuous, reliable and profitable production.

Four years of records (1943-1946) at the Amarillo, Texas, Conservation Experiment Station show an increase of wheat yields resulting from stubble-mulch treatments over plowing and disking, in addition to leaving the surface protected from wind erosion. The average yield from stubble-mulched areas was 11.4 bushels per acre in comparison to only 8.6 bushels per acre from plowing and disking methods, a difference of 2.8 bushels or a 25 percent increase in grain yield.

Cultural Practice	Wheat Yields (Bu. per acre) 4-year average, 1943-1946
Continuous Wheat—Moldboard Plow	7.5
Continuous Wheat—Oneway Disk	9.8
Continuous Wheat—Subtillage	11.4

Stubble-mulching operations have been efficiently performed by a redesigned sweep implement and by the Noble cultivator.

Wheat seeding with a deep-furrow, shoe-type drill has been successful through heavy residues.

Stubble field trials on the farms of two soil conservation district cooperators in the Texas Panhandle during 1945-46 gave an average wheat production of 19.9 bushels per acre on stubble mulched area compared with 12.8 bushels per acre on a non-mulched area.

The average wheat production on field trials in the Oklahoma and Texas Panhandle (1941-1943) was: stubble mulch treatment, 18.3 buhsels per acre; on non-mulched area 17.3 bushels per acre.

Strip cropping is of most importance in those areas subject to wind erosion. Its use along with cover crops constitutes a major phase of the soil conservation program in the Cross Timbers.

A cover crop of rye and vetch planted in the fall provides protection against soil loss from wind and water erosion. It can be grazed during the winter and early spring, then worked into the soil as a green manure, or left for seed production.

I would like to state here that in my opinion the Cross Timbers area of Oklahoma and Texas has possibilities of producing enough hairy vetch seed to fill its own needs as well as those of the entire South and Southwest. Approximately 2,000,000 pounds of hairy vetch seed were produced and harvested in the area in 1946. Local sources of seed are essential to successful application of a cover and soil-improving program on an extensive scale.

The planting of four to eight rows of peanuts following a cover and green manure crop in a strip cropping pattern with crotalaria, grain sorghum, or other tall-growing crops provides protection against wind and water erosion. Alternating the crops in the strips from year to year provides a sound conservation cropping system. The residue from the strips is left on the land or worked into the soil, supplying needed organic matter and essential elements. Forty-nine soil conservation district cooperators in the Cross Timbers who operate a total of 8,721 acres report that as a result of conservation farming their average yield of peanuts per acre was increased 49 percent and the peanut hay yield increased 27 percent.

PASTURE PRACTICE

Because pasture is a most desirable land use from the standpoint of soil conservation, and because forage from pastures is the cheapest feed that can be produced, the importance of this phase of agronomy in a soil conservation program can readily be recognized.

On pasture land the agronomic program consists of the planning, establishment and management of adequate grazing land to conserve the soil and meet the economic needs of the farm or ranch. I am sure that the soil-conserving value of grass is recognized by all of you. Pastures afford one of the most effective and economical means of holding and enriching the soil, provided they are managed properly. When vigorous plant growth is maintained and regulated grazing followed, very little soil is lost from pasture land. Measured losses are frequently less than 100 pounds per acre annually and average only 700 pounds of soil per acre annually on 13 important soils in the eastern half of the United States when a dense cover of grass is maintained. This average rate of loss is probably no greater than the rate at which new topsoil is formed. In clean-tilled crops the same soils lose an average of about 34 tons of soil annually, or 97 times as much as when they are well covered with grass.

Data obtained at the Red Plains Conservation Experiment Station at Guthrie, Oklahoma, over a 15-year period give the following soil and water losses from various kinds of land cover:

Kind of cover	Runoff water	Soil loss per acre
	Percent	Tons
Bermuda grass	.84	.016
Continuous cotton	11.38	13.674
Bare hard fallow	26.29	17.644

Thousands of acres of land throughout the state, because of steepness of slope, degree of erosion, poor drainage, or susceptibility to overflow, are not suited for cultivation. Much of this land, under proper treatment, will produce profitable growths of grass and legumes.

Proper seedbed preparation, seeding or sodding adapted base grasses, fertilization, liming, cultivation and overseeding with supplemental grasses and legumes are all involved in the establishment of a good pasture.

Proper stocking and weed and brush control are two of the most important management practices.

Oklahoma is blessed by having vigorous, palatable grasses and legumes for use as pasture throughout the state. She is making profitable use of them.

In my opinion the best job of revegetating eroded and depelted lands with native grasses anywhere in the United States is being done right here in Oklahoma. The intense interest of the college, experiment stations, agricultural workers, and the farmers and ranchers in the problem and the cooperative efforts given, have made this possible.

The following excerpts taken from the Grady County Soil Conservation District news column April 10, 1946, are typical of the interest and activity in the revegetation problem:

"Every day Farmer—District Cooperators and other farmers who are waiting on the grass seeding drills to use in making their grass plantings or who for some other reason haven't been able to get their grass planted, come into the Grady County Soil Conservation District Office at Chickasha to counsel about their grass plantings.

"J. L. Salter is using a cotton planter to seed a mixture of buffalo, blue grama, and bluestem grass seed on 25 acres of needle grass land on his farm northeast of Tabler. This land was retired from cultivation a few years ago. Mr. Salter is planting his grass as nearly on the contour as he can.

"Everett Hulsey has just finished sowing approximately 55 acres of lovegrass and buffalograss on his farm northeast of Tabler. Hulsey is planting his grass in a dead sorghum stubble cover. In addition, Hulsey is planting 12 acres of sweet clover.

"I. G. Harrell who lives northeast of Tabler planted four acres of lovegrass and eight acres of native grasses on his farm this week.

"Rudolph Frey, north of Chickasha, planted two acres of hubam clover in bermuda grass sod. Mr. Frey sodded the bermuda grass this spring. Frey also planted two acres of lovegrass and hubam clover in one patch and eight acres of lovegrass in another.

"Ray Culbertson planted fifteen acres of mixed native grasses on his farm north of Chickasha this week. Culbertson planted the grass seed into a dead sorghum stubble cover.

"J. C. Dabney who lives four miles east of Amber was in the local District Soil Conservation Office this week and reported that he is planting bluestem on some more of his eroded land this spring. Mr. Dabney planted bluestem in the spring of 1942 from which he began to harvest seed last fall (1945). He began harvesting one afternoon and the seed was making about 150 pounds per acre. The following day was a very windy Sunday which blew off the seed to where it wasn't worth harvesting the rest of the seed. The Soil Conservation Service technicians helped Dabney get started planting his first seed in 1942, as planned in his Soil Conservation program with the District, using a broadcasting method on disked ground. The planting he is making now is the second one made since that time without any further help from the District."

The progress being made in the seeding of Bermuda grass is going to help a great deal in speeding up the establishment of this most important pasture and meadow plant. There is much interest in this activity and I have observed and received reports of success in Oklahoma, Arkansas, Louisiana and Texas. Much of the land which had become practically worthless because of loss from wind and water erosion while in cultivation is now protected from erosion and is devoted to profitable grazing use. Steep, badly eroded land is being retired from cultivation and established to pasture.

Supplemental pastures and meadows also play an important part in a complete conservation program. Such hay crops as kudzu, lespedeza sericea, sweet clover, alfalfa, sudan grass, small grains, bluestem grasses and others are, for the most part, soil-conserving and soil-improving crops. They are needed on practically every farm, and fit well into a coordinated conservation program.

A very important phase of agronomy as it pertains to soil conservation is that of producing, harvesting, and processing seeds of grasses and legumes which are not readily available on the commercial market. Many of the native grasses and some of the legumes are not available in sufficient quantities to meet the needs for use in seeding pastures, meadows, terrace waterways, and for use as cover and soil-improving crops. As a result of the demand for these seeds from farmers and ranchers practicing conservation farming, more of them are being produced and harvested; however, the demand far exceeds the supply.

In order to be of maximum assistance to farmers and ranchers in the application and maintenance of the agronomic phases of the soil conservation program, I believe that we need to concentrate upon giving assistance in: (1) The production and harvesting of native grass seeds; (2) the production and harvesting of adapted summer and winter legume seeds; (3) helping to make available the needed harvesting and seeding equipment; and (4) establishing Bermuda grass by seeding. I do not intend to minimize the other activites but feel that these four phases are more or less "bottlenecks" which need to be overcome as rapidly as possible.

In conclusion, I want to stress again the fact that the vegetative method of controlling erosion is Nature's way. Accelerated erosion of soil by wind and water is almost always the direct result of the disturbance of the plant cover of the land. Burning, overgrazing, and plowing that destroy the balance between the soil and its protective cover of plants permit damaging erosion, which, in turn, contributes to floods and dust storms.

Sound soil and crop management of cultivated land, and the development, management, and maintenance of a permanent cover on meadow and pasture land, will permit the safe, permanent use of these lands without damage by soil erosion and depletion.

How Can Agronomy Be Made More Interesting in Youth Programs?

By C. L. ANGERER

Head, Department of Agricultural Education, School of Agriculture, Oklahoma A. and M. College

As teachers we are concerned with the effectiveness of our instruction with rural youth in Oklahoma—the ultimate outcomes in terms of desired changes made in farming practices and growth on the part of the individual in his effort to become a successful young farmer.

To be a successful farmer demands for its pursuit, a wider knowledge, more initiative, resourcefulness and adaptability than is required of the average successful worker in most other fields. H. D. Carver, economist, Harvard University, says, "To be a scientific farmer requires an education comparable in breadth and thoroughness with that of an enginer or the physician." The above statements, together with the studies which have been made of a large number of young men who have had vocational agriculture in high school and who are becoming established in farming in Oklahoma, show the training needs of young men who have from $5,000 to $100,000 invested in a farm business. The management side of their occupation demands foresight and careful planning. With high priced land and expensive machinery, success depends upon many factors, chief among which are the maintenance of soil fertility, the securing of high crop yields, the efficient use of machinery, the combination of crops and livestock, and the establishment of a business that will return a high labor income. Therefore our responsibility as teachers is to direct the activities of rural youth while in our classes into these worthwhile and productive channels.

In the early days of agricultural education the plan for the four-year training program consisted of livestock the first year, crops and soils the second, community specialties the third, and farm management and economics the fourth year. Many difficulties arose in using this plan:

(1) Since farmers do not have livestock on their farms one year and crops and soil the next, this presented an unnatural picture to boys.

(2) Although livestock projects were started the first year, these enterprises were not included in the teaching plan the second year; hence those who had continued these projects found related problems arising with which they needed assistance.

(3) If a boy started with dairy cattle and needed to grow legumes as a part of his feed, he usually waited until the second year before receiving training in the production of alfalfa, cowpeas, or Korean clover.

This situation resulted in our looking for a solution to our difficulty and seeking the assistance of leaders in education in the field of curriculum construction for a guide to follow in the selection and organization of subject matter.

Understanding is one of the first steps in learning. It is when we understand that we are able to appreciate the importance of a given subject, such as soils, crops or livestock, in the total picture of the farm business. Today, in order to bring about an early understanding of the various enterprises which make up the business of farming in a community, each boy makes a survey of his home farm. This includes soil types, erosion conditions, crop yields, amount of land in pasture, carrying capacity of pasture in animal units, crop rotation followed, and use of fertilizers. Also, a test is made of the soil to determine the deficiencies in calcium and phosphorous. These farm surveys of the thirty to sixty boys enrolled in a department are summarized in class, and with the assistance of the group the subject matter is classified and the major problems common to all farms are listed. This gives farm boys an early opportunity to understand the relative position in which farmers have placed the enterprice into a combination on their farms and also the differences which exist even on neighboring farms. It is rather surprising how first-year students are able to determine the reasons why farms vary due to such factors as soil, topography, climate, marketing costs, and price.

Some may wonder why we now base the subject matter included in a four-year training plan on the type of farming in a community. A study which we are now completing in Oklahoma shows that more than 90 percent of the boys who have studied vocational agriculture in high schools and go to farming either remain in the same community or go into a type of farming similar to the one at home (i. e, wheat-beef, corn-hogs, etc.). Similar studies in Indiana and Minnesota show the same high percent. I once asked one of our American Farmers in this State why he didn't move to another area to farm and his answer was, "I would have too much to unlearn and too much to relearn."

The next step is for the teacher to use the principles developed by curriculum specialists as a guide in selecting and organizing the subject matter material for the four years. These are: Doing ability, relative importance, needs of students, relationship with other subject matter, seasonal sequence, difficulty, proved superior merit and interest. I would like to take up each one of these principles briefly to show how teachers go about the job.

1. **Doing Ability** refers to the supervised farming program which each boy conducts on his farm at home. Our central problem in agricultural education is to select the kind of present experiences that will live fruitfully in subsequent experiences. An example may be cited at Grandfield where a majority of the boys have wheat as a part of their farming programs. Their surveys show early in their training program the importance of wheat in terms of farm income, in terms of percent of cropland in wheat, and in terms of its value as pasture for their livestock. When these facts have been brought out in class, interest at once becomes intensified and the problems of seedbed preparation, selecting varieties, treatment for smut, etc., are those which they are eager to discuss because of the position which wheat occupies on their farms.

In fact today at Grandfield smut is not a problem in wheat production because the young farmers have been taught control methods and the value in terms of higher yields. The same may be said for any crop produced on their farms, whether as a cash crop or as feed for livestock. When a legume or pasture improvement is included in their farming programs, it is because they understand the importance of and need for protein feed, or of reseeding, fertilizing, mowing, or planning a year-round pasture to increase the carrying capacity of livestock. They know that livestock is dependent upon ample feed of high nutritive value and that they will not be able to have numbers or pounds of beef to sell in the fall unless on the given acres they are able to produce sufficient feed. An example of this is at Broken Arrow where the Star American Farmer of the South has increased his carrying capacity of one animal unit to 1.9 acres compared to an average for the county of approximately 7.5 acres.

To learn is to acquire a way of behaving—a thing has been learned when at the appropriate time that kind of conduct can and will take place. What we learn we must practice. All boys are given an opportunity to put into practice the results of their study. This enables them to reach the highest level of learning, the "doing level." A broad and comprehensive supervised farming program is therefore a very essential part of the educational program in agriculture.

2. **Relative Importance.**—In the above, relative importance has been combined with doing ability or assisting each boy to select those projects as part of his farming program which will be of greatest importance. The need for selection by the teacher will be those enterprises or jobs which under existing conditions will count most. Importance is determined in the last analysis by use, and all values are determined by the effect they have on needs.

3. **Needs of Students** refers to immediate needs, knowledges, abilities, skills, etc., to be developed. Content material should be selected on the basis of the greatest amount of preparatory value to the students. The most important influence which should determine in what year a job should be taught is the need in connectoin with each boy's supervised farming program.

4. **Relationship with Other Subject Matter.**—In organizing subject matter today, the major enterprises and those which contribute to their success are taught in the same year. Since these enterprises are arranged on their fathers' farms in that manner, they can understand the reason for producing corn for their hogs, alfalfa for their dairy animals, and temporary pasture for their sheep. This permits a supervised farming program to be carried out on their farms consisting of crops and livestock in the same year. Recently a boy at Lawton was just as much interested in showing me his prize field of alfalfa as he was his prize dairy animals. Much depends upon the teacher whose job it is to show the dependence of livestock on crops and crops in turn on good soil. When students understand these relationships, interest does not lag but is manifested in reading additional references for a solution of their problems and in carrying out the needed practices on their farms.

5. **Seasonal Sequences.**—In pursuing his work, a farmer must make plans. Each day presents new problems which demand solutions. There are certain seasons when farm jobs must be done. It is apparent that teaching about treating seed wheat for smut or inoculating legume seed would be of little value after the time for the job had passed. But teaching these farm jobs in their natural time brings about a discussion in class and a carry-over into practice on the home farm. I recently talked with a banker in one of our prominent farming communities and he told of the great amount of information that boys took home, and with this information convinced their fathers of the need for introducing certain practices. This banker should know because he has loaned a number of these farmers money to buy Pawnee seed wheat, fertilizer and side delivery

rakes as a result of their sons' interest in and knowledge of new ideas that bring fruitful results. Interest is correlated with seasonal sequence. It is important, therefore, that the selection of content material should be appropriate to the solution of the problems that arise or occur in the typical progress of farming in a given area.

6. **Difficulty.**—Certain subject matter may be of use, but also may be so difficult to learn that interest would be killed if it is presented before the boy is ready for it. It is recognized and agreed that subject matter should be chosen with reference to the pupil's maturity. This factor, together with his previous experience, will undoubtedly guide us in selection of the less difficult materials in the early years and the more difficult or technical in the later years. It must in all cases be adapted to the learner's stage of maturity. Thus in the case of planning a four-year program, the material with regard to breeding problems, mixing sprays, figuring balanced rations, and economic and management problems are left until the third and fourth years. This is the time when the boy will be able to understand and also will have use of such information in his now expanded farming program.

7. **Proved Superior Merit.**—There are certain standard methods and practices among farmers in any farm vocation, and there are better methods and practices than the standard. It is the latter that should be taught. When an increasing number of good farmers find it profitable and satisfactory to use Wintok oats, though the majority still use a spring oat which returns a lower yield, it is only proper that we teach prospective farmers to use the one giving greater yields. Such is the case in the community of Chelsea where this variety is becoming firmly esablished on the farms of the Vocational Agriculture students and is spreading to other nearby farms. In a locality where little wheat is produced, where dairying is important, where winter pasture is needed, when protein feed is scarce and high priced, and where fields last spring showed an increase the first year of over fifteen bushels compared to spring oats, interest is quickly aroused and results became apparent.

8. **Interest.**—In the discussion of the above factors we can readily see how interest is closely tied with each. The teacher who observes these principles and uses them as a guide in assisting farm boys to plan their farming programs can make agronomy intensely interesting through discussion and solution of the many problems which they will have during their four years in high school.

After the boys are out of school, they will remember because they have had experience. And because they have had experience, they will become proficient in maintaining soil fertility and in adjusting to new ideas developed by our agricultural experiment stations. Because these young men have gone to school longer than many others, they will be more successful. Their continued interest can be maintained by a flow of knowledge that they can use in their business. Let us be mindful of our responsibilities in arousing in these young men an active quest for information and an interest in new ideas for bettering their farming conditions.

Should Hybrid Corn Be Planted at a Higher Rate Than Open-pollinated Varieties?

By ROY CHESSMORE and JAMES S. BROOKS

Respectively, Assistant Agronomist, and Associate Agronomist (Corn)
Oklahoma Agricultural Experiment Station

The planting rate for open-pollinated corn has been fairly well established over a period of years. Each farmer, through experience and observation, has found the most desirable rate for the variety which he has been planting from year to year. Many of these farmers are now planting hybrid corn and do not have previous experience to guide them in selecting the proper planting rate. They may also have several hybrids of different maturity planted on their farm each year. Experience with hybrids of different maturity has demonstrated the need of different planting rates for each maturity class. If previous experience with open-pollinated varieties can be used in selecting the proper planting rate for hybrids, it will give us a dependable guide in this problem.

Experimental results show that the planting rate of open-pollinated varieties can be increased as soil fertility increases. Years of experience have also shown that early maturing varieties must be planted at a thicker rate than later varieties to get the same yield from the same soil These same factors will apply to hybrids. However, hybrids have a few characteristics that are not common to open-pollinated varieties. Hybrids are made up of four pure lines of corn, each of which has been selected for uniformity of specific factors. Some of the more important factors considered are plant and ear height, ear size and quality, resistance to diseases and insects, and resistance to stalk and root lodging. When four good inbred lines are combined by crossing, we can expect planting seed that will produce uniform plants with better than average performance.

In 1944 and 1946 experiments on rate of planting were conducted at the Perkins Experimental Farm. The test was on upland soil of medium fertility. Several hybrids and open pollinated varieties with maturity ranges from early to late were used in the test. U. S. 13 and Hays Golden were used as typical of the medium early maturity group and Texas 12 and Reid Yellow Dent as typical of the late maturity group. The seed was planted in hills to permit hand planting with a check-row planter. The number of seed per hill ranged from 1 to 4 in 1944 and from 1 to 5 in 1946.

The effect of different planting rates on size and number of ears in 1944 is shown in Table I. As indicated by the table, the number of ears produced by 100 plants decreases as the rate of planting increases. However, the decrease is greater for open-pollinated varieties than for hybrids. The percentage of barren plants is considerably larger for open-pollinated varieties than for hybrids, regardless of maturity.

Results of the test indicate that ear size decreases as planting rate increases, as shown by the number of ears required to make one bushel. Hybrid and open-pollinated varieties are quite similar in respect to decrease in ear size.

The test made in 1946 shows there is considerable difference in the effect of planting rate on the total yield of hybrids and open-pollinated varieties (Table II). In the medium early maturity class, U. S. 13 reaches its maximum yield at 3 grains per hill while Hays Golden had maximum yield at one grain per hill. In the late maturity class both Texas 12 and Reid Yellow Dent had the highest yield at one grain per hill. In 1946 the latter half of the growing season was very dry and late corn on low fertility soil

TABLE I.—The Effect of Different Planting Rates on Size and Number of Ears. (Upland Soil, 1944)

Variety	Number of ears per 100 plants	Number of ears per bushel
1 grain planted per hill		
U. S. Hybrid 13	163	179
Hays Golden	142	184
Texas Hybrid 12	163	206
Reid Yellow Dent	96	194
2 grains planted per hill		
U. S. Hybrid 13	105	171
Hays Golden	102	212
Texas Hybrid 12	122	226
Reid Yellow Dent	84	194
3 grains planted per hill		
U. S. Hybrid 13	101	219
Hays Golden	93	259
Texas Hybrid 12	107	250
Reid Yellow Dent	76	233
4 grains planted per hill		
U. S. Hybrid 13	92	250
Hays Golden	79	269
Texas Hybrid 12	92	280
Reid Yellow Dent	50	250

had distinctly low yields. Under more favorable growing conditions the late maturity class will follow the same trend as the early maturity class. However, under conditions favorable to both maturity classes the early corn should be planted somewhat thicker because early maturing hybrids and open-pollinated corn produce a shorter plant with smaller leaves and ears.

The planting guide presented in Table III gives the approximate planting rate for corn of different maturity planted on soils of different fertility. Under similar soil and moisture conditions, early maturing hybrids can be planted as much as 40 percent thicker than open-pollinated varieties. Hybrids of late maturity can be planted about 20 percent thicker than open-pollinated varieties.

Thicker planting rates increase the number of days from planting to silking, as shown in Table II. However, the thicker plantings with slightly smaller ears will probably dry out in the field as soon as the thinner plantings.

In selecting hybrid seed corn for planting, the size and grade must be considered. All sizes of a particular hybrid carry the same inheritance factors and will produce the same type plant. The small round grades will plant more acres per bushel. However, they require a special planter plate to assure even spacing of the seed. Corn that is drilled in the row has given slightly better yields than the check-row method. Single spacing of the plants in the row is also better adapted to mechanical harvesting than having several plants in each hill. Uniform spacing will provide maximum utilization of available moisture and plant food. This plant food must be replaced each year by the addition of organic matter and commercial fertilizer if continued high yields are to be expected.

TABLE II.—Effect of Different Planting Rates on Yield and on Number of Days from Planting to Silking. (Upland soil, 1946)

Variety	Yield in bu. per acre	No. of days from planting to silking
1 grain per hill		
U. S. Hybrid 13	27.7	87
Hays Golden	20.4	87
Texas Hybrid 12	23.5	94
Reid Yellow Dent	20.2	95
2 grains per hill		
U. S. Hybrid 13	28.4	90
Hays Golden	16.9	90
Texas Hybrid 12	15.0	97
Reid Yellow Dent	10.6	97
3 grains per hill		
U. S. Hybrid 13	29.5	92
Hays Golden	16.9	92
Texas Hybrid 12	13.3	98
Reid Yellow Dent	8.3	98
4 grains per hill		
U. S. Hybrid 13	18.8	93
Hays Golden	9.9	95
Texas Hybrid 12	7.6	99
Reid Yellow Dent	3.5	99
5 grains per hill		
U. S. Hybrid 13	20.5	95
Hays Golden	9.5	95
Texas Hybrid 12	6.0	99
Reid Yellow Dent	3.2	99

TABLE III.—Planting Guide.

This table is based on 42-inch row spacing. It is a guide rather than an absolute recommendation.

Estimated average production of field to be planted (Bushels per acre)	Earliest Strains		Mid-Maturity Strains		Later Strains	
	Distance apart in row (inches)	Acres one bu. will plant*	Distance apart in row (inches)	Acres one bu. will plant*	Distance apart in row (inches)	Acres one bu. will plant*
25 to 35	18	10	20	10½		
35 to 50	14	7½	16	8½	20	10½
Over 50			12	6½	16	8½

* The acres which a bushel of seed will plant is based on "medium flat" size. Larger grain sizes will plant a smaller acreage.

The Small Grain Program in Oklahoma

By A. M. SCHLEHUBER

Agronomist U. S. Department of Agriculture, Agricultural Research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering; and Oklahoma Agricultural Experiment Station.

Projects now approved by the Oklahoma Agricultural Experiment Station dealing with investigations of small grains include hard and soft red winter wheat, and fall- and spring-sown oats and barley. Of these, hard red winter wheat is the most important—in fact, it is the most important crop in Oklahoma.

During the 10-year period 1936-1945 there was an annual production of 57,031,800 bushels grown on about 4,356,000 acres of winter wheat, and of this acreage approximately 95 percent was devoted to the production of **hard** red winter wheat. During this same period an average of 26,053,500 bushels of oats was produced on 1,352,300 acres and 5,263,100 bushels of barley on 323,800 acres.

Requests for appropriations and the apportionment of the Experiment Station personnel for research were made in keeping, to a large extent, with the economic importance of the crop as well as the acuteness of the problem.

In the breeding and improvement of varieties of winter wheat, oats, and barley, and in the solving of problems affecting production of these crops, the Oklahoma Agricultural Experiment Station and the U. S. Department of Agriculture are in active cooperation.

In this paper, the different crops will be discussed separately.

WINTER WHEAT

The ultimate aim is that each section of the wheat-growing areas of the State will grow the variety or varieties of wheat that are best adapted to that section, and which will best fit the needs of the grower, the processor, and the consumer.

Specific objectives vital to this aim, and which are urgently in need of more thorough investigation to accomplish the desired results, involve the development of varieties having the following characteristics:

(1) High and stable yield, high test weight, desirable grain appearance, and superior milling and baking characteristics and qualities.

(2) Factors enabling them to resist or evade drought damage. Drought contributes more to wheat acreage abandonment than any other one factor.

(3) Early, medium, and late maturing habits to increase the harvest period.

(4) Resistance to lodging and to shattering.

(5) Disease resistance, primarily to the rusts, the smuts, septoria, and root diseases.

(6) Insect resistance, especially to greenbugs, chinch bugs, and hessian fly.

(7)) Sufficient winterhardiness to escape any serious damage due to winter killing.

Varieties of hard red winter wheat at present recommended for growing in Oklahoma are: **Cheyenne, Comanche, Pawnee, Tenmarq**, and **Turkey** (Kharkof). The performance of these varieties along with three others at the experiment stations located at Stillwater, Lawton, and Woodward is presented in Table I.

TABLE I.—Average Grain Yields of Eight Hard Red Winter Wheat Varieties Grown Uniformly at Three Oklahoma Stations During All or Part of the Period 1938-1945 (4).*
(Bushels per acre)

Variety	C. I. No.	Lawton 1940-44	Stillwater 1939-45	Woodward 1938-45	Weighted average (20 station-years)
Pawnee	11669	26.5	28.8	39.8	32.6
Comanche	11673	28.4	28.7	37.2	32.0
Cheyenne	8885	25.1	26.6	34.9	29.5
Tenmarq	6936	27.4	23.2	34.8	28.9
Blackhull	6251	22.9	26.6	31.4	27.6
Early Blackhull	8856	26.2	24.6	30.5	27.4
Chiefkan	11754	22.9	23.5	33.4	27.3
Kharkof	1442	21.9	23.6	31.1	26.2

* Figures in parenthesis refer to "Literature Cited," page 41.

The high yield and generally acceptable agronomic characteristics accounting for the recent popularity of Comanche and Pawnee are well recognized. These varieties are an improvement over many of the older varieties; however, it must not be inferred that they are the "perfect" varieties.

Leaf rust is one of the most, if not the most, important wheat disease in Oklahoma. None of the varieties now grown commercially in the State has any appreciable resistance to the attacks of the leaf rust organism. Pawnee, the result of a Kawvale (semi-hard) × Tenmarq cross released by the Nebraska and Kansas Agricultural Experiment Stations, in tests throughout the State piror to its commercial introduction into Oklahoma, had shown a moderate degree of resistance to leaf rust. Races of leaf rust to which Pawnee is susceptible are apparently on the increase so that this variety is now showing very little, if any, resistance. The Agronomy and Plant Pathology Departments of the Oklahoma Agricultural Experiment Station in cooperation with the Division of Cereal Crops and Diseases are actively engaged in a project which has the breeding of disease resistance as one of its objectives.

Another important factor affecting the production of wheat in Oklahoma is the damage frequently inflicted by greenbugs. The estimated loss of wheat in Oklahoma caused by greenbugs in 1942 was over 7 million bushels, destroying about 11 percent of the total wheat crop (1).* Unofficial estimates of greenbug damage to wheat in 1946 indicate the destruction was at least as great as that of 1942. Whatever the actual percentage of the total wheat crop lost by attacks from greenbugs, it is known that some farmers lost their entire wheat acreage, and the 1946 winter wheat variety tests at Lawton were not harvested because of damage by greenbugs amounting to almost complete destruction.

Investigations by Atkins and Dahms (1) indicate that there may be differential response of varieties to the attacks of greenbugs. Some of their results are reported in Table II.

The data in Table II and field observations during 1946 indicate that Pawnee is extremely susceptible to the attacks of greenbug. Unfortunately, very little, if any, wheat material has been found with a high degree of resistance. However, a project recently begun by the Departments of En-

* Figures in parenthesis refer to "Literature Cited," page 41.

tomology and Agronomy of the Oklahoma Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture has for its objectives: "1. To investigate the resistance of different small grain varieties to greenbug attack and to investigate phases which may have a bearing on the cause or causes of resistance. 2. To determine if it would be feasible or economical to control greenbugs under certain conditions with insecticides."

If and when resistance is found in one or more varieties and if otherwise unacceptable, the variety or varieties will be crossed immediately with others possessing desirable agronomic characters, not only in an effort to develop agronomically desirable resistant wheats, but also to study the inheritance of resistance.

It should not be inferred from the above sttaements regarding some of the shortcomings of Pawnee that it is an inferior wheat, but they do serve to stress the importance of a continuous breeding and improvement program.

All of the seven specific objectives (page 35) in the improvement of wheat are being studied to some extent in the various wheat experiments and tests throughout the State. However, because of shortages of equipment, funds, and personnel, very few of these objectives are being studied to the extent that is warranted by the economic importance of the crop.

OATS

Varieties of oats presently recommended for Oklahoma are:
- Fall-sown: Wintok, Tennex, Forkedeer, and Stanton (Strain 1).
- Spring-sown: Kanota, Fulton, Red Rustproof (Texas Red or Red Texas), and New Nortex.

The majority of oats grown in Oklahoma is produced from spring seeding, although there seems to have been a slight shift toward more fall-seed-

TABLE II.—Greenbug Damage to Varieties and Strains of Winter Wheat Grown in Nursery Plots, Denton and Chillicothe, Texas, 1942 (1).

Variety or Strain—Selection No.	C. I. No.	Date Headed (May)	Estimated damage at	
			Chillicothe, average of 4 replications	Denton, 1 replication
			Percent	Percent
Tenmarq × Blackhull Wd.** 36h29157	----	4	11.2	
Marquillo × Oro Ks. F. N.† 790-1	----	12	15.0	5
Blackhull	6251	12	22.5	10
Red Chief	12109	9	35.0	90
Chiefkan	11754	12	42.5	10
Comanche	11673	11	57.5	10
Turkey	1558	8	60.0	30
Tenmarq	6936	12	60.0	40
Kharkof	1442	12	73.8	30
Pawnee	11669	15	82.2	20
Kanred-Hard Federation 142 × Tenmarq 33-34-111	----	12	87.5	30

Least significant difference between the estimated damage of two varieties at Chillicothe at 0.05 point=14.6 percent.

** Wd.=Woodward, Oklahoma.

† Ks. F. N.=Kansas Fly Nursery.

ing in recent years. The percentages of spring- and fall-sown acreages for 1944-1946 were estimated (2) as follows:

	Spring-Sown	Fall-Sown
1944	83	7
1945	93	17
1946	80	20

No doubt the small amount of winterkilling during the three mild winters of 1944, 1945, and 1946 accounts for a large part of this shift toward more fall-seeding of oats, although the development of more winter-hardy types may also have been a factor.

Certain yield data obtained at the Oklahoma Agricultural Experiment Station, Stillwater, for Wintok and Tennex, typical fall-sown varieties, and Red Rustproof and Kanota, recommended spring-sown varieties, are presented in Table III.

The pooled average yields from Table III of Wintok and Tennex is 54.7 bushels per acre compared with 33.4 for Red Rustproof and 37.8 for Kanota, differences of 21.3 and 16.9 bushels, respectively.

Another comparison of yields from fall-sown vs. spring-sown varieties of oats obtained at Stillwater is presented in Table IV. In this table, the average yield in bushels per acre of the three highest yielding fall-sown varieties of oats is compared with the averge yield of the three highest yielding spring-sown varieties for the four years 1943-1946. The average difference of 32.7 bushels per acre between the fall-sown and spring-sown varieties is somewhat greater than in the comparisons between Wintok or Tennex and Red Rustproof or Kanota presented in Table III. However, it must be remembered that the data in Table IV are for four years and three of these were mild winters; whereas the data in Table III include both mild and rigorous winters. Although the same difference might not be obtained under field conditions, the advantage in yield from fall-seeding of winter varieties over spring-seeding of spring varieties obtained under experimental conditions is too large to be ignored.

Quality of fall-sown oat varieties compared with spring-sown varieties has been investigated by Hill (3). He found, in general, that winter oats have higher total digestible nutrients than do spring oats. One measure of quality is the relative percentage of groats compared with the percentage of hulls. A preliminary study of this was made at Stillwater from samples of both spring and winter varieties grown at Stillwater and at Cherokee, Oklahoma, in 1946. For eight fall-sown varieties grown at Stillwater the average percentage of groats ranged from 69.6 for variety Victorgrain to 77.2 for Wintok; at Cherokee, this range was from 68.0 for Winter Turf to 78.8 for Wintok. Comparing the spring-sown varieties for percentage of groats, the range at Stillwater was 67.0 for Mindo to 73.0 for Kanota and at Cherokee, 66.4 for Mindo to 71.3 for Kanota. The average percentage of groats for the fall-sown varieties was considerably above that of the spring-sown varieties at both Cherokee and Stillwater.

Numerous problems in oat improvement for both fall- and spring-seeded varieties are urgently in need for further investigation. Among these are (1) hardiness to drought and freezing, (2) resistance to crown (leaf) rust and smut, (3) resistance to lodging, and (4) resistance to greenbugs. Projects now under way at the Oklahoma Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture include studies of these problems.

TABLE III.—Average Yield of Wintok and Tennex from Fall Seeding Compared with Red Rustproof and Kanota from Spring Seeding; Stillwater, Oklahoma.

Variety	Yield (Bushels per acre)							
	1939	1940	1941	1944	1945	1946	Av.	Percentage of Red Rustproof
Wintok (fall seeding)	82.4	29.0	39.3		68.4	59.6	55.7	155
Red Rustproof (spring seeding)	36.9	39.8	38.8		4.2*	60.0	35.9	100
Kanota (spring seeding)	40.0	44.1	24.6		24.3	63.6	39.3	100
Tennex (fall seeding)		30.2	33.5	77.4	64.6	62.8	53.7	174
Red Rustproof (spring seeding)		39.8	38.8	11.3	4.2*	60.0	30.8	100
Kanota (spring seeding)		44.1	24.6	24.6	24.3	63.6	36.2	118

* New Nortex (Red Rustproof selection).

TABLE IV.—Average Yield for the Three Highest Yielding Fall-sown Oats Compared With the Three Highest Yielding Spring-sown Varieties for 1943-1946, Stillwater, Oklahoma.
(Bushels per acre)

When Seeded	Year				Average
	1943	1944	1945	1946	
Fall	40.5	87.4	77.3	79.9	79.3
Spring	33.9	27.6	24.8	68.1	38.6
Difference	6.6	59.8	52.5	11.8	32.7

BARLEY

As indicated in the introduction, barley is a relatively minor small grain crop in Oklahoma, the 10-year average production 136-45 being 5,263,100 busrels. The northwestern portion of the State is the most important barleygrowing section—the area in which chinch bugs are not as serious as in other parts of the State. Probably the most important factor limiting barley production in Oklahoma is the yearly damage inflicted by chinch bugs. However, barley is also extremely susceptible to greenbugs and in certain years the barley losses due to this insect are extremeely high. Atkins and Dahms (1) estimated that 36 percent of the total 1942 barley crop in Oklahoma was lost as a result of greenbug damage.

Rather large differences in the degree of damage inflicted on different varieties of barley were noted by Atkins and Dahms (1). Some of their results with winter barley are reported in Table V.

These authors feel that "greenbug resistance is inherited and may be transmitted in crosses."

TABLE V.—Greenbug Injury to Winter Barley Varieties Spring-seeded at Lawton, Okla., 1942 (1.)*

Variety	C. I. No.	Origin or Source	Leaves injured April 7[1]	Total injured April 25[2]	Plants killed April 30[3]
			Percent	Percent	Percent
Mignon	999	U. S. S. R.	24.7	10.0	0
Omugi	5144	Chosen	24.3	13.3	.6
Esaw	4690	Nakano Wase × Unknown	42.3	50.0	10.4
Tenkow	646	Tennesse Winter × Hankow	48.7	66.7	59.5
Cape	557	----------------	54.0	70.0	55.8
Texan	6499	Selection from Composite Cross, C. I. 5530	58.3	73.3	72.2
Wintex	6127	Selection from farmer's field in Texas	64.3	80.0	80.8
Tennessee Winter	6034	Virginia seed service	66.3	80.0	97.2
Reno	6561	Farm in Kansas	66.0	88.3	85.8

* In 5-row 10-foot nursery plots in triple-lattice design.
[1] Estimate of leaves injured taken on 100 plants, 25 plants in each of 4 locations in plot.
[2] Estimate of total injury of entire plot, including leaves injured and plants killed, by general observation of entire plot, based on percentage of nearest check plot.
[3] Estimate of plants killed, taken on 100 plants in center row of plots, after greenbugs had disappeared and growth was resumed.

In addition to an active project on studies of greenbug reaction, other problems being investigated include: (1) high and stable yield, high test weight, and desirable grain appearance; (2) resistance to disease, including smuts, rust, scab, and stripe; (3) resistance to chinch bugs; (4) ability to withstand or evade drought; (5) resistance to lodging and to shattering; and (6) sufficient winterhardiness to escape any serious damage due to winterkilling.

Just as in wheat and oats, all barley projects of the Oklahoma Agricultural Experiment Station are conducted in cooperatoin with the U. S. Department of Agriculture.

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Preliminary Report of Chemicals for Brush Control

By HARRY M. ELWELL

Soil Conservationist, Red Plains Conservation Experiment Station, Guthrie, Oklahoma.*

In the spring of 1945 small quantities of Ammate (ammonium sulfamate), Weedone and Dow's powder 2,4-D compounds were obtained and tested at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma (3). This work and similar tests throughout the country have intensified public interest in brush control and land clearing (1, 2) for pastures, meadows, drainage ditches and orchards. The compound receiving the most discussion is bichlorophenoxyacetic acid, commonly called 2,4-D. There are many commercial brands containing this ingredient. It may be obtained in tablets, powders of sodium, ammonium salts, liquids of acids or esters and amine salts. Ammate is a yellowish granular water soluable powder. Like the 2,4-D it is not poisonous to man, animal or the soil.

Larger quantities of Ammate, Weedone and Dow's powder of 2,4-D, and other Dichlorophenoxyacetic acid compounds such as DuPont's powder, Weedex, Dow's liquid, Weed-no-more and Tufor-40 were again tested in 1946. They were used on the Guthrie station and in field trial studies in soil conservation districts in Comanche, Pottawatomie, Johnston, Adair and Rogers counties.

For complete defoliation it was essential that the leaves and twigs be uniformly covered with the spray solution. A rather coarse mist applied

* This paper is a cooperative contribution from the Oklahoma Agricultural Experiment Station and Soil Conservation Service Research. Mr. Elwell wishes to thank Clifford Elder of the Agronomy staff of the Oklahoma Agricultural Experiment Station for helpful suggestions in conducting field work and preparing the manuscript. He also wishes to thank Dr. H. F. Murphy, head of the Oklahoma Station agronomy staff, for contributing the chemicals and supplies purchased and contributed from various companies.

at a pressure ranging from 100 to 150 pounds has given the best results when applied to green, growing brush. Higher pressure appears to break up the particles so completely that it does not adhere to the leaf surface. If spreader-sticker materials were not already present in the stock solution, in order to make it stick to the foliage a small quantity of powdered soap or similar substance was added to the spray solution.

EFFECT OF 2, 4-D

The percentage of plants affected by different brands of 2, 4-D, at various times of application, are recorded in Tables I and II. Spray solutions were prepared by mixing 2,000 parts per million of the dichlorophenoxyacetic acid with water. The highest percentage of plants affected occurred on brush ranging from four to seven feet high. The 2, 4-D spray did not seem to be effective on the larger trees.

From this preliminary study it appears that some species of trees and brush are susceptible to 2, 4-D and others are not. Even the second application has little or no effect on many species. Therefore an attempt was made to classify the plants tested (Table I) in the order of their susceptibility. However, this arrangement represents tests made only in 1946 and the percentage of susceptibility may change as more information is obtained regarding the proper stages of growth, weather conditions, etc., necessary for maximum results.

In general, the 2, 4-D's appear to cause a gradual dying of the trees and brush. The leaves turn brown and often the twigs curl and twist in two to three weeks. The plants most readily affected soon developed an abnormal knotty growth of the cambium layer along the main stems. This condition often caused cracking, splitting, and deterioration of the wood.

These sprays were not toxic to native grasses but they did kill broadleafed plants such as cotton and legumes. The mist from sprays of these products is light and drifts readily. Therefore, extreme caution (4) should be used when applying them in orchards, gardens, or near any valuable broadleafed plants.

EFFECT OF AMMATE

Practically all of the trees, brush, grass and other plants sprayed with Ammate were affected and began to turn brown within 24 to 48 hours. The spray solution was prepared by mixing one pound of the powder to each gallon of water. Ammate readily affected the species of trees and brush recorded in Table I, but the percentages were determined only for those recorded in Table III. If the leaves did not fall soon after treatment, they turned a light straw color. The terminal twigs were nearly always killed by one application. However, the plants, quite often produced clusters of new leaves along the main stems and sometimes a few sickly sprouts appeared from the roots. These sprouts usually did not have much vigor. The new leaves remained green unless treated a second time. Sometimes a third application was necessary to completely kill this growth.

Ammate sprays appear to be heavy, and drifting of the mist can be controlled. For this reason it can be used advantageously for controlling underbrush, weeds, etc., in orchards and gardens.

AMOUNT OF SPRAY MATERIAL USED

Based on the present prices of these products, the cost of applying Ammate and 2, 4-D was high. The amount of solution used, in the 1945-46 tests, was 250 gallons per acre (Ammate one pound per gallon of water and dichlorophenoxyacetic acid at 2,000 parts per million) on approximately 20,000 shrubs with an average height of four feet. This quantity was in-

TABLE I.—Woody Plants Affected by 2,000 Parts per Million of 2, 4-D Spray.

Species of Trees or Brush[1]		Percent of plant defoliation with one Application of 2, 4-D at 2,000 ppm; 1946
Common Name	Scientific Name	
Sumac	Rhus glabra	80-95
Sand plum	Prunus angustifolia	"
Black locust	Robinia pseudoacacia	"
Honey locust	Gledilsia triaconthos	"
Persimmon	Diospyros virginiana	"
Sassafras	Sassafras varifolium	"
Blackjack oak	Quercus marilandica	50-75
Post oak	Quercus stellata	"
Dwarf chinquapin oak	Quercus muhlenbergii	"
Willow	Salix nigra	"
American elm	Ulmus americana	None
Winged elm	Ulmus alata	"
Mesquite	Prosopis juliflora glandulosa	"
Hackberry	C. occidentalis crassifolia	"
Hickory	Hicoria buckleyi	"
Bois d'arc	Toxylon pomiferum	"
Red cedar	Juniperus virginiana	"

[1] The species were all readily affected by Ammate when applied at the rate recommended by the manufacturer.

TABLE II.—Results of 2, 4-D Sprays on Brush in Oklahoma.

Materials Used	Location[1]	Date Applied[2] 1946	Weather conditions	Percent of affected plants[3]
Powder of 2, 4-D				
Dow's (A 510)	Guthrie	April 22	rainy	19.1
Dow's (A 510)	Tishomingo	May 7	dry	45.2
DuPont's 2, 4-D	Cache	July 10	dry	25.0
DuPont's 2, 4-D	Tishomingo	July 29	dry	79.2
DuPont's 2, 4-D	Guthrie	July 16	dry	81.5
Liquid of 2, 4-D				
Weedone	Guthrie	May 8	rainy	68.6
Weedone	Guthrie	April 22	rainy	31.7
Weedone	Tishomingo	May 8, July 29	dry	54.7
Weedone	Cache	July 10	dry	25.0
Weedone	Stilwell	July 26	dry	33.7
Weedone	Shawnee	July 30	dry	75.2
Weedone	Claremore	August 29	rainy	91.7
Weedex	Guthrie	May 16	rainy	77.6
Weed-no-more	Guthrie	April 22	rainy	20.6
Dow's	Guthrie	April 22	rainy	29.0
Tufor-40	Guthrie	May 16	rainy	70.7

[1] The predominating plants at all locations were blackjack, white and chinquapin oak except those at Claremore which were persimmon.
[2] Chemicals all applied in a spray solution at the rate of 2,000 parts per million with water.
[3] Plants defoliated and did not produce new leaves.

TABLE III.—Results of Ammate Spray on Brush in Oklahoma.

Location[1]	Date applied[2] 1946	Weather conditions	Percent of affected plants[3]
Guthrie	May 22[4]	rainy	93.5
Guthrie	May 22[5]	rainy	83.6
Guthrie	April 22	rainy	69.6
Tishomingo	May 7	rainy	65.0
Cache	July 10	dry	40.0
Stilwell	July 26	dry	98.9
Guthrie	July	dry	97.8
Shawnee	July 30	dry	86.8
Claremore	August 28	rainy	99.0

[1] Predominating woody plants at all locatoins were blackjack, white and chinquapin oak except those at Claremore which were persimmon.
[2] Spray solution one pound of Ammate per gallon of water.
[3] Plants defoliated and did not produce new leaves.
[4] Second application, the first made May 28, 1945.
[5] Second application, the first made September 1, 1945.

creased to 600 gallons per acre on the more dense trees and brush that averaged about six feet high. The cost of applying the sprays varied from $20 to $100 per acre. However, the price of these products has declined greatly during the last year. It is the opinion of those who are working with these materials that if the volume of production could be increased sufficiently, prices would be reduced to a practical level.

GIRDLED TREES

In 1945 and 1946, trees were completely girdled with an axe near the ground level. Undiluted Weedone, Esteron, a saturated solution of Dow's (A 510), DuPont's 2,4-D, Ammate, and sodium arsenite were applied individually in the incisions. The sodium arsenite was prepared by mixing one pound of the powder to one gallon of water. (The arsenite compound is very poisonous and must be handled carefully.)

In general poor results were obtained with 2,4-D compounds. Ammate was quite effective on small trees. Sodium arsenite was the only chemical that killed large trees. These compounds were not effective when applied in holes punched in trees or stumps.

The best time to girdle the trees and apply arsenite or Ammate compounds seems to be during a summer dormant period or about two or three weeks before the leaves drop in the fall. During this period the sap moves slowly and the evaporation is low.

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The Latest in Weed Control

By W. C. ELDER
Assistant Agronomist
Oklahoma Agricultural Experiment Station

The science of weed eradication always has been far behind other pest control developments. Our knowledge and use of herbicides is elementary, compared with our knowledge of fungicides and insecticides. Yet the loss from weeds is greater than that from insects and diseases combined. In the past, very little technical study has been given to weed eradication. Weed control has been considered just another chore for the individual farmer. Most of the herbicides that have been submitted to the farmer in the past, for use on weeds, have not given satisfactory results, or have been too expensive to use except on small areas. It is no wonder the farmer is enthusiastic when reading of new wonder weed chemicals.

He will not have to wait long for new weed herbicides to appear on the market. The war brought a great expansion to the chemical industry, and the manufacturers are now looking for markets. Weed control chemicals have great possibilities as an outlet for these products. Many of the chemical companies are setting up weed control research organizations of their own and are anxious to cooperate with the experiment stations on weed research.

The discovery of 2, 4-D (dichlorophenoxyacetic acid) has not only excited the farmer, but it has given the chemical companies a tip on a new market. Upwards of fifty different 2, 4-D products appeared on the market in 1946 as weed killers. It would take a large catalog to list the weed killers that will appear on the market in the future.

Several different types of 2, 4-D formulations are now made. The reactions of the different types are about the same on a large number of plants. However, for 2, 4-D resistant plants, and for use under conditions unfavorable for effective kills, the ester type of 2, 4-D is desirable. It seems to be more active and will kill weeds two to three days earlier than the other formulations.

After two years of use 2, 4-D has proved itself to be by far the best herbicide for grass lawns and turfed areas. Lawn grasses are checked some in growth by 2, 4-D treatments, but a minimum amount of yellow color is given to the grasses. Under some conditions some injury may be found in Buffalo grass after a 2, 4-D treatment. Bermuda grass lawns are very resistant to the treatments.

The most injurious lawn weeds in Oklahoma are the dandelion, chickweed and henbit. These weeds usually come up in the fall months, live through the winter, and compete with the lawn grass in the spring. The best itme to use 2, 4-D on these weeds in Oklahoma is in late October, early November, or early in March when the dandelion starts to bloom. Poor results are obtained from summer treatments on dandelion. Henbit can be killed with 2, 4-D while young, but it is somewhat resistant when the growth is advanced.

2, 4-D can be recommended for areas where plowing is impossible, such as fence rows, right-of-ways, and stony areas. It can be used on pastures where legumes are not grown. Perennial ragwed is common in pastures and is difficult to control by mowing. Ragweeds are easy to kill with 2, 4-D.

Unfortunately, 2, 4-D has not lived up to the early publicity and claims when used on perennial weeds that are difficult to eradicate. Results similar to the bindweed experiments in Oklahoma are being obtained in other states on weeds that are difficult to eradicate, such as knapweed, hoary cress, Canada thistle, and leafy spurge. Under favorable conditions 95 percent or more of bindweeds can be killed. From 1000 to 2000 bindweeds are found per square rod on dense bindweed growth. If it is possible to kill 98 percent, then there will still be 20 or more plants to the square rod. The 20 plants will cover the entire area again in one season if left undisturbed. Respraying of the weeds that survive the first treatment will not give the same percentage of kill as the first treatment. It sems there is some resistance built up in the plant to withstand later treatments.

It should be recognized that bindweeds cannot be eradicated by one application of 2, 4-D. Bindweed is being eradicated by careful cultivation and cropping practices. To be effective in bindweed control, 2, 4-D must fit into these practices. The best ways to combine 2, 4-D with cultivation and cropping systems must be worked out in the future. Some of these ways will be suggested, but there are no experimental results to back them up. Bindweeds could be treated in the spring in grass crops, such as the small grains, and after harvest the area could be clean cultivated until the next planting date. The small grains should not be past the jointing stage at the time of treatment. Small grains, such as wheat, could be planted early in the fall and treatments made just before frost. This will delay the bindweeds until harvest time. Then follow the harvest with clean cultivation or with a smother crop, such as broadcast cane. These systems may let the farmer grow a crop every year and at the same time eradicate bindweeds.

Since 2, 4-D will be used by many persons before definite recommendations can be given for its use on bindweed, some factors should be mentioned which affect the result of 2, 4-D treatments. The weed should be in the active growing stage and about ready to start blooming when treated. Treatments in hot dry weather give very poor results. Treatments can be made at much lower etmperatures than was first recognized.

A standard solution of 2, 4-D is 0.1 percent concentration, but more concentrated solutions must be used on more resistant plants and under unfavorable conditions. 2, 4-D is usually applied as a spray, although the dust form might be used. It will take about one gallon of spray per square rod for low-growing plants. All leaves of the weed should be wet. Sprays are best applied to weeds at a pressure of 75 pounds to 100 pounds and with a fan-shaped nozzle that gives a coarse spray. The chemical is not poisonous to man or animals. 2, 4-D is toxic to the soil for a short peroid of time. It is quickly leached and decomposed by wet soils, but may stay longer periods in dry soils. Seed should not be planted in soil that has been treated with 2, 4-D for at least 40 days. Some crops, such as the grasses, can be safely planted earlier than legumes and cotton.

Things that are new now in chemical herbicides will be soon replaced by newer products. There is a great demand for this method of killing weeds. The chemical companies would like to have a herbicide market similar to the insecticide and fungicide markets. The discovery of 2, 4-D has started a great deal of interest and research in chemical weed control work. The science of weed eradication has just started, but progress will be rapid.

Comparison of Soil Texture and pH with Exchange Capacity and Lime Requirement

By W. ELMO BAUMAN and LESTER W. REED*

Respectively, Soil Scientist, and Sp-5 Soil Science Aid, Soil Conservation Service State Soils Laboratory, Stillwater, Oklahoma.

The quantities of agricultural limestone applied to the cultivated and pasture soils of Oklahoma have increased rapidly during the past few years. At the present time county agents, soil conservation district technicians, and vocational agriculture teachers are equipped to make "quick tests" for acidity and available phosphorus. This rapid expansion of the lime program, in connection with the inability in many cases to secure phosphorus to balance the fertility program, has raised a number of problems. There is ample evidence that the application of unneeded agricultural limestone in excessive amounts can be, in addition to a waste of money and effort, actually harmful to plant growth.

In consideration of the statements above, a partial review of the literature and a study of data assembled from the analyses of soils received from the soil conservation district cooperators in Oklahoma have been made. The purpose of this review and study is to bring to the attention of the workers in the State these problems, as well as some of the factors affecting their solution. The present method of determining lime requirements has been studied to ascertain if a more exact method of securing the liming rate is feasible.

REVIEW OF LITERATURE

Agricultural lime in its various forms was first used primarily to correct "sour" conditions of the soil, with no attention paid and little enough thought given to the effect on other plant nutrients in the soil.

Previous investigators have shown that excessive liming brings out many other problems. Cooper (5) has found on gray sandy soils of South Carolina that excessively limed areas show deficiencies of manganese, boron, and copper. Willis (25) reports that overliming of sandy soils in North Carolina results in poor phosphate nutrition, boron deficiency, and the wasteful use of nitrates. Miles (17) of North Carolina recommends that lime be applied to raise the pH of acid soils to 6.0 because some plants, such as soybeans, on the sandy coastal plains soils show potash deficiencies if the pH is carried above 6.0. He reports further that if other plant nutrients are in balance, alfalfa and sweet clover will usually do well on these soils at pH 6.0. Work at Oklahoma Experiment Station** and on field trials over the State shows this to be too low for the optimum growth of alfalfa or sweet clover. These frequently fail when both surface and sub-surface soils are below pH 6.1. Below pH 6.5, weed and grass competition is serious, especially with old stands.

Hester (12) has shown that tomato plants on coastal plains soils with an original pH of 5.1 will suffer from phosphate deficiency if limed, and will give a decreased yield unless phosphated, even though the pH is not carried above 6.2. Dunn (7) states that the presence of lime in alkaline soils makes soil phosphorus less available. Low liming rates gave a significant increase over high rates (excessive) of application. Heavy rates on soils in western

* The authors wish to take this opportunity to express their appreciation for much additional unpublished information thathas had a direct bearing on this problem made available for study and guidance by Dr. Horace J. Harper and also for his valuable suggestions in reading and preparing this manuscript.

** Unpublished data from Oklahoma Experiment Station by Dr. Horace J. Harper.

Washington caused a decrease in yields, except when used with complete fertilizers. Excessive liming may cause or intensify deficiencies in soluble iron, manganese, boron, and potassium. From his studies, Truog (22) has concluded that in northern states a pH of 6.5 is best for alfalfa.

Pierre and Browning (20) have shown in greenhouse studies that 9 out of 10 soils in West Virginia gave a decrease in yield of alfalfa when brought to near pH 7.0. The average decrease was 46 percent when pH was raised to pH 7.0 or above. (Original pH was 4.4 to 5.6). The only soil that gave no depression of yield from liming to pH 7.0 or above was one with a high fertility level. Liming appeared to depress availability of potassium and trace elements as well as of phosphorus.

Gardner and Kelley (9) state that phosphate solubility on Colorado soils apparently reaches a minimum near the neutral point. These investigators have pointed out that all liming must be to correct reaction within certain narrow pH ranges (6.5 to 7.0 for alfalfa and sweet clover.) Others have investigated the effect of using limestone and fertilizer at low rates per acre but concentrated in narrow bands by row application. This has been found (2, 15) to give significant increrases in the production of legumes with high lime requirements.

Kingebiel and Brown (15) have found that row application of limestone to soils with pH of 4.9 to 5.7 gave good increases in forage and total nitrogen produced by alfalfa grown in greenhouse plots. Greater increases, however, were secured on fully limed soils.

The data in Table I from the Oklahoma Agricultural Experiment Station sweet clover field plots compiled by White (23) show that increases in the yield of this crop on moderately to strongly acid soils where small quantities of lime and phosphate were applied in rows and compared with phosphate applied alone are highly significant, ranging from an increase of 880 pounds to 2,450 pounds per acre.

TABLE I.—Yields of Sweet Clover from Light Applications of Limestone and Phosphate in Rows as Compared to Phosphate Alone.

No.	pH	m. e. Exch. Ca	m. e. Exch. H	% Base Sat.	Liming Rate	Increase in yield No. (A)
4463	5.7	6.5	3.3	74	100	880
P345	5.9	6.4	3.4	77	400	1200
P338.	5.8	4.5	2.0	77	400	2450
P359	5.6	5.2	2.0	81	100	1615

In 1936 the senior author established row plantings of sweet clover near Stigler, Oklahoma, on a medium to strongly acid soil of very low fertility. Liming was at the rate of 70 pounds per acre of limestone with 30 pounds rock phosphate per acre in 36 inch rows. This area has been used as a pasture since 1936 and permitted to reseed. In the beginning reseeding occurred over the entire area, but plants died that were not adjacent to rows that were limed and fertilized. The last two crops (1943 and 1945) have survived over the entire area. The present farm operator did not know that the clover was originally planted in rows.* Comparison of rates and methods of applying lime and phosphate to determine the amount necessary to secure growth of sweet clover were made by Harper (Bul. B-248) during the years 1931 to 1936 inclusive at different locations over the State. He

* Observations were maintained on this area by W. C. McCollum, Work Unit Conservationist, Stigler, Okla., from date of planting.

found that row applications of lime and phosphate at much less than the normal rate were effective in producing yields of clover, even on low fertility, acid soils. Sweet clover grown in wide-spaced rows with cultivation the first year produced a root and top yield approaching that of clover grown in 7-inch rows. Lime and fertilizer should be applied approximately three inches deep. Soils with pH of 6.3 (slightly acid) in the surface do not give profitable response to liming when the subsoils are neutral or basic.

The effect of variation in base saturation on lime need and crop response has been studied by numerous investigators. It is generally agreed that soils with a high total exchange capacity apparently are capable of supplying adequate calcium for plant growth at a much lower percent of base saturation and lower pH than soils with low total exchange capacity and a higher pH. Injury to plant growth from overliming seldom occurs on highly buffered soils.

Pierre (19) found no correlation of corn yields and poor correlation of sorghum yields with percent base saturation. Barley gave somewhat better correlation. A study of his data indicates that where other factors are not limiting production, a base saturation of about 50 percent appears adequate for these crops. This varies considerably for the 13 soils used in the study. One of the soils with only 20 percent base saturation but a high fertility level gave a relative yield of 92 for the three crops grown, in comparison with the highest yielding soil of the group. Pierre concludes that sandy coastal plains soils having 50 percent to 60 percent base saturation at pH 6.0 do not generally give crop response to liming; these soils have a low lime requirement.

McGeorge (16) states that soils with low exchange capacity (sands) can have a higher pH than high exchange capacity soils (clays) and not damage crops.

A study of comparable data presented by White (23) indicates that sweet clover responds to liming on medium textured soils with less than 75 percent to 80 percent saturation and on fine textured soils with saturation of less than 70 percent to 75 percent. There is, however, some question as to whether the response was caused by raising the pH or increasing the quantity of available calcium by liming.

Bauer (4) concludes from his work that 80 percent saturation level with calcium and magnesium is probably most desirable for corn, wheat, oats, and clover rotation. This figure is quite variable, depending on the general fertility level. Conversion of his graph comparing percent base saturation with percent yield increase from lime by groups of soils of decreasing productivity gives the following approximate data:

Soils 79 percent saturated gave decrease in yield from liming
Soil 76 percent saturated gave increase of 5 percent
Soils 74 percent saturated gave increase of 32 percent
Soils 55 percent saturated gave increase of 10 percent
Soils 28 percent saturated gave increase of 75 percent
Soils 15 percent saturated gave increase of 150 percent
Soils 35 percent saturated gave increase of 150 percent

Crop increase on the group of soils 74 percent saturated with a 32 percent increase in yield was approximately equal by weight to the increased yield on the soils in the 28 percent, 15 percent and 35 percent saturated groups. The great difference shown by percent increase is caused by difference in natural fertility of the soil groups. Bray and DeTurk (5) state sweet clover grows best at pH 6.5 to 7.0 and 80 percent base saturation.

The extremely variable results on optimum degree of base saturation that have been secured by different investigators is probably caused mainly by four major differences:

1. Different methods of analysis to determine percent base saturation.
2. Difficulty of assigning the benefits between change in pH and change in base saturation as a result of liming.
3. The widely different chemical character and fertility of soils studied by various investigators.
4. The variation of organic matter content and its effect on exchange capacity.

METHOD OF STUDY

Analytical results on a portion of the samples received at the Soil Conservation Laboratory in Oklahoma during the past year of operation were used in this study. Exchangeable bases were determined by the official A. O. A. C. method (3), except the soil was leached rather than extracted. Exchangeable calcium was determined by a method proposed by Williams (24). Exchangeable hydrogen was determined by calcium hydroxide titration developed by Dunn (8) and modified by White (23). Total exchange capacity was calculated from the sum of exchangeable hydrogen and exchangeable bases in the soil. The milli-equivalents (m. e.)* of calcium determined by calcium hydroxide titration to bring the soil to a desired pH was used to determine the amount of limestone needed to establish a pH of 7.0 (neutral) on 2,000,000 pounds of soil or approximately 6⅔ inches over one acre of land.

Calcium hydroxide titrations have been checked by Dunn (8) and found to give lime requirements slightly higher than the amount necessary to bring the soil under field conditions to a desired pH, but variations were not wide enough to warrant the use of a correction factor. Previous studies by the junior author, using soils of varying pH treated with 200-mesh calcium carbonate at rates determined by calcium hydroxide titration, were studied over a period of one year. Soils were maintained at optimum moisture and the pH determined with a glass electrode at monthly intervals. The soil pH increased to 7.0 (neutral) in one to six months and remained constant for the remainder of the study.

In addition to securing data on lime requirements at any given pH, the variation in buffer capacity of soils is shown by the steepness of the curve plotted from the calcium hydroxide tritration figures.

DATA** AND DISCUSSION OF RESULTS

A study of the data on percent base saturation of 206 samples divided into different pH groups (Figure 1) shows that in the pH range 6.5 to 7.0, 28 out of 31 samples were over 90 percent saturated with bases and no sample was less than 85 percent saturated. In the pH range of 6.0 to 6.5, 67 out of the 72 samples were over 80 percent saturated with bases and no sample of this group was below 73 percent saturated. In the pH range 5.0 to 5.5, 15 samples were over 60 percent saturated and only 3 of the 29 samples studied were less than 50 percent saturated wih bases. In the pH range of 4.5 to 5.0, only 10 samples were studied and 4 of these were above 55 percent saturation.

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* The abbreviation m. e. represents milligram equivalents in 100 grams of soil 1 m. e. of calcium carbonate in 100 grams of soil is equivalent to 1,000 pounds of calcium carbonate in 2,000,000 pounds of soil, or approximately 1 acre of land 6⅔ inches deep, assuming limestone 100 percent neutralizing power and 100 percent available.

** Complete analytical data used as a basis for charts and tables in this paper were submitted by the author. These data will be made available in mimeographed form, should demand warrant.—The Editor.

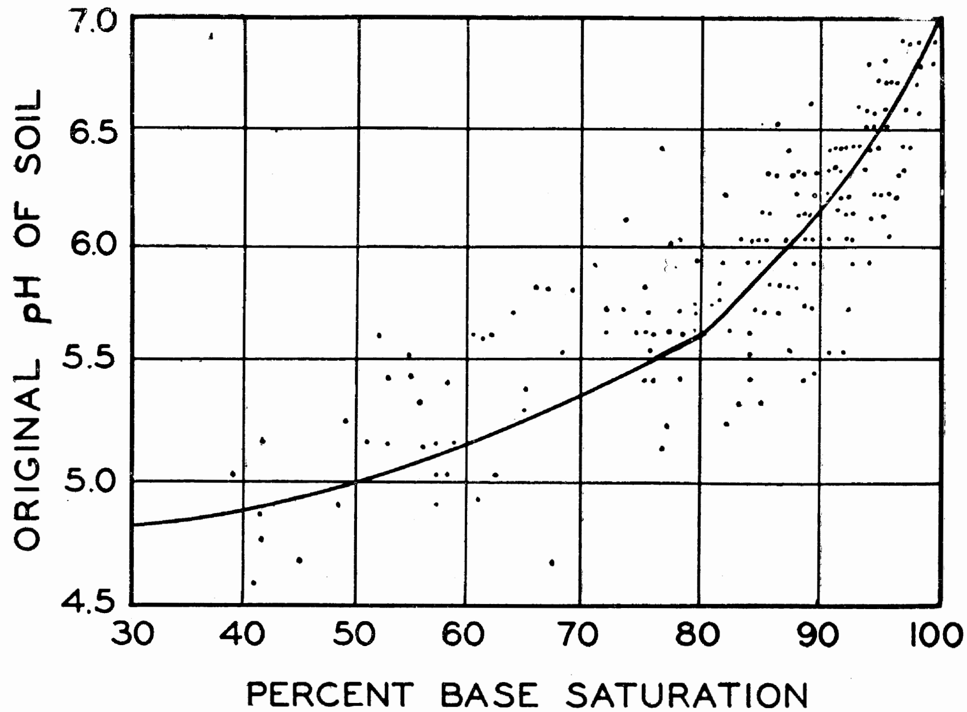

Fig. 1.—Comparison of pH and Percent of Base Saturation.

In summation of these data, only 13 samples out of 167 with a pH of 5.5 or above had their base exchange capacity less than 70 percent saturated and none less than 50 percent saturated. Based on these data only, these 13 in the pH range above 5.5 are low enough in base saturation to affect crop yields because of calcium deficiencies, if a minimum of 70 percent saturation is required for maximum crop production. Only 3 samples would be deficient if 60 percent is taken as the critical saturation point.

Below pH 5.5, 27 out of 39 samples were below the level of 70 percent saturation and probably would require lime to correct calcium deficiencies for moderate to high calcium requirement plants. This pH range is one in which the need for lime to correct acidity as well as increase the calcium supply for most field crops is generally recognized.

From the above data as well as the uncertainty of actual minimum base saturation level at which calcium becomes a limiting factor, it is concluded that it is not necessary to determine percent base saturation for general liming recommendations on Oklahoma soils. The application of limestone to bring pH to a level for optimum plant growth of most field crops will automatically bring the percent base saturation up to or above the general minimum level for adequate calcium nutrition.

A discussion of the curve developed in the study of percent base saturation may help explain the rather broad nature of the plot, and the steep slope from 70 percent to 100 percent saturation.

Bray and DeTurk (5) state that the breadth of these curves may be partially explained by varying amounts of soluble salts in the soil. Further variations may be caused by organic matter, clay content, and type of soil colloid. The steepness of the curve from 70 percent to 100 percent base saturation may be partially explained by a review of the general theory of the pH system. The amount of lime required to change pH from 6.0 to 7.0 is only one-tenth of the amount required to change pH from 5.0 to 6.0 in pure solutions. The buffer effect of soils materially alters this condition, but does not change the general relationship. A study of the curve in Figure 1 shows that a slight change in base saturation past 80 percent will cause a much larger change in pH than a corresponding saturation change at a lower pH and saturation value.

Recent studies have pointed out that a sufficient supply of exchangeable calcium must be present in the soil regardless of pH, in order to grow crops adequately supplied with calcium. Horner (13) states that the amount of calcium present in the soil is important, regardless of pH, if plants are to be adequately supplied with calcium. Albrecht (1) determined by work with soybeans that soil pH was the limiting factor in growth and nodulation below pH 5.0, but that above 5.0 the limiting factor was the available calcium supply.

Poor calcium nutrition and insect injury correlation has been shown by Wittmer and Haseman (26). Spinach was grown under varying nitrogen and calcium fertility levels in a greenhouse infested with thrips. Damage to young plants was greatest on low nitrogen level plants, but as growth continued damage was confined almost entirely to low calcium level plants.

Kelley, Dore, and Brown (14) have pointed out that the chief replaceable bases of a normal soil are usually calcium. Wynd and Romig (27) have shown that replaceable bases in soils of East Central Kansas (Douglas County) are 75 to 90 percent calcium. Harper (10) found by the Morgan test that only 5.3 percent of 3,100 samples collected from Oklahoma soils were very low in exchangeable calcium.

In order to determine if the results on percent base saturation afforded an index of percent of exchangeable calcium in the soils, the percent calcium in the exchangeable bases was determined for a group of soils from various parts of the state (Table II). The results secured agree with those reported above. In a pH range from 4.9 to 7.6, 56 samples were analyzed and in only 4 samples did calcium make up less than 60 percent of the total exchangeable base. In 39 samples, 70 percent of the total exchangeable bases was calcium. About 90 percent of the bases other than calcium is magnesium and 2 percent to 6 percent potassium.

A study of these results indicates that in the normal soils of Oklahoma, with a pH of 5.5 or above, calcium deficiencies will not occur. Some loose sands, however, with a very low total exchange capacity may show calcium deficiencies at high pH. At pH levels below 5.5, liming to correct soil acidity as needed for most general crops will, in addition to raising the pH, increase the base saturation, and furnish the necessary calcium for adequate plant nutrition. It is concluded that for normal Oklahoma soils it is not necessary to test for available calcium to determine lime requirements. Some loose sands may be exceptions.

The need for enormous quantities of lime on Oklahoma soils has been pointed out by Murphy (18) and Harper (10). It is recognized first that there is an extensive liming program in the State to partially satisfy this crop yield where rock phosphate or no phosphate at all is used. A restudy of the method of determining lime requirements now is in common use in Oklahoma was made to determine its accuracy.

TABLE II.—Percent Calcium of Total Exchangeable Bases at Different pH and Textures.

Sample No.	Soil Unit	Texture	pH	m. e. Bases per 100 Gm. Soil	% Base Saturation	m. e. Exch. Ca per 100 Gm Soil	% Ca in Exch. Bases
4	7x-CT	FSL	6.2	3.7	90.2	2.5	67.60
5	12-CT	LFS	6.0	3.8	92.2	2.7	71.00
6	7-ZH	FSL	6.0	2.2	84.6	1.55	70.40
7	6-ZH	SiL	6.1	3.1	72.8	2.45	79.03
8	5-ZHA	SiL	5.6	2.8	60.3	2.00	71.40
9	6-OH	FSL	6.0	5.9	76.6	4.90	83.05
10	20-OH	FSL	5.6	2.9	61.2	2.0	69.00
12	9H-RP	SiL	5.8	9.5	87.5	6.85	72.10
14	7-RR	FSL	6.6	5.5	93.8	4.25	77.30
20	7-RP	VFSL	6.1	7.4	88.5	4.30	58.10
23	5-RP	VFSL	5.8	9.0	87.9	4.7	52.20
34	5-CP	VFSL	6.0	16.0	90.1	8.8	55.00
35	7-CP	VFSL	5.9	13.9	87.4	9.2	66.20
459	24-RP	VFSL	8.2	53.6	100.0	42.76	79.80
508	5-RP	SiL	6.0	16.3	89.1	12.48	76.60
527	7-CT	FSL	6.9	7.13	99.4	4.60	64.50
530	20-RP	FSL	5.6	4.00	76.9	3.19	79.70
574	2-BH	CL	7.5	34.91	100.0	32.20	92.20
575	5-BH	SiL	6.2	14.26	68.1	12.15	85.20
726	6d-OH	FSL	5.8	3.72	62.8	2.99	80.40
830	2-GP	C	7.8	65.06	100.0	59.23	91.00
862	7-CP	VFSL	5.3	2.42	54.7	2.39	98.70
863	6-CP	SiL	5.4	4.73	54.8	3.85	81.30
866	6-CP	SiL	4.9	3.02	59.9	2.46	81.50
935	3H-RP	C	7.6	64.10	100.0	57.90	90.30
935-A	3H-RP	C—	8.1	70.58	100.0	55.18	78.20
936	6-CP	VFSL	5.6	5.06	77.9	4.32	85.40
G-1	6-RP	FSL	5.4	3.86	89.8	2.79	72.30
G-2	6-RP	FSL	6.2	7.27	91.0	4.88	67.10
G-3	6-RP	FSL	6.4	4.61	92.8	3.45	74.80
G-4	2-RP	CL	6.0	7.42	89.4	5.01	67.50
G-5	6-RP	FSL	7.0	6.54	100.0	5.28	80.7
G-6	2-RP	CL	6.2	9.58	90.5	6.6	68.8
G-7	2-RP	CL	6.9	8.47	99.1	7.0	82.6
G-8	6-RP	FSL	7.1	9.88	100.0	8.33	84.3
G-9	6-RP	FSL	6.3	6.72	90.3	4.68	69.6
G-10	6-RP	FSL	7.3	7.47	100.0	6.28	84.1
G-11	6-RP	SiL	6.5	9.73	93.8	6.74	69.2
G-12	6-RP	FSL	7.2	9.03	100.0	7.4	81.9
G-13	6-RP	VFSL	6.1	5.92	85.1	4.88	82.4
G-14	2-RP	CL	6.5	10.83	94.4	6.47	59.7
G-15	2-RP	CL	7.3	9.38	100.0	7.73	82.4
G-16	2-RP	CL	6.7	10.43	95.4	6.81	65.3
G-17	2-RP	CL	7.3	10.43	100.0	7.97	76.4
G-19	2-RP	CL	7.6	13.04	100.0	11.55	88.6
G-20	6-RP	FSL	7.3	8.23	100.0	6.14	74.6
G-21	6-RP	FSL	7.8	11.63	100.0	10.52	90.5
G-23	6-RP	FSL	7.0	5.77	100.0	4.28	74.2
G-24	6-RP	FSL	8.5	9.38	100.0	8.4	89.5
G-25	6-RP	FSL	6.6	3.31	93.2	2.82	85.2
G-26	6-RP	FSL	7.5	9.63	100.0	8.4	87.2
G-22	6-RP	FSL	6.1	11.83	92.2	8.13	68.7
G-27	6-RP	FSL	6.6	5.72	94.1	4.48	78.3
G-28	6-RP	FSL	7.2	6.72	100.0	5.48	81.5

To this end those samples on which the maximum amount of analytical data was available were selected for study. These data were grouped and plotted by the following textural classes:

1. Fine sandy loam (contains 6 samples of loamy fine sands or fine sands).
2. Silt loam and very fine sandy loams.
3. Clays and clay loams.

The following acidity classes were used:

1. Slightly acid—pH 6.1 to 6.7.
2. Moderately acid—pH 5.5 to 6.0.
3. Strongly acid—pH 4.9 to 5.4.
4. Very strongly acid—less than pH 4.9.

The lime requirement determined for each of the textural groups by acidity classes is an average of $CaCO_3$ needed to bring 2,000,000 pounds of soil to pH 7.0 based on m. e. of exchangeable hydrogen for all soils in an acidity class. To get liming rate, this figure is increased by a factor to account for percent purity of agricultural limestone and percent availble in first year.

Texture used is that determined by field men. It is recognized that some of these textures are not correct, but field men are not equipped to make a mechanical analysis and must determine texture by feel. The texture given by them is used to place the soil in the various textural groups. The authors wish to point out that had mechanical analyses been made, many of the soils that are at wide variance from the average probably would be in another textural group plotted on a different figure and as a result would have a different liming rate. By careful attention to classification of texture, one source of error in determining liming rate by pH and texture will be reduced.

The data for fine sandy loams and loamy fine sands given graphically in Figure 2 may be summarized as follows:

Acidity Group		Average Lime Requirement Per Acre
Slightly acid	pH 6.1-6.7	1035 lb. or ½ ton
Moderately acid	pH 5.5-6.0	2739 lb. or 1½ tons
Strongly acid	pH 5.0-5.4	4858 lb. or 2½ tons
Very strongly acid	pH 4.9- or less	8560 lb. or 4¼ tons

A greater number of samples in the strongly acid range probably would reduce the average requirement.

Data for the silt loams and very fine sandy loams is given on Figure 3. If a band one m. e. wide representing a lime need of 1,000 pounds of pure $CaCO_3$ is laid over the average curve on this figure, the major portion of the points fall within this spread. The data for this figure may be summarized as follows:

Acidity Group		Average Lime Requirement Per Acre
Slightly acid	pH 6.1-6.7	2140 lb. or 1 ton
Moderately acid	pH 5.5-6.0	4643 lb. or 2¼ tons
Strongly acid	pH 5.0-5.4	5692 lb. or 3 tons
Very strongly acid	pH 4.9- or less	10000 lb. or 5 tons

The moderately acid soils of this textural group contains the greatest number of samples. It is used to show that a general liming rate based on pH and texture may be as accurate in the field as a specific one made from a more complete analysis of each sample.

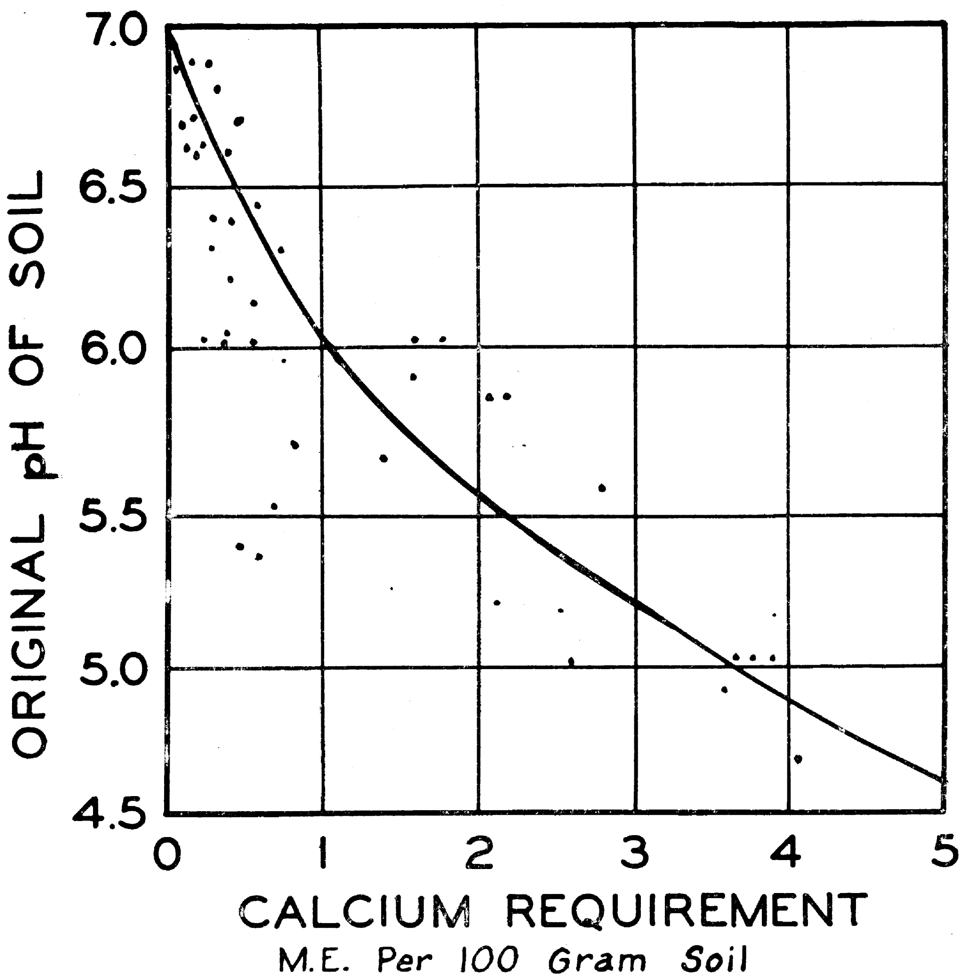

Fig. 2.—Calcium Required to Neutralize Loamy Fine Sands and Sandy Loams.

In addition to the differences in soil sampling technique, which varies considerably from place to place and may produce considerable error, there are at least four other major factors over which the individual making lime recommendations has little control. Namely:

1. Variation in rate of spreading from recommended rate.
2. Variation in depth of plowing.
3. Source of material from which limestone is secured.
4. Adequacy of mixing with the soil.

A typical sample of agricultural limestone analyzed by the Soils Laboratory has been used for determining the liming factor. This sample has 88 percent neutralizing power and based on the evaluation method of Schollenberger and Salter is 53 percent available at the end of the first year and 62 percent at the end of the fourth year. The amount of this limestone necessary to furnish 1,000 pounds of calcium carbonate to neutralize soil acidity in one year is 2,140 pounds or a factor of 2.14. The amount of calcium carbonate needed to neutralize the acid in 2,000,000 pounds of soil represented by 1 m. e. exchangeable hydrogen (acid) per 100 grams soil is 1,000 pounds. Liming rate with above limestone is determined by using m. e. exchangeable hydrogen × 1,000 × 2.14.

There are 34 samples of the very fine sandy loams and silt loams in the moderately acid group, pH 5.5 to 6.0. They range in m. e. of exchangeable hydrogen per 100 grams of soil from .7 to 4.93. This represents a variation of liming rate of 1,498 pounds to 10,550 pounds per acre actually needed to correct pH to 7.0. The average value is 2.17 m. e. of hydrogen per 100 grams of soil or 4,600 pounds of agricultural limestone.

In applying limestone a local distributor states that 500 pounds more or less than the recommended rate is as accurate as he can be. The variation may be wider under adverse field conditions.

In mixing lime with the soil, the farmer may mix it in 4 inches or less to 8 inches or more of soil, even though the recommended rate is based on treating approximately 7 inches of soil.

Based on a recommended rate of 4,600 pounds per acre, because of the above two variables, the lime applied may be the correct amount to neutralize only 1.6 m. e. of hydrogen, or it may be the correct amount to neutralize as much as 3.4 m. e. per 100 grams of soil in the soil with which it

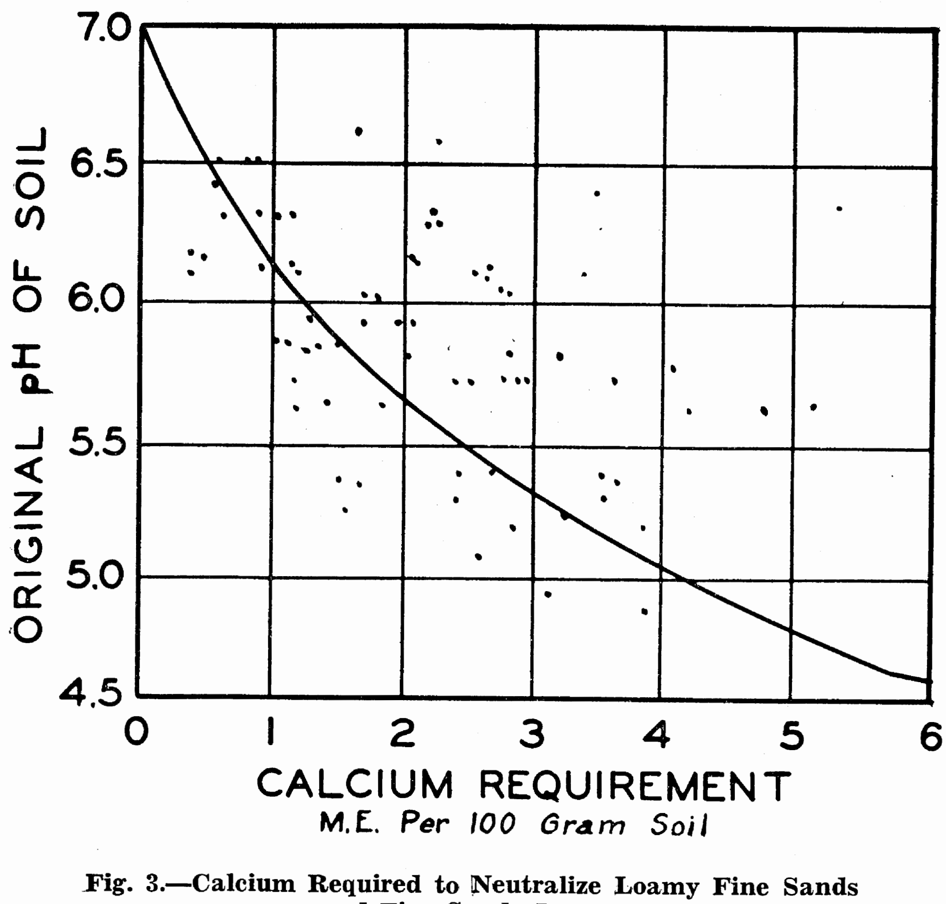

Fig. 3.—Calcium Required to Neutralize Loamy Fine Sands and Fine Sandy Loams.

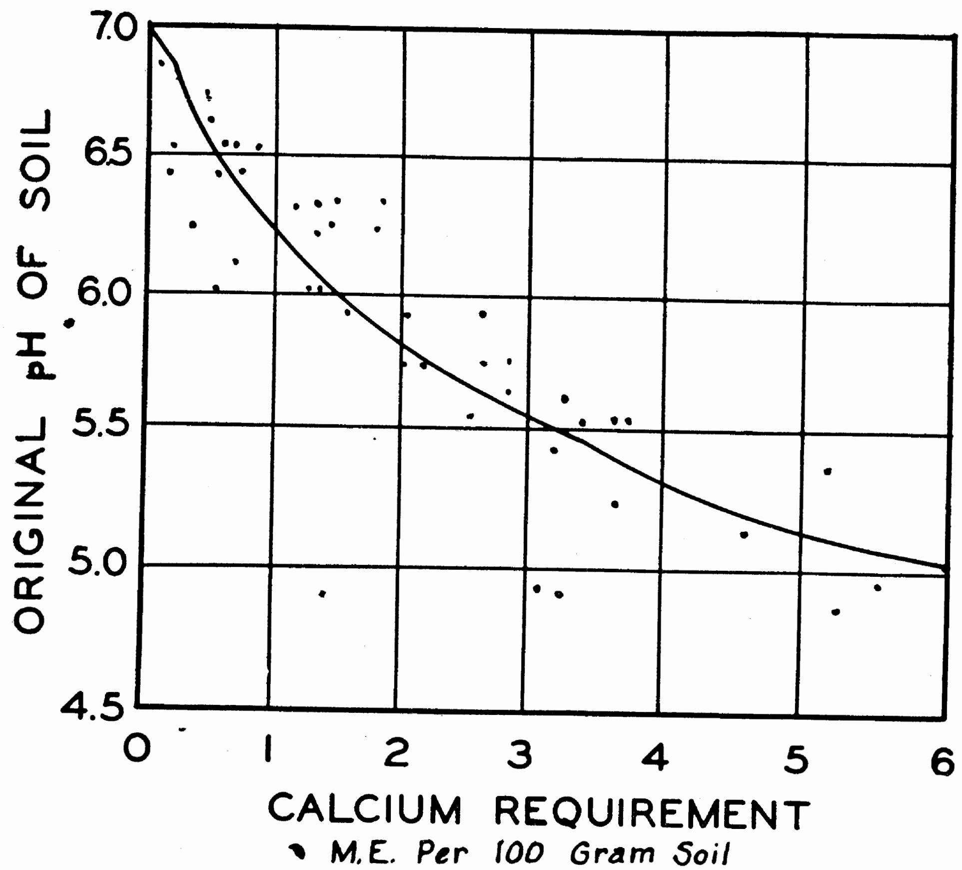

Fig. 4.—Calcium Required to Neutralize Clays and Clay Loams.

is actually mixed.* This is a variation in effective liming rate from 3,424 pounds to 7,286 pounds. If the variation of material from different sources is considered, the spread will be widened considerably.

A study of the basic data on the soils in this group shows that 10 out of the 15 that have less than 2 m. e. of acid per 100 grams of soil to be neutralized are either reddish prairies, bottomlands from reddish prairie material, or chert prairies soil. It is recognized that these soils normally have a lower lime requirement per degree of acidity than do many other soils. Liming rates are adjusted accordingly when recommendations are made.

Because of lack of data to develop a curve on clays and clay loams separately, Figure 4 is a combination of these two textures. The slightly

* The variation of 3,424 pounds to 7,286 pounds was determined as follows:

1. The recommended rate of 4,600 pounds was varied from an actual rate of 4,100 pounds to 5,100 pounds based on variation in application of 500 pounds more or less from the recommended rate.
2. The effective rate was determined by applying these actual rates to the average weight of soil contained in as little as 4 inches and as much as 8 inches. It is recognized that the lime may be mixed with even less than 4 inches or more than 8 inches of soil.
3. The source of material would widen this range. Limestone samples from two other sources than the one used in the above calculation have a factor of 1.925 and 2.23 respectively in comparison to the 2.14 factor used in the above calculations.

acid group contains most of the clay loams. The clay texture predominates in the other acidity group. Lime requirements based on these data for clays and clay loams are:

Acidity Group		Average Lime Requirements Per Acre
Slightly acid	pH 6.1-6.7	2140 lb. or 1 ton
Moderately acid	pH 5.5-6.0	5350 lb. or 2½ tons
Strongly acid	pH 5.0-5.4	9630 lb. or 4½ tons
Very strongly acid	pH 4.9- or less	11770 lb. or 5½ tons

The data presented for these three textural classes is in essential agreement with that in the chart now in use, developed by Dr. Horace J. Harper, Soil Scientist, Oklahoma Agricultural Experiment Station. The main points of disagreement are in acidity groups where number of samples are limited and in the slightly acid group. Therefore, the continued use of the present table is recommended, with one exception, until knowledge of source of limestone, method of application and tillage, and previous history of use of the land is known at the time of making recommendations. The exception is that lime requirement of slightly acid clays and clay loams should be reduced to 1 ton per acre or less.

A discussion of the curves on lime requirement compared with pH may help clarify the wide variation from the average by some samples. As previously noted, these soils were placed in textural groups on the basis of field men's determination of texture. A change in textural class would, in many cases, have placed a soil in a group in which it fitted much closer to the average.

It is generally agreed that the seat of base exchange, and therefore active acidity, is on the soil colloids. These colloids are closely associated with the clay fraction. A soil in which there is a large amount of clay may have the same pH value as a soil with a small clay content. The soil high in clay will require a much larger amount of calcium to satisfy the exchange complex. There is a considerable variation in clay content possible within the same textural group.

Soils such as those found in the reddish prairie generally have considerable active acidity, but a high degree of base saturation. Lime in smaller amounts than indicated by the average figure will usually correct acidity.

SUMMARY

1. Effect of agricultural limestone on the soil and the other nutrients therein has been pointed out by a number of investigators. They have also brought out the dangers that may result from excessive overliming.
2. To secure results from agricultural limestone applications, it is not necessary to correct the reaction, base saturation, or level of available calcium of the entire root zone. The establishment of small areas of the correct reaction base saturation and calcium level within the upper 2 or 3 inches will adequately feed the plants grown thereon.
3. Because of the low level of mineral fertility of Oklahoma soils, excessive overliming may become a considerable problem. Therefore, when lime is applied the available phosphorus and potash level should always be determined and additions made when necessary.
4. When rock phosphate is used it is better to underlime than overlime.
5. It is not necessary to determine the percent base saturation of normal soils in Oklahoma to arrive at a proper liming rate.

6. It is generally not necessary to determine the level of the available calcium supply of normal soils in Oklahoma to arrive at the necessary liming rate.
7. The application of agricultural limestone to the soil to correct active acidity to optimum pH will make the percent of base saturation and available calcium level adequate for all general farm crops in Oklahoma.
8. The existence of numerous variables in connection with the application of agricultural limestone, over which the person making liming recommendations has not control, makes it impossible at present to apply calcium at an exact rate. Therefore approximate rates are practical and adequate in a majority of cases.
9. It is recommended that the present limestone requirement table developed by Dr. Horace J. Harper be continued in use except reduce the minimum application rate on clays and clay loams to 1 ton per acre
10. The pH of a soil without information has little bearing on lime requirement.
11. A maximum amount of information as to kind of soil, texture, and past history is needed to reduce the spread of variation and to point out those few soils that vary widely from the average.
12. Samples must be as carefully taken as possible to represent the area to be treated and reduce the spread of the variations as much as possible.
13. Agricultural limestone is relatively slow to neutralize soil acidity and is difficult to mix uniformly with the soil. The application of a sufficient amount of limestone to furnish small neutral zones that will adequately supply the crop needs for calcium possibly would not affect the test of subsequent samples from this area taken within 3 to 5 years. Resampling and testing the soil on areas previously limed will not reflect the true lime requirement unless the lime has been uniformly spread and mixed into the sampled zone for 3 to 5 years.
14. Where the factors affecting application of limestone can be controlled, more accurate determinations of liming rates are desirable than are given in the figures (Fig. 1 to 4) of texture and pH. The calcium hydroxide titration method will give accurately the amount of calcium carbonate needed to bring the soil to any desired pH.

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Physical Land Conditions in the Cross Timbers of Oklahoma

By EDWARD J. ANDERSON
Survey Supervisor, Soil Conservation Service
Anadarko, Oklahoma

The Cross Timber or "blackjack" areas of Oklahoma make up some five and one-half million acres of land in the state. (See map, Fig. 1). There is no other section in Oklahoma that has experienced such rapid decline in crop production in so short a time. Much of the Cross Timbers was opened to settlement around 1900; large acreages soon were cleared and cultivation was begun. Some 32,000 farm families live on this land; their work and their farms furnish many more thousands of people with products necessary for healthful living. This has been the center of the cotton, cane, peanut and watermelon production in Oklahoma. And yet these crops that have made the area prosperous now are making it poor.

One of the great inland cotton centers of the United States was located in the Southern part of this area; long since it has relinquished the title. Where bumper cotton crops grew, tickle and poverty grasses now prevail on at least 90 percent of the upland cultivated fields. This area has been called the watermelon country in Oklahoma, but as much as half of the cultivated land is so badly eroded or so low in fertility that it has been abandoned in the past seven years. There is no area in Oklahoma of such importance that is being destroyed as rapidly as the blackjack lands.

The Soil Conservation Service has long recognized the importance of basic physical land information in developing sound conservation practices on farmlands. This physical inventory, or farm planning soil conservation survey, shows in detail the kind of soil, erosion condition, slope of the land, and present land use. These factors are closely related. The first three determine, to a large extent, the use to which the land is best suited and the conservation and soil management practices necessary to maintain it permanently in that land use.

Soil conservation surveys, in progress for the past ten years, cover over half the total area and provide good samples of physical land conditions in practically every soil conservation district in the Cross Timber. We have measured and tabulated survey data until we now have definite information about the physical land condition in this area.

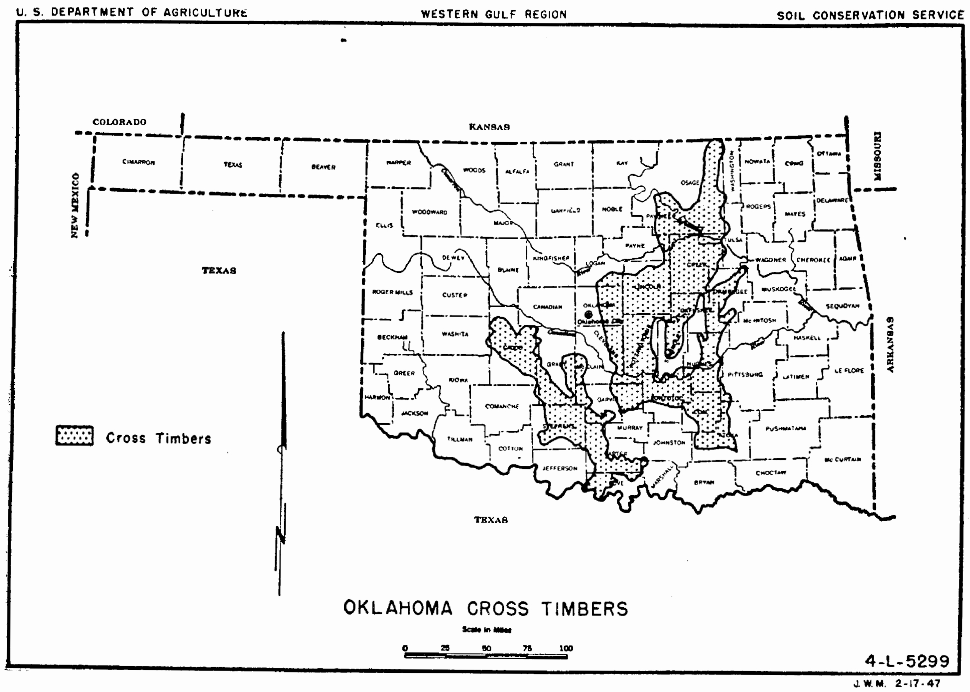

Figure 1.

In the Oklahoma Cross Timbers, 34 percent of the land is used for crops, 15 percent is in pasture, and 51 percent is in woodland. Of all land that has been used for the production of cultivated crops, 82 percent has been affected by moderate or more serious degrees of erosion. Erosion has already destroyed for further cropping 27 percent of this area.

Physical land information will serve as a basis for treating each acre according to its needs, using it for the purpose to which it is best suited, and planning a better, more effective conservation program. As mentioned before in this paper, there appears to be a definite relationship between soils, erosion, slope, and land use.

Soil Grouping Used.—For convenience in analyzing our survey, we have put the soils in seven groups:

Soil Group 1 includes bottomland soils. These differ greatly in profile characteristics, but their treatment and erosion characteristics are similar. They are subject to various frequencies of overflow and deposition and various drainage conditions. They make up 459,000 acres, or 8.1 percent of the Cross Timbers.

Soil Group 2 includes fine sandy loam and very fine sandy loam soils having a favorable root zone more than 20 inches in depth. These soils have sandy clay loam to sandy clay subsoils. Small amounts of soils having heavy clay subsoils are included in this group. These soils are considered deep soils. In general, they are the most productive upland soils in the Cross Timbers. They occupy 2,326,000 acres, 41.8 percent of the area.

Soil Group 3 includes fine sandy loam and very fine sandy loam soils from 10 to 20 inches in depth over sandstone or shale bedrock. Subsoils are sandyclay loam or sandy clay. These are referred to as shallow soils. They are low to moderate in productivity. They occupy 961,000 acres, 15.3 percent of the area.

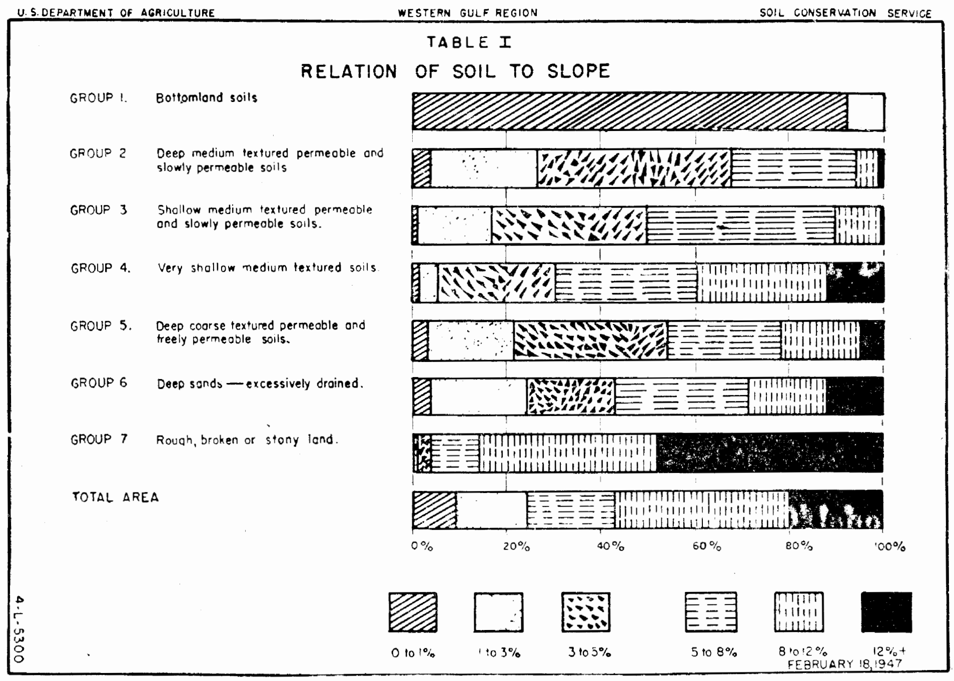

Table I.

Soil Group 4 includes very shallow coarse and medium-textured soils less than 10 inches in depth. These soils can be used only for producing range and pasture forage. They make up 5.5 percent of the area, or 306,000 acres.

Soil Group 5 includes loamy fine sand and loamy sand soils more than 20 inches in depth. These soils have subsoils of loamy sand or fine sandy loam. This group of soils is moderately productive if fertility is maintained. They occupy 486,000 acres, 8.8 percent of the area.

Soil Group 6 includes deep, extremely sandy soils having subsoils of incoherent sands. The soils are extremely low in fertility and have excessive internal drainage. They produce fair yields only under high rainfall and fertilization. Their total extent is 74,600 acres, 0.4 percent of the area.

Soil Group 7 includes rough broken and stony land suitable only for grazing. It occupies 1,038,000 acres and makes up 20.1 percent of the Cross Timbers.

Relation of Soil to Slope.—Those familiar with the "blackjack" lands of Oklahoma know that the soils of these areas occur on a wide variety of slopes. It is not surprising to find that 47 percent of the area occupies slopes of over 5 percent. It is of interest here to study the data in Table I to determine the relation of soil to slope. As we should expect, 99 percent of Soil Group 1 occupies slopes of less than 3 percent. In the medium-textured soils (Groups 2, 3, and 4), there is a definite relation between the depth of soil and the steepness of slope. Sixty-seven percent of the deep soils (Soil Group 2) occurs on slopes of less than 5 percent. Forty-nine percent of the shallow soils (Group 3) and 30 percent of the very shallow soils occupy these slopes. There is no definite correlation in the coarse-textured soils on slopes under 5 percent on Soil Groups 5 and 6. However, 10 percent more of the extremely sandy soils, Soil Group 6, occur on slopes over 5 percent.

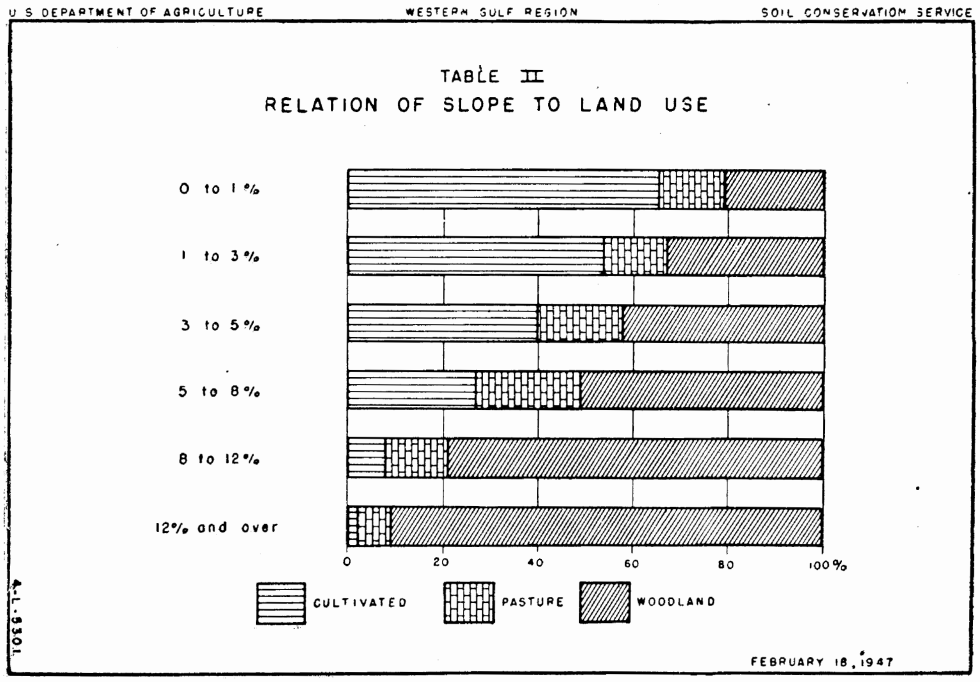

Table II.

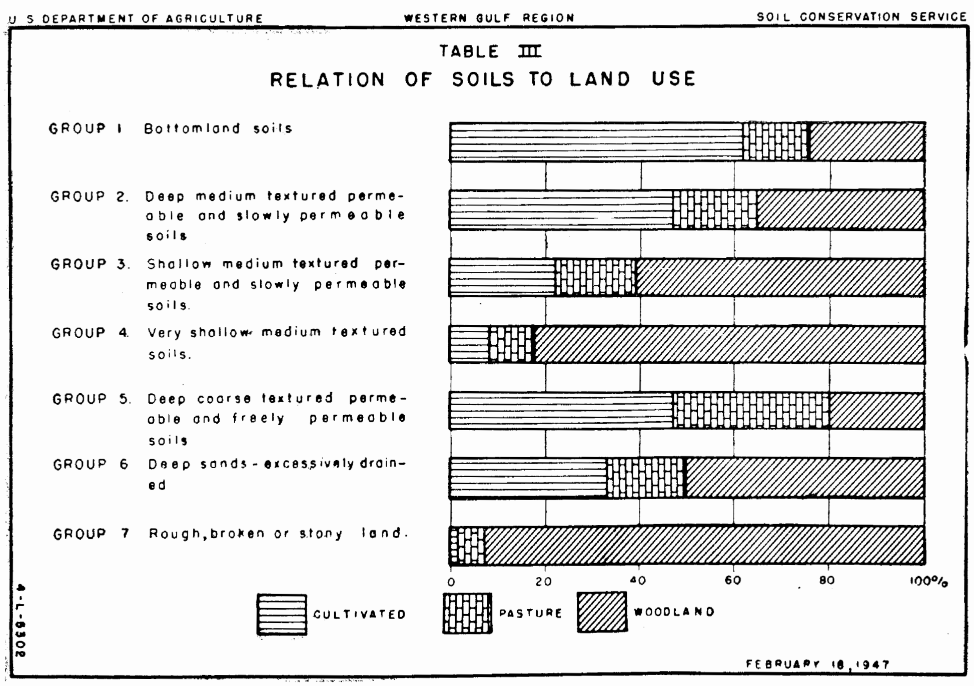

Table III.

Relation of Slope to Land Use.—The use to which land is put is influenced by the slope of the land. As expected, the largest percentage of cultivated land is found on the more level areas. This is because they are easy to clear and cultivate and probably because the farmers understand that erosion hazards increase with steepness of slope. Table II shows that farmers chose level or gently sloping land for production of most of their cultivated crops. Approximately 65 percent of the land on slopes of less than 1 percent is cropped. About 54 percent is cultivated on slopes of 1 to 3 percent, 40 percent on 3 to 5 percent slopes, 27 percent on 5 to 8 percent slopes, 8 percent on 8 to 12 percent slopes, and 2 percent on slopes of over 12 percent. Conversely, on the steeper slopes there is more woodland. The same cannot be said of pasture land because considerable areas of it were once cultivated.

Relation of Soils to Land Use.—Do farmers recognize good land for crops when they see it? By referring to Table III the answer is an emphatic "yes." However, some farmers did not have any good land; through necessity these farmers picked the best they had for cultivated crops. The "pickings" got pretty slim at times.

Perhaps the greatest misuse of land has occurred in Soil Group 6, the excessively drained sands. Some 33 percent of this group, amounting to 24,000 acres, is used for crops. These soils are not suitable for cultivation, although on the eastern edge of the Cross Timbers where rainfall is high they will produce fair yields if commercial fertilizer is applied frequently.

Relation of Soil to Erosion by Land Use.—To analyze adequately the relation of soil to erosion, it is first necessary to consider land use. That is because similar soils erode at different rates under various land uses. Table IV shows erosion conditions in soil groups by land use. Cultivated soils erode faster than land in pasture or woodland; the degree of erosion is an index of erodibility if the history of cultivation is fairly uniform. A study of these soils tells us the following: Fine sandy loam and very fine

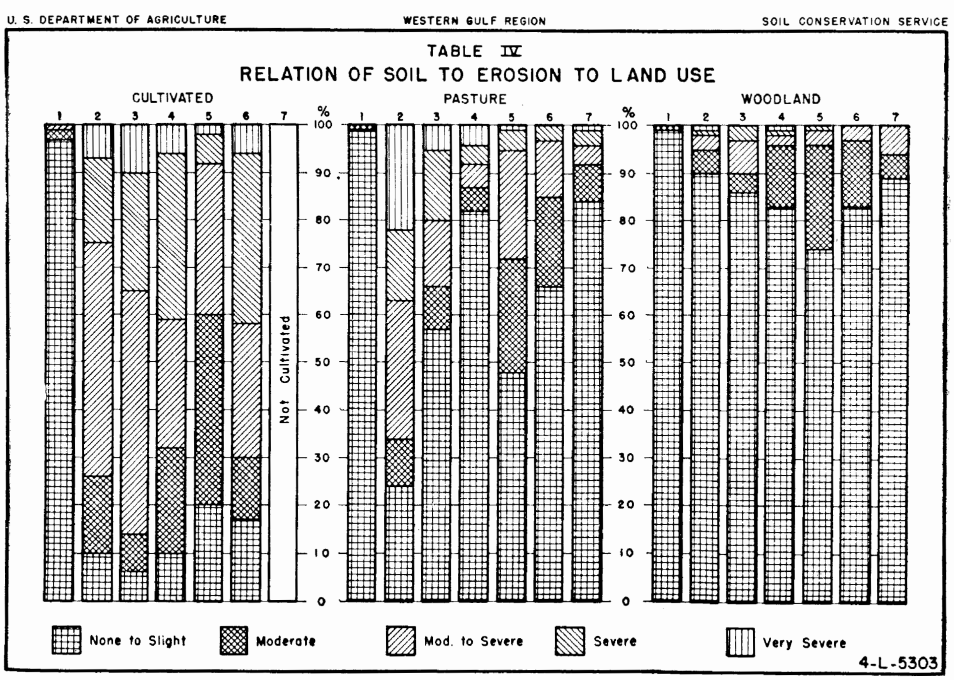

Table IV.

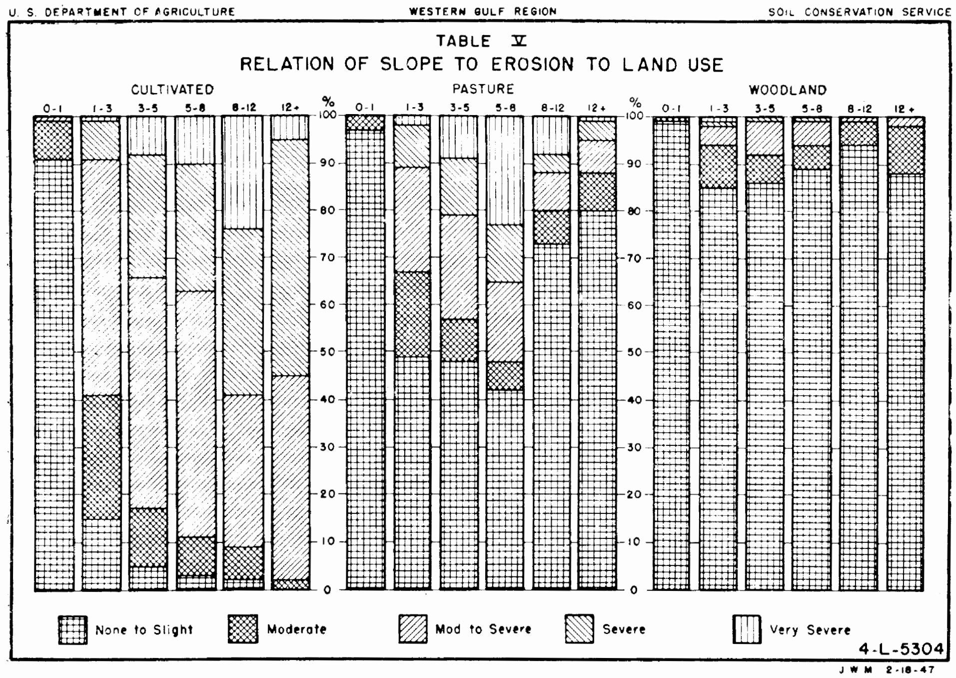

Table V.

sandy loam soils with sandy clay loam subsoils erode at faster rates than loamy fine sand soils with moderately permeable or freely permeable subsoils, if the total depth of soil is about the same. Significant is the relation of soil depth to erosion rate. In the deep medium-textured soils (Group 2) 21 percent of the cultivated land is affected by severe or very severe erosion. Shallow soils with the same surface textures (Group 3) have 35 percent of the area affected by severe or very severe erosion, while on the very shallow soils (Group 4), 41 percent is severely or very severely eroded.

On pasture land the reverse is true. On the medium-textured upland soils, 36 percent of the deep soils (Group 2) are severely or very severely eroded; 20 percent of the shallow soils (Group 3) and only 8 percent of the very shallow soils are affected by this degree of erosion. This is because considerable acreages of the pasture land were once cultivated and the deeper and more productive soils were more intensively cultivated. The same relation exists in the coarse-textured soils of Groups 5 and 6.

There appears to be only slight relation between soils and erosion on woodland areas. Here there has been more erosion on the very shallow and shallow soils than on the deep soils in the medium-textured groups.

Relation of Slope to Erosion by Land Use.—Soil erosion is influenced very much by the slope of the land and the use to which it is put. This relation is shown in Table V. As we have seen, cultivated land erodes faster than pasture or woodland on similar slopes. Pasture land has large areas with serious erosion, but this is primamily because many formerly cultivated fields are now used for pasture. On pasture land there is less land severely eroded on slopes steeper than 8 percent than on lesser slopes. Very little land on the steeper slopes has ever been used for cultivation. Erosion on woodland areas is small in extent and cannot be correlated with slope. This leads us to believe that the erosion here is caused primarily by burning and overgrazing.

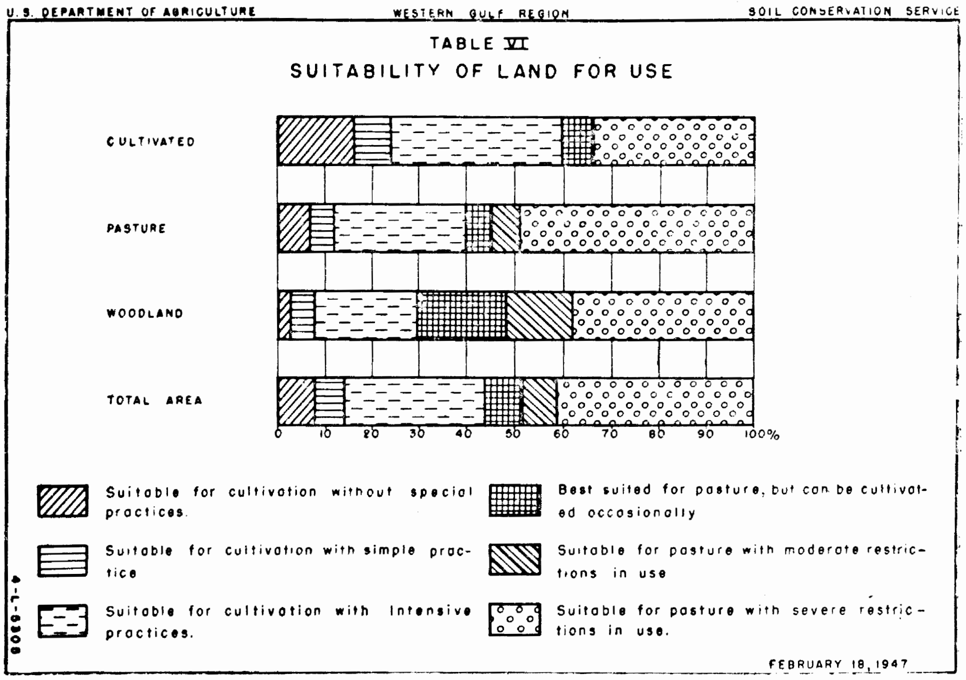

Table VI.

It is very significant that on cultivated land with 0 to 1 percent slope, only 1 percent is affected by more than moderate erosion, while on slopes of 1 to 3 percent, 58 percent has more than moderate erosion. As the slope increases from 3 to 5 percent, 83 percent of the land has more than moderate erosion. This indicates that only very slight slopes are safe for cultivated crops under present farming methods.

Physical Factors That Determine Use.—Since soil, slope, and erosion are related, they determine largely the use to which land is best suited and determine the practices necessary to control erosion. In Table VI information is grouped to show the suitability of the Cross Timbers soils for various uses and the intensity of practices necessary to maintain them in those uses. For the total Cross Timber area, 8 percent is suitable for cultivation with simple conservation practices, 29 percent is suitable for cultivation with intensive conservation practices, and 7 percent could be cropped occasionally but is best suited for pasture; another 7 percent is suitable for pasture with moderate restrictions in use, and 41 percent is suitable for pasture with severe restrictions in use.

The Advantages and Disadvantages of Vegetative Mulches in Small Grain and Row Crop Farming

By WILLIAM L. GARMAN
Assistant Soils Scientist
Oklahoma Agricultural Experiment Station

The purpose of this report is to review some of the advantages and disadvantages that have been studied in the various investigations of subsurface tillage now under way.

With the change of harvesting methods from the header and binder to the combine, the utilization of the crop residue presents a greater problem than it formerly did in soil management in the Western Great Plains area. Mathews (8) of the Division of Dry Land Agriculture has pointed out that experiments begun in 1906 first demonstrated that crop residues on the surface might serve a useful purpose. In these experiments it was found that stubble standing on the land throughout the winter held and retained snow, thereby increasing the moisture and the yield over land which had been plowed soon after harvest, even though it was previously believed that early plowing would conserve more moisture.

Since this early observation on the usefulness of a surface cover, a large amount of investigation has been undertaken. The results of these undertakings have not yet been generally agreed upon; consequently we might say that the status of surface tillage is still in the experimental stage. The special problems which require more study are: (1) The amount and placement of crop residues to be left on the surface; (2) an overall plan of tillage method including the manufacture of efficient machinery adaptable for a wide range of moisture conditions; (3) the effect of nutrient availability of changes in the carbon-nitrogen ratio in the surface soil; and (4) the physical effect on soil structural relationships.

ADVANTAGES OF A VEGETATIVE MULCH

Advantages favoring subsurface tillage methods which result in a considerable accumulation of crop residues on the surface of the soil include: (1) Reduction in the amount and velocity of run-off water, which reduces rilling, gullying, and sheet erosion; (2) an increase in absorption of high intensity rains; (3) protection of the surface soil aggregates from the dispersive action of falling raindrops; (4) conservation of moisture by reduction in evaporation and surface temperature; (5) increase, or at least a stabilizatoin, of surface aggregates through increased biological activity; and (6) reduction of wind erosion.

The Soil Conservation Service has expended a large amount of effort in studying the effect of surface cover on water run-off and soil loss. Duley and Russel (3) at the Nebraska Experiment Station measured the amount of run-off and soil erosion from a three-year rotation of corn, oats, and wheat where the annual precipitation was 27.99 inches. The loss shown by their experiments (Table I) may be considered serious, since at this rate the surface 7 inches would be lost in 130 years under plowing as compared to the same loss in 500 years under subsurface tillage. They pointed out that the erosion was much less on wheat land than it was on oat or corn land where the residues remained for a shorter period of time.

The limiting factor in crop production in a very large part of the Western Great Plains area is an adequate supply of moisture. Therefore any tillage system which would increase the percolation and retention of mois-

TABLE I.

		No residues, plowed	Residues; sub-tilled
Run-off (inches)		2.21 (7.9%)	0.94 (3.36%)
Erosion (tons/acre)		7.83	2.02
Relative amounts:	Runoff	2.4	1
	Erosion	3.9	1

ture would certainly have merit. Many of the better wheatland soils have tremendous capacities for storing water if surface soil conditions are favorable for maximum moisture absorption.

To study the rate of moisture intake, Duley and Kelly (2) selected two widely different soils, (1) a Marshall silt loam (heavy subsoil), and (2) a Lancaster sandy loam. With water applied artifically by sprinkling, they compared the freshly tilled bare soils with soils covered with wheat straw at the rate of 2.5 tons per acre. Some of the results of their experiments are tabulated in Table II. There was no run-off for the first 10 minutes of test (1). Test (2) was performed following day after test (1). At the end of the last test on the bare soil, the rate at which water was entering the soil was 0.30 inch per hour. After this same plot was dried for two days, cultivated, and covered with straw, the rate of intake did not fall below 1.2 inches per hour during the 14 hours of application. This data clearly illustrates the value of surface protection by a mulch of straw.

In a four-year study by the same investigators (2) on summer fallowed land, the amount of water stored in the top 6 feet of a soil and the run-off was as given in Table III. These data show the value of crop residues on the surface of soil in not only decreasing run-off and increasing moisture penetration but also in increasing the amount of stored water available for crop use.

TABLE II.

	Test No.	Application rate (inches per hour)	Runoff (inches per hour)	Infiltration rate (inches per hour)
I. Marshall silt				
A. (Bare soil; cult. 6″ deep)	(1)	1.59	1.1	0.5 (at end 3 hrs.)
	(2)	1.59	1.29	0.3 (end 5.75 hrs.)
B. Straw-covered plots*	(3)	1.68	0	1.68 (for 6 hrs.)
	(4)	1.68	0	1.68 (for 5 hrs.)
	(5)	3.29	1.39	1.90 (for 1 hr.)
	(6)	3.46	2.26	1.20 (for 2 hrs.)
II. Lancaster sandy loam				
A. (Bare soil)	(1)**	1.82	0.62†	(end of 2.5 hr.)
	(2)	1.82	0.32	(end of 1 hr.)
B. (Straw covered)	(3)	3.67	3.08††	(end of 5.25 hr.)
	(4)	3.67	1.20	(end of 2 hrs.)

* Tests were on the same soil at various time intervals.

** Tests (1) and (2) on same plot. Test (2) following day after test (1).

† Water was applied for 17 minutes before run-off began.

†† Only .78 in. of run-off during the first 5.25 hours of the test.

TABLE III.

Treatment	Moisture* stored in inches	Run-off** inches
No residues, disked	1.03	1.97
2 tons straw, disked	1.96	1.39
2 tons straw, subtilled	3.78	.60

* 4 years. ** 3 years.

Data showing increased infiltration rates, especially during high intensity rains, bring about the question as to why surface residues should promote or increase moisture absorption. In 1874, Wollny, a German soil physicist, observed the dispersive effect of falling raindrops after a hard rain. Today it is generally agreed that the protection afforded by surface mulches decreases the disperison of relatively stable soil aggregates. Photographs (4) have shown that a dispersed layer of soil as little as 1/16 inch thick at the surface which has been caused by high intensity rains will impede the infiltration of water. Since soils with high percolation rates contain a high percentage of large non-capillary pores it is reasonable to believe that once these are filled or clogged, water intake will drop off quickly.

Before the impact of a falling drop of water can be evaluated it is necessary to know its velocity of fall. Experimental study (11) on the rate of fall of water drops of different sizes from varying heights showed that their acceleration varied approximately inversily as the square root of the time. Acceleration was most rapid during the first second but decreased steadily and became almost negligible a few seconds after starting. The data showed that constant velocity had been reached after 7 to 10 feet of fall. Impact then would be determined by the number and size of the drops plus any increase in velocity due to the driving force of the wind. Therefore any substance which would intercept, disperse, and deflect the drops of water would decrease their velocity, thereby reduce the impact on the soil body.

Nichols and Gray (13) have shown that 2 inches of rain falling on an acre exerts 6,000,000 foot-pounds of kinetic energy. This is enough to lift a 7-inch layer of soil over an area of 1 acre to a height of 3 feet. A surface mulch would intercept much of this energy. Then the question arises: Once moisture has entered the soil, can it be retained there for crop use? The two forces operating in this connection are reduced evaporation and lower surface soil temperatures. Moisture studies on both bare soils and soils covered with crop residues have shown higher amounts of stored moisture under the residues—particularly in the surface layer. The amount of evidence along this line is not conclusive enough, however, to show a large advantage.

The effect of a surface mulch of straw or stalks on the mechanism of soil aggregation is not completely understood. Investigation has shown that aggregation is greatest in soils containing from 3 to 10 percent organic mattter. Having this amount of organic matter in the soil, however, will not insure a good granular structure. The organic matter must be of the right type and accompanied by biological activity. Probably one of the wisest reasons for not burning residues is the stabilizing effect rendered to soil aggregates, especially on medium to fine textured soils. Waksman (18) has reported that the binding effect from crop residues is most pronounced during stages of active decomposition which occur soon after an addition of fresh organic matter to the soil. The binding effect evidently is produced by the cell material of the living organisms or by the slimy substances produced by them which act as biochemical cements.

Perhaps the safest conclusion is that, given certain proportions of sand, silt, and clay, and some decomposing organic matter, together with a suitable biologic population, as well as a favorable temperature and moisture relationship, an improved state of aggregation will ordinarily result.

Probably one of the greatest merits of a vegetative mulch, especially in the more arid regions and on soils containing less than 8 to 10 percent of clay in the plow layer, is the protection it affords from wind erosion. During the late winter or early spring the soil frequently mellows to such an extent that it will move unless protected by a growing crop, a crop residue, or an emergency cultivation. Few actual measurements of wind erosion have been made comparing bare plowed ground with stubble mulch land prepared by subtillage. However, numerous field observations indicate a distinct advantage for the latter. It has been noted that the first soil which begins to move by heavy winds is on areas which have been plowed, pulverized, and smoothed for seedbed preparation.

A large amount of further investigation is needed to detemine the amount of surface residue required to protect the land not only from blowing but also from water erosion. The research on this matter to date is very incomplete.

DISADVANTAGES OF A VEGETATIVE MULCH

So far a great deal has been said for the vegetative mulch—but, like any new idea, there are a large number of unfavorable aspects to be explained, or overcome, before it can be recommended as a general practice.

Outstanding among these are: (1) The depressing effect on nutrient availability created by a surface residue of high C:N ratio; (2) the increased difficulty in controlling weeds by subtillage methods; and (3) the poorer physical condition of the soil created by inadequate mixing.

Various investigations have shown that the carbon and nitrogen exist in the soil in a more or less constant ratio of from 8:1 to 12:1. Even though organic materials added to the soil may have C:N ratios as high as 100:1 they will in a period of time drop down to an average of 10:1. This change may occur, however, at the expense of available soil nutrients—thereby causing a reduction in vegetative growth if the soil cannot supply nitrogen for both organisms and plants.

Organic residues such as straw or stalks often have C:N ratios varying from 200:1 to 50:1, and the higher the ratio the slower will be the rate of decomposition. Waksman (17) has shown that plant materials which contain less than 1.5 to 2.0 percent nitrogen decompose slowly unless extra nitrogen is obtained from an outside source. When substances of wide C:N ratio (like straw) are added to a soil which is already low in nitrogen, a condition of nitrogen starvation will be observed as long as the excess carbon lasts. The microorganisms using the carbon as a source of energy will assimilate every trace of available nitrogen that would otherwise be utilized by crop plants, and a period of low nitrate availability may ensue for a period of six months or more depending upon climatic conditions mainly moisture availability. It has been estimated that as much as 1.5 to 2.0 pounds of soil nitrogen may be used in decomposing each 100 pounds of a substance like wheat straw which contains only 0.2 to 0.5 percent nitrogen.

Waksman (13) has shown that sooner or later the nitrogen fixed by microörganisms will become available when the dead cells begin to decompose.

TABE IV.*

Organic Matter Added	Milligrams of nitrate nitrogen per 100 grams of dry soil						
	At start	After, Weeks:					
		12	20	24	28	32	40
None	0.59	0.74	0.55	1.25	1.50	3.51	2.65
Straw (0.6 percent N)	0.50	0	0	1.81	2.20	3.18	3.70
Clover (0.44 percent N)	0.59	1.22	2.01	2.40	2.00	3.62	3.82

* From Hill (5).

Table IV illustrates the rate of NO_3 availability from different types of organic material in Cecil clay. Table V shows that the greatest bacterial growth occurred the first month after the crop residues were applied, and that after 4 to 6 months time an equilibrum was established between soil, organic material, and biologic life. These results indicate that whenever a readily available source of nitrogen is required immediately, a substance containing more than 2 percent of nitrogen must be added to the soil. It should also be pointed out that should a limited amount of rainfall occur during the summer months, fall sown crops may suffer from NO_3 deficiency when large quantities of undecomposed crop residues are present in the soil. On the other hand, the decomposition of the mulch on the surface of the soil may be held in check so that the nitrates wlil not be leached out before the following crop reaches its active growing period.

McCalla and Russel (10) at the Nebraska Experiment Station found that the outstanding influence of surface residues was not so much an effect on production as on translocation of nitrates downward with percolating water. They found that only during very dry periods were the nitrates in the upper six inches of soil as high under residues as under plowed areas. In most instances the influences of residues extended beyond the third foot, and in some cases they extended beyond the sixth foot. These investigations show that the advantages of greater moisture intake and reduced evaporation through residue protection cannot be had without an increased movement of nitrates downward into the soil.

The data of McCalla (10) and Mathews (8) indicate substantially the same level of nitrate production under subsurface tillage practice with residues left on the surface as that obtained under the more common methods of tillage and residue disposal. The one exception to this statement was at Pendleton, Oregon, where straw on top or mixed with the surface soil reduced wheat yields materially below those obtained on plowed land. This was due to a nitrate deficiency, as nitrogen was the limiting factor in crop production.

One of the outstanding problems in sub-tillage farming has been the control of weeds and grass. More weeds usually emerge on land cultivated with implements that leave the crop residues on the surface than on plowed

TABLE V.*

Organic Matter Added	Millions of bacteria per gram of soil after, weeks				
	4	12	16	20	30
None	6.619	2.433	1.707	1.001	2.056
Straw	5.665	4.716	3.707	1.721	2.005
Clover	22.522	3.416	2.036	1.921	2.136

* From Hill (5).

TABLE VI.—Wheat Yields Under Three Systems of Tillage.
(Bushels per acre)

Location	Years	Sub-surface tilled; straw on surface	Plowed early; straw buried	Part of straw buried
Woodward, Okla.	1941	23.4	26.1	25.7
	1942	16.7	18.3	14.9
	1943	21.5	21.2	20.5
Lawton, Okla.	1924-43	11.7	14.7	14.6
Colby, Kans.	1932-43	8.6	8.5	8.5
	1932-43	13.6	13.7	14.1
Hays, Kans.	1930-42	14.6	12.3	13.3
	1941-43	13.2	12.4	11.5
	1943	10.3	10.6	11.8
Akron, Colo.	1928-41	12.0	11.8	11.8
	1941-42	34.6	35.3*	32.4
Mandan, N. Dak.	1933-43	20.3	19.9	18.3**
Dickinson, N. Dak	1928-40	18.3	18.2	----
	1924-42	18.3	16.2	----
Archer, Wyo.	1938-42	15.8	15.5	14.5
Sheridan, Wyo.	1925-42	20.1	20.5	----
Harve, Mont.	1926-43	13.1	15.4	----
Judith Basin, Mont.	1932-43	13.4	12.3	12.0
Pendleton, Oregon	1931-40	----	41.8	36.8

* Spring plowed.
** 1930-43 burned.

or listed land. Weeds not only offer competition to the oncoming crop but they use up valuable stored water. If the weather is dry several days after sub-surface tillage operations, weeds are usually killed. When rains follow cultivation a high percentage of the weeds are likely to continue to grow.

Additional research is needed in providing adequate tillage machinery for a mulch system of farming. Residues left on the surface may blow or be washed away, and may require some sort of packing or tillage operation which will cover or incorporate them into the soil deep enough for safe anchorage.

The physical structure of the soil is influenced considerably by the condition of the soil when it is tilled and by the tillage implement used. Since many different types of tillage implements have been used in the investigations to date, the relative effect on soil structure has not been evaluated. There is some opinion, however, that sub-tillage does not stir and mix a fine textured soil adequately enough to promote optimum tilth. It is possible that an organic residue accumulation at the soil surface has a tendency to defocculate some of the less stable granules.

Comparisons of different tillage methods have been made at various state experiment stations in cooperation with the Soil Conservation Service. Mathews has compiled a large amount of the data available in a recent mimeographed report (8, 9). Some of the comparisons at the differnt stations in the country are shown in Table VI. Mathews states that in the Great Plains differences in yield resulting from the presence or absence of crop residues on the surface have generally been small, and that factors other than yield can safely be used to determine the extent to which the practice should be used.

The evidence to date indicates that sub-surface tillage methods have a definite advantage on the sandier soils of the Great Plains Region.

The greatest advantages to be had from vegetative mulches are through their use in the prevention of wind erosion and increased moisture penetration. But until more satisfactory machinery is developed or methods of handling various residues are perfected, general recommendations to farmers should not be made.

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A Basis for the Scientific Management of Farm Woodlands

By HOMER C. MITCHELL
Regional Forestry Chief
Soil Conservation Service
Fort Worth, Texas

Most agricultural workers who contact farmers would like to be able to give a sound answer to any practical question a farmer might ask. It need not necessarily be the best answer, but a sound one that would be helpful and satisfactory to the farmer should he accept it and act upon it.

The purpose of presenting "A Basis for the Scientific Management of Farm Woodlands" is to demonstrate and explain a simple fact of forest growth which is easily memorized and, once its full significance is comprehended, gives a factual base from which a surprising number of practical woodland management questions can be answered.

The fact or principle is that within the oak-hickory-yellow pine ecological type of Southeastern United States, dominant trees of the same diameter require the same minimum crown space regardless of species, age, or site. ("Site," in forestry, refers to the combination of all habitat factors affecting tree growth.)

The thesis that all trees of the same diameter within a given forest type have the same minimum space requirements is probably more readily acceptable by ecologists than by foresters. The former do not have certain misconceptions to un-learn as do the latter. It seems entirely reasonable, however, that if the size-space relationship did not hold true for all species within a type, the several species would not have been able to live together on competitive terms throughout the centuries. If any one species had less space requirement than its associates, it would drive out all others in the course of a few generations of trees.

Let us consider the proof that the uniform size-space relationship does exist for the tree species comprising the upland forest types of Eastern Oklahoma and the southeast generally.

Figure 1 shows the number of dominant trees per acre by average diameter at breast height for the three upland forest types of Eastern Oklahoma. For each type, the data are shown for best and poorest sites because, among foresters, there is much misconception that poor sites support more stems per acre than good sites and vice versa. Showing data for the extremes of site conditions emphasizes the extreme effect of site upon stocking of dominants.

The pine data are from Miscellaneous Publication No. 50, issued by the Southern Forest Experiment Station in 1929, from tables 59 and 60 for loblolly pine and tables 123 and 124 for shortleaf pine. The upland oak data are from tables 16 and 17 of Technical Bulletin No. 560, issued in 1937. While these data have been available for many years, it apparently occurred to on one to plot them in this particular fashion; so the size-space relationship for dominant trees has remained obscured. For this reason the plotted points each · represent an average of the actual figures obtained by measurement of many sample plots. The plotted data shown here give a fair picture of the observations on more than 700 sample plots. Not all of the available figures are shown, to avoid cluttering the chart; but data for intermediate sites not shown fall in the same approximate position as those shown for the best and poorest sites.

The curve as drawn is not an average of the plotted points. It is a mathematical curve based on the formula that the number of dominant trees per acre at any given diameter equals $\frac{43{,}560}{(D+4\ \text{ft.})^2}$ wherein D is an abstract number equal to the diameter of the tree at breast height in inches. By usage in the Soil Conservation Service over a period of years, the formula is referred to simply as "D plus 4." In this form it means that the minimum crown space requirement for a dominant tree of 10 inches dbh is $(10+4)^2$ or 196 square feet.

Logic presents several good reasons why the formula may not be precise, but the coincidence of curve with actual data at nearly all points should be sufficient evidence that it can be used safely as a measure of the degree of stocking in any stand composed of species native to the uplands of the southeast.

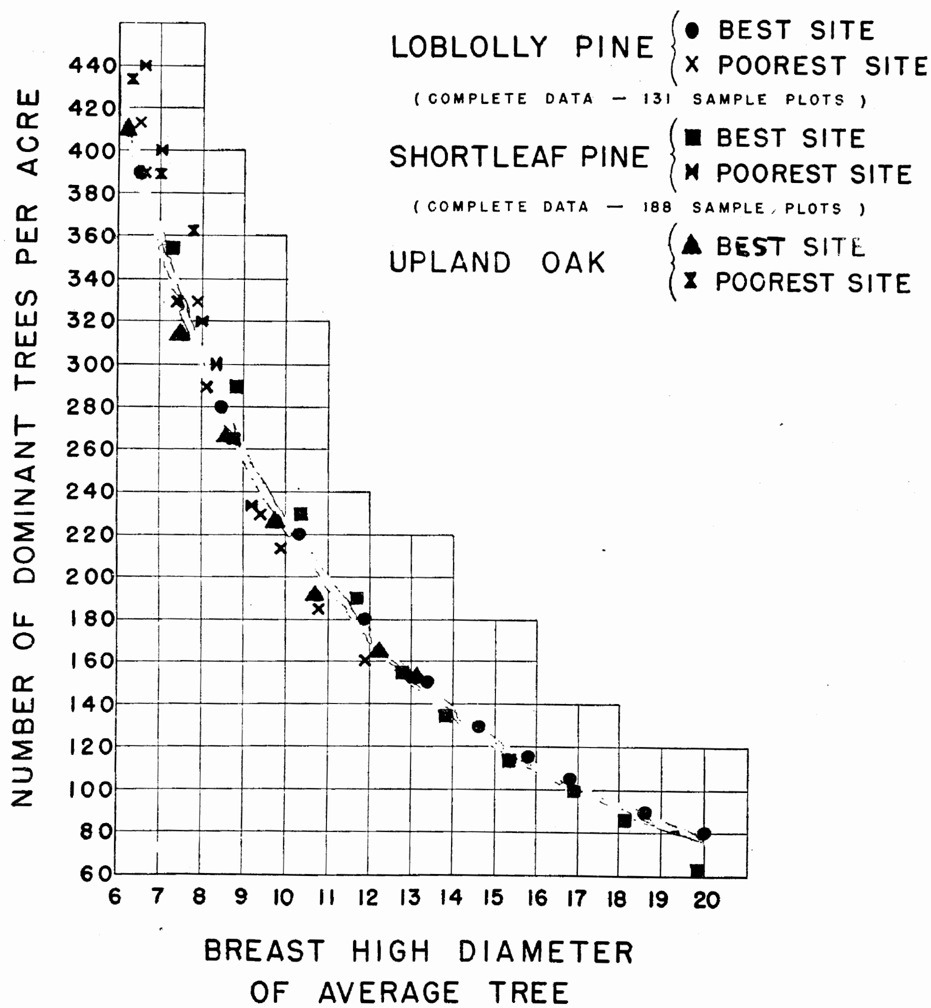

Fig. 1.—Selected Data Showing Normal Stocking of Dominant Trees for Three Southern Forest Types.

Now for some examples as to how the D+4 formula can be used to answer certain practical questions of woodland management:

1. How should a dense stand of trees be thinned? Obviously, if D+4 represents the minimum space that a tree can have and retain dominance and a thrifty rate of growth, then it should have somewhat more space than that after thinning so that it will still have space in which to grow and retain dominance for a period say of five years. Exactly how much additional space it should have depends upon the site and the planned interval between thinnings. Based on average sites and a five-year interval between thinnings, two is the figure commonly used for the sake of uniformity of recommendations to farmers. The formula then becomes D+6 for the average spacing between trees after thinning.

2. Is a stand well stocked? The answer is nearly always "'yes' and 'no'" because one seldom encounters uniform stocking over so little as an acre, much less over 40 or 160 acres. Invariably there are dense clumps and open spots representing overstocking and understocking. The D+4 formula gives a concrete basis for pointing out this condition. The traditional method of comparing average acre stocking with an ideal standard is extremely crude by comparison because, while a paper average of bad overstocking and bad understocking may approach the ideal, it does not change the fact of bad stocking throughout nor does it point the way for management to correct the situation. Application of D+4 to groups of trees as they exist in the woods tells at once whether the group needs thinning, supplemental planting, or merely additional growth on the trees present.

3. Is grazing injuring a woodland? This may seem like a forced point to be inserted here. Many discussions on the subject, however, quickly degenerate into an argument because either one party or both parties do not know how to judge whether the area in question is properly stocked with trees. It is frequently contended that there is no damage when actually the stand is severely understocked. Of course, continued understocking may be due to frequent fires as well as to grazing, but the cause is always evident.

4. How should trees be spaced when a planting is made? A good answer is: Use D+4 as a basis for judgment in conjunction with a consideration of the object of the planting and the size at which the trees will be useful for the objective in mind.

If it is a pine planting to produce commercial products, the farmer should remember that peeled fence posts for treating are about the smallest marketable product. Trees for posts should be at least 5 inches in diameter and, by D+4 rule, there is space for only about 540 such trees per acre. If the usual 20 pecent is allowed for losses, an initial spacing of about 8x8 feet, providing 680 trees per acre, is indicated. Why plant 1,210 trees at 6x6-foot spacing or 1,740 trees at 5x5-foot spacing, as has sometimes been done? Other combinations of factors that might influence initial spacing in a plantation can be figured the same way.

5. How much wood may a farmer take out at one time in a selective cutting and have a sustained-yield operation? This question baffles many foresters. As good an answer as any is provided by the D+4 formula. First it is necessary to decide what sized trees should be produced. If, for example, it is sawlog size at 18 inches in diameter, D+4 shows that there may be 90 such trees per acre. A ring count on trees of that size showing a uniformly good rate of growth will reveal their approximate age. This may be done by using an increment borer or counting rings on stumps. The number of trees per acre divided by the age gives the number of crop trees that can be cut per acre per year for a sustained yield operation producing

18-inch trees. As an aside, it might be stated that, for sawlog rotations, the answer on all sites is so close to one crop tree per acre per year that this figure can be used safely in making general recommendations to farmers.

The definite relationship which exists between diameter and space requirements for dominant forest trees is useful as a basis for solving many of the problems of woodland management. Such size-space relationship can be expressed simply by the D+4 formula. This formula is easily memorized and easily taught to non-forestry technicians and to farmers, especially by a simple demonstration in the woodland. While D+4 as a definition of full stocking of dominant trees is not all there is to forestry, by any means, it does clear up some confusing points. Extensive trial shows that it does give non-forestry technicians a great deal of necessary self-confidence in discussing woodland management problems with farmers.

The Chinese Jujube: A Promising Fruit Tree for the Southwest

By L. F. LOCKE
Horticulturist, U. S. Southern Great Plains
Field Station, Woodward, Okla.

The jujube belongs to the buckthorn family (Rhamnaceae) and is a not distant relative of New Jersey tea or redroot here in Oklahoma. It is a member of the genus Zizyphus, which derives its name originally from the Arabian word Zizouf applied to one species of the genus. The genus Zizyphus comprises about 50 species which are widely scattered throughout the temperate and tropical regions. The plants are shrubs or small trees; the branches are spiny at the nodes; the leaves are alternate, 3-nerved, in the axils of the spines; flowers are small, in axillary clusters.

Of all the species, some known for hardwood or fodder plant uses, the Chinese jujube (**Zizyphus jujuba**) is the most important horticulturally. While this fruit is relatively new in the Southwest, it is by no means a complete novelty. It had been cultivated in China centuries before the beginning of the Christian era. A Chinese work by Li Shi Chen published over three hundred years ago listed 43 varieties. Hundreds of varieties have been described in more recent works.

The Chinese jujube is now widely distributed from northern and central China through northern India, Persia, Armenia, and Syria, to the Mediterranean region, in Spain and France. It was introduced into these countries several hundred years ago, and is now found both wild and cultivated.

Although grown for hundreds of years in China, knowledge of the jujube was long meagre in western Europe. There are few references to it in early botanical or horticultural literature. Since its introduction into the Mediterranean region it has become better known, and all the more important dictionaries and works on gardening in Europe contain accounts of it.

The jujubes known and sold in the markets of Europe are from seedling trees, the fruits of which are about the size of an olive and would probably never attract much attention in the American markets. European horticulturists appear never to have investigated the possibilities of the Chinese varieties of jujube.

Frank N. Meyer's explorations have shown that there are hundreds of varieties of this valuable fruit in China, varying in size from that of a cherry to 2 inches or more in diameter.

Mr. J. H. Hammad of the Mandate Government of Palestine, who recently visited Woodward, reported that a small-fruited, very delicious variety grows in Palestine.

Numerous varieties were introduced into the United States beginning as early as 1837. The patent office distributed seeds of the jujube in 1854. The nursery catalog of P. J. Berkmans of Augusta, Georgia, for 1861, lists the jujube. As an ornamental and hedge plant, it attracted a good deal of interest during the seventies. Jujube trees, mostly seedlings, have been grown in Florida, Georgia, South Carolina, Louisiana, Mississippi, Texas, and District of Columbia, and as far north as Germantown, Pennsylvania. The jujube was introduced into California in 1876.

From 1897 to 1908 the United States Department of Agriculture through the Office of Foreign Seed and Plant Introduction received seed from explorers and others. All of these produced small fruits, none more than an inch in diameter.

With the establishment of the large-fruited varieties from the scions sent in by Meyer in 1908 and subsequent years, the interest in this fruit has been renewed. A total of 83 introductions were made by him.

The seedling types attracted little or no attention as a commercial fruit; but, with the bearing of the larger-fruited varieties, many horticulturists and others who have grown them see for the jujube a future as a commercial fruit and also as a home-owned fruit in the drier sections of the Southern and Western States.

Many varieties were introduced into the United States, but four were finally selected by the U. S. Department of Agriculture for distribution. These varieties are Lang, Li, Mu Shing Hong, and Sui Men. Nursery-grown trees of these varieties were first planted at the Southern Great Plains Field Station at Woodward, Oklahoma, in 1924. One variety, the Lang, produced one fruit that year, it produced about one quart the next season. Other varieties came into bearing more slowly, but within three or four years. Since reaching full production, all four varieties have produced maximum crops of 89 to 130 pounds per tree.

The remarkable thing about this fruit at Woodward is that there has never been a crop failure from any cause. It blooms late, starting in May or occasionally in early June. It blooms over a period of several weeks. The fruit ripens late, usually during September and October. The color is green until ripening starts, at which time reddish brown spots appear on the green fruits. These spots expand until they merge in a dark, chestnut brown color.

In addition to tests at Woodward, the jujube has been grown for periods varying from 8 to 25 years at State and Federal Experiment stations at Garden City, Kansas; Dalhart, Big Spring and Lubbock, Texas; Tucumcari, New Mexico; and Lawton, Oklahoma. There has never been a complete crop failure from any cause at any of these stations. During the drought years crops were materially reduced at some locations, but the tree responds well to favorable conditions. The Lubbock Station reports severe damage by worms, but no spraying has been done to control them. All of station superintendents agree that the Chinese jujube is reliable in production. All point out its habit of sprouting from the roots. Some have seen no particular value as a fruit for the Southern Plains area, others consider that it has value but call attention to the lack of general information in regard to it. One suggests that it will probably never become popular until someone takes enough interest to conduct an active campaign in its behalf.

The jujube grows vigorously in hot climates and reaches its best development where the weather is dry, the sunshine brilliant, the nights warm, and the summers long and hot. The southwestern section of the United States, with the exception of the elevated portions where the summer nights are too cool, and limited areas such as coastal regions where the humidity may retard fruit production, is well adapted to jujube culture. The drier sections of some of the Southern states have produced some excellent fruit. The jujube has withstood temperature of −22° F. without injury. Growth in regions where the summers are cool is very slow and the number of fruits produced is few or none, as compared with the rapid growth and abundant and regular fruiting secured where the temperature sometimes reaches 120° F.

Because of its late flowering, the jujube is free from spring frost injury. In regions where the peach, almond, and apricot bloom in February, the jujube does not begin to flower until about May 20, long after danger from frost is over. Those who have lost fruit crops from frost can appreciate the great advantage of a tree that produces a good crop year after year without being injured by late frosts.

Sufficient data are not available to determine the minimum water requirement. The trees do well in Texas without irrigation; they also do well in California both with and without irrigation. The jujube has also done well in New Mexico under irrigation and in Oklahoma without. During the first few years they require about the same quantity of water as any young deciduous orchard tree under similar conditions. After they have become established they will withstand more drought than other deciduous fruit trees under the same conditions.

The jujube is very high in food value, as shown by Table I. Sugars, which were present in fairly large quantities, particularly in the dried fruit, undoubtedly form the most valuable food constituent of the jujube. The percentages of invert sugar and sucrose varied to some extent, apparently depending upon variety and time of picking. Little change seemed to take place in the total sugar content during the period of harvesting. The percentages of protein, considered to be the second most important element, are fairly high for fruit. The protein tended to increase slightly with the advance of the season. Little variation occurred in the titratable acidity during the season. The percentage of fat seems unimportant, and pectin is present in very small quantities. The crude fiber (not shown in table) is not excessive for this type of fruit and does not seriously impair its eating quality. Small differences in ash content are noted between fruit of different varieties, and no great change in the proportion appears to take place with maturity.

TABLE I.—Edible Matter of Jujubes, Figs, and Dates.*
(Percent; moisture-free basis)

	Protein	Fat (ether extract)	Total sugars	Ash	Acid
Fresh jujubes	3.35	0.81	69.69	2.45	1.24
Fresh figs	6.41		73.80	2.75	
Dried jujubes	5.28		71.67	2.77	1.37
Dried figs	5.03	1.78	72.21	3.86	1.00
Dried dates	3.33	0.74	76.18	2.25	1.55

* Data from U. S. Department of Agriculture Bulletin No. 1215, The Chinese Jujube.

The jujube compares very favorably with the fig and the date in point of edible matter, including protein, total sugars, acid, and ash, except that the protein content of dried dates is considerable lower than that of dried jujubes. In appearance, texture, and flavor the dried or candied jujube is more like the date than any other fruit, and the greatest demand for it probably will be in these two forms.

In the jujube we have a fruit of high food value and extreme reliability in bearing, a rare combination in the southwest. It is not particularly good to eat fresh, although many acquire a taste for it. There are a number of methods of preparation and use, such as: confections, sweet pickles, graham bread, cake, cake filling, pudding, mock mince meat, butter, and marmalade combined with other fruits.

As the jujube is not well known in this area and there is no developed market, no one should be encouraged to plant heavily. However, the confection is far superior to many of the candied and honeyed fruits that sell at relatively high prices, and accordingly it should not be impossible to develop a market for this product. It seems advisable, however, that for the present, only home plantings of a few trees should be encouraged.

The jujube is little known, but is highly dependable fruit of high food value, and for that reason I thought it worth while to call it to the attention of this group.

A Preliminary Report on the Potash Needs of Oklahoma Soils

By H. F. MURPHY
Head, Department of Agronomy
Oklahoma Agricultural Experiment Station

Because of the recent interest in the use of potash fertilizers in the State, it was thought that a brief discussion of some general information and of some limited soil data might serve as a guide to further research. Furthermore, it is possible that some practical use could be made of this preliminary report.

Potassium is one of the elements absolutely required by all plants, although its exact role in plant nutrition is not exactly known. Practically all of the potassium in a plant can be leached out with water, indicating that it is not combined in complex organic forms. It is found most abundantly in the rapidly growing parts of the plant. Physiologically, it functions in the intake of other elements, in the synthesis of carbohydrates, oils, and proteins, in chlorophyll development, and in respiration processes. It influences the rate of transpiration, the development of a root system, the balancing of maturation, and the general vigor of the plant. It is associated with quality of product as well as actual growth processes. Schuster (3) has pointed out that there is evidence of potassium aiding the development of quality in potatoes, sugar crops, tobacco, soybeans, and wheat. It has been suggested that luxury consumption beyond that needed for actual yield may contribute to a better quality of the crop. With plants where there is an actual potash deficiency so far as growth is concerned, the leaves become dull in color; and when the deficiency is greater the leaves turn yellow at the tips and along the margins, with death of these tissues ensuing.

Hartwell (1) grouped some plants with respect to their response to potash fertilization as follows:

Low K-response plants—oats, rye, wheat, millet, and carrots.

Medium K-response plants—barley, rutabagas, parsnips, potatoes, and cabbage.

High K-response plants—tomatoes, mangels, buckwheat, corn, and onions.

In considering the needs of plants for this element it would be well to review the general potash content of certain plants and plant products. The grains of cereals range from approximately 0.35 percent to 0.50 percent. Oil-bearing seeds are in general considerably higher; cottonseed approximates 1.00 percent while soybeans approach 1.65 percent. Legume hays contain about 1 to 2 percent potassium, which means that a ton of legume hay removes from the soil from 20 to 40 pounds of potassium. The straw from small grains ranges from 0.50 percent to 1.00 percent, wheat and rye straws being somewhat lower in potassium than oats and barley straws. Corn and sorghum stalks average about 1.50 percent. Prairie hay contains about 16 pounds of potassium per ton.

Systems of farming involving the removal of legume hay or legume forage, crop residues (such as stalks and straw), and oil-bearing seeds from the land remove considerable potash from the soil. Some root crops are also heavy users of potash, and tobacco has an unusually high requirement.

There has been considerable comment in recent years as to the best use for a lot of the land in eastern and central Oklahoma. Much of this land, because of topography or for other reasons, has remained uncultivated. It is commonly referred to either as pasture or open range land, although there may be only sparse growth of suitable vegetation for grazing, especially in the eastern area. In other cases the land was once under cultivation, but due largely to a lack of fertility of the soil it was abandoned and put back to pasture. Great interest has been manifested in planting grasses on these areas, and especially bermuda grass as a pasture base in eastern Oklahoma to be followed by a top seeding of pasture legumes such as lespedeza, hop clover, ladino clover, black medic, and others. Many of these soils are too poor in organic matter to get a quick grass cover without some nitrogen fertilization, and to get a satisfactory growth of legumes, lime and phosphate have been used. Legumes are high users of these mineral nutrients.

It has already been pointed out that legumes also have a high potash requirement, yet up to the present time potash has been given little consideration in the development of the ideal grass-legume pasture in the area. A study of the soils on which this kind of a pasture program has been recommended will reveal whether potash fertilization is a problem there.

Mineral soils with some few exceptions are usually well supplied with total potash, therefore an analysis for total potash often does not reveal too much information of immediate value. The soil's potash comes from the silicates; and, as these are quite resistant to weathering, the matter of potash deficiency largely resolves itself into that of availability. The data which follow are therefore concerned with that fraction of the potassium which is replaceable by neutral dilute salt solutions and which is usually recorded as being readily available for plant use. Pursuing this method of procedure and correlating the laboratory results with the few field tests available, Table I (page 84) was published (2).

The data in Table II and Figure 1 were secured by tabulating the data used in preparing Table I and grouping them into three categories:

Good response, to include soils containing under 60 ppm replaceable potassium.

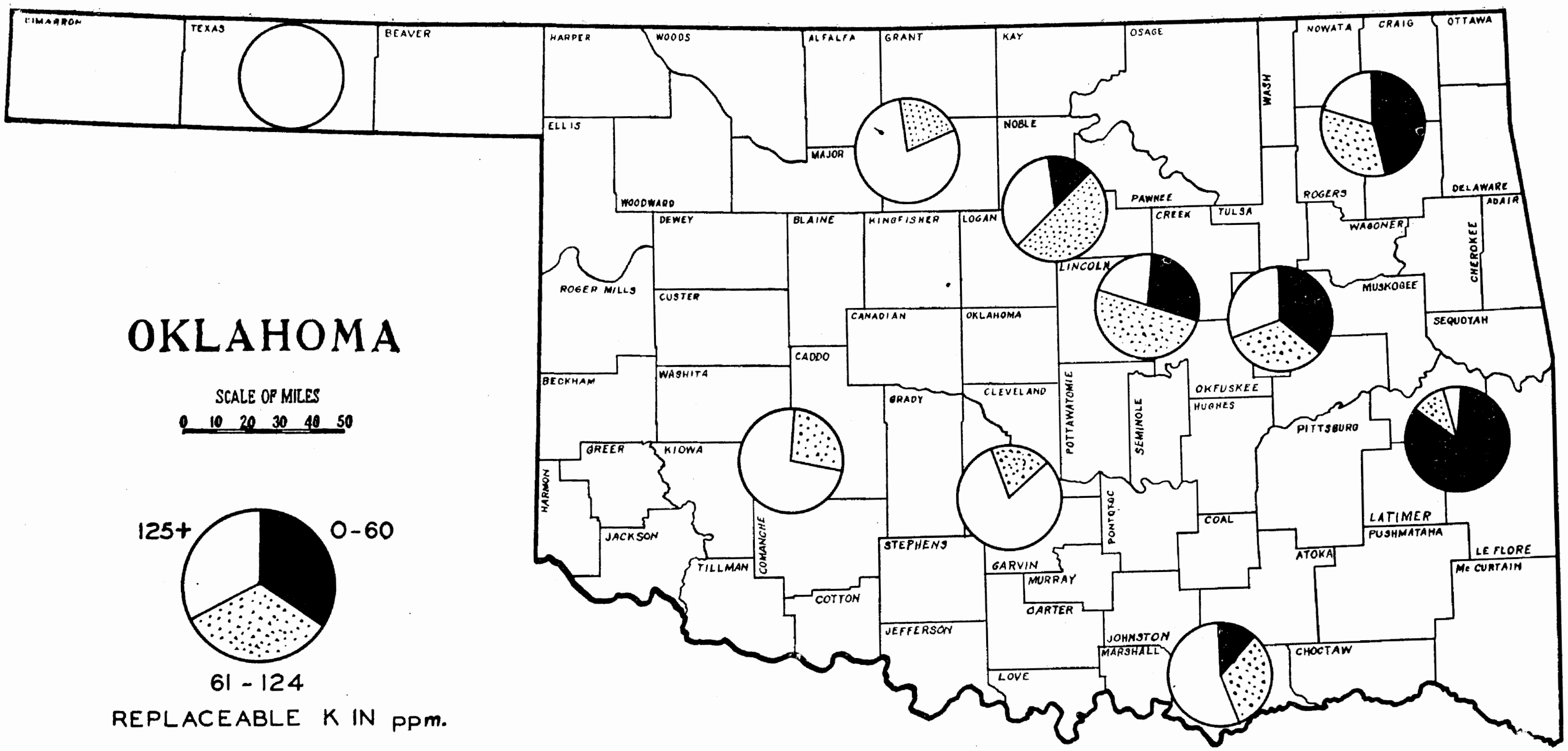

Fig. 1.—Soil Areas Having Different Levels of Replaceable Potassium (Preliminary).

Table I.—Amount of Replaceable Potassium; and Crop Response.

Replaceable K (ppm)	Crop Response
Under 60	Good response
60- 79	Response in many cases
80- 99	Doubtful
100-124	Very doubtful
125-199	No response ordinarily
Over 200	No response

Doubtful response, to include soils containing 61 to 124 ppm replaceable potassium.

No response, to include soils containing over 125 ppm replaceable potassium.

While the total number of soils examined was not large enough to present an accurate picture so far as the general acreage of the different areas are concerned, the data are sufficient to sound a potash warning to the pasture program, and to the growing of other crops on certain soils in the eastern half of the state. More research work needs to be done to determine the extent to which potash fertilization may be valuable in the cropping of the area, and especially to the grass-legume pasture program. The above data indicate that it may be a very significant factor.

Table II.—Estimated Percentages of Soils Within Given Replaceable Potassium Ranges, by Areas.

Area	Parts per million of replaceable potassium		
	0-60 ppm[1]	61-124 ppm[2]	125 ppm and over[3]
Panhandle	0.0%	0.0%	100.0%
Southwest	0.0	30.0	70.0
Garfield-Alfalfa	0.0	12.5	87.5
McClain-Garvin	0.0	12.5	87.5
Payne	10.0	53.0	37.0
Bryan	14.0	28.0	56.0
Lincoln-Creek	30.0	50.0	20.0
Okmulgee	33.3	33.3	33.3
Northeast	47.0	40.0	13.0
Haskell-LeFlore	85.0	12.5	2.5

[1] Response to potash fertilization.
[2] Doubtful.
[3] Sufficient generally.

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The Effect of Fertilizers on Grass Seed Production

By H. F. MURPHY, HI W. STATEN, and W. C. ELDER*
Oklahoma Agricultural Experiment Station

A considerable acreage of land in this State needs to have a vegetative cover established on it. This acreage includes shallow soils which have been cultivated but are not suitable for cultivation, sparsely vegetated pastures, and land undesirable for cultivation because of topography or outcrop features. Some of these soils are now classified as abandoned land due to erosion and/or general lack of fertility. In some cases erosion has so gullied the land that the use of farm machinery is impractical. Some of these soils have a very low nutrient content, either inherently or because of depletionary factors. A number of these soils are so shallow that any more erosion than what has already taken place would render them worthless.

In general it takes a long time for nature to revegetate these soils, and one of the reasons man has not been able to help nature too much is that very little grass seed has been available. Grass seed of adapted species is scarce in this area. Seed production of the native species is not dependable every year. Only within the last few years has the question of revegetation been given much concern, and while other things such as proper methods of seedbed preparation, methods of seeding, and machinery for seeding have been vitally important, the fact that the seed supply has been low has kept down the reseeded acreage. This paper reports the results of some experiments where fertilizers were used on weeping love grass (an introduced species) and on some native bluestem areas to determine how such treatments might influence seed yields.

In the early spring of 1945 just preceding the start of growth of grass, soil samples were taken to a depth of approximately six inches under several species of grasses. The nitrate content of these samples was determined and in every case it was very low. There are several reasons why such results might be expected: In the first place, grasses tend to grow until late in the fall and would therefore continue to remove nitrates from the soil. This is particularly the case with weeping love grass; and this grass also starts growth early in the spring. Second, the dormant period of these grasses coincides with unfavorable temperature conditions for nitrification; and, third, grass residues have a very high C/N ratio which would interfere with nitrate accumulation.

Reasoning from the above, it was decided to set up some field experiments to test out the application of nitrogen; and, since most of these soils were also deficient in phosphorus, certain phosphate combinations were included. Such treatments had been used previously to study hay yields; but the grasses had never been allowed to advance to the seed stage, therefore no data were available to determine how effective the treatments might be from a seed production standpoint.

EXPERIMENTS WITH NATIVE BLUESTEM

Two locations were used in 1945. They were on shallow sandy loam soils west of Stillwater. Since the bluestems start growth rather late, the fertilizers were not applied until June 18. This was done to avoid the use of the nitrogen by the early spring weeds. Broadcast applications were made. Little bluestem (**Andropogon scoparius**) was the predominating grass at each location. The influence of the fertilizers was determined by calculating the number of seed stalks per square rod for the several treatments. The results are shown in Table I.

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* Respectively: Head, Department of Agronomy; Agronomy (Grasses and Legumes); and Assistant Agronomist.

TABLE I.—Yield of Seedstalks per Square Rod.[1]

Nitrogen Treatment	Without phosphorus	With 200 lbs. superphosphate	Superphosphate treatment	Without nitrogen	With 150 lbs. ammonium nitrate
Experiment 1					
None	1491	----	None	1560	----
75 lb. Am. nitrate	1870	1802	100 lb. Super Phos.	881	2512
150 lb. Am nitrate	2284	3058	200 lb. Super Phos.	868	2990
300 lb. Am. nitrate	3007	4297	400 lb. Super Phos.	1174	2897
Experiment 2					
None	844	----			
75 lb. Am. nitrate	1274	1319			
150 lb. Am. nitrate	2507	2638			
300 lb. Am. nitrate	1663[2]	2342[2]			

[1] Fertilizer treatments are in pounds per acre.

[2] Perennial weeds were bad in these plots.

On March 9, 1946, a series of plots of little bluestem were treated with different nitrogen fertilizers applied so as to furnish 40 pounds of nitrogen per acre. To one-half of each plot enough treble superphosphate was applied to supply 40 pounds of P_2O_5 per acre. The grass had just barely started growth. The season was unfavorable and the experiment was a failure so far as practical results are concerned. It was observed, however, that there were no seed heads on the unfertilized areas, a few heads on the nitrogen plots, and slightly more on the NP plots.

The only conclusion which can be drawn from these experiments on little bluestem are: (1) Nitrogen increases seedstalk production, and when reinforced with superphosphate on these phosphorus deficient soils there is a greater increase; (2) a light application of nitrogen is not sufficient; and (3) superphosphate alone may actually decrease the seedstalk yield.

EXPERIMENTS WITH WEEPING LOVE GRASS

Because of the great demand for weeping love grass seed in Oklahoma and other Southern states, and because of the limited acreage planted for seed, fertilizer studies were inaugurated to see how they might influence seed yields. It had been observed that land which was planted to this grass would often fail to produce seed heads after a year or so, especially if the soil fertility level was low. The probable reason for this is that this grass grows until very late in the fall and starts growth here by the first part of March. This does not give time for any nitrate accumulation in the soil. The grass grows rapidly if nutrients are available and makes a seed crop in June. It had been observed that an application of nitrogen greatly stimulated hay production.

In the early spring of 1945 several locations where the grass had been planted in rows 3 to 3½ feet apart were selected for testing the influence of fertilizers on seed yields. All of the fertilizers were applied in March or early April by broadcasting except in a few instances where the applications were deferred until after the first crop was mowed in June. The results of the tests on seed yields are recorded in Tables II and III.

TABLE II.—Yield of Weeping Lovegrass Seed, 1945.
(Pounds per Acre.)

Treatment	Pounds of N applied per acre	Pounds of P_2O_5 applied per acre	Lone Grove Farm Carter Co.	Mullen Farm Lincoln Co.	Sudenheimer Farm Lincoln Co.	Carberry Farm Payne Co.[2]	Perkins No. 2 Payne Co.[5]	Heavener No. 1 LeFlore Co.[3]	Perkins No. 1 Payne Co.	Av. all locations
No fertilizer[1]	0	0	11.1	17.6	132.9	10.9	7.8	5.9	117.4	45.0
140 lbs. Ammomium Nitrate	45	0	134.4	75.1	285.4	56.7	89.9	46.7	331.5	131.4
210 lbs. Ammonium Nitrate	67.5	0	201.7	21.2	304.4	39.3	75.0	56.5	295.4	141.9
280 lbs. Ammonium Nitrate	90	0	193.8	50.6	325.6	19.6	89.9	62.0	373.6	159.3
420 lbs. Ammonium Nitrate	135	0	144.0	69.8	323.6	17.5	75.8	89.0	362.9	154.6
100 lbs. Treble Superphosphate +140 lbs. Am. Nitr.[4]	45	45	76.8	189.4	245.0	41.5	67.2	54.5	356.4	147.3
100 lbs. Treble Superphosphate +210 lbs. Ammonium Nitrate	67.5	45	220.8	166.3	299.4	91.7	92.5	78.6	352.6	186.0
100 lbs. Treble Superphosphate	0	45	9.7	24.0	172.5	6.5	15.1	16.4	70.7	45.0
100 lbs. Treble Superphosphate +280 lbs. Ammonium Nitrate	90	45	235.7	175.9	379.4	207.3	109.1	183.3	373.2	237.7
100 lbs. Treble Superphosphate +420 lbs. Ammonium Nitrate	135	45	211.3	157.8	360.0	257.5	88.0	203.4	374.8	236.1
Pounds of seed per pound of N with the 45 pound N rate			2.74	1.28	3.39	1.02	1.82	0.91	4.76	1.92

[1] Average of 5 plots.
[2] Wind damage shattered much seed.
[3] Ammonium sulfate and superphosphate were used as the sources of nitrogen and phosphorus.
[4] Ammonium nitrate.
[5] Fertilizers were applied June 20 after a crop of hay was harvested.

TABLE III.—Yield of Weeping Lovegrass Seed, 1945.

Treatment[1]	Stillwater[4] (lbs. per acre)	Heavener No. 2[2] (lbs. per acre)	Heavener No. 3[3] (Seed heads per acre)
No fertilizer	00.0	4.9	880
20 lbs. nitrogen	14.8	----	2400
40 lbs. nitrogen	32.2	23.3	30160
60 lbs. nitrogen	34.4	----	56720
80 lbs. nitrogen	39.4	70.6	----
20 lbs. P_2O_5	00.0	----	----
40 lbs. P_2O_5	00.0	00.0	1120
60 lbs. P_2O_5	00.0	----	----
20 lbs. N+40 lbs. P_2O_5	16.4	----	24640
40 lbs. N+40 lbs. P_2O_5	30.2	52.4	239200
60 lbs. N+40 lbs. P_2O_5	34.8		244400
80 lbs. N+40 lbs. P_2O_5	42.4	110.8	----
40 lbs. N+80 lbs. P_2O_5	----	54.6	----
80 lbs. N+80 lbs. P_2O_5	----	147.6	----
80 lbs. P_2O_5	----	00.0	----

[1] The rates given are for actual pounds of nitrogen and P_2O_5 applied per acre. Superphosphate (20% P_2O_5) was used. At Stillwater ammonium nitrate was the source of nitrogen; at Heavener, ammonium sulfate.

[2] Only one plot of the three check plots produced seed. The yield on this plot was 14.6 lbs.

[3] Seed heads per acre. The wind had whipped out most of the seed, hence seed yield yield would be unreliable. This test was on a solid planting of the grass.

[4] The fertilizers were applied in June after mowing the first crop.

Soon after the nitrogen was applied the vegetation took on a much deeper green color than where no nitrogen was applied and there was a much greater density of grass growth. After harvesting the seed and mowing the grass, the next growth of grass on the plots receiving the higher rates of nitrogen still had a somewhat darker green color and greater density, but few seed heads appeared. Apparently the first growth used the nitrogen to such an extent that there was not enough left to develop seed stalks. In one of the tests a seed crop was harvested June 13, the field was mowed and the second crop was mowed on August 17. A second application of nitrogen was made at that time, but the lack of rain prevented any further seed development.

In 1946 several experiments were conducted, some on a field basis and others on a plot basis. In all cases the the use of a nitrogen fertilizer greatly increased the yield of seed. (Tables IV and V.) Different sources of nitrogen were compared on Fields 1 and 2 (recorded in Table IV); but since there was no consistent difference between the several sources, the average yield is recorded. These fertilizers were applied broadcast about the middle of March.

Data on some of the soils used in these experiments are recorded in Table VI. The Sudenheimer soil was land which had been in cultivation about 10 years, and while its total nitrogen content was low it apparently had a high availability as shown by the acre yield of approximately 133 pounds of seed per acre on unfertilized soil. The Perkins No. 1 soil was an old soil, but it had been in cowpeas before the lovegrass was planted. The cowpeas were combined for seed yields and the vines left on the land. This left a very desirable type of organic matter for the liberation of nitrogen for the love grass. The 117 pounds of seed per acre on unfertilized

TABLE IV.—Influence of Fertilization on Love Grass Seed Production, 1946.

Treatment	Lbs. of N per acre	Yield of seed (pounds per acre): Field 1	Field 3	Field 2	Field 4
Check	0	9.7	13.1	12.8	4.1
Nitrogen[1]	48	55.8	97.3	120.8[2]	88.8[3]
Ammo-Phos[4]	48	125.6	227.1	----	----
Pounds of seed per pound of nitrogen applied[5]		0.96	1.75	2.25	1.76

[1] The sources of nitrogen included nitrate of soda, ammonium sulfate, cyanamid, uramon, and ammonium nitrate.

[2] Cyanamid only.

[3] Ammonium sulfate only.

[4] 16-20-0 grade.

[5] Does not include Ammo-Phos.

Field 1, Carberry farm; Field 2, Murphy farm; Field 3, North Field, Blackwell Lake; Field 4, South Field, Blackwell Lake.

soil shows the value of a legume, since this soil is otherwise very mediocre. The other soils used in these experiments were either abandoned because of low fertility or had a low productive capacity. Some of them had a higher total nitrogen content than the. Sudenheimer and Perkins No. 1 soils, but apparently the nitrogen in them had a very low availability as measured by seed yields. It is interesting to note that the soil with the highest availability of nitrogen produced the largest amount of seed per pound of applied nitrogen (see Sudenheimer and Perkins No. 1, Table II, 1945) as well as returning a higher yield of seed per acre when untreated. This bears out the fact that while fertilizers on poor soils will increase yields, they will give better returns when the soil is not worn out. This had also been noticed in earlier tests of fertilization for hay production; the better soils showed a tremendous response to fertilization so far as grass yields were concerned. In both hay and seed tests the lovegrass growing on soils deficient in available nitrogen had a decided yellow cast, lacked triftiness, and soon became high in crude fiber.

TABLE V.—Influence of different rates of applying nitrogen and the influence of superphosphate on seed yields—1946.

Location, and soil type	Pounds of N[1] per acre	Yield of seed in pounds per acre: Without P	With P[2]
Lone Grove: Durant fine sandy loam			
	0	8.6	8.9
	40	59.2	81.2
	60	79.5	121.2
	80	94.4	130.7
	120	123.5	144.5
Heavener No. 1: Very fine sandy loam			
	0	15.2	12.1
	48	164.5	196.7

[1] Ammonium sulfate was the source of nitrogen. Applied broadcast on Lone Grove field April 10, 1946, and on the Heavener farm in March 1946.

[2] 40 pounds of P_2O_5 per acre using superphosphate 20% P_2O_5 grade.

TABLE VI.—Soil Data on Areas Which Weeping Love Grass Tests Were Conducted.

Location	Texture	Seed yield lbs. per acre unfertilized soil	Organic matter (percent)	Total Nitrogen[1] (pounds)	Available P[2]	Year of test
Heavener No. 1	Very fine sandy loam	6	0.70	720	Very low	1945
Heavener No. 2	Very fine sandy loam	5	0.65	680	Very low	1945
Heavener No. 3	Very fine sandy loam	_	0.49	670	Very low	1945
Mullen farm	Sandy loam	17	0.82	764	Low	1945
Perkins No. 1	Sandy loam	117	0.76	750	Very low	1945
Stillwater	Sandy loam	0	1.47	1336	Very low	1945
Field 1: Carberry Farm	Very fine sandy loam	10	1.51	1526	Very low	1946
Field 2: Murphy Farm	Sandy loam	13	1.13	1144	Very low	1946
Field 3: North Field, Blackwell Lake	Yahola silt loam	13	1.74	1356	Very low	1946
Field 4: South Field, Blackwell Lake	Yahola sandy loam	4	1.43	1208	Very low	1946
Lone Grove, Carter Co.	Durant sandy loam	11	Low	----	Very low	1945-1946
Sudenheimer, Lincoln Co.	Sandy loam	133	1.37	1082	Very high	1945

[1] In the surface 2,000,000 pounds of soil.

[2] As determined by leaching with 0.1 normal acetic acid.

From Tables II and IV it can be seen that each pound of nitrogen in the 45-48 pounds range of application produced 0.91 to 4.76 pounds of seed. Considering the current price of seed of $3.50 to $5.00, nitrogen has been worth from $3.19 to $23.80 per pound. It is costing less than 20 cents per pound. From this it can be seen that the price of love grass seed can decrease tremendously and still the fertilizer can be used profitably.

The conclusions which can be drawn from the love grass fertilization tests are:

(1) Love grass responds very definitely to a liberal treatment of nitrogen.

(2) Each pound of nitrogen applied returns a good income in seed yields.

(3) Soils deficient in phosphorus give increases in seed yields when both nitrogen and phosphorus are supplied.

(4) Phosphorus fertilization alone does not increase seed yields.

(5) Nitrogen produces a more luxuriant growth of vegetation.

(6) Love grass growing on soil deficient in available nitrogen produces little if any seed, and the vegtation soon becomes woody in character.

"Tickle Grass" Pastures

By HI W. STATEN
Agronomist (Grasses and Legumes)
Oklahoma Agricultural Experiment Station

Oklahoma and Indian Territories before the advent of white settlers were covered with luxuriant climax native grasses. The early explorers who made tours through the prairies found the native grasses, predominantly big and little bluestem, densely covering most of the land area of the two territories, with the exception of a small area in northwestern Oklahoma. Washington Irving in his tour through the prairies made the significant statement at one of his stops not far from Stillwater, "It looks like a parkland."

The federal government less than 60 years ago permitted homesteaders to start making a run on this fine prairie soil. One hundred and sixty acres were allotted to each homesteader, with the provision he must break out and put into cultivation a definite acreage of each quarter section. The prairie grasses in many thousands of years had not only protected the surface but had developed a deep, rich, loamy textured soil. The deep-rooted bluestem grasses in the course of a few years were replaced by acres of corn, cotton, wheat, oats, rye, barley, and grain sorghums. In those early pioneer days the soil was so fertile and so productive that it gave point to the statement of Cyril G. Hopkins: "It is an old saying that any fool can farm when farming consists chiefly in reducing the fertility of new, rich land secured at practically no cost from a generous government; but to restore depleted soils to high productive power in complex economic systems is no fool's job, for it requires mental as well as muscular energy."*

In these few more than 50 years of soil mining in the now state of Oklahoma we have, by growing continuous cotton, corn and other clean-cultivated crops, completely worn out and abandoned better than 2½ million acres of this rich prairie soil and an equal number of acres are in a dangerous submarginal condition. This abandoned cultivated land, mined of its soil fertility, left exposed to wind and water erosion, is now covered with a sickly yellow vegetation commonly known as triple-awn, needle, poverty, poor Joe, or dog-hair, and now unappropriately designed as "tickle grass pastures."

There is no doubt that many of these abandoned acres have been idle for 10 to 25 years, and nature has made a last standing fight to save them from complete destruction by growing the only vegetation the soil will support. In some instances silvery beard bluestems, panic grass, dropseeds, windmill, Texas crabgrass, purple top, and even little bluestem are slowly making their appearance in the vegetation composition.

What to do about this large acreage of abandoned and nearly abandoned land has been one of the number one research projects of the Oklahoma Agricultural Experiment Station for the last five years. One quarter section of land in the Blackwell Lake Land Utilization Project Area has been used for this study. This quarter section of land, with the exception of 30 acres of pasture and 10 acres of meadow, had been worn out through the process of clean cultivation. The fertility level was so low that some areas were completely denuded and the balance would not grow cane tall enough to develop a stubble mulch cover crop.

* In his publication, *The Farm That Won't Wear Out.*

In 1941 an area was set aside for a seedbed preparation method study. The different methods used were: Dam listed, plowed and harrowed, plowed and cultipacked, disked and mulched, disked and not mulched, and contour basin listed. The seedbed was prepared in early May and cross seeded to big bluestem, blue grama, side-oats grama, and little bluestem. Each grass species was seeded in separate strips at a rate of 18 pounds per acre. A good stand of blue and side-oats grama was obtained on all of the seedbed preparation methods. The big and little bluestem stand was very poor, no doubt because of the poor quality of seed. A considerable percentage of prairie dropseed was present in the big bluestem and this species developed an excellent stand. The little bluestem was reseeded in April, 1943. The side-oats grama made the best growth and a good seed crop was produced in 1943 and 1944.

The results of this experiment indicate that there was very little difference in the stand and growth of the different species with any of the seedbed preparation methods. At the present time the blue grama is gradually being replaced by triple-awn, the side-oats grama is being crowded by triple-awn, but the little bluestem is persistently competing with the annual grasses and weeds. The reversion back to the weedy annuals in the case of the gramas is perhaps due to the low soil fertility level and non-utilization of the grass. The results also appear to indicate that a mixture of the species would afford more competition for the triple-awn and a much better stand could be maintained.

Another area consisting of 20 acres was plowed in May, 1941, and seeded to darso for the purpose of developing a stubble mulch crop in preparation of a seedbed for seeding in 1942. The sorghum crop did not make enough growth to provide a cover; however, in April, 1942, a mixture of little bluestem, Indian, switch, side-oats grama and weeping lovegrass was seeded. This seeding was very successful and was ready for light grazing in the spring of 1944. At the present time this area has a good stand and is now being winter grazed.

Another area consisting of about 30 acres was set aside in 1943 for seeding in a triple-awn weedy vegetation cover. Two seeding methods were employed: (1) Seeding alternating 100-foot strips across the area to a mixture of desirable native species plus 8 pounds of Korean lespedeza; and (2) mulching with mature, seeded hay from a nearby meadow. The results of these seedings indicate a nearly complete failure where the strips were seeded with a grass drill in the weedy competition and a very poor stand where the seed-hay mulch was used. The Korean lespedeza failed to survive the first summer season.

In March, 1945, another 40-acre area located on the north side of Blackwell Lake was selected for further study. This area had been out of cultivation approximately 10 years and a good stand of triple-awn was present. The replicated seedbed preparation methods employed consisted of: (1) Plowing with a one-way about 3 inches deep; (2) disking heavily; (3) sweeping 4 inches deep with a 36-inch wing sweep; and (4) no seedbed preparation. The seedbed was prepared in March. Two hundred-foot strips were surveyed crosswise the seedbed preparation strips and fertilized with 200 pounds of superphosphate, 40 pounds of nitrogen singly and in combination, and additional strips limed at the rate of 2 tons per acre. Four untreated strips were used as a check. This system of cross fertilizing permitted study of fertilizers on each seedbed preparation method. The entire area was seeded to a mixture of little bluestem, Indian, switch, big bluestem and purpletop, then overseeded with 10 pounds of Korean lespedeza and the red clay areas to 8 pounds of sweet clover per acre. The grass mixture was seeded with a grass drill and processed seed was used.

One and one-half pounds of processed native grass seed were planted per acre. The date of planting was April 10, 1945. An electric fence was constructed around the entire area for the purpose of excluding all livestock.

A 10-acre adjoining area which had been worn out by cultivation and abandoned approximately 20 years ago was also fenced in with the above 40-acre field. This area was studied for the purpose of determining nature's progress in re-establishing native grasses. It was found that the entire area had passed through the triple-awn tsage and was fairly well stabilized with silver beard bluestem and several other semipermanent species which normally are first to appear in the succession stage. Little bluestem had encroached into this area on the side bordering the highway and where seed had been blown in from the roadside. A considerable quantity of sumac had become established and the size of the shubby plants indicated the field had not been cultivated for at least 20 years. During the past two years this area has been mowed, sumac removed, and part of the field fertilized wtih 150 pounds of superphosphate. At the present time no noticeable difference in vegetative growth can be detected.

The Korean lespedeza and sweet clover planted on the area where seedbed methods were being studied made a good growth in May and June of 1945, especially on the one-way and disk strips. The growth of both these legumes was much better where the superphosphate was applied. By July 10 the lespedeza had made an excellent growth over the entire area, especially where phosphate was applied; and cattle were turned in for summer grazing. The field was grazed until September 15 and it made a good pasture during the summer season. Livestock was excluded until July 10, 1946, and the area again grazed for a three-month's period.

During both summer grazing periods the lespedeza and sweet clover provided considerable pasture. The livestock grazed the phosphated areas much more intensely than any other strip. Both the 1945 and 1946 summer seasons from July to October were extremely dry and not very favorable for grass growth.

At the present time it is not possible to make a stand count of the native grasses, but the drill rows are beginning to show up. In many instances the livestock had eaten off young grass plants, but no noticeable damage was done.

No conclusions relative to this experiment can be drawn at the present time, but from observations made last summer the following report of progress is being presented:

1. The strips which had been plowed with a one-way made the best seedbed and controlled the triple-awn grass much better than any other method. The disked strips were not as good, but better than sweeps or the check. The sweeps did not make much change in the weedy vegetation, except that several species of weeds, particularly black-eyed susan, daisy fleabane and the ragwed were much more common in the check strip.

2. The strips which were one-wayed showed a very radical change in weedy plant composition. The annual weeds—particularly sunflowers, lambs-quarter, cocklebur, crabgrass and others which are common in cultivated fields—made their appearance. This type of weedy competition was also present the second summer.

3. Korean lespedeza made a much better growth where the land was stirred more completely.

4. Nitrogen stimulated weed growth.

5. Phosphorus stimulated the growth of lespedeza.

6. The drill rows where the grass mixture was used is showing up more definitely on the plowed area.

The work heretofore reported for the years of 1941 to the present seemingly indicates that soil fertility, weedy competition, especially triple-awn grass, and seedbed preparation are the limiting factors in establishing grass in "tickle grass" pastures. It appears that it is a waste of time and money to plant high-priced grass seed in a dense growth of triple-awn. We must first set the triple-awn back by plowing and planting a sorghum crop and seeding in the sorghum stubble or plowing shallow so that the young grass seedlings may have a chance to become established. When one plows and changes the triple-awn grass composition, other annuals will come in, but they are not a factor because mowing will keep them under control.

The soil of these abandoned land areas is generally low in nitrogen, phosphorus and calcium. It is very important that phosphorus, and calcium if needed, be applied prior to seeding. A legume like lespedeza and sweet clover will help in providing some of the nitrogen.

What to do with "tickle grass" pastures in Oklahoma, especially in central and eastern Oklahoma, is one of the most important problems confronting research workers today. All of us in research, extension or action programs should work cooperatively in collecting more information about this question.

Again quoting from Hopkins: "To restore depleted soils to high productive power is no fool's job, for it requires mental as well as muscular energy." This statement is especially true in Oklahoma in attempting to convert "tickle grass" pastures to the more economic grasses.

Forage Production of Winter Small Grains and Annual Ryegrass,* and Effect of Clipping

By HI W. STATEN
Agronomist (Grasses and Legumes)
Oklahoma Agricultural Experiment Station

The urgent need for winter pasture crops which will supply some grazing such seasons of the year as do not afford succulent native grass or sown pasture crops is of primary importance in Oklahoma. The value of green pastures, especially during the fall, winter and spring months, is being given major consideration at the present time because of the large number of livestock, the limited amount of protein concentrates, and the cost of dry feeding. The utilization of winter wheat for pasture is a common practice in Oklahoma where around six million acres are planted annually. In addition to the winter wheat acreage, approximately two million acres of rye, winter barley and oats and annual ryegrass are planted and used quite extensively for winter pasture. The open and dry winters make it feasible to graze livestock on winter small grains from November to late March. In recent years it has become commercial practice among the larger Oklahoma wheat growers and livestock operators to ship in young cattle and lambs from the ranges of Texas, New Mexico and other states to be grazed on winter wheat. Such livestock is grazed on green wheat from 80 to 120 days or more and the gains compare very favorably with those produced on summer grasses.

* *Lolium multiflorum.*

The extensive use of the small grain crops for winter pasture has caused farmers to ask many questions pertaining to best management practices. Some of these questions are: What crops and varieties produce the most forage? How long can these crops and varieties be grazed without injury to the grain? What varieties produce the earliest pasture? How does annual ryegrass compare with the winter small grains for total forage production and time of grazing? What is the protein percentage and what other food constituents are found in small grain pastures? Is it profitable to plant the winter grain crops for complete pasture utilization?

Advantage is taken of small grain pasturage in Oklahoma more often than is neglected, so that ordinarily the problem is not one of full utilization but one of avoiding over-grazing or other abuse. Through clipping experiments, an attempt has been made to answer some of the questions about the relative merits of different varieties of winter small grain crops and annual ryegrass (**Lolium multiflorum**) for pasture. This is of very particular importance at the present time because the trend in thinking of livestock farmers is toward a more complete year-round pasture program.

MATERIALS AND METHODS

In 1942, twenty winter small grain varieties including wheat, rye, oats and barley, and annual ryegrass (**Lolium multiflorum**) were selected for the experiment. The commonly grown varieties of each small grain crop which were used are:

Hard wheat—Cheyenne, Turkey, Tenmarq, Chiefkan, and Blackhull.

Soft wheat—Kawvale, Clarkan, Currell, and Fulcaster.

Rye—Common, Balbo, and Abruzzi.

Oats—Winter Fulghum, Lee, and Wintok.

Barley—Ward, Michigan winter, Missouri Early Beardless, Tenkow, and Manchuria.

All of these varieties were planted on Kirkland silt loam soil at Stillwater, Oklahoma. This soil is considered a good wheat land type. The rate of planting was based on the seeding rate for pasture rather than for grain: Wheat and rye, 1 bushel per acre; barley, 2 bushels; oats, 2½ bushels; and ryegrass, 25 pounds. All plantings were made in early September. Special attention was given to the seedbed before and after planting. After the seeding was done the soil surface was smoothed and rolled to permit uniform operation of a lawn mower.

To obtain the relative forage and grain yielding capacities of the various crop varieties, four treatments were employed: (1) Clipped all season, (2) clipped to March 15th to 20th or to the jointing stage, (3) clipped to April 1st to 10th or an average of two clippings beyond the jointing stage, and (4) no clipping. The termination of clipping dates was governed by the plant development for the given season. Clipping to a height of about one inch was done with a lawn mower and the prostrate leaves were left on the plants. The entire plot design consisted of four series, and within each series all crops and varieties were planted four times. A triple system of randomization, including randomized treatments, crops, and varieties, was used (See Figure 1). The plots consisted of four drill rows 8 inches wide and 16 feet long. Two border rows were planted on both sides of each crop. The seed to be planted in each drill row was weighed prior to planting. A large funnel fitted to a one-inch pipe was attached to a Columbia drill and the seed was dropped through the funnel by hand. This method of planting facilitated rapid planting and even distribution of the seed in the drill row. The grass was clipped with a lawn mower as often as the forage reached a height that would afford good grazing. The height was about 3 to 5 inches. Each time the forage plots were clipped a composite 500-gram sample was taken from each variety for chemical analysis.* A 50-gram sample of green forage from one variety of each crop was taken before each periodic clipping and delivered to the chemical laboratory immediately for carotene, vitamins, protein and other chemical analyses.

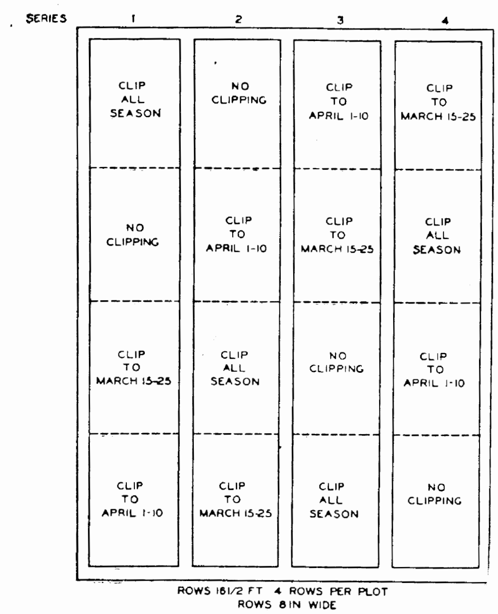

Fig. 1.—Arrangement of Plots.

DISCUSSION AND RESULTS

All seedings were made in early September, which is about 10 to 20 days before the small grain crops are planted for a grain crop. The early planting date, if soil moisture is available, naturally makes pasture several days earlier than the normal planting for grain, therefore the forage yields are considerably higher than ordinarily obtained from the general acreage. Rust epidemics often occurred and affected the forage yield of the wheat varieties during the fall season. Some of the crop varieties—particularly Lee winter oats, Manchuria and Tenkow barleys—were affected by low temperatures, thus reducing the stands and resulting in lower forage yields in the spring months. Lee winter oats and Manchuria barley varieties were so badly damaged by low temperatures both were dropped from the experiment.

Forage Yields.

The average green forage yield of all varieties of each crop and for the three clipping treatments is graphically shown in Figure 2. Annual ryegrass was consistently high in total forage production throughout the "all season clipping" treatment. This crop starts slowly in the fall and spring but makes a very rapid growth in the months of April and May. It is green and in an optimum pasture condition several weeks after the small grain crops are tough and unpalatable. The late growth period accounts for the unusually high total forage production. The winter oat varieties are second to ryegrass in total forage production because they are later in

* Results of chemical analyses are reported in the following paper.

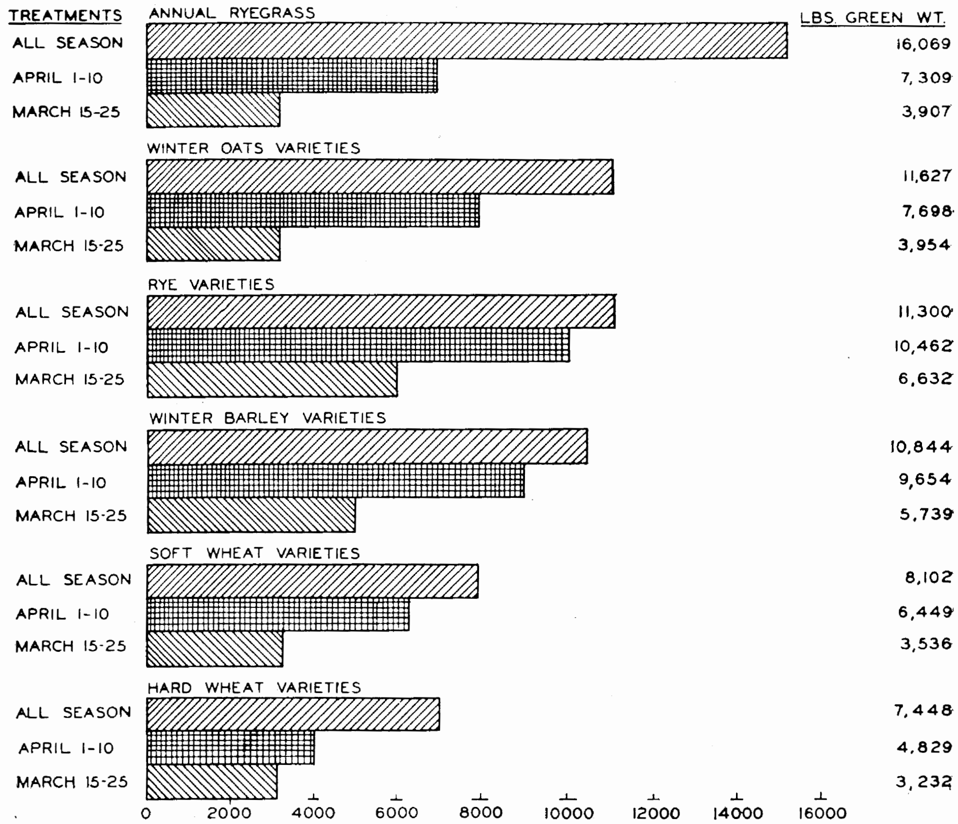

Fig. 2.—Total Green Forage Yield of Different Pasture Crops (Average of Varieties), by Dates of Clipping.

maturity than the other small grain crops. One clipping was obtained from the winter oats after the wheat, barley and rye varieties terminated vegetative production. The yield of the winter barley and rye varieties are close to the oats and are far ahead of any of the other crops in the production of quick, early pasture in the fall and early spring. Hard and soft wheat varieties are considerably lower in total forage production. The soft wheat varieties consistently produce more total green forage than the hard wheats. The hard wheat, soft wheat, and oat varieties and ryegrass are about equal in forage production up to the jointing stage, but rye and barley are considerably higher. The average accumulative forage production of all varieties of each crop is illustrated in Figure 3.

Grain Yield.

The average grain yield of all varieties of each crop and for the three clipping treatments is graphically presented in Figure 4. Clipping to about April 1st to 10th or two clippings beyond the jointing stage materially reduced the grain production of all varieties of hard and soft wheat and rye. The grain reduction is so great and the forage produced after this clipping treatment is so valuable all season grazing would be more practical. The oat and barley varieties were reduced somewhat. The jointing stage clipping treatment slightly reduced the grain yield of the all crop varieties except oats. The rye varieties maturing somewhat earlier in the spring were more seriously affected.

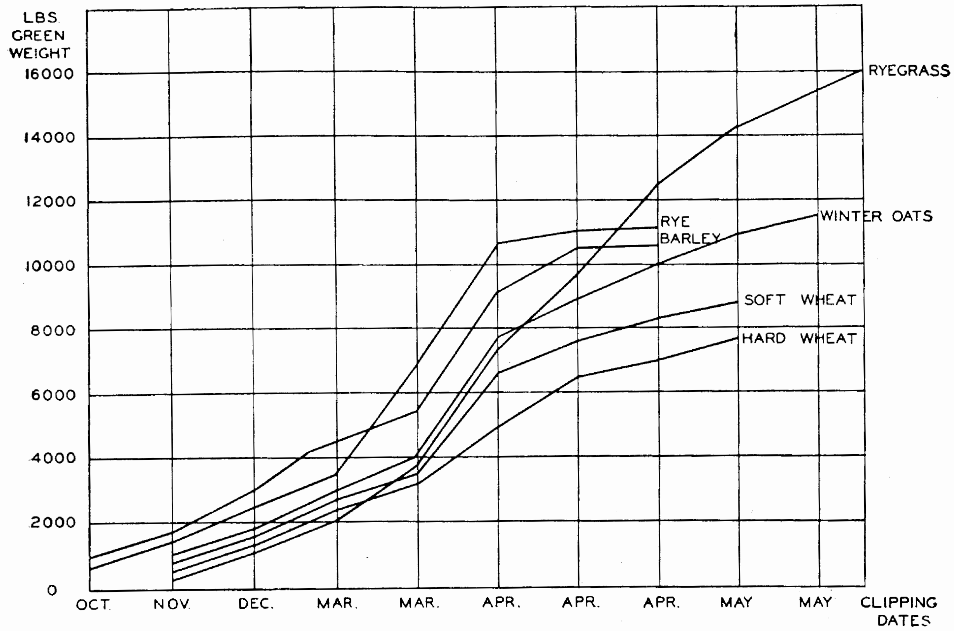

Fig. 3.—Cumulative Green Forage Yield of Different Pasture Crops (Average of Varieties).

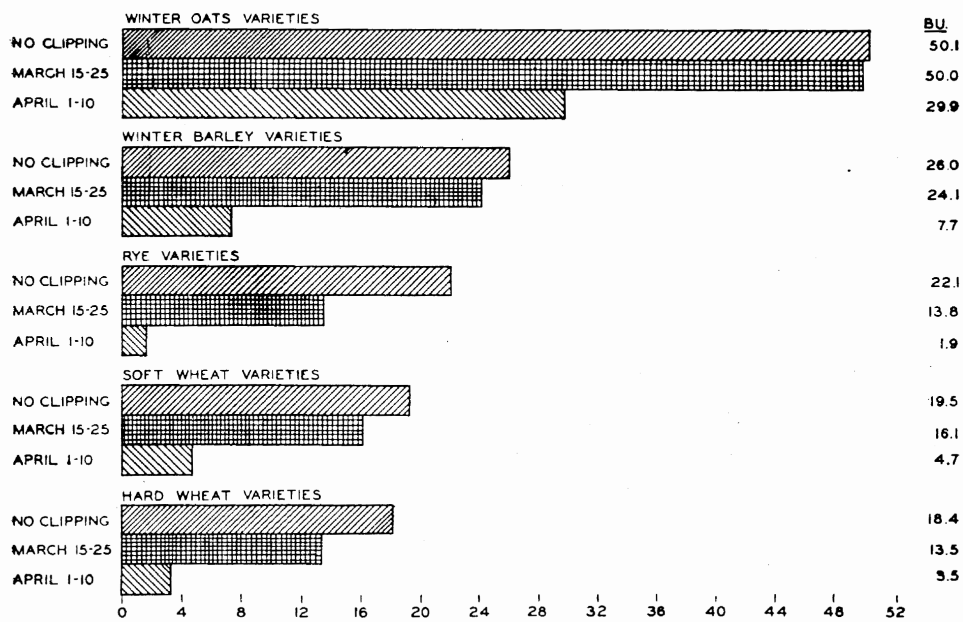

Fig. 4.—Total Grain Yield of Different Pasture Crops (Average of Varieties), by Dates of Clipping.

Varietal Response.

Forage Yields.—Very little difference was found in the forage production of all the hard and soft wheat varieties for the three clipping periods. Kawvale, a soft wheat variety, and Turkey, a hard wheat variety, were slightly ahead of all other wheat varieties. Balbo and Abruzzi rye varieties produced considerably more forage in all three treatments than common rye. Both these varieties were more upright in growth habit and were ready to clip earlier in both fall and spring than the common variety. Winter Fulghum oats produced considerably more forage than Wintok or Lee varieties. Wintok, a very winter hardy variety, is very prostrate in growth habit. Ward, Michigan and Missouri Early Beardless barley varieties were about equal in forage production and did not show any indications of winter injury. Ward and Michigan winter are more leafy and not as coarse as the other varieties. These two varieties are slightly later in maturity and remained in pasture condition seven to ten days after the other varieties disappeared in the "all season clipping" treatment.

Grain Yields.—Abruzzi rye produced the most grain far all three treatments. Balbo and common were about equal but 3 to 5 bushels under Abruzzi. Wintok oats were slightly ahead of all other varieties for the no clipping treatments but Winter Fulghum led in all the plots which were clipped. Kawvale, a soft wheat, produced considerably more grain than the other soft wheat varieties or the hard wheats in all clipping treatments. Blackhull, a hard wheat variety, was slightly ahead of all others in the no clipping and in the clipped to the jointing stage of growth. Very little difference was found in the yields of hard wheat varieties for the late clipping dates.

CONCLUSIONS

Twenty winter small grain varieties (hard and soft wheat, rye, oats, and barley) and annual ryegrass (**Lolium multiflorum**) were clipped for a four-year period (1942-45) for the purpose of determining the forage production, effect of clipping on grain yields, and chemical composition. Four treatments were employed, namely: Clipped all season, to the jointing stage of growth, beyond the jointing stage, and no clipping.

Annual ryegrass (**Lolium multiflorum**) was consistently high in total forage production. It is very slow in starting growth in the fall and early spring but makes a heavy growth late in the spring and after the small grains have discontinued production of green leaf area.

Winter oats produced more forage than any other small grain crop, followed closely by rye and barley. The hard and soft wheat varieties were lowest in total forage.

The barley and rye varieties make a quick growth in the fall and spring seasons and are ready to graze several days before the other crops and varieties studied.

The soft wheat varieties, on an average, produce more forage than the hard wheats.

Periodic clipping through fall and spring to the jointing stage of growth reduced the grain yields of all hard and soft wheat varieties 3 to 5 bushels per acre and the rye varieties 5 to 7 bushels, but did not materially affect the yield of the winter barley and oat varieties.

Clipping beyond the jointing stage materially reduced the grain yields of all small grain varieties.

Chemical and Nutritive Value of Cereal Grasses

By V. G. HELLER

Head, Department of Agricultural Chemistry Research
Oklahoma Agricultural Experiment Station

Oklahoma was originally a livestock state. In fact, even today this industry is of greatest economic worth. It can safely be said that our future economic security hinges upon livestock and farm products.

Oklahoma has an abundance of grass and hay which furnishes an ample tonnage of feed, but at certain periods of the year its chemical content is not adequate for the best growth and development of young animals. This defect has been recognized for the winter months, when most feeders resort to the use of cottonseed cake to balance the protein deficiency of winter grass. Unfortunately, few of the protein concentrates add any vitamins to the rations. It is only since the accumulation of much chemical data that we recognize that this dry feed is deficient not only in protein but in many cases, and usually always, in the vitamin A precursor, carotene. During the past five years the increased production of livestock and competitive demand for animal and plant protein concentrates have created an unprecedented demand, and any new sources of nitrogen are of great interest. Only in recent years have we recognized that often during period of drought a similar deficiency of protein and carotene inhibits profitable growth of cattle. Results of analyses to be reported here show green cereal grasses or their dehydrated products are rich sources of protein, phosphorus, and carotene and would serve to relieve such deficiencies.

It has been the custom in Oklahoma to pasture green wheat for certain periods. It was always observed that cattle which had been confined to dry winter feed made remarkable gains when they received the green grass supplement. For these reasons it was deemed advisable to investigate the possibilities of producing cereal grass for this special purpose rater than as a grain crop.

The details of producing these cereal grasses—the care, time and manner of harvesting—have been outlined in the previous article. Suffice it to say that samples of each of these green grasses were taken from each plot at stated intervals, placed in sealed containers, and rushed to the laboratory where they were at once weighed and ground. Samples were analyzed by extracting with alcohol-ether mixture in a Waring blendor by the method of Kelley. ("Determination of Pure Carotene in Plant Tissue." Ind. Eng. Chem., Anal. Ed., **15**:18 (1943)). Other samples were used to determine the moisture. The dried grass was ground in a Wiley mill and sealed for other determinations. Analyses for total nitrogen, ether-soluble extract, crude fiber, and nitrogen-free content were made by the accepted A. O. A. C. methods. Calcium and phosporus were determined by a modification of the same methods which seemed by many trials best suited to this material. Long ashing periods at low temperatures produced the most desirable results, the calcium being removed as an oxalate and phosphorus as the molydate complex as originally outlined.

From the start of these analyses, certain very interesting results have been obvious. A surprisingly high protein content calculated on the dry basis, from the total nitrogen, was observed. Of equal or even more interest is the remarkably high carotene content together with a reasonably ample supply of phosphorus. It becomes immediately apparent that we have in these grasses the three deficient components in winter range hays or fodders, in amounts at a price that is available to any desired extent. The preceding paper has demonstrated for you the possible acre production.

TABLE I—Seasonal and Average Composition of Forage of Winter Wheat.*

Date of clipping	Mois-ture	Dry Matter Content							
		Ash	Protein	Fat	Fiber	N. F. E.	Ca	P	Carotene
	%	%	%	%	%	%	%	%	ppm
10/20/45	85.6	19.05	32.18	4.27	16.05	28.45	.445	.290	854.2
10/29/45	79.2	13.88	33.53	5.27	12.26	35.07	.345	.339	763.5
12/ 4/45	74.9	11.59	33.50	4.14	12.85	37.88	.357	.300	
3/ 2/46	74.4	13.75	32.48	5.87	13.89	33.99	.354	.280	434
3/15/46	77.8	11.04	35.01	5.22	17.08	31.66	.246	.222	536
3/29/46	77.6	15.04	28.16	4.10	21.29	31.40	.401	.299	531
4/11/46	72.1	13.93	29.05	4.60	15.40	37.04	.512	.323	259
Averages									
1943-44	81.7	15.70	27.6	4.37	15.13	36.98	.370	.291	433
1944-45	78.0	11.36	31.04	4.47	18.68	34.39	.422	.345	405
1945-46	77.3	14.04	31.98	4.78	15.54	13.64	.380	.293	563
3-yr. Av.	79.0	13.70	30.2	4.54	16.45	28.34	.391	.310	467

* Clipped each time forage reached good grazing height. This table is for the Tenmarq variety.

To best illustrate the chemical values of these grasses, a Table I has been prepared showing the chemical composition of one variety of wheat at stated periods from early fall until the final summer clipping the following year. This table not only shows the high percentages of nitrogen, phosphorus and carotene previously mentioned, but the changes that occur as the season progresses.

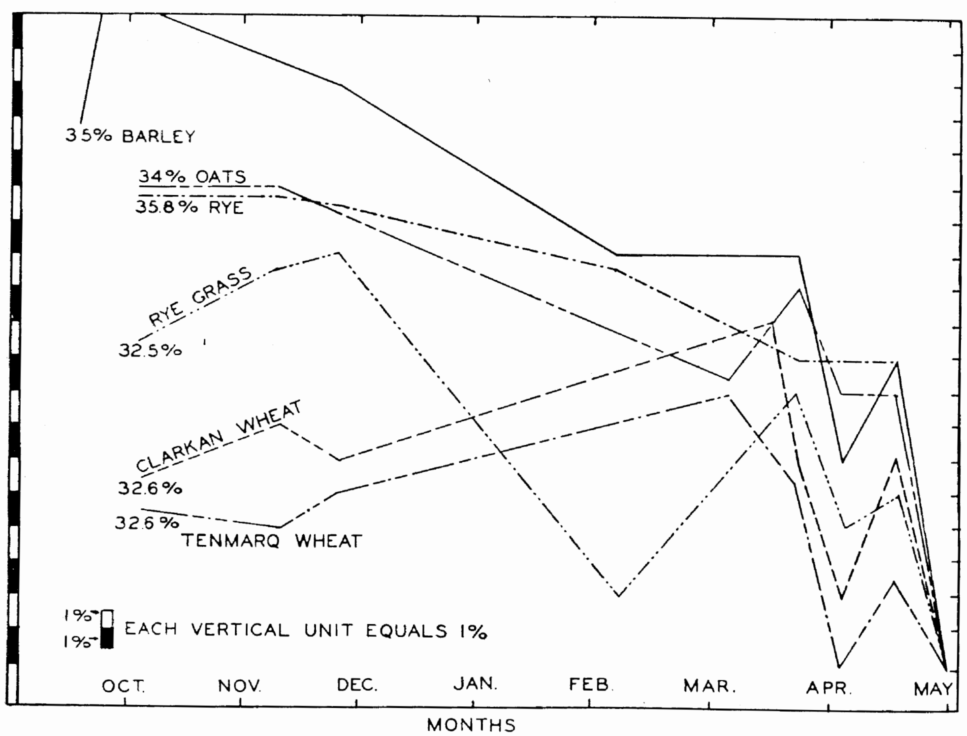

Fig. 1—Protein Levels of Cereal Grasses.

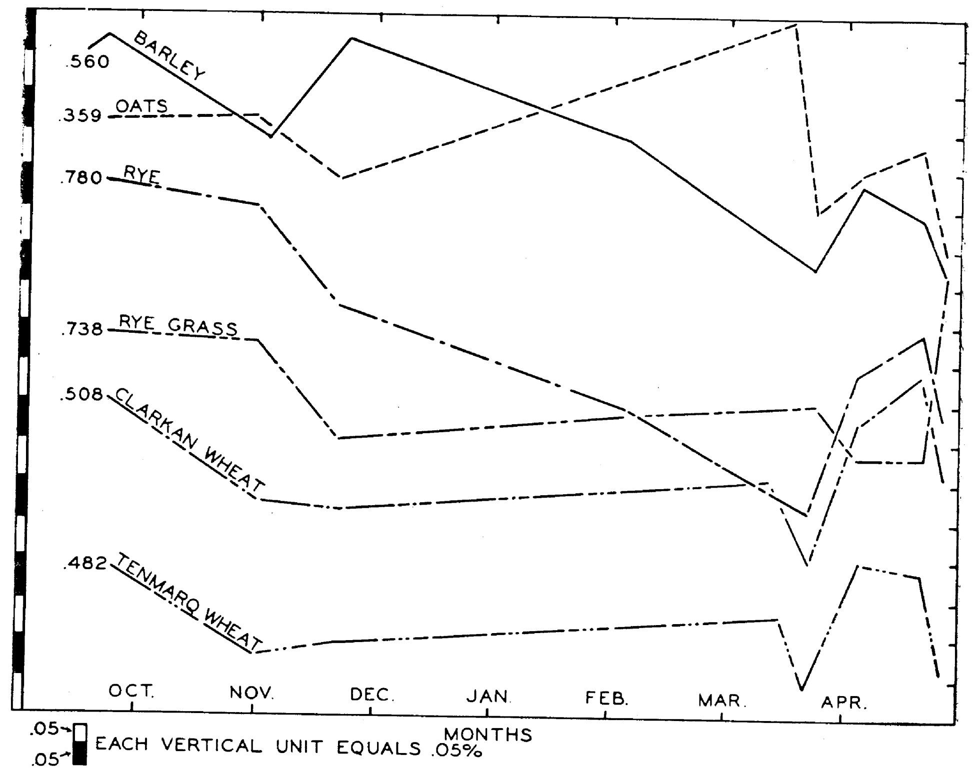

Fig. 2.—Calcium Levels of Cereal Grasses.

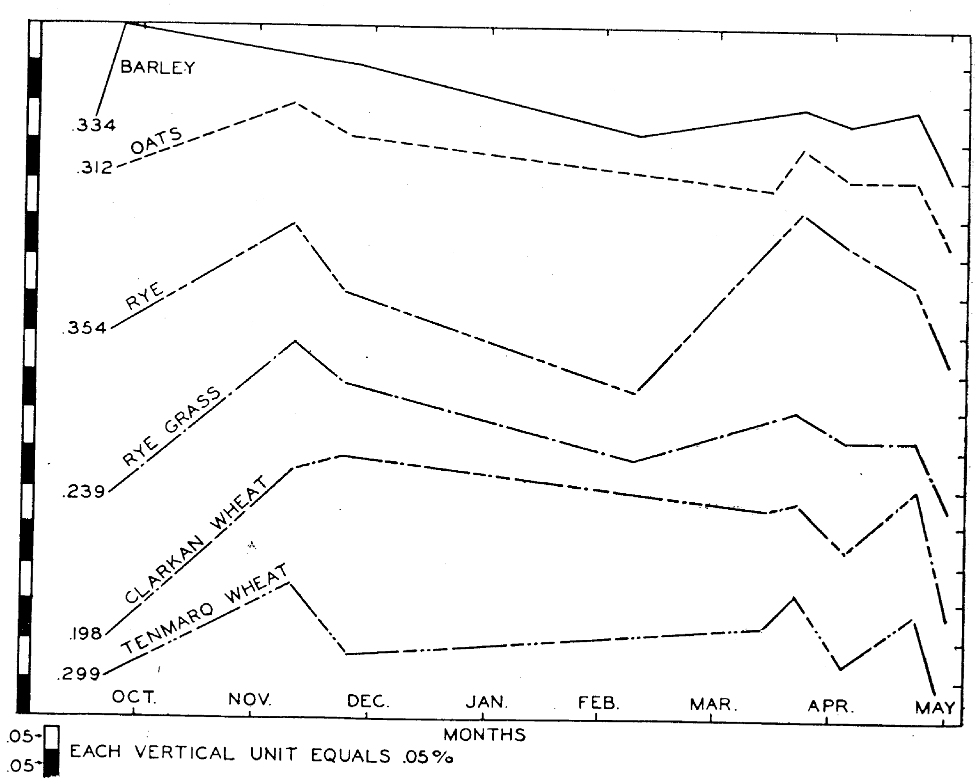

Fig. 3.—Phosphorus Levels of Cereal Grasses.

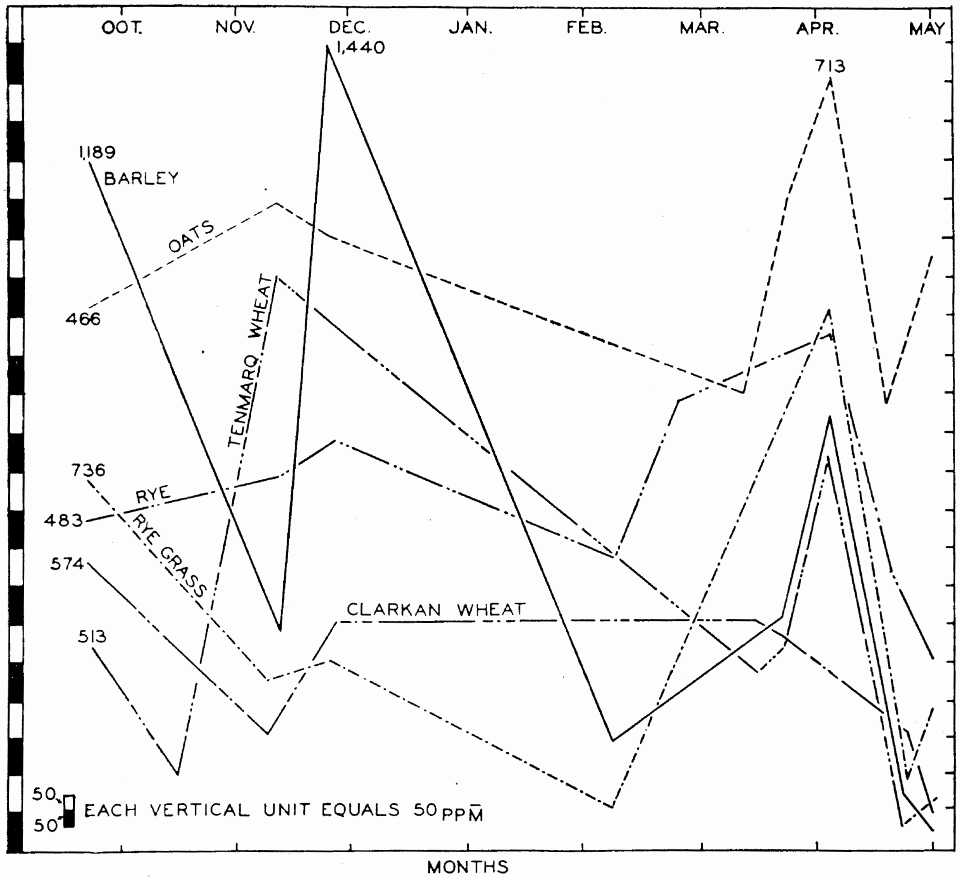

Fig. 4.—Carotene Levels of Cereal Grasses.

This table presents data to substantiate the statements previously made. The chemical components shown in the first line give the composition of the green succulent grass from the first cutting in early fall. The change in composition at following intervals is illustrated in the following row of figures. The average of each component for each year and the grand average for the three years is given at the foot of the table. Similar tables for each of the 26 varieties show similar trends. It will be noted in the table that the nitrogen, phosphorus, and carotene contents decrease with age of the plant despite the fact that results are of similar size cuttings. This changing trend is best illustrated in graphs. Figure 1 shows the protein levels of six varieties of cereal grasses, namely, barley, oats, rye, rye grass, and Clarkan and Tenmarq wheat, at approximately monthly periods from September until May. It will be noted that the percentage increases early in the fall, then diminishes during the winter. In the case of the wheat samples there is an increase with the spring growth, after which all varieties decrease until summer heat stops growth. In fact, the grand average of the year is somewhat reduced by the late cuttings. A similar chart (Figure 2) shows the trend of the calcium content during similar intervals. It will be observed that there is less change than for the nitrogen content. Figure 3 shows the changing phosphorus percentage. Again it will be observed that the phosphorus follows very closely the rate of growth of the plant, rapid growth producing high phosphorus content. This is indicated both in the fall and early spring.

The carotene content illustrated in Figure 4 is, as might be anticipated, more closely associated with climatic conditions. The rate of growth, speed of germination, or bad growing weather conditions show a very marked change in the carotene metabolism. Throughout all analysis one is impressed with very high content; and, while this constituent has been less discussed, yet there is ample evidence that the very rapid improvement in the condition of animals when permitted access to these green grasses is responsible for the improvement more than any other single nutrient.

CONCLUSION

Data presented in this and the preceding paper suggest that green cereal grasses grown for feed purposes alone afford an opportunity for producing an abundance of feed having a surprisingly high protein composition and that this protein remains high as long as rapid growth continues. The minerals are also of interest, as calcium is ample and phosphorus is plentiful throughout the year. The exceedingly high carotene should provide a splendid source of supply for the synthesis of the necessary vitamin A, probably the most deficient vitamin for cattle consuming dry grass, hay or fodder.

Conservation of Grazing Land in Oklahoma

By B. W. ALLRED
Chief, Regional Range Division
Soil Conservation Service
Fort Worth, Texas

GRAZING LAND IN OKLAHOMA

Grazing land has to be given an important consideration in Oklahoma because of its economic importance. There is a gross area of 44,836,480 acres in the state. Crops were harvested on 14,088,000 acres in 1945, and most of the remaining area of grass and forest land is grazed to some extent by domestic and game animals during some period of the year. The densely timbered areas produce comparatively little forage for either game or farm animals. Enormous quantities of forage are required to care for the following Oklahoma grazing animals each year:

	1945	1946
All cattle	3,091,000	2,936,000
Sheep and lambs	29,000	257,000
All horses and colts	347,000	330,000
All mules and mule colts	109,000	98,000
Goats	41,822	

Income to Oklahoma from grazing animals represents a large segment of the total annual agricultural income and is divided between livestock and crops as follows:

		Livestock and Livestock Products	Crops
	1944	$236,874,000	$201,793,000
	1945	259,271,000	171,175,000
Jan.-Oct.	1946	226,536,000	172,382,000

Most of Oklahoma land is privately owned and this, together with small amounts of state and miscellaneous holdings, total 92.8 percent of the area. Six-tenths of 1 percent of the land is owned by the U. S. Department of Agriculture and 6.6 percent by the U. S. Department of the Interior. The government lands are as follows: **U. S. Department of Agriculture**—National forests—159,399 acres; Title III Jones-Bankhead—101,250 acres; and **U. S. Department of the Interior**—General land office—23,157 acres; Indian land—2,851,384 acres; national parks—3,076 acres; game refuges—80,939 acres; and reclamation lands—6,690 acres.

THE NATURAL PLANT COMMUNITIES

Much attention is being given to the study of forage plants, for upon them humanity ultimately depends. Climate largely determines the type of land vegetation that grows naturally. The three guiding factors in climate that control plant growth are temperature, water supply and light. Temperature largely determines the geography of native and crop plants. Moisture supply is the ruling factor in determining the distribution of plants and crops within belts of somewhat similar temperature conditions. Light varies greatly in intensity in different areas, and the length of daily illumination varies in different areas and at different seasons of the year.

Moisture supply, natural or artificial, classes with temperature as the major influence in determining where native or crop plants can be grown. Plants are classified into three great groups in accordance to their adaptation to different moisture conditions: (1) Hydrophytes, plants which grow under water or with part of the plant structure above or floating in water; (2) Mesophytes, plants with medium water requirements which compose most of our trees and food crops; and (3) Zerophytes, those plants that are drought-enduring like crecote bush and other desert vegetation. Growing herbs are generally composed of 75 percent to 90 percent water.

Down through the ages, numerous plants have engaged in ceaseless warfare for possession of the land and, in time, the winners form somewhat stable communities of the type that is best adapted to the habitat. Many habitat factors influence the lives of individual species and change the trend in development of plant communities. Generally, without human interference, a plant community grows and remains fairly stable for considerable time before being modified to fit some changing condition of the site.

Nature has partitioned Oklahoma into three major climatic zones and, except for conditions to be discussed later, the patterns of native vegetation bear the obvious stamp of the climate. The humid area of the eastern part of the state supports forests which are interrupted by occasional oak and bluestem savannahs. The bluestem grassland, or true prairie association, is natural to the central sub-humid belt. The semi-arid area in the western part of the state is the homeland of the short and mid grasses which distinguish the mixed prairie association.

There are circumstances where the controlling influence of the climate is modified sufficiently by natural factors to improve or deteriorate the growing conditions of the local habitat. Some of the conditions that may cause this are extreme changes in soil, elevation or slope. For example, sandy soils generally mature more rapidly than clays or loams because leaching is more readily brought about. Sandy soils usually support plant communities which are representative of the pioneering or less mature stages of plant succession. Sand tends to equalize the soil-water relationships between dry and humid areas. In humid regions, water percolates so quickly into sand that plants are left in a well-aerated moist soil. In dry areas, the little rain that falls sinks deeply out of the reach of evaporation but still within reach of plant roots. Moisture conditions round off at about the same level under both situations. That is why eastern hardwoods survive on sand in semi-arid regions and why semi-arid vegetation may be found in wet climates on sand. However, soil development under the two conditions is dissimilar because leaching is greatest in wet areas and, in addition, in the dry areas the poorly covered sand is thrashed about by the wind.

One of the notable instances of where forests persist in a grassland climate is found in the Cross Timbers region of Oklahoma where a stunted forest of blackjack and postoak are able to survive on soils of large sand fraction. Another example is the shinnery oak and bluestem belt of the Oklahoma Panhandle. Oak has increased as the grasses become reduced under grazing.

PLANTS IN OPERATION

Scientists once believed that plants received most of their food from the soil. This fiction was corrected when a scientist observed the growth of a willow which he planted in a tub holding 200 pounds of soil. Nothing but water was added for 5 years, when he took out the well-grown willow and reweighed the soil. It weighed slightly over 199 pounds. For a long time following this, people believed that water was the source of life. Finally, the principle of photosynthesis and assimilation of carbon dioxide by plants was discovered. The leaves are the essential food-forming organs of the plants. The green leaves of plants have the unique property for converting the energy of the sun and storing it within its tissues as starch, sugar, cellulose, proteins, fats and other carbonaceous products. Therefore, grazing by animals must be limited so that sufficient leafage is left to keep the vital processes of food manufacturing in operation. Plants draw most of their food from the atmosphere; and, when ungrazed, their decaying tissues return far more to the soil than they took from it.

The Prophet Isaiah says that all flesh is grass. He's right. Grass, the product of soil, water and sun, is the true cash crop of the stockman. His livestock are really grass stored on the hoof in the form of meat. Since meat is grass and grass is a reflection of the soil's ability to yield, the soil conservation districts in the range parts of the Southwest have become greatly concerned with how to raise and keep raising good quality grass. They recognize other major items are a big part of the meat-producing business. No stockman discounts the value of improved breeding on animal production. Net income from well-bred animals is about 40 percent greater than is income from scrubs. However, without plenty of high quality feed yearlong, fine breeding qualities have no chance to be expressed. You can't fatten a pedigree, but a pedigree is a big help when feed is adequate.

Plant production goes to feed animals and protect the soil. Whenever we cheat the soil of its share, soon total production starts to decline. Almost half for the soil seems a lot, but actually the part that should be left to cover the soil is the coarse tufts near the base or less palatable upper stems of the larger coarser grasses. The vegetation that is left shields the soil from sun, rain and wind and the decaying parts become food and tonic to small unseen soil life which must thrive first to digest food for plant growth.

In summer, bare ranges of the Southwest may become 25 to 50 degrees higher in temperature than soil under grass on good and excellent ranges. Evaporation from bare soil is greater than from soil well covered with grass. The activity of minute soil life is cut down as soil temperatures rise above 115 degrees.

The plant litter on ranges is valuable, then, as insulation against the sun's rays and as an absorptive layer through which rainfall can penetrate into the soil. Soil tilth, soil aeration to the plant roots, and soil life are best under such conditions.

A large part of soil-life food comes from decaying roots. Roots of tall grasses outyield those of short grasses and hence provide more abundant food for soil life. For every pound of tops produced, plants provide from two to four pounds of roots. For instance, Dr. J. E. Weaver of the University of Nebraska has found that the first 12 inches of the soil contained the following per-acre weights in roots of the following grasses: big bluestem, 8,705 pounds; little bluestem, 3,841 pounds; and blue grama, 2,571 pounds.

The deep roots of plants tap deep sources of minerals which are deposited in the surface soil with plant residue and, when decomposed, are used again by plants. The elements of which plants are composed are used on a natural revolving lend-lease proportion. During their life processes, the growing plants have produced quantities of starches, sugars, cellulose, proteins and fat, and most are returned to the soil when the plant dies. The materials are used and re-used, the current plants deriving part of their nourishment from the disintegrating bodies of their ancestors.

The first three feet and particularly the first four inches of soil compose a zone of active biological life. The greatest part of the living plant grows in the ground. When a cow grazes off one ton of grass from an acre, she is leaving two to four tons of grass roots behind in the first foot of soil.

In addition, the top soil is teeming with bacteria, fungi, algae, and protozoa. Numerous insects, earthworms and burrowing animals and their parasites find homes or food in the soil. According to Weaver and Clements "Plant Ecology," a gram of rich soil may hold from 12 to 60 million bacteria and upwards of 2 million individual protozoa have been found in one gram of soil. These numerous soil organisms feed on decaying plant roots and residues and the products of their digestion in turn become food for growing plants. Weaver, et al., have pointed out that the quantity of living organic materials in bluestem prairie soils may be as great as 3 to 4 tons per acre in the first 4 inches. They also found that living roots and rhizomes constitute about one-tenth of the combined organic matter in the first 6 inches of soil, thus about 30 to 40 tons of organic matter are to be found in surface soil of climax prairie. Some of this organic matter comes from the aerial parts of plants and carcasses of small soil life. According to E. J. Russell, this microscopic soil life may weigh one or more tons per acre.

Probably the first most important information developed about the influence of soil life on soil and plant relationships came from Charles Darwin. He found around 50,000 earthworms per acre in a summer garden in England where soil-water relationship are high. Some authorities claim that earthworm activity is minor in grasslands, especially those in the drier regions. However, examinations made by the Soil Conservation Service in the bluestem prairies, Texas Panhandle and South Dakota showed that earthworms are particularly active in good and excellent bluestem ranges.

While their activities are reduced in the semi-arid ranges compared to the prairies, they are quite numerous in such areas when ranges are in excellent condition.

Darwin found that earthworms penetrate deeply into the earth and remain inactive when the soil is extremely dry or frozen. However, during the period of activity the weight of worm castings thrown up was about 18 tons per year. They eat organic soil, dried and sometimes fresh parts of the plant. These digested materials are left on the surface and aid materially in absorption of water and improve soil tilth.

CRITICAL GRAZING PERIODS

There are two critical periods in plant development which must be regarded by grazers. Arthur W. Sampson states that the removal of growing grass several times in a season, particularly if the first clippings are made shortly after growth has begun, greatly weakens the grass and decreases its productivity at once. Dr. J. E. Weaver of the University of Nebraska has shown that continuous close cropping reduces total yield of sideoats grama and the bluestems and decreases root development several times. Therefore, deferment or light grazing is effective during the early growing period of the grass.

Grass manufactures food rapidly during favorable spring weather when the leaves are tender and active. Food is consumed readily when new grass blades are developing at the time stored nutrients are lower than any other period during the year. One of the brome grasses produces about 10 percent of its annual growth from previously stored food. After maturity and seed production, the plant stores its reserve food in the roots for use in continuing life next year. Therefore, light grazing or deferment is recommended following seed production since over-use at this time may reduce the amount of stored food in the roots.

WHAT HAS HAPPENED TO THE GRASSLAND

It is difficult to assign an absolute depreciation factor to condition of grazing lands, but a broad general appraisal indicates that about 75 percent of the grassland has less than 50 percent of the climax grasses and subdominant forbs that were natural under primeval conditions. This means that the bulk of the grazing lands grade fair and poor condition, with some areas in good condition and with very little in excellent condition.

A description of these four range condition classes is as follows: ranges in excellent condition would have 75 to 100 percent of climax plants present; good condition has from 50 to 75 percent climax plants; fair condition has from 25 to 50 percent climax plants; and poor condition has from 0 to 25 percent of climax plants in the cover.

The Wichita Mountains Wildlife Refuge, west of Fort Sill, Oklahoma, is an admirable area on which to see climax grasslands and the original wildlife that prevailed in the nation's central grasslands. A survey made by Soil Conservation Service range men in September 1946 showed that 13,816 acres were in excellent condition, 21,098 acres were in good condition, 21,096 acres were in fair condition, and 3,158 acres were in poor condition. This is the largest single body of grassland in good and excellent condition in the prairie.

Vegetation in different condition classes were studied in more detail, using the line-interception transect method of measurement. Some of the results are given in Table I. It is shown that the short grasses dominated the prairie dog town and the site where cattle had formerly concentrated. The latter is improving under present management, as indicated by the presence of considerable amounts of little bluestem and sideoats grama and

TABLE I.—Percentage Total Cover by Plant Species; Wichita Mt. Wildlife Refuge, September, 1946.

Perennial Plants	Prairie dog town	Area overgrazed by cattle until 8 years ago	Properly grazed by buffalo for 30 years or more
Buffalograss	65.1	6.4	----
Dogtown dropseed	27.2	----	----
Tumblegrass	4.1	----	1.2
Purple three-awn	2.4	----	----
Fringeleaf paspalum	.6	----	----
Flatsedge (Cyperus)	.6	----	----
Little bluestem	----	18.1	48.7
Sideoats grama	----	13.3	25.6
Big bluestem	----	----	5.8
Indiangrass	----	----	5.8
Mourning lovegrass	----	----	3.2
Tall dropseed	----	----	2.6
Scribner's panicum	----	----	2.6
Switchgrass	----	----	1.3
Canada wildrye	----	----	1.3
Prairie clover	----	----	1.3
Stiff sunflower	----	----	.6
Hairy grama	----	59.6	----
Blue grama	----	1.6	----
Blazing star	----	.5	----
Goldaster	----	.5	----

high class forbs. The buffalo pasture was dominated by mid and tall grasses and high class forbs and there were few or no short grasses, annuals, or low quality perennial forbs.

Relative productivity of ranges in different condition classes was determined by clipping a fraction of an acre of each. Several clips were taken and averaged together. The productivity of the buffalo pasture, which would class as excellent, was about twice that of the old cattle pasture which would class as upper fair. Production of litter or mulch was about twice as much on the range in excellent condition as on the range in fair condition.

The areas with a great deal of weedy vegetation have become poor habitats for domestic animals but have become a favorable home for weedy members of the animal kingdom. Philip F. Allan, regional biologist, Soil Conservation Service, Fort Worth, Texas, has presented the following information to show the relation between range condition and insects and rodents:

1. In Arizona, jackrabbits made 50 percent greater use of overgrazed ranges than on exclosures protected from cattle.

2. In the Wichita Mountains Wildlife Refuge in Oklahoma, properly grazed ranges had only 24 percent of the total insect population as compared to overgrazed ranges, and grasshoppers were 9 times greater on overused ranges. Also, a prairie dog colony was crowded out as tall grass ranges recovered during 1938 to 1946 from grazing abuses prior to 1938.

Mr. D. A. Savage, senior agronomist at the Southern Plains Field Station, Woodward, Oklahoma, reports that a combination of field mice, kangaroo rats, jackrabbits, cottontails, pack rats, and other rodents occur in alarming numbers on the Woodward experimental range, consume significant amounts of the vegetation, and destroy other plants in their burrowing operations. Their method of estimation usually showed that the closely grazed pastures had more rodent injury and supported heavier populations of rodents than did the moderately grazed areas. The closely grazed ranges also had more grasshoppers.

Savage says that "mowing sagebrush appeared to reduce the quantity of rodents. A survey conducted in December 1942 showed that the total weight of rodents varied from 15.4 to 19.1 pounds per acre on non-mowed pastures, as compared with 7.9 pounds on mowed areas. These figures are highly significant in consideration of the fact that much more forage is reported to be required in producing a pound of rodent weight than a pound of gain in cattle."

The degeneration of grasslands is attended by many other unfortunate corollaries beside curtailment of production and advancement of rodents and insects. Rainfall glides off the bare soils into muddy runnels that become the source of floods and siltation. There are no damage estimates on either for Oklahoma, but on a national scale, annual flood damage amounts to about ½ billion dollars a year and siltation of reservoirs about 50 million dollars a year. In addition, several million acres have been invaded by woody vegetation like mesquite, oak and sagebrush, plus hosts of undesirable annual and perennial weeds which smother the ground until but little useful vegetation can grow. Such indicator plants advertise what poor condition the ranges have reached. These undesirable plants transpire more water into the atmosphere than runs off through the channels that drain the areas where the plants grow. Clearing woody vegetation and then seeding the land and keeping it clear of further plant invasion is costly.

SOIL AND HEALTH

We can add poor health to the list, too, because the plants which produce our food from the soil are too often short on needed body-building elements. For example, when the government inducted men into military service during the war, about 50 percent of the men in one southern state had to be rejected because of physical disabilities. In contrast, 75 percent of the men from Colorado, where soils are still fairly fertile, passed the examinations. Yes, soils, and the condition of the people who live on them, are related. Consider the areas of high rainfall. There we find soils are inherently deficient in soil food material. And it is in the rain forests paralleling the equator where soils are normally low in bone-building minerals that we find the people with whom cannibalism is primarily associated. In those high rainfall areas human captives are sold for meat with sanction of the church and society, just as we approve the sale of cattle, sheep and hogs on our markets.

Soil erosion removes plant food from the soil about 20 times as fast as growing plants. This is more rapidly than it can be replaced even by good soil management practices. A bale of cotton has been found to remove 246 pounds of 16 percent nitrogen, 78 pounds of 20 percent superphosphate, and 30 pounds of 50 percent muriate of potash, and lime equivalent to 6 pounds of ground limestone, 90 percent pure. Twenty-five bushels of wheat takes out 197 pounds of nitrogen, 74 pounds of superphosphate, and 16 pounds of muriate of potash. Two tons of pasture forage removes 270 pounds of nitrogen, 133 pounds of superphosphate, 186 pounds of muriate of potash, and lime equivalent to 66 pounds of limestone, 90 percent pure.

GREEN FORAGE FOR WINTER

There are about five million acres of Oklahoma land that needs to be seeded to perennial grass. Some of these acres are grazing lands that have lost their useful perennial plants, some are abandoned farms, and others are risky acres that are too shallow or steep to keep in farming. With proper foresight in planting, the rejuvenation of these lands can serve to help provide livestock grazing during the cool season when the foliage of our warm season grasses, which now occupy the bulk of our native grazing land, are dormant and lowest in food nutrients.

Livestock make greatest and cheapest gains on green forage but often lose a large amount of this gain in winter when grass is dry. For instance, the winter weight losses on one group of cattle totaled 1,500 pounds per cow during a ten-year period. Winter weight losses are highest in the subhumid and humid areas of Oklahoma. After maturity the withered, chaffy stems of forage plants generally become low in palatability and feeding value. In drier areas, grass cures on the stalk as standing hay without the heavy loss of nutrients that is common farther east. However, some winter weight losses are common to livestock in this section as well.

D. A. Savage reports that during the winter of 1944-45 steers wintering on cool season grasses and native range weighed 69.3 pounds per head more than steers wintering on native range alone. The following winter, steers going through on western wheatgrass and 148 pounds of cake each gained 158 pounds apiece. Comparable steers wintering on native range and 267 pounds of cotton cake each gained 125 pounds a head. The western wheatgrass steers made gains the following summer than the others but they weighed 16 pounds more each for the year than those that were on native range yearlong.

SOIL CONSERVATION DISTRICTS IN OKLAHOMA

While disintegrative changes in land went on almost unchecked for a long time, the landowners of Oklahoma have organized almost statewide to forestall damage from the forces of erosion. Since the State Soil Conservation District Act was passed in 1937, 77 locally-managed soil conservation districts have been voted in by the landowners. Nearly the whole state, 41,352,000 acres, are within the boundaries of soil conservation districts. The records to date indicate the following accomplishments:

1. 26,751 farmers and ranchers have started developing coordinated conservation programs on their land.

2. Over 3 million acres of range and farm pastures have conservation plans.

3. Plans have been made to seed over 1 million acres of range and pasture to perennial grass and nearly half has already been established.

4. Over 13 thousand farm and ranch ponds have been planned and nearly ten thousand of them have been constructed.

Grassland improvement is a rewarding enterprise because returns from its care are usually forthcoming immediately. For an example of what soil conservation districts have done, the following statements made by Hardy Robinson, Chairman, Board of Supervisors, Central North Canadian Soil Conservation District, Geary, Oklahoma, are quoted:

"We've got serious erosion to contend with here in the Central North Canadian Soil Conservation District. One place or another we have to use just about every soil and moisture conservation measure that has been invented.

"All our land here in this district needs coordinated soil conservation measures, for nothing less than a complete set of dovetailing practices is enough to tie down our soil and build its fertility up so that it will yield at a profit. We've got cultivated land here that needs terraces and outlets, crop rotations and crop residue management.

"We've got meadows and pastures that need mowing. We've got gullies needing sloping and sodding after diversion terraces are built to cut runoff water out of them. We've got land needing drainage; land needing stock ponds.

"And we've got several thousand acres of land that need seeding to range and pasture grasses. Some of that land now is crops, but because it is subject to severe erosion under cultivation, it needs to be planted to grass. Some of our land now in pasture and range has been so depleted by years of overgrazing that it isn't profitable to run livestock on it.

"Getting that revegetation job on our depleted grassland and on our washed and blown cropland has been the prime concern of our board of soil conservation district supervisors for several years.

"Our board of supervisors—it is made up of five of us farmers elected by the landowners and operators—sat down with Soil Conservation Service and Indian Service technicians assigned to this district and figured that we'd have to go a long way to get better grasses than some of the good-quality native ones that were dominant here when this land was first settled.

"We figured that there ought to be enough of those good grasses of the pioneer days left here and there in odd corners for us to get at least a few seeds. We asked several of the farmers in the district who were installing coordinated soil conservation measures on their farms to help us out by harvesting any blue grama, sideoats grama, little and big bluestem, buffalo, switch and Indian grass wherever they could find any. They pitched in, using mowers, binders, combines and sometimes their hands and a cotton sack. They got some seed; there just wasn't a whole lot to be had. None of the seeds they harvested could be bought commercially.

"The farmers planted the seeds. Each year since, they've harvested and planted more. And now the total plantings are around 10,000 acres in this district. We're harvesting seed from some of the plantings now, occasionally getting a pretty good yield at the end of the second year. Usually we have to mow the plantings once or twice a year to keep down weed competition. Besides the native grasses, we've planted some plots of weeping lovegrass, a good adapted grass brought in from Africa. These, too, are yielding seed. Altogether, we have a pretty good start of seed to use in revegetating our eroded areas.

"This year the district has bought up $18,500 worth of buffalograss, blue grama grass, and weeping lovegrass seed from our own cooperators and from other sources. That's enough to plant another 3,500 to 4,000 acres back to grass. And that's exactly what we're going to do with it—right here in the Central North Canadian Soil Conservation District.

"When that 3,500 or 4,000 acres of native grass seed and lovegrass is planted, we'll be that much further toward our objective of controlling our soil erosion and improving our soil productivity. But even when in the district we do get all the acres that need regrassing returned to grass, we will still have scratched only the surface of our whole soil conservation job.

"We have 438,094 acres in the Central North Canadian Soil Conservation District. Since the district was voted in as a unit of state government in the fall of 1938, cooperating farmers and ranchers have contour farmed 29,000 acres. They've put cover crops on 31,000 acres; practiced crop residue management on 30,000 acres; seeded the 10,000 acres of range and pasture back to grasses; built 352 farm ponds; 1,600 miles of terraces and 319,079 linear feet of diversion terraces, to name a few of the soil conservation measures which have been installed."

The Central North Canadian Soil Conservation District has found that it does a better job when more farmers and ranchers work with it. Already more than 750 landowners in the district are following coordinated conservation measures in cooperation with the district.

The Canant brothers, Wayman and Julius, of Idabel, Oklahoma, are proving that excellent pastures can be developed and good livestock grown in the southeastern part of the state. They got their start in the area in 1941.

At that time, as Wayman Canant puts it, "We took all the nerve, ambition, and credit we had and bought an equity in 400 acres of land near the new bridge on Little River." The place is between Idabel and Broken Bow in the Little River Soil Conservation District. Although situated near the river, all the open land on the farm is upland.

The first two years the brothers owned the farm they tried a row crop system with little success. During the two years, however, they improved 12 acres of pasture enough that it would carry two cows to the acre during the growing season. Seeing the profitable returns from the pasture, and comparing the results of their efforts on the cultivated acres, the brothers decided that they needed more pasture and better pastures—and soon.

With the assistance of the Soil Conservation Service technician assigned to the soil conservation district, they began work. Underbrush had to go first. They began by removing it by hand, progressed to using a mowing machine, and finally ended up using a tractor-powered brush saw. Following this, they fertilized the land, disked, harrowed and seeded with just about every kind of grass, lespedeza and clover seed recommended for their part of Oklahoma.

The pasture development program well under way, they bought eleven registered Hereford cows and increased their number of grade cattle to 25 head.

Both the pasture and the cattle have done so well that 600 acres adjoining the Canant "ranch" have been bought by the brothers and a pasture development program begun there.

The plan of coordinated soil conservation measures which the brothers worked out with the help of the Little River Soil Conservation District is designed to make the best possible use of each acre on the place while controlling erosion and improving the productivity. That means using the land according to its capability and treating it according to its needs.

One of the more important conservation practices the Brothers Canant carry out is mowing. They have found that by mowing the bushes and weeds twice a year, the quality of their grass and clover is much improved and the growth is increased. That leaves more forage on the ground available for fall and winter grazing. This year, about 200 acres of pastureland on the place have been mowed.

The Canant farm could have carried no more than 25 head of cattle before the pasture program was started. Now it carries 100 head. To make a good thing better, two farm ponds and a dipping vat which have been constructed help in making the place an efficient one to operate.

Bradley O. Pigg, a rancher near Mangum, Oklahoma, and a supervisor on the Greer County Soil Conservation District board, has a paying ranch conservation program under way. He has planted weeping lovegrass and western wheat grass for early spring grazing and winter wheat is also grazed. There are 5,100 acres of land of his place; 350 acres are cultivated. He has cooperated with the Greer County Soil Conservation District 4 years and here is a list of what he has done: Contour planting—309 acres; protected with cover crops—309 acres; crop residue conservation—309 acres; range properly stocked—4,706 acres; ponds constructed—9; farm terraces—10 miles; range and pasture seeded to cool season grasses—15 acres; springs developed —1; and mesquite trees killed—90 acres.

He killed the mesquite trees by pouring kerosene on the trunks at ground level. The 5,300 gallons of kerosene used cost $371. About $125 went for outside labor.

Pigg's grassland has improved one range condition class and is now close to excellent. His well-managed grassland has a good cushion of litter and rainwater penetrates it about twice as deep as on "skinned off" range. He estimates that his yield on farm and grazing land has increased about 25 percent. His cows have plenty to eat year-long and calf production has increased until it has become the equivalent of an extra calf crop in a 5-year period. His cows are 100 to 150 pounds heavier than average. His cattle numbers were cut fom 300 to 150 four years ago; but now that the grass has improved the place is supporting 200 rugged purebred Herefords.

Pigg's pastures work into a natural summer and winter rotation scheme because his upland grazing lands are composed primarily of warm season grasses while the low-lying grasslands adjoining the creeks are made up of both cool and warm season grasses.

His upland pastures are grazed in summer. The grasses there are the warm season kinds such as sideoats grama, buffalo, blue grama, little bluestem, sand bluestem and besides, there are several edible legumes and asters. His lowland pastures have these summer grasses, too, but in addition, have a large amount of western wheatgrass and Texas bluegrass which provide green feed during late winter and early spring.

Pigg believes in holding flesh, once the cattle gain it. Summer flies are notorious gain-killers, so he sprays his cattle with DDT and does away with much of this trouble. How much beef he saves this way is unknown. However, yearling steers sprayed with DDT at the Southern Great Plains field station, Woodward, Okla., gained 26.7 pounds more than unsprayed steers.

Men in soil conservaion districts—stockmen like Bradley Pigg—are working to see that our soil is kept permanently productive. They are providing not only for themselves but right now they are storing up yielding power which will help supply the nation in years to come. Soil conservaion practices, installed as a result of a firm understanding of the natural laws and requirements which govern plants and soils, are good national insurance. We can't afford to be without them.

Grazing Value of Reseeded Grasses

By E. H. McILVAIN, Jr.*

Assistant range ecologist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Enginering, Agricultural Research Administration, U. S. Southern Great Plains Field Station, Woodward, Oklahoma.

Ten years of intensified grass research in the Southern Great Plains have greatly increased our knowledge of which grasses can be grown, when where and how to plant and grow them, how much and what type forage they will produce, how well cattle will graze them, and considerable about the management of native range. However, before our knowledge of the grasses is complete it will be necessary to determine which of the several grasses or grass mixtures, outstanding in other respects, will support the most cattle and produce the most beef per head and per acre. The need for concrete information of this kind has long been apparent, since early in the work it was observed by several investigators that reseeded grasses produced more and better quality forage than did native range. Several tests are now being conducted on the Southern Plains Experimental Range near Woodward, Okla., to obtain information concerning relative grazing value, beef-producing quality, and carrying capacity of the important native and introduced grasses and grass mixtures.

EXPERIMENTAL PROCEDURE

These special grazing tests of reseeded grasses include five 50-acre pastures now being grazed and 8 others in the process of establishment, One of the 5 pastures, containing a cool-weather grass, was grazed in conjunction with native range in the winter of 1944-45 and as a pure seeding during the winter of 1945-46. Four of the pastures, consisting mainly of warm-weather grasses, were grazed during the summer of 1946 in comparison with many native range pastures that have been grazed experimentally since 1941.

The grade Hereford steers used in the experiments are obtained in the fall each year at weaning age from herds of uniform breeding. After being received on the experimental range the calves are branded with individual numbers; dehorned, castrated, and vaccinated as necessary; and treated for important cattle parasites. They are then given about a three-week rest period to recover from the weaning and working operations and to learn to eat cottonseed cake. The steers are then divided into extremely uniform lots on the basis of 3-day average initial weights, feeder grades, and other considerations. The cattle are weighed individually on the last day of each month during the season and on three successive days at the end.

Every reseeded pasture is stocked at a moderate rate, a rate designed to harvest all possible beef per acre and yet maintain or improve the forage crop. Numbers of cattle are changed during the season if necessary to effect that degree of use.

COOL-WEATHER GRASSES COMPARED WITH NATIVE RANGE

The useof cool-weather grasses to provide green winter pastures can add greatly to the forage resources of this region. Cool-weather grasses, such as native western wheatgrass and Texas bluegrass, produce green forage extremely high in protein and other nutritional qualities during the winter.

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* Mr. McIlvain's paper is based on investigations conducted by the Bureau of Plant Industry, Soils, and Agricultural Enginering in cooperation with the Oklahoma Agricultural Experiment Station, the Bureau of Animal Industry, and other agencies.

This green grass greatly reduces the requirement for protein supplements at that time. Chemical analyses of many grasses from the experimental range, made during a 6-year period by Dr. V. G. Heller, Department of Agricultural Chemistry Research, Oklahoma Agricultural Experiment Station, disclose that the protein content of cool-weather grasses varies from 12 to 21 percent during the winter when the warm-weather grasses range from 3 to 8 percent protein.

Starting in the fall of 1944 with two steer lots of equal weight and grade, the one having access to a considerable acreage of cool-weather grass in addition to native range weighed 69.3 pounds per head more in the spring than the lot grazed exclusively on native range.

Steer calves grazed last winter on a reseeded pasture of western wheatgrass gained 158.5 pounds per head and produced 38.0 pounds of beef per acre, in contrast with comparable lots on native range that made 125.0 pounds per head and 30.9 pounds per acre. The cattle on this reseeded pasture received a total of only 148 pounds of protein concentrates during the winter, while the cattle on native range were fed 267 pounds per head. Moreover, the western wheatgrass pasture possessed much more reserve feed at the end of the winter.

Winter Gains as Affecting Summer Results.

The steers that made heavy gains on western wheatgrass during the winter made less gain on native range the following summer than comparable lots grazed yearlong on native range. The average summer gain of the better-wintered steers was 295.5 pounds per head, compared with 313.1 pounds for the others. However, the year-long gain of the steers grazed on western wheatgrass during the winter was 16.0 pounds per head greater than the year-long gain of the lots grazed continuously on native range.

The combined results of this test (Table I) show that stockmen can greatly increase their winter gains of beef cattle and materially reduce their requirements for protein concentrates by establishing reseeded pastures of native western wheatgrass for use during the cooler months of the year. The permanence and high winter grazing value of western wheatgrass offset the cost of establishing it and indicate the importance of including this grass in winter-summer rotations with native range.

Economic Returns Based on Year-long Grazing Results:

Results of the grazing test with western wheatgrass and native range were analyzed on an economic basis by Dr. Peter Nelson and E. A. Tucker, Department of Agricultural Economics, Oklahoma Agricultural Experiment Station, and W. F. Lagrone, Bureau of Agricultural Economics. The winter-

TABLE I.—Reseeded Western Wheatgrass (a cool-weather grass) Compared with Native Range.

Type of pasture	Acres per head			Cake per head	Winter gain		Summer gain		Yearly gain	
	Winter	Summer	Total year		Per head	Per acre	Per head	Per acre	Per head	Per acre
Rotation of reseeded western wheatgrass (winter) and native range (summer):										
Pas. 11-15	4.2	5.0	9.2	148	158.5	38.0	295.5	59.1	454.0	48.6
Rotation of winter-summer native range:										
Pas. 27, 26-32	4.2	7.1	11.3	267	125.0	30.0	313.1	44.7	438.0	37.4

TABLE II.—Economic Analysis of Grazing Test With Western Wheatgrass and Native Range.

Item	Rotation of Western Wheatgrass (Winter) and Native Range (Summer)	Rotation of Winter-Summer Native Range
Pasture No.	11-15	27, 26-32
No. steers per section:		
Winter	76	76
Summer	64	45
Value of beef produced above selected costs* on the basis of a 640-acre unit:		
Winter	$1656	$1007
Summer	2338	1781
Total year	3994	2788

* Selected costs include charges for protein supplement fed during the winter grazing season, salt, vaccination, dipping, interest, additional fence for the rotation pastures, and rent, but do not include a charge for establishing western wheatgrass.

summer rotation of western wheatgrass and native range showed an economic advantage over year-long grazing of native range. The steers on western wheatgrass made exceedingly favorable winter gains with less supplemental feeding than was required by similar steers on native grass. This resulted in low-cost winter gains. Yearly returns from the wheatgrass-native range combination were over $1200 per section higher than from exclusive native range (Table II).

RESEEDED PASTURES OF NATIVE AND IMPORTED GRASSES

The four reseeded pastures grazed with yearling sters during the summer of 1946 include pure stands of native sand lovegrass, buffalo grass, and weeping or "African" lovegrass and a native mixture of blue grama, side-oats grama, western wheatgrass, and Texas bluegrass.

Every reseeded pasture supported more cattle, produced more gain per acre, and had more unused forage at the end of the season than did the native range pastures (Table III). In respect to gain per head, the native grass mixture and sand lovegrass were greatly superior to native range. The gain per head on buffalo grass was equal to native range. The steers on weeping lovegrass gained 22.0 pounds less per head than those on native range.

The average stocking load on the different pastures, when converted to the basis of a section of land, was 194 head for sand lovegrass, 178 head for weeping lovegrass, 152 head for the mixture, 128 head for buffalo grass, and

TABLE III.—Grazing results on reseeded pastures and native range.

Kind of grass	Acres per head	Head per section	Average initial Wt.	Summer gain, lbs.	
				Per head	Per acre
Reseeded pastures:					
Sand lovegrass	3.3	194	463.6	338.2	102.9
Mixture	4.2	152	462.1	351.2	84.3
Weeping lovegrass	3.6	178	463.6	291.1	81.5
Buffalo grass	5.0	128	461.8	313.4	62.7
Native range	7.1	90	461.4	313.1	44.7

90 head for native range. The native range was properly grazed at this stocking rate, but all of the reseeded pastures were under-grazed to the extent that they are stocked with the same number of head this winter (1946-47).

The average gain per head on weeping lovegrass was exceeded by a margin of 60.1 pounds on the native grass mixture, 47.1 pounds on sand lovegrass, and 22.3 pounds on buffalo grass. The weeping lovegrass was much more fibrous and less palatable than the other grasses. Contrarily, sand lovegrass is perhaps the most palatable summer grass in this region. It is often referred to as an "ice cream" grass.

In respect to total gain per acre the native range was exceeded to the extent of 58.2 pounds by sand lovegrass, 39.6 pounds by the grass mixture, 36.8 pounds by weeping lovegrass, and 18.0 pounds by buffalo grass. These per-acre gain advantages undoubtedly would have been much greater if the reseeded pastures had been stocked heavy enough to have obtained proper use.

SUMMARY

The results of this work are summarized as follows: Abandoned farm land, or submarginal crop land reseeded to good perennial grasses, will produce grass crops equal to or more valuable than the adjacent native range. Cool-weather grasses make excellent permanent winter pastures high in protein, with a consequent saving of supplemental feed. Pure seedlings of native sand lovegrass, one of the most palatable grasses of this region, and of the introduced weeping lovegrass, which is not readily eaten by yearling steers, produce pastures of exceedingly high carrying capacity and resultant gain per acre. A native grass mixture consisting of side-oats grama, blue grama, western wheatgrass and Texas bluegrass shows considerable promise as a year-long pasture. Buffalo grass, the common favorite of the stockman, is very palatable, cures well to make a good winter pasture, and has a slightly higher carrying capacity than native range. Actual grazing tests of reseeded pastures on the Southern Plains Experimental Range, though just begun, are being vastly expanded to give more fundamental concrete knowledge of the grazing value of the important range grasses adapted to this region.

Pollen Dissemination by Grasses

By MELVIN D. JONES
Assistant Agronomist (Genetics and Plant Breeding)
Oklahoma Agricultural Experiment Station

The improvement and increase of some grasses present certain problems. The problem of maintaining genetic identity differs with self-fertilized and cross-pollinated grasses. Procedures and requirements for use in the production and maintenance of superior varieties or strains of cross-pollinated grasses must be based on facts regarding their pollination habits and the wind dissemination of their pollen. Plant breeders have given much thought to the requirements for isolation of wind-pollinated plants. In spite of the interest in this subject, there has been reported in the literature little experimental evidence upon which proper distances for field isolation may be based. Information has been obtained at the Nebraska Agricultural Experiment Station which should be of aid to the plant breeder and to certify agencies dealing with these grasses. The primary objectives of these investigations were to determine the time of day and the number of days that certain grasses shed pollen, and to determine the relative amounts of pollen of selected grasses dispersed in the air at various distances from their source.

POLLINATION CYCLES

A series of investigations was conducted at Lincoln, Nebraska, during 1944 and 1945 to determine the characteristic pollination habits of various grasses. This information was desired in order to know when adequate quantities of pollen could be obtained and to facilitaate the development of hybridization techniques applicable to an improvement program with these grasses. The effects of temperature, light, humidity, and wind on anthesis, exertion of the anthers and stigmas, and pollen shedding were considered. In this paper the term **blooming** is used to denote anthesis and exertion of anthers and stigmas.

From observations that were made on many grasses, it was found that when meteorological conditions were favorable, blooming occurred daily at a rather regular time for each grass studied in its particular season. This phenomenon of regularity of blooming and pollen shedding is designated as a **daily pollination** cycle throughout this discussion. It was found that a succession of blooming of florets within a spikelet, and of blooming of florets in different spikelets within an inflorescence constitutes a **seasonal pollination cycle** which lasted several days for a single inflorenscence. The seasonal cycle for a variable population of plants would naturally be extended in time over that of a single inflorescence. This would result because of the blooming of a succession of florets on different tillers of a plant and from variable plants in a grass field. These inherent variations in time of blooming and pollen shedding of a plant population account in part for the daily amount of pollen shed. In addition to these inherent variations, environmental factors affect the time of occurrence and duration of both these cycles.

Isolated breeding blocks of spaced plants or small seed-increase fields were used in these studies. To determine the time of day of pollen shedding, microscope slides having an area of one square inch and coated with a thin film of vaseline were exposed at the height of the plant in the center of the field. The slides were placed in holders that were attached to weather vanes at an angle of 45°. This method of exposure kept the vaseline-coated side of the slide exposed against the prevailing wind and facilitated catching the pollen that was impinged against the slide, whether it was blown through the air or fell as a result of gravitation. The slides were changed at intervals of 30 minutes during the period of active pollen shedding. Slides exposed for such a short time seldom contaminated by dust or other pollen. For each of the grasses these intensive studies were continued for periods of two to six days each year. The total number of pollen grains on 10 random low-power microscope fields (16 sq. mm. or 1/40 square inch area) per slide was used os the unit of measure of the amount of pollen being dispersed. All counts were recorded on the basis of central standard time.

The time of day of pollen shedding was studied in detail for 13 grasses by the method described. Approximately 2000 microscope slides were exposed and examined. The cool-season grasses included bromegrass, crested wheatgrass, western wheatgrass, intermediate wheatgrass, tall fescue, Kentucky bluegrass, and rye. The warm-season grasses included buffalograss, blue grama, switchgrass, and corn. In addition, 16 grasses of both types were studied by field observation rather than with the use of pollen-intercepting slides.

Bromegrass proved to be one of the most interesting in its blooming and pollen shedding habits. On typical days of pollen shedding, the majority of the plants began anthesis in the 15-minute period from 4:25 to 4:40 p. m. Shortly after maximum blooming occurred, "clouds" of moving pollen were observed. Data obtained from exposed slides showed that as an average for six days 95 percent of the daily amount of pollen was shed between 4:00 and 6:00 p. m.

A temperature of 80° to 85° F. was found to be optimum for blooming in this grass; however, active blooming has been observed to take place throughout a range of 74 to 90° F. The average daily peak of pollen shedding did not occur until 5.30 p. m., although readings made at 30-minute intervals showed that temperatures were favorable during the entire afternoon on most days.

The following wheatgrass species were studied: crested wheatgrass, western wheatgrass, and intermediate wheatgrass. Most of the plants began anthesis between 3:00 and 3:15 p. m. in western wheatgrass and intermediate wheatgrass and between 3:30 and 3:45 p. m. in crested wheatgrass. An average of the data for each grass indicates that maximum pollen shedding occurred at 3:30 p. m. for western wheatgrass and intermediate wheatgrass and at 4:00 p. m. for crested wheatgrass. Approximately 90 percent of the pollen of each of these grasses was shed between 3:00 and 4:30 p. m.

Data obtained from these species of wheatgrass as well as observations made on species of grama and bluestem indicate that blooming tends to take place at approximately the sametime of day for closely related species within a genus, providing the meteorological conditions affecting the function of blooming are the same.

Data obtained from slides exposed for 30-minute periods in a field of tall fescue showed that maximum pollen shedding occurred at 2:30 p. m. The period of greatest activity was 1:30 to 3:30 p. m., while a small number of pollen grains were caught on each exposure until 5:30 p. m.

In Kentucky bluegrass and rye the daily pollination cycle occurred in the morning. With both grasses it was necessary to begin exposure of slides before dawn. With bluegrass, 87 percent of the pollen was caught on slides exposed from 9:00 p. m. until 4:30 a. m. The peak of pollen shedding in rye occurred during the period 6:00 to 6:30 a. m. The minimum temperatures at which blooming was absorved in these grasses were 51° F. for bluegrass and 57° F. for rye.

The most active period of pollen shedding in buffalograss extended from 7:00 until 8:30 a. m., with the peak being reached at 7:30. The peak of pollen shedding in bluegrama was found to occur at 5:00 a. m. Active shedding occurred from 4:30 until 5:30 a. m.

With switchgrass the peak of pollen shedding was at 11:00 a. m., with the most active period extending from 10:30 a. m. until 12:00 noon. Pollen shedding in switchgrass took place later in the morning than in any of the warm-season grasses studied. The optimum temperature for it appeared to be 85° to 95° F.

The peak of pollen shedding in corn occurred at 9:30 a. m. Active shedding extended from 7:30 until 11:00 a. m.

The fact that Kentucky bluegrass and rye originated in a very cold climate may explain why bluegrass and rye shed pollen at lower temperatures than the other grasses investigated. With the other cool-season grasses—bromegrass, tall fescue, and wheatgrasses—in which blooming was observed to occur under high temperatures in the afternoon, it seemed essential to have the full impact of the heat radiated throughout the morning and early afternoon to produce enough growth to maturation of the anthers and for blooming to take place in the afternoon of that day. With most of the warm-season grasses, blooming and pollen shedding occurred later in the season and under higher mean temperatures than with the cool-season grasses. All of the grasses in this group bloomed and shed pollen in the morning.

It was found that when a grass reaches the blooming stage, the time of actual blooming and shedding of pollen may be greatly delayed or even inhibited by unfavorable atmospheric conditions. Temperature is the most important external factor affecting the time of blooming and pollen shedding. The optimum temperature varies for different species. For each grass there is a minimum temperature below which blooming is delayed for hours or even days. With buffalograss and blue grama, high relative humidity delays dehiscence of the anthers and dispersal of the pollen. The daily pollen shedding periods of 13 of the grasses studied occur partially or entirely during darkness. The others normally shed pollen in daylight. Wind movement is important in speeding up anthesis, dehiscence of the anthers, and pollen dispersal.

The observations made during this investigation show that the time of day of blooming of grass florets is the result of the interaction of inherent and external factors. When florets reach the blooming stage, the exact time of blooming is determined by the existing meteorological conditions.

To determine the number of days of pollen shedding, microscope slides were exposed and examined in the same manner as described for the time-of-day studies, except that the slides were exposed for periods of 24 hours. Pollen-intercepting slides were used for bromegrass, Kentucky bluegrass, rye and corn, while 25 other grasses were studied by general observation in the field. With most of these grasses the cycle of pollen dispersal continued 7 to 8 days, with 4 and 12 being the extremes. During 1944 and 1945 in a genetically heterogeneous field of bromegrass, the pollen dispersal cycle continued for an average of 12 days, while a field planted to a uniform selection it continued for only 8 days.

Alternation of days of light and heavy pollen shedding occurred more frequently in the cool-season than in the warm-season grasses throughout the seasonal cycle. This is explained by the greater daily variation in temperature at the time of year when the cool-season grasses shed pollen. Low temperatures reduced the number of florets that bloomed and consequently the number of pollen grains dispersed. However, by the following day a greater number of florets had grown to maturity during this prolonged period, resulting in heavy blooming and pollen shedding.

POLLEN DISPERSAL

The maintenance of strain purity in cross-pollinated grasses must be based primarily on the distances that their pollen is dispersed by the wind. For the most part, the isolation requirements used as standards in certified seed production have been based on observation rather than extensive experimentation. This investigation had as its purpose the determination of the amounts of pollen dispersed at various distances from a field, as this is a factor in the undesired outcrossing with other strains. Some data were obtained concerning the viability of pollen subjected to conditions resembling those encountered in traveling such distances.

Investigations were conducted during the 1944 and 1945 pollination seasons to determine the relative pollen loads carried by the wind at distances of 5, 15, 25, 40 and 60 rods from the fields of several cross-pollinated grasses. Bromegrass, crested wheatgrass, intermediate wheatgrass, switchgrass, rye, and corn were studied during the two years and buffalograss in 1945.

Grass fields of 1/10 to 1/4 acre in area were chosen for the dispersal studies. Slides were exposed in the manner described on page 119 at elevations of 2.5, 5.0, and 10.0 feet, at several points about a selected grass field. In the initial stages of the investigation, stations were located in eight directions at distances of 5, 15, 25, 40, and 60 rods. It was later found that sufficient data could be obtained from exposures made in northerly directions from the field (directions opposite from the prevailing winds) and only at selected check stations in other directions. After exposure the slides were collected and labeled as to distance, direction, and elevation at which each was exposed. The total number of pollen grains on ten random low-power microscope fields (16 sq. mm. or 1/40 square inch area) per slide was used as the measure of pollen dispersal.

The dispersal of the pollen of all the grasses followed approximately the same general trend. For example, the data obtained with bromegrass will serve to show the trend of dispersal. On the basis of the daily average number of pollen grains for 1944 and 1945, 513 pollen grains were caught in the center of the field compared with 253 at 5 rods, 61 at 15 rods, 15 at 25 rods, 7 at 40 rods and 3 at 60 rods to the north. The amount caught at 60 rods from the field was only one-half of 1 percent of the amount caught in the center; the average daily number, 3, caught at 60 rods is the equivalent of 17,280 pollen grains per sq. foot.

Using the average amount of pollen caught in the center of the field for all of the grasses studied, as 100 percent, approximately 31.0 percent was caught per unit area at 5 rods, 10.0 percent at 15 rods, 4.4 percent at 25 rods, 1.2 percent at 40 rods, and 0.8 percent at 60 rods to the north.

Striking differences in the amounts of pollen produced by the several grasses were shown; however, the relative amount of pollen caught at 60 rods for each of the grasses compared with the amount caught in the center of the field was about the same for all of the grasses studied. With gravity acting on the pollen and with dispersion occurring as it is blown from the source, a rapid decrease occurs in the pollen load.

On the basis of the data obtained, it appears that considerable quantities of pollen remain in the air at 25 rods from the field. Not until 40 rods is reached is the amount reduced to relatively small quautities. At 60 rods the amount is further reduced to about 1 percent of that caught at the field source. One percent of pollen is usually the equivalent of several thousand pollen grains per square foot, which would be sufficient to effect much fertilization in the absence of competition. However, when it is considered as a contaminant, the odds are approximately 100 to 1 in favor of a field's own pollen. But these odds would be drastically reduced within selections of certain grasses, in which partial sib-sterility or self-sterility exists, or in which a differential rate of pollen tube growth occurs. The data from these investigations suggest that the chances of maintaining genetic identity are much greater when seed is produced under an isolation of 60 rods or greater as compared with 25 or 40 rods.

In 1944, studies were made on the amount of fertilization effected by pollen of buffalograss and corn which had been stored under different conditions of temperature and humidity. A large amount of the pollen remained viable for several hours under rather severe conditions. If it is assumed that pollen travels approximately as fast as the wind, under a wind velocity of 9 m. p. h., it would require only 1.67 minutes to travel 80 rods. Based on this assumption it appears probable that most of the pollen remains viable at this distance under field conditions.

In 1945, several detasseled plants of corn were located 50 rods to the north of a field that was shedding pollen. After two days of pollen dispersal by south winds, it was shown that 7.2 percent of the ovules per ear had set seed. On this basis, about 40 percent of the ovules might become outcrossed and set seed, if free of competition throughout a pollination cycle of 12 days. This amount of cross-fertilization is sufficient to cause the loss of genetic identity.

With milo in which as little as 6 percent of cross-pollination may occur in adjoining rows under natural conditions, 40 to 60 rods are required as the minimum isolation for the production of certified and foundation seed, respectively, in most official seed certification programs. The effects of cross-pollination in many of the sorghums are visible in the resultant seed and crop. The phenomena of xenia and hybrid vigor have been instrumental in setting the isolation requirements at the distances above indicated. It appears that with certain perennial grasses, in which a much higher percentage of cross-pollination is recognized, the isolation distances should be as great or greater than those for sorghums in order to insure the maintenance of genetic identity. According to Pedersen (2) and to the seed certification standards of the International Crop Improvement Association (1), a greater isolation is required for the production of certified and foundation seed of forage grasses in certain foreign countries than in the United States.

Since the breeding of forage grasses is in its infancy, no critical work has yet been done with genetic testers to determine the extent of such cross-pollination. Until such critical work has been done, it would seem desirable to base the choice of isolation requirements on information obtained from studies of pollen load in the air.

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Tucson Side-oats Grama; An Improved Strain

By J. R. HARLAN

Associate Agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering
U. S. Southern Great Plains Field Station
Woodward, Oklahoma

Tucson side-oats grama is a vigorous, fast growing, high producing strain developed at the U. S. Southern Great Plains Field Station, Woodward, Oklahoma. It starts growth earlier in the spring and remains green later in the fall than other strains. It has the ability to grow in late summer when other strains are likely to go dormant. Those of us who have worked with it in the breeding nurseries and foundation increase blocks have become quite enthusiastic as to the possibilities of this strain in grass plantings in western Oklahoma, the Texas Panhandle, and possibly eastern New Mexico. Actually, the strain has not yet been tested on a field scale nor by controlled grazing trials. Until this is done and the tests prove favorable, the strain cannot be released for certification.

An adequate testing program has been planned and will be carried out in the next two years. Test plantings on a field scale are to be made this year in 12 to 14 counties in western Oklahoma, the Texas Panhandle, and eastern New Mexico. In each case Tucson will be planted in direct comparison with a good bulk strain of southern origin. In addition two 50-acre pastures are to be established on the Experimental Range Unit of the Woodward Station near Fort Supply, Oklahoma. One pasture will be planted to a pure stand of Tucson side-oats, the other pasture to a pure stand of the bulk strain. When established, both will be grazed with carefully selected groups of steers from the experimental herd used for other grazing studies on the Range Unit.

The seed for the proposed tests was obtained from a 9-acre foundation block established on land of the Western Oklahoma Hospital in 1946. The establishment of this block was delayed until the last day in May because of a very dry spring. The seed germinated in 24 hours and seedlings emerged in 72 hours. Despite one of the driest growing seasons on record, despite extremely severe weed competition in the early stages, and despite an unavoidable delay in harvesting of several days beyond the optimum date, 60 pounds of clean caryopses were obtained. The harvest was made only 4½ months after planting.

On the main station, two seed crops were produced under similarly adverse conditions on smaller second-year increase blocks. In the breeding nurseries, under favorable conditions, three seed crops in one season are possible. One of the characteristics of the strain is the continuous production of flowering stalks, beginning about two weeks earlier in the spring than other strains and continuing until frost.

Tucson side-oats is apparently able to produce an aftermath following cutting in the hottest part of the summer when other strains are completely unable to do so. While this feature has not yet been tested under grazing conditions, clipping and mowing tests indicate that the Tucson strain may be able to provide green grazing during the latter part of the summer when other native forage is usually more or less dormant. As a late summer pasture, it might help to check the decline in daily rates of gain experienced by livestock at that time of year.

The original collection of bulk material from which the Tucson strain was derived was made by Charles R. Proctor (S. C. S.) near Douglas, Arizona in 1935. This bulk source was grown at the S. C. S. Nursery at Tucson under the number A-2405 and later sent to Lincoln, Nebr., where it winter killed completely the first year. Material was sent to Woodward, Okla., in 1937 under the Nebraska number A-1387 where it was grown in the grass nurseries established by the Division of Forage Crops and Diseases. During the first two years at the Woodward station differential winter injury was noted. Hardier types were selected both artificially and naturally through advance in generation. Material now on hand appears quite winter hardy and has withstood temperatures of 11° F. Early in 1947 a new low-tempertature record of —28° F. was made, which may result in further selection of types within the strain.

The breeding behavior is in striking contrast to other strains in the collection. Seed from single plant selections produce progenies of great uniformity which duplicate the maternal parent very closely. Similar progenies from other material are always highly variable. This behavior alone is good evidence for apomixis. Cytological investigations have confirmed this evidence.

The chromosome numbers of individual plants of Tucson vary from plant to plant. The range of several plants examined was 85 to 101. The degree of pairing is very low, ranging from 0 to 15 pairs. In microsporogenesis the first division is regularly asymetrical. The plate is usually formed near one end or one side of the cell and the homologues of the several bivalents and members of the occasional trivalents separate to the opposite end or side of the cell. The bulk of the chromosomal material remains more or less in place. A cell wall separates the unequal masses. In the second division, the cell with the low number of chromosomes divides regularly, producing two sporads with a few chromosomes each. The other cell divides irregularly, with many lagging chromosomes. The cell products from this irregular division frequently divide again, forming irregularly shaped sporads of various sizes. The sporads were observed to vary from diads to octads, but the majority were tetrads. It is interesting to note that after the first division the two cells are often very nearly the same size despite the fact that one cell may contain only 3 chromosomes while the other contains 90 or more. If tetrads are formed in such cases they are almost normal in appearance except for the micronuclei in the two cell derivaties with the large number of chromosomes. As would be expected, the pollen grains vary greatly in size.

Megasporogenesis was examined in an effort to discover the apomictic mechanism. Pairing was found to be about the same as in the P. M. C's. The first division was again regularly asymetrical. The homologues of the several bivalents separated from the plate and moved toward the micropyle. The second division is usually regular in both cells resulting in four cell products, two at the micropylar end, each with a small number of chromosomes, and two distal ones with an unreduced number of chromosomes. In this case there is great difference in size of the two kinds of cells. The cell wall separating the two small micropylar sporads is oriented more or less at random while the two unreduced cells are arranged in a normal manner. The more distal of the latter develops into the embryo sac, pushing the other cells to one side.

The stages by which the unreduced embryo sac develops an embryo were not observed, since sectioning equipment was not available. Later stages of embryo development appeared to be normal and closely resemble the development of buffalo grass seed as described by the writer in a previous publication.*

The extent of occurrence and importance of apomictic forms in side-oats grama is not yet known. Four accessions were obtained from the Tucson nursery in 1944 and planted in the 1945 breeding nursery. These were under the Tucson numbers of A-2969-S2-37, A-2969-S7-37, A-3357, and A-3360. None resembled the Tucson strain very closely. The first two lots showed considerable winter injury during the winter of 1945-46, the third lot was completely winter-killed, but the fourth lot showed very little injury. The first three lots appear to be sexual, because of their variability. Accession A-3360, however, suggests an apomictic reproduction by its uniformity. Cytological investigations have not yet been made.

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Native Sand Lovegrass: a New Seed and Pasture Crop for the Great Plains

By D. A. SAVAGE

Senior Agronomist, Forage Division, Bureau of Plant Industry*
U. S. Southern Great Plains Field Station
Woodward, Oklahoma

Native sand lovegrass has proved to be one of the most valuable and useful grasses under trial at the U. S. Southern Great Plains Field Station, Woodward, Okla., since 1937. This extremely palatable grass had received practically no attention until the Woodward Station hand-collected 180 pounds of the seed in 1937 and circulated it for testing by experiment stations, county agents, soil conservationists, and stockmen in the region. Before that time scientists had not even recognized the grass by giving it a common name, although some ranchmen in northwestern Oklahoma had referred to it as "ice cream" grass because of its high palatability to livestock.

The natural occurrence of this grass is limited to sandy soils from Nebraska southward through the southern Great Plains. However, it appears to be worthy of general use on soils ranging from very sandy to fairly heavy, since it has done remarkably well on heavy soils when seeded there.

This lush-growing, fine-stemmed, medium-tall bunch grass with its rich growth of soft basal leaves is much more palatable to livestock and produces much higher gains of beef cattle than does weeping lovegrass, its relative from South Africa. The native resembles the introduction in general habit of growth and in adaptability to reseeding purposes, but is far superior as a valuable and permanent grazing plant.

Sand lovegrass is one of the best grasses of the Great Plains in yearlong grazing value, according to palatability determinations and other grazing comparisons made at Woodward, Okla., and analytical work conducted with 29 Woodward range grasses through the cooperation of Dr. V. G. Heller, Department of Agricultural Chemistry Research, Oklahoma Agricultural Experiment Station. Sand lovegrass is superior to the famous short grasses —buffalo and blue grama—in average content of calcium, phosphorus, and provitamin A. Its protein is nearly equal to the short grasses on a yearlong basis and exceeds the tall grasses—switch grass, little bluestem, and sand bluestem—by 1.31 percent during the winter. This represents 57.2 percent more protein. These tall grasses average to contain 7 percent more fiber than sand lovegrass. This difference accounts for the preference for sand lovegrass by livestock.

Sand lovegrass not only provides good yields of highly palatable and nutritious forage from early in April to late in October but also has the ability of the short grasses to retain in its winter-cured condition a large percentage of the high food value it possesses during the growing season. Most other grasses retain less of their summer nutritive value when they become dormant during the winter. In respect to average phosphorus content, for example, sand lovegrass decreases from 0.224 percent during the summer 6 months to 0.112 during the winter; the short grasses, from 0.207 to 0.089; and the tall grasses (switchgrass, little bluestem, and sand bluestem), from 0.211 to 0.082. These results show that sand lovegrass retains 50.0 percent of its summer phosphorus content during the winter; the short grasses, 43.0; and the tall grasses, 38.9. Similar trends are obtained by a

* Based on results of cooperative investigations conducted by the Bureau of Plant Industry, Soils, and Agricultural Engineering and the Bureau of Animal Industry of the Agricultural Research Administration, and the Soil Conservation Service, U. S. Department of Agriculture; and the Oklahoma Agricultural Experiment Station.

comparison of the average protein content of these grasses. Sand lovegrass retains during the winter 6 months 43.7 percent of its average protein content during the summer 6 months, as compared with a retention of 47.5 percent for the short grasses and only 26.7 for the tall grasses.

Cattle prefer the short grasses when all of the range forage is dry, but sand lovegrass is eaten more readily in the cured stage than any other tall or medium-tall grass. Sand lovegrass often provides the only forage eaten by cattle when the short grasses have been grazed off or are wholly covered with snow. Cattle will nose down through the snow and consume the entire plant of sand lovegrass. Under similar conditions, the cattle usually ignore other tall grasses or eat only the choicer portions of them.

Grazing tests conducted with beef cattle at Woodward, Okla., since 1941 show the high grazing value of native grasses in general and of sand lovegrass in particular. During the last five years the native range pastures that possessed the greatest amounts of this grass usually produced the highest gains of cattle. The outstanding gains recorded for pastures mowed to control sagebrush were largely due to the increase in stand, production, and availability of sand lovegrass afforded by the treatment. Seedlings of many grasses have been grazed free choice by cattle since 1944. In these palatability cafeterias the cattle showed a distinct preference for sand lovegrass and usually ignored weeping lovegrass when other forage was available.

Separate reseeded pastures of sand lovegrass and other grasses were grazed for the first time in 1946 to determine their relative carrying capacity and beef-producing ability in comparison with native range land that had never been plowed. During the 175-day summer grazing season a pure seeded stand of sand lovegrass supported yearling steers at the rate of 194 head to a section (640 acres) of land. This pasture possessed enough unused growth in the fall to accommodate an equal number of steer calves all winter. A mixture seeding of blue grama and side oats grama containing considerable cool-weather grasses supported 152 head per section during the summer and an equal number during the winter. Weeping lovegrass accommodated 178 head per section last summer and a like number this winter. A pure seeding of buffalo grass handled 128 head per section during the summer and had enough growth left in the fall to graze an equal number of cattle during the winter. In contrast with these reseeded pastures, the native range land that had been moderately grazed since 1940 supported only 90 head per section during the summer and was grazed just right at that rate, having no growth left in the fall above that required to maintain the stand.

These results were obtained during the driest grazing season recorded in this locality since 1886. They show that sand lovegrass was superior in carrying capacity to every other reseeded pasture and supported over twice as many cattle during the entire year as the native range did during the summer only.

The yearlings gained an average of 338.2 pounds per head on sand lovegrass during the summer, 313.1 pounds on native range, and 291.1 pounds on weeping lovegrass. In this comparison the sand lovegrass gains exceeded those on native range by a margin of 25.1 pounds or 8 percent and those on weeping lovegrass by a difference of 47.1 pounds or 16 percent.

Gain per acre under proper grazing use is the best single expression of the over-all grazing value of a grass, because it combines carrying capacity and gain per animal in indicating total production. In this grazing test sand lovegrass produced 102.9 pounds of liveweight steer gain per acre. This amounted to 130 percent more than that of the native range or one-third more than double the results from native range. The per-acre gain advantage of the other reseeded grasses over the native range was less than that of sand lovegrass but amounted to 89 percent for the mixture, 82 percent for the weeping lovegrass, and 40 percent for the buffalo grass.

Sand lovegrass, like the other perennial grasses, renews growth from the roots each year and is capable of persisting for many years, although it is less drouth resistant and probably shorter lived than the extremely permanent blue grama or buffalo grass. However, sand lovegrass reseeds itself better than most other natives, which helps the stand to persist in the face of injury due to drouth or other causes.

Sand lovegrass has proved to be superior to all others tested at Woodward for reseeding thin pastures and depleted range land of a sandy nature. Seedling plants of this grass are able to survive competition with weeds better than other grasses. Despite this advantage, sand lovegrass can be established best by drilling it in close-drilled sorghum stubble. This method of seeding affords a firm, clean seedbed with sufficient stubble to reduce wind and water erosion, retard surface evaporation, and prevent baking of the soil.

The extremely small reddish brown to black seeds of this grass usually exceed a million to a pound of clean seed. The seed is low in germination when harvested in the fall but increases through after-ripening processes to 70 percent or more by seeding time in the spring. Recommended rates of seeding are ½ pound per acre in mixtures with other grasses, ¾ to 1 pound in 3 to 3½-foot rows for seed production under cultivation, and 1½ to 2 pounds in close drills. Since many of the seeds are hard-coated and delayed in emergence, it is advisable to sow the crop in late February or early March so that these seeds will receive the benefit of freezing action to promote germination. Special garden-planter type drills or well constructed alfalfa-seeder atachments to ordinary grain drills are required to obtain proper seeding rates of the extremely fine seed. The seed should be sown to a depth of one-half to three-fourths inch and the soil firmly pressed over the seed with heavy press wheels on the drill and a surface roller following the drill.

Sand lovegrass makes a highly satisfactory grass to use in mixtures with side-oats grama, blue grama, and other palatable grasses. However, it is so highly palatable that, if used with other grasses, it should represent a substantial part of the mixture. A light sprinkling of sand lovegrass in a mixture is almost certain to be sought out by livestock, heavily over-grazed, and eventually eliminated. A pure stand of sand lovegrass or a heavy proportion of the grass in a mixture can be stocked properly to obtain maximum gains without abusing the stand by excessive use. Sand lovegrass should never be used in a mixture with the much less palatable weeping lovegrass.

The Woodward Station has never experienced a permanent stand failure in numerous seedings of sand lovegrass conducted annually since 1937. The grass usually comes up satisfactorily the first year; but if it fails to do so because of the delayed emergence of hard seeds, a good stand can be expected the second or third year.

Most native grasses fail to make sufficient growth to justify grazing until the second fall after seeding. However, sand lovegrass usually becomes established and ready for grazing more rapidly than the others. Under favorable conditions at Woodward a 40-pound per acre crop of sand lovegrass seed has been harvested from a drilled stand on upland six months after seeding, and the aftermath of green basal growth left by the combine made highly satisfactory fall grazing.

Moderate seed supplies of this valuable grass are now available commercially. The present demand for seed of this grass is likely to continue over a period of years. The price is expected to decline as seed supplies become more generally available. However, the grass should continue to be an excellent crop to grow for both seed and pasture purposes. Seed production would still be a profitable venture if seed prices fell from their present level of several dollars a pound to as low as 50 cents. Seed yields ranging from 40 to 125 pounds per acre have been obtained on dry land and 600 pounds per acre have been harvested under irrigation. Clean cultivated row plantings of this grass usually produce two to five times as much seed as are obtainable from close-drilled seedings. The seed can be harvested readily with an ordinary combine and cleaned easily with fanning mills.

Soil Conditions and White Clover Production

By HORACE J. HARPER
Soil Scientist
Oklahoma Agricultural Experiment Station

White clover, **Trifolium repens,** was introduced into the New England states about 200 years ago (3). It spread rapidly into the Ohio and upper Mississippi river valleys along with Kentucky bluegrass because of favorable soil and climatic conditions. White clover has been observed in moist locations in eastern Oklahoma for many years. It grows in many Bermuda grass lawns in central Oklahoma but is seldom found in native pastures. Summer drought may limit the growth of this plant on some soils; however, good stands of white clover have been observed in Bermuda grass where no water was applied to provide more favorable conditions for growth during periods of hot, dry weather. This plant frequently occurs on the north and east side of trees where shade has reduced the density of Bermuda grass cover. Is survival under such conditions due to more shade, less competition from the grass, more available moisture in the surface soil, or a combination of these factors? Chemical tests have shown that lawn soils on which white clover grows luxuriantly always contain a good supply of available phosphorus.

Many pasture fertility experiments have been conducted in older agricultural areas to show the beneficial effect of soil treatment on the production and nutrient content of pasture herbage. But, too often, published reports contain no information on the chemical characteristics of the unfertilized soil. Although the results of a fertilizer study cannot be applied to soil types of different physical and chemical characteristics in the same area or to similar soils under a different climatic environment, some knowledge of the minimum plant requirements for the growth of white clover would be helpful in determining whether soil or climatic conditions are responsible for poor yields or the disappearance of this crop when planted in areas of favorable rainfall.

REVIEW OF LITERATURE

Karraker* of the Kentucky Agricultural Experiment Station has observed that white Dutch and Ladino clover have lime requirements slightly below that of red clover. Spurway (7) reports that a soil pH of 5.0 is a minimum for white clover with an optimum range of 5.6 to 7.0. Sturgis* recom-

* Personal correspondence.

mends that Louisiana soils be limited to a pH of 6.0 for the optimum growth of white clover. Increased production was obtained on the Donaldsonville farm** by the application of one ton of lime on a soil having a pH of 5.2 to 5.4. Very little clover grow on the unlimed area.

Winters* of Tennessee reports that white clover is fairly acid tolerant and fair stands have been observed where the soil pH was 5.0 to 5.5. However, liming to a pH of 6.0 to 6.5 will improve the growth of this crop. A medium level of available phosphate and 150 pounds of exchangeable potassium per acre is also required for optimum production.

Experimental studies† conducted at the United States Regional Pasture Research Laboratory at State College, Pennsylvania, have shown that disking an unproductive pasture which had not been cultivated for at least forty years and fertilizing the area with two tons of lime, 200 pounds of phosphoric acid and 150 pounds of potash per acre greatly increased the yield of bluegrass and white clover without reseeding the area. The pH of this soil was 4.8. When the land was reseeded in addition to fertilization, a good crop was obtained the first season. A period of two years was required to establish a good cover of white clover and Kentucky bluegrass without reseeding.

Thornton (8) reported that fertilization alone was not sufficient to obtain a maximum production of white clover on non-productive pasture land in Pennsylvania. The air dry forage from fertilized land contained 19 percent clover and the total production was 1,390 pounds per acre where no tillage occurred. Renovation combined with fertilization increased the clover content of the air dry forage to 58 percent and the yield was 2181 pounds per acre.

McLendon and Mayton (6) found that 200 pounds of superphosphate, 50 pounds of muriate of potash and one ton of lime applied to Norfolk sandy loam on the Gulf Coast Substation in Alabama produced about the same yield as 400 pounds of superphosphate and 50 pounds of muriate of potash without lime. The acidity of this soil was not reported but the available potassium was low. Mayton (5) states that phosphate is the most needed element for pasture improvement; however, it is most efficient when applied with lime and potash. Potash supplied with superphosphate was not as effective in increasing yields as potash added with superphosphate and lime. Warner (9) studied the growth of white Dutch clover on Ruston and Norfolk fine sandy loam in Florida and observed that the percentage of white clover declined and hop clover increased on plots of lower fertility levels. Hop clover utilized rock phosphate, or basic slag, as a source of phosphorus more efficiently than white clover on a Dunbar fine sandy loam.

Brown (1) found that Ladino clover seeded with nine grasses on Charlton fine sandy loam at Storrs, Connecticut, produced a higher yield than was obtained from these grasses fertilized with 84 pounds of nitorgen applied a scalnitro in three equal applications in April, June and August. The pH of this soil was 5.6. On soil wtih a pH of 5.2 and very deficient in easily soluble phosphorus, no clover developed on the unfertilized plot. Where superphosphate was applied 6 percent of the area was covered with clover. Plots treated with lime and phosphate had 15 percent cover. Where potash was included with lime and phosphate 17 percent of the area was covered with clover. More white clover persisted in bunch and coarse stemmed grasses than in turf-forming grasses such as Kentucky bluegrass and bent. Competition from grasses which are greatly thickened and invigorated by

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* Personal correspondence.

** Letter from C. I. Bray.

† Letter from V. G. Sprague.

fertilizer treatment and the association with clover, appeared to be much more potent than weather condtiions in reducing the stand of white clover in these experiments.

EXPERIMENTAL

Strains of white clover, principally white Dutch and Ladino, have been growing in a few Oklahoma pastures for many years. Since few experimental studies had been made to show the effect of fertliization or liming on the growth of white clover, soil samples were collected in the spring of 1943 by Soil Conservation Service technicians from 50 locations where white clover was growing in 15 east central and eastern Oklahoma counties.

It was assumed that a chemical analysis of a large number of soil samples collected from areas where white clover was growing should provide some information on the lime requirement and relative quantity of available plant nutrients that should be present in other soils to grow this crop successfully without treatment. A majority of the soil samples were collected from white clover spots in Bermuda grass pastures. Two soil samples were obtained from ryegrass-white clover plantings, one from a Kentucky bluegrass-orchard grass mixture, one from a solid stand of white clover, two from native grass pastures, and three from areas containing a mixture of lespedeza and white clover. Most of the samples were taken from 0 to 2, 2 to 4, 4 to 6, 6 to 12 and 12 to 18 inches in depth. White clover has a relatively shallow root system, consequently, it was assumed that a soil sample taken to a depth of six inches might obscure some of the chemical conditions that might be favorable for the growth of white clover on some soils. In most instances the vigor of the vegetative growth was indicated by the individual collecting the soil samples, but no standards were set up to obtain a uniform classification based on height of plants or density of cover. These samples were analyzed for: pH value; total nitrogen, organic matter, and phosphorus (easily soluble phosphorus by extracting with .2N sulfuric acid and leaching with .1N acetic acid) and exchangeable potassium. The results of these analyses are given in Table I.

pH Values.

Although 36 of the 50 surface soils had a pH of 6.0 or higher, good clover was growing on three soils which had a pH below 5.5 in the surface 0 to 2 inch layer. The principal advantage of keeping the pH of a soil above 6.0 would be to increase the efficiency of soluble phosphate fertilizers or available soil phosphates by reducing the rate at which they are changed to relatively unavailable forms. The fixation of soluble phosphates goes on more rapidly in moderately acid to strongly acid soils than in slightly acid soil. A strongly acid soil should also receive an application of lime to counteract the acidifying effect of nitrogen fixation. Liming to produce a soil pH of 6.0 will not only provide a favorable condition for the growth of white clover but it will also be more economical than an application which will produce a higher pH, since calcium is lost more rapidly by leaching from soils which have a high percentage of the exchange complex saturated with bases.

Organic Matter and Nitrogen.

Although white clover is a legume and growth theoretically should be independent of soil nitrogen, if the proper kind of nitrogen fixing bacteria are present in the soil the organic matter content of a soil has an important effect on the growth of this crop under natural conditions. Only one of the surface samples obtained from areas where white clover was making a good growth contained less than 2.0 percent of organic matter. When organic matter decays, plant nutrients such as phosphorus, sulfur, calcium and

TABLE I.—A Study of Soil Acidity, Total Nitrogen, Organic Matter and Phosphorus and Available Phosphorus and Potassium from Areas Where White Clover Was Growing in 1943.

No.	County	Farm	Growth of White Clover	Depth of soil in inches	pH	Total Nitrogen	Organic matter	Total Phos-phorus	Easily Soluble Phosphorus p. p. m.*		Exchange-able Potassium p. p. m.*
									.2 N Sul-furic acid	.1 Acetic	
1	Bryan	Martin, Frank Durant, Oklahoma	Excellent	0-10	6.9	.18	4.0	.02	100	14.4	187.0
				10+	6.9	.20	4.3	.03	26	16.0	144.5
2			Good	0-10	6.7	.21	4.2	.02	40	20.8	232.5
				10+	6.9	.04	.8	.01	4	0	54.0
3			Excellent	0-10	6.6	.27	5.9	.03	36	0	688.0
				10+	5.9	.11	1.8	.02	36	0	800.0
4		Haygood, Floyd Durant, Oklahoma	Poor	surface	6.4	.08	1.6	.02	14	0	14.5
				10	5.4	.06	.8	.01	18	0	11.0
5			Good	surface	7.3	.16	3.5	.02	8	0	104.0
				8-9	7.7	.09	1.8	.02	2	22.8	45.0
				30	7.2	.11	2.5	.01	8	22.8	no sample
6	Cherokee	Crawford, M. T. Tahlequah, Oklahoma	Good	0-2	6.5	.08	2.4	.02	18	0	69.0
				2-4	7.5	.05	2.1	.03	105	8.0	32.5
				4-6	7.1	.03	.9	.02	16	6.4	37.5
				6-12	7.1	.03	1.0	.02	18	3.2	40.0
				12-18	7.2	.02	.8	.02	18	3.2	35.0
7		Wilson, C. C. Tahlequah, Oklahoma	Good	0-2	6.7	.14	4.8	.05	170	9.6	182.5
				2-4	6.1	.18	4.4	.16	200	12.8	113.0
				4-6	6.5	.17	4.0	.06	220	12.8	101.0
				6-12	6.6	.17	4.1	.04	8	12.8	85.0
				12-18	7.0	.15	3.7	.04	14	20.8	74.5
8		Baker, Jim Tahlequah, Oklahoma	Good	0-2	6.6	.27	3.5	.04	16	20.8	167.5
				2-4	6.7	.13	3.9	.05	20	3.2	97.5
				4-6	7.0	.03	1.0	.02	28	8.0	66.0
				6-12	6.5	.04	.8	.03	40	11.2	63.0
				12-18	6.2	.04	1.1	.03	18	3.2	82.0

TABLE I.—(continued).

No.	County	Farm	Growth of White Clover	Depth of soil in inches	pH	Total Nitrogen	Organic matter	Total Phos-phorus	Easily Soluble Phosphorus p. p. m.* .2 N Sul-furic acid	Easily Soluble Phosphorus p. p. m.* .1 Acetic	Exchange-able Potassium p. p. m.*
9	Coal	Jones, Herman			5.9	.34	6.6	.03	20	0	77.0
		Coalgate, Oklahoma			5.7	.09	1.9	.02	12	0	30.0
10		Whitely, Carl			5.8	.18	4.3	.02	20	0	69.0
		Coalgate, Oklahoma			6.4	.08	1.8	.01	12	0	18.0
11	Haskell	Townsend, J. E.	Fair	0-2	5.4	.16	3.5	.02	30	9.6	42.5
		Keota, Oklahoma	6% slope	2-4	5.1	.08	1.8	.02	14	3.2	24.0
				4-6	5.1	.06	1.2	.02	10	4.8	18.0
				6-12	5.4	.05	.9	.01	2	0	14.5
				12-18	7.2	.04	.6	.01	2	0	21.0
12		Townsend, J. E.	Very Good	0-2	5.6	.12	2.2	.07	40	4.8	227.0
		Keota, Oklahoma		2-4	5.6	.11	2.2	.10	38	1.6	160.0
				4-6	5.5	.13	2.5	.09	28	1.6	144.5
				6-12	5.1	.13	1.9	.05	26	0	187.0
				12-18	5.0	.12	1.5	.05	24	0	285.0
13	Hughes	McCoy, Ida	Fair	0-2	6.0	.23	6.0	.06	20	9.6	297.0
		Wetumka, Oklahoma		2-4	5.8	.19	4.3	.04	24	3.2	210.0
				4-6	5.8	.16	3.2	.05	14	3.2	167.5
				6-12	5.8	.12	2.8	.04	14	1.6	144.5
				12-18	6.0	.11	2.8	.03	6	0	130.0
14		City of Wetumka	Excellent	0-2	7.3	.18	4.3	.03	36	32.0	126.0
		Wetumka, Oklahoma		2-4	7.5	.11	2.8	.02	14	14.4	116.5
				4-6	7.5	.09	1.9	.01	32	1.6	97.5
				6-12	7.3	.08	1.7	.02	6	0	74.5
				12-18	7.0	.08	1.5	.02	6	0	52.5
15		McKinney, David J.	Excellent	0-2	7.0	.14	3.2	.02	90	72.0	196.0
		Wetumka, Oklahoma		2-4	7.3	.10	2.2	.02	40	72.0	182.5
				4-6	7.7	.09	2.1	.03	100	96.0	178.0
				6-12	8.0	.08	2.0	.03	140	36.0	291.0
				12-18	7.9	.08	2.0	.02	28	32.0	208.5

TABLE I.—(continued).

No.	County	Farm	Growth of White Clover	Depth of soil in inches	pH	Total Nitrogen	Organic matter	Total Phos-phorus	Easily Soluble Phosphorus p. p. m.*		Exchange-able Potassium p. p. m.*
									.2 N Sul-furic acid	.1 Acetic	
16	Latimer	Smallwood, J. L.	Very Good	0-2	5.3	.24	4.8	.05	12	3.2	88.0
		Wilburton, Oklahoma		2-4	5.3	.18	3.8	.05	10	1.6	60.0
				4-6	5.3	.10	1.9	.03	2	1.6	40.0
				6-12	5.3	.09	1.6	.03	2	0	35.0
				12-18	5.5	.08	1.5	.02	2	0	35.0
17		Pace, H. E.	Fair	0-2	6.2	.38	3.6	.04	24	9.6	50.0
		Wilburton, Oklahoma		2-4	6.1	.10	2.1	.03	16	3.2	30.0
				4-6	6.2	.08	1.7	.02	16	1.6	21.0
				6-12	5.8	.06	1.3	.02	8	1.6	18.0
				12-18	6.2	.04	.8	.02	2	0	18.0
18		Utzman, Clinton	Very Good	0-2	6.2	.12	2.5	.02	16	3.2	35.0
		Wilburton, Oklahoma		2-4	6.5	.12	2.2	.02	14	3.2	35.0
				4-6	6.5	.08	1.8	.02	8	0	40.0
				6-12	6.2	.08	1.7	.02	4	0	57.5
				12-18	6.1	.07	1.4	.01	2	0	60.0
19	LeFlore	Polone, D. J.	Good	0-2	5.8	.30	7.1	.06	14	3.2	104.0
		Poteau, Oklahoma		2-4	5.6	.20	4.4	.06	24	0	66.0
				4-6	5.4	.17	4.0	.06	24	0	55.0
				6-12	4.8	.13	2.6	.05	8	0	50.0
				12-18	4.7	.09	1.9	.04	8	0	40.0
20		Anderson, W. R.	Very Good	0-2	5.6	.15	3.1	.03	2	4.8	47.4
		Poteau, Oklahoma		2-4	5.7	.08	1.7	.03	2	0	32.5
				4-6	5.8	.07	1.7	.03	2	1.6	35.0
				6-12	5.8	.08	1.7	.02	6	0	32.5
				12-18	5.4	.09	1.9	.03	2	0	30.0
21		Polone Farm, D. J.	Good	0-2	5.7	.10	2.8	.06	40	0	144.5
		Poteau, Oklahoma		2-4	5.7	.09	1.8	.06	40	0	101.0
				4-8	5.0	.05	1.0	.05	14	1.6	42.5
				8-16	5.0	.04	.7	.05	16	0	52.5

TABLE I.—(continued).

No.	County	Farm	Growth of White Clover	Depth of soil in inches	pH	Total Nitrogen	Organic matter	Total Phos-phorus	Easily Soluble Phosphorus p. p. m.* .2 N Sulfuric acid	Easily Soluble Phosphorus p. p. m.* .1 Acetic	Exchange-able Potassium p. p. m.*
22	Mayes	Hardy, O. L. Pryor, Oklahoma	Very Good	0-2	7.0	.19	4.3	.04	28	26.6	285.0
				2-4	6.6	.14	3.8	.04	100	19.0	247.0
				4-6	6.3	.15	3.4	.04	75	32.0	201.0
				6-12	6.2	.13	3.2	.03	70	36.0	110.0
				12-18	6.0	.06	1.1	.01	2	0	82.0
23		Meyers, Frank Pryor, Oklahoma	Fair	0-2	6.0	.16	4.0	.06	4	0	101.5
				2-4	6.4	.13	3.1	.08	6	0	57.5
				4-6	6.9	.11	2.6	.05	8	0	69.0
				6-12	7.6	.09	1.9	.03	8	0	79.5
				12-18	7.7	.06	1.5	.03	2	0	66.0
24	McIn-tosh	Lawson, A. A. Eufaula, Oklahoma	Poor	0-2	6.7	.10	2.2	.02	12	6.4	37.5
				2-4	6.2	.09	2.1	.02	2	1.6	32.5
				4-6	6.0	.08	1.7	.02	2	0	26.5
				6-12	6.0	.06	1.4	.02	2	0	24.0
				12-18	6.0	.06	1.1	.02	2	0	24.0
25		Town Lot back of Post Office Eufaula, Oklahoma	Excellent	0-2	6.6	.13	3.4	.03	14	3.2	134.0
				2-4	6.6	.09	2.3	.02	64	32.0	123.0
				4-6	6.6	.08	1.8	.02	30	25.6	94.0
				6-12	6.6	.06	1.1	.01	12	19.2	85.0
				12-18	6.6	.06	1.4	.01	18	19.6	85.0
26		Prate, Fred Eufaula, Oklahoma	Excellent	0-2	6.5	.12	2.4	.02	16	12.8	85.0
				2-4	6.4	.10	2.0	.02	4	3.2	141.0
				4-6	6.6	.06	1.3	.02	6	3.2	90.0
				6-12	6.9	.05	1.0	.02	2	1.6	69.0
				12-18	7.0	.04	.6	.01	8	0	42.5
27	Okfus-kee	City of Weleetka Weleetka, Oklahoma	Excellent	0-2	6.6	.09	2.1	.02	2	1.6	104.0
				2-4	6.7	.07	1.6	.01	6	1.6	94.0
				4-6	6.6	.05	1.3	.01	6	1.6	60.0
				6-12	6.5	.05	1.3	.01	4	1.6	55.0
				12-18	6.3	.06	1.3	.01	4	1.6	42.5

TABLE I.—(continued).

No.	County	Farm	Growth of White Clover	Depth of soil in inches	pH	Total Nitrogen	Organic matter	Total Phos-phorus	Easily Soluble Phosphorus p. p. m.* .2 N Sul-furic acid	Easily Soluble Phosphorus p. p. m.* .1 Acetic	Exchange-able Potassium p. p. m.*
28		Novatney, Tony Okemah, Oklahoma		0-2	6.3	.14	4.0	.06	40	5.2	123.0
				2-4	6.5	.11	2.7	.03	28	6.4	85.0
				4-6	6.5	.10	2.2	.02	4	1.6	63.0
				6-12	6.4	.09	2.1	.03	2	1.6	57.5
				12-18	6.4	.08	2.0	.04	6	1.6	43.0
29	Okmul-gee	Morris, Virgin Okmulgee, Oklahoma	Very Good	0-2	6.1	.11	3.4	.02	2	3.2	85.0
				2-4	6.6	.10	2.2	.02	2	4.8	42.5
				4-6	6.8	.07	1.5	.02	2	3.2	35.0
				6-12	6.7	.03	.6	.01	8	3.2	26.5
				12-18	6.7	.04	.8	.01	4	1.6	24.0
30		Bingman, W. B. Okmulgee, Oklahoma	Very Good	0-2	6.6	.08	1.8	.02	8	0	107.0
				2-4	6.7	.06	1.1	.01	14	11.2	101.0
				4-6	6.7	.04	1.0	.01	4	9.6	101.0
				6-12	6.2	.06	1.4	.01	2	4.8	77.0
				12-18	6.3	.05	1.1	.01	2	0	63.0
31	Push-mata-ha	Van Loon, J. N. Albion, Oklahoma	Good	0-2	5.7	.12	2.8	.02	6	1.6	43.4
				2-4	5.7	.09	1.9	.02	6	0	26.5
				4-6	5.7	.09	2.0	.02	4	0	26.5
				6-12	5.3	.07	1.3	.01	2	0	26.5
32		Gearhart, W. B. Antlers, Oklahoma	Good	0-2	6.4	.09	3.4	.02	12	0	77.0
				2-4	6.5	.09	2.7	.02	12	0	60.0
				4-6	6.6	.06	2.6	.02	12	0	60.0
				6-12	6.3	.05	1.9	.01	8	0	53.5
33		Stewart, Paul Antlers, Oklahoma	Very Good	0-2	5.9	.10	2.7	.02	36	6.4	88.0
				2-4	6.2	.09	2.6	.02	32	3.2	85.4
				4-6	6.4	.04	.5	.01	14	1.6	55.0
				6-12	6.7	.05	.2	.02	32	0	40.0

34 Semi-nole	East of Wewoka Wewoka, Oklahoma	Excellent	0-2	7.6	.15	3.7	.05	210	56.0	110.0
			2-4	7.6	.10	2.0	.04	26	52.0	123.0
			4-6	7.5	.09	2.0	.02	18	9.6	101.0
			6-12	7.6	.09	2.1	.04	70	16.0	94.0
			12-18	7.7	.09	1.9	.03	24	3.2	120.0
35	East of Wewoka Wewoka, Oklahoma	Excellent	0-2	6.7	.14	3.2	.03	36	28.8	134.0
			2-4	6.8	.11	2.7	.02	28	12.8	120.0
			4-6	6.9	.09	2.0	.02	26	9.6	77.0
			6-12	6.9	.05	1.1	.02	18	9.6	52.5
			12-18	6.9	.04	.8	.01	34	12.8	42.5
36	West of Wewoka Wewoka, Oklahoma	Excellent	0-2	7.1	.10	2.4	.02	70	28.8	91.0
			2-4	7.4	.08	1.8	.02	90	28.8	94.0
			4-6	7.4	.04	.7	.01	40	20.8	45.0
			6-12	7.3	.03	.7	.01	26	20.8	45.0
			12-18	7.3	.03	.6	.01	22	14.4	97.5
37 Sequo-yah	Moody, J. W. Vian, Oklahoma	Excellent	0-2	6.7	.15	3.3	.04	32	0	109.5
			2-4	6.8	.13	3.0	.04	200	22.4	88.0
			4-6	7.0	.11	3.1	.04	200	14.4	92.0
			6-12	7.2	.11	2.4	.04	220	20.8	97.5
			12-18	7.2	.03	1.2	.03	240		94.0
38	Mize, Carl Sallisaw, Oklahoma	Very Good	0-2	6.8	.17	4.3	.04	12	16.0	77.0
			2-4	6.3	.10	2.8	.02	12	3.2	35.0
			4-6	6.8	.06	1.4	.02	6	0	21.0
			6-12	6.1	.02	1.3	.02	4	0	21.0
			12-18	5.6	.05	1.3	.02	4	0	24.0
39	Weaver, H. N. Sallisaw, Oklahoma	Excellent	0-2	5.1	.14	2.9	.03	18	0	63.0
			2-4	5.1	.13	2.8	.03	16	0	45.0
			4-6	5.2	.12	2.5	.03	12	0	45.0
			6-10	5.0	.12	2.4	.03	4	0	63.0
			10-24	4.9	.07	1.3	.02	8	0	35.0
40 Tulsa	Baker, Dave	Failed		6.0	.10	2.2	.02	4	3.2	126.0
41	Kindley, W. J. Broken Arrow, Okla.	Good		5.6	.11	2.3	.02	2	1.6	126.0

42	Walker, Jessie Broken Arrow, Okla.	Failed (7% slope)	5.9	.13	2.8	.03	6	1.6	120.0
43	Hurd, F. S. Broken Arrow, Okla.	Fair	5.8	.24	5.6	.03	16	16.0	101.0
44	Hurd, F. S. Broken Arrow, Okla.	Good	7.3	.15	3.0	.02	8	4.8	160.0
45	Anderson, Paul Broken Arrow, Okla.	Excel- lent**	7.6	.17	3.4	.02	12	9.6	63.0
46	Anderson, Paul Broken Arrow, Okla.	Fair	6.0	.20	4.3	.03	12	4.8	66.0
47	Ritberger, C. B. Broken Arrow, Okla.	Excel- lent**	7.1	.15	3.2	.02	8	3.2	45.0
48	Lancaster, E. L. Broken Arrow, Okla.		7.5	.13	2.9	.02	16	3.2	50.0
49	Anderson, H. M. Broken Arrow, Okla.	Fair	7.7	.13	2.7	.03	8	3.2	55.0
50	Anderson, H. M. Broken Arrow, Okla.	Poor***	6.1	.12	3.1	.01	8	6.4	84.0

* p. p. m.—parts per million.
** Wet area.
*** Dry site.

magnesium are liberated. Garman (4) found that one-third to one-half of the total phosphorus in a large number of the surface soils from different areas in Oklahoma was present as organic phosphorus. This may account for the favorable growth of white clover on high organic matter soils when the available mineral phosphorus is relatively low. Organic matter also contains sulfur. About two-thirds as much sulfur as phosphorus is present in white clover. Beeson (2) reports an average of .25 percent sulfur and .34 percent phosphorus. On low organic matter soils white clover would not be expected to make a good growth unless the soils were high in available mineral nutrients or fertilizer is applied to supply them.

Total and Available Phosphorus.

White clover made an excellent growth on many soils which contained less than 400 pounds of total phosphorus in the surface 0 to 6 inch layer of soil. In some of these soils the available mineral phosphorus was low or very low by acetic acid leaching and sulfuric acid extraction. It is quite probable that increased production would be obtained from applications of superphosphate on these soils, especially during those seasons when weather conditions are not favorable for the liberation of organic phosphorus by the decay of soil organic matter. Superphosphate was drilled in rows 14 inches apart on the Pasture-Fertility Research Station near Coalgate to increase the efficiency of this fertilizer.

Exchangeable Potassium.

Most of the surface soils in Table I were high in exchangeable potassium. Pood growth of white clover usually occurred when exchangeable potassium (determined by extracting with 2N ammonium acetate) was less than 30 to 40 parts per million.* If a soil was sampled to a depth of six inches, this value would be 60 to 80 pounds per acre. Winters** of Tennessee has suggested 150 pounds per acre of exchangeable potassium as favorable for white clover. Thirty-four of the 50 surface soils were above this figure. In one instance the growth of white clover was limited by an unfavorable condition of the soil. The combined effect of unfavorable soil acidity and low available phosphorus may have restricted growth on some soils adequately supplied with potassium.

Results from Southeastern Pasture Fertility Station.

White Dutch and Ladino clover were planted along with several other winter legumes on the North nursery of the Southeastern Pasture Fertility Station near Coalgate in the fall of 1945. Several different fertilizer treatments were applied to this soil, which is similar to Dennis fine sandy loam. The surface soil has a pH of 5.8. It is very low in available phosphorus and contains about 150 pounds of exchangeable potassium in the surface 0 to 6 inch layer. The organic matter content is 2.7 percent.

Samples of big hop and ladino clover were harvested from plots receiving different fertilizer treatments when these plants were in full bloom. These samples were analyzed and the data on total calcium, phosphorus and potassium are given in Table II. It will be observed that phosphorus fertilization increased the quantity of total phosphorus in both plants. One of the important differences in the composition of the ladino and hop clover is in the potassium content. Either hop clover requires less potassium than ladino clover or the ladino clover has the ability to obtain more potassium

* Preliminary studies indicate that leaching a soil with 2N ammonium acetate will remove more potassium than extration.

** Personal correspondence.

TABLE II.—A Comparison of the Calcium, Phosphorus and Potassium Content of White and Hop Clover.

	Data from Coalgate Experimental Farm, 1946			Average Data from Beeson (2)		
	Calcium %	Phosphorus %	Potassium %	Calcium %	Phosphorus %	Potassium %
White Clover*						
No treatment	1.17	.11	1.72	1.42(65)**	.37(64)	2.87(41)
Superphosphate	1.62	.15	1.70			
Superphosphate and limestone	1.82	.15	1.86			
Hop Clover†						
No treatment	1.14	.09	1.03	1.18(3)	.33(3)	1.94(31)
Superphosphate	1.10	.15	1.13			
Superphosphate and limestone	1.15	.16	1.24			

* Ladino clover in full bloom.

** No. of samples in parenthesis.

† Big hop clover in full bloom.

from the relatively insoluble forms of potassium in the soil. Crop yields were also increased by an application of superphosphate on this soil. The unfertilized land produced 1920 pounds of air big hop clover and 672 pounds of ladino clover. Plots fertilized with 200 pounds of 20 percent superphosphate produced 2595 pounds of big hop clover and 3720 pounds of ladino clover. Lime applied at the rate of two tons per acre with superphosphate did not increase the yield of the hop clover over superphosphate applied alone. The lime and superphosphate treatment produced 4150 pounds of air dry ladino clover. Potash applied as muriate of potash, 100 pounds per acre, with lime and superphosphate did not increase the yield of big hop clover but increased the ladino clover to 4465 pounds per acre.

More comparisons between crop response to soil treatment and analytical data will be needed before the relation between the supply of available plant nutrients in soil and probable response to soil treatment can be detedmined. There are some indications that plant composition may be a better guide to fertilizer requirements than soil tests on many soils.

SUMMARY

Soil samples were collected in the spring of 1943 from 50 locations where white clover was growing in 15 counties in central and eastern Oklahoma. Chemical analyses were made on these samples to obtain information on the lime requirement and minimum quantity of available plant nutritents that should be present in a soil to grow this crop without fertilizer treatment.

White clover was growing on three soils which had a pH below 5.5, which indicates that this crop can grow in moderately acid to strongly acid soil when other factors are favorable for plant development.

Only one of the soils collected from areas where white clover was growing well contained less than 2.0 percent organic matter. Since a large amount of phosphorus is present in soil organic matter and is released when the organic matter decays, white clover can obtain the necessary phosphorus to grow on high organic matter soils low in available mineral phosphorus. High acidity tends to reduce the availability of organic phosphorus in soil organic matter.

The available phosphorus in a high percentage of the soils tested was low to very low. Experimental studies indicate that an increased production of white clover will be obtained when superphosphate is applied to these soils, since white clover grows during the cooler part of the year when the rate of decomposition of soil organic matter is slower than during the summer months.

The exchangeable potassium content of most of the soils was high. There was some evidence that a poor growth of white clover will be obtained on soils containing less than 60 to 80 pounds of exchangeable potassium in the surface 0 to 6 inch layer of soil.

A preliminary study of the chemical composition of ladina and big hop clover shows that superphosphate fertilization will increase the phosphorus content of these plants on soils low in available phosphorus. The potassium requirement of ladino clover is higher than big hop clover. This factor may be responsible for the decrease or disappearance of white clover when these two plants are seeded on soils low in exchangeable potassium.

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Behavior of Summer Fallow Under Varying Seasonal and Climatic Conditions

By H. H. FINNELL
Research Specialist, Soil Conservation Service
Amarillo, Texas

In the dryland farming areas of the Southern Great Plains, the effective management of crops is related to more than one variant. There are seasonal moisture fluctuations, wind erosion hazards, and economic necessity. These considerations involve to no small degree the use of summer fallow. In the immediate vicinity of experiment stations, where a lengthy record of the results of summer fallowing is available, farmers have had adequate guidance in the development of their crop management practices. In areas not specifically represented by experiments, trial and error observations, supplemented by judgment, have had to serve as guides.

The object of this study is to set forth such correlations as may be established between the behavior of the summer fallowing in the cropping system and certain seasonal and climatic factors as may serve more accurately to project experimental information.

In dryland crop management the practice of summer fallowing has been developed in such a way as to serve two important purposes. First, in areas of extremely scant total moisture supply, the practice may be used to double up on the preparatory accumulation of a favorable soil moisture and fertility condition. Second, it may serve the purpose of facilitating crop succession where too short a time would normally be allowed between harvest and sowing.

Experiment station research and farmer experience have developed definite viewpoints on the proper place of summer fallow in certain parts of the Southern Great Plains (2, 3, 4, 7, 10). For example, in northwest Kansas and extreme northeast Colorado, summer fallowing has been recommended and accepted generally. There it is employed systematically in a fixed rotation. At the opposite extreme, in the Texas High Plains area, the results have been so highly variable it has never been widely accepted on a systematic basis, and only recently has it been definitely recommended for accessional use in a flexible rotation. Between these extremes there must be some kind of logical transition.

Where the wheat yields from summer fallowed land approximately double those from continuous cropping, only one major problem will usually arise from its use. Stronger precautions are needed to protect the land from occasional severe wind erosion hazards. Strip cropping, coupled with modification of tillage practices designed to keep sufficient quantities of straw at the surface of the soil for wind erosion control, aid greatly in meeting this need.

The other problem which may be encountered where summer fallow results are less dependable concerns the efficient use of land resources. Where or when excessive rainfall saturates the root zone or soil storage capacity, quantities of moisture accompanied by soluble plant food may go to waste during the fallow season by penetrating beyond reach of the crop root systems. This may happen in deep soils during wet seasons as well as in shallow soils during moderate seasons. In either case the losses are caused by overdoing the preparation of the land. The remedy for such waste on the deep soils is to watch more carefully the progress of soil moisture accumulation and to make adjustments in the cropping plans where necessary. In shallow soils the root zone is limited by the nature of the subsoil or substratum. Shallow soils lack the storage capacity to benefit fully from the practice of summer fallowing, either in a wet or dry climate.

In addition to soil limitations, there are climatic variations which determine the most effective manner of using the practice. It is equally desirable to define the pattern of water supply relations. Figure 1 shows the location of the southern semi-arid plains farming area and adjacent territory. The eastern boundary of this zone is located on the 25-inch rainfall line. It represents roughly the division between plains and prairies. The western boundary of this zone, which follows the 17-inch rainfall line, has been selected principally on the basis of agricultural experience during the past four decades. It follows very closely the boundary between brown and dark brown soils (1). The area immediately west of this zone may be designated as arid ranges in comparison with the semi-arid plains, and since the eastern boundary is hardly far enough east to represent the beginning of sub-humid scrub timber area, we introduce an intervening zone designated "mid-moist prairies."

Going southward across western Kansas and southwestward across the Texas panhandle there is a significant shift in the normal seasonal distribution of annual rainfall (5, 8, 9, 11, 12). More of it comes during the first half of the year at the northern and eastern parts of the region, while more comes during the last half of the year in the southern and western portions of the area.

Now, since the ability of a summer-fallowed field to produce more than a stubble-sown field depends not only on the capacity but also on the opportunity to accumulate a superior moisture and fertility supply, the incidence of rainfall combining with the normal interval of time between harvesting of the last crop and the sowing of the next must be brought into the picture. This has been done in Figure 2, where both the percentage of total rainfall and the inches of seasonal rainfall between harvest and sowing dates are indicated.

From the dryland farming areas of extreme northeastern Colorado to the south plains of west Texas, the proportion of the annual rainfall coming during the preparatory period for continuously cropped wheat increases from 20 to 40 percent. The inches of rainfall involved in this period increases from northeast to southwest. Third is the total amount of rainfall. It increases from west to east. No two of these factors vary in exactly the same direction. The particular division points selected here represent 5-, 10- and 14-bushels prospects at sowing time. For example, 3.5 inches of rain puts enough moisture into the soil previous to sowing to provide a 5-bushel prospect, 6.5 inches a 10-bushel prospect, and 9.5 inches a 14-bushel prospect (4, 7). This is an average from which variations of major extent depart, but never without a substantial discernible cause.

The result is a geographic pattern which does not conform to any single, well recognized factor (see Figure 3). It does, however, have the merit of being consistent with the summer fallowing results published by those experiment stations (3, 6, 10) which fall within the various areas.

Area 1 contains four experiment stations reporting an average yield increase due to summer fallowing of 77 percent; area 2 contains three stations reporting an average yield increase due to summer fallowing of 25 percent; one station in area 3 reported a yield increase due to summer fallowing of 12 percent. For area "M," which is largely outside the territory of a permanently established dry farming industry, we have no consistent results. Such as we do have vary from 21 to 111 percent increase of yield due to summer fallowing. In area 1, the recommendation of systematic summer fallowing in a fixed rotation is quite widely accepted (2, 10). It is consistent

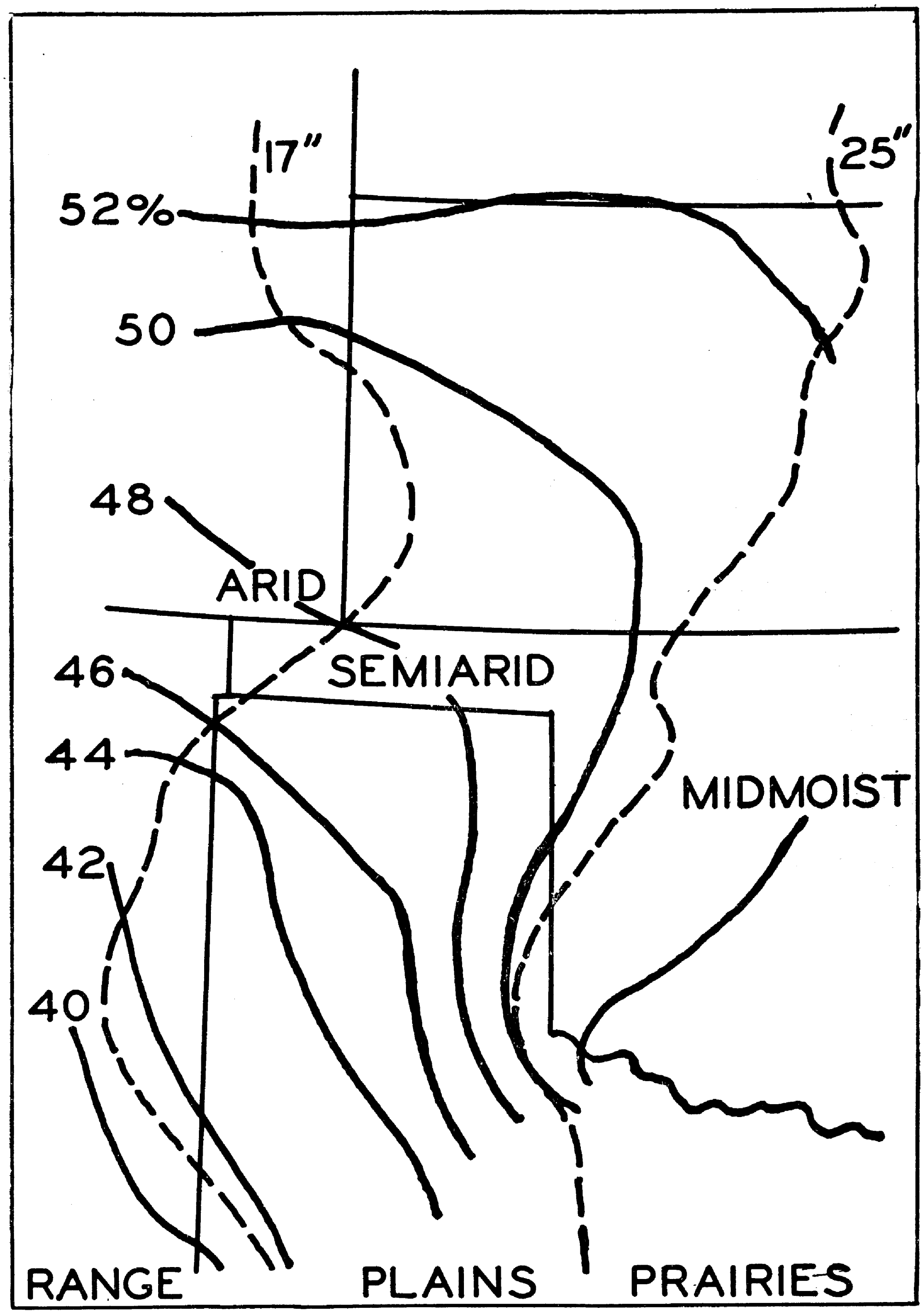

Fig. 1.—Rainfall Distribution Shift; Percentage of Total Annual Rainfall Occurring Before July 1.

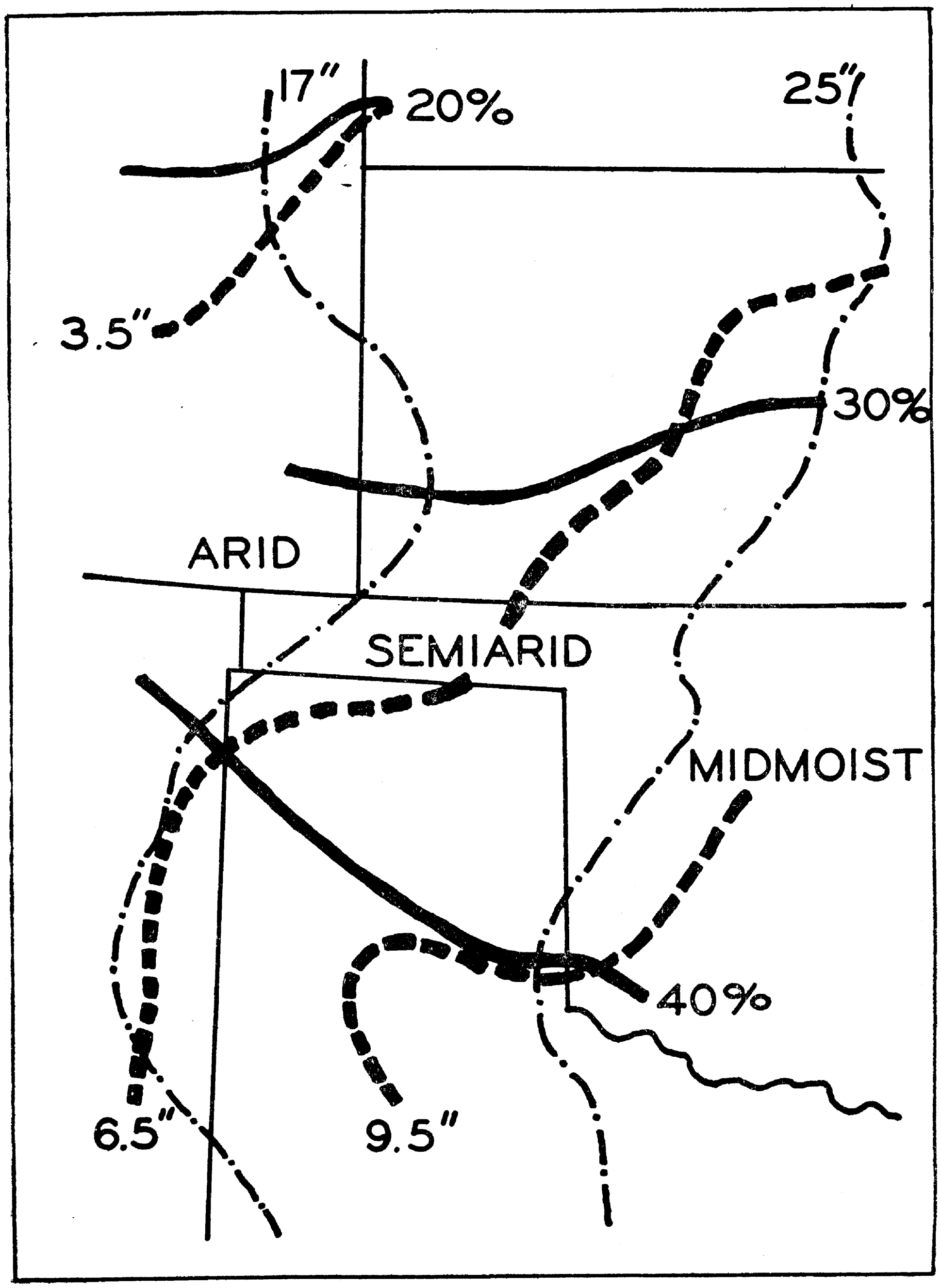

Fig. 2.—Moisture Supply Normally Between Date of Harvest and Date of Sowing Winter Wheat.

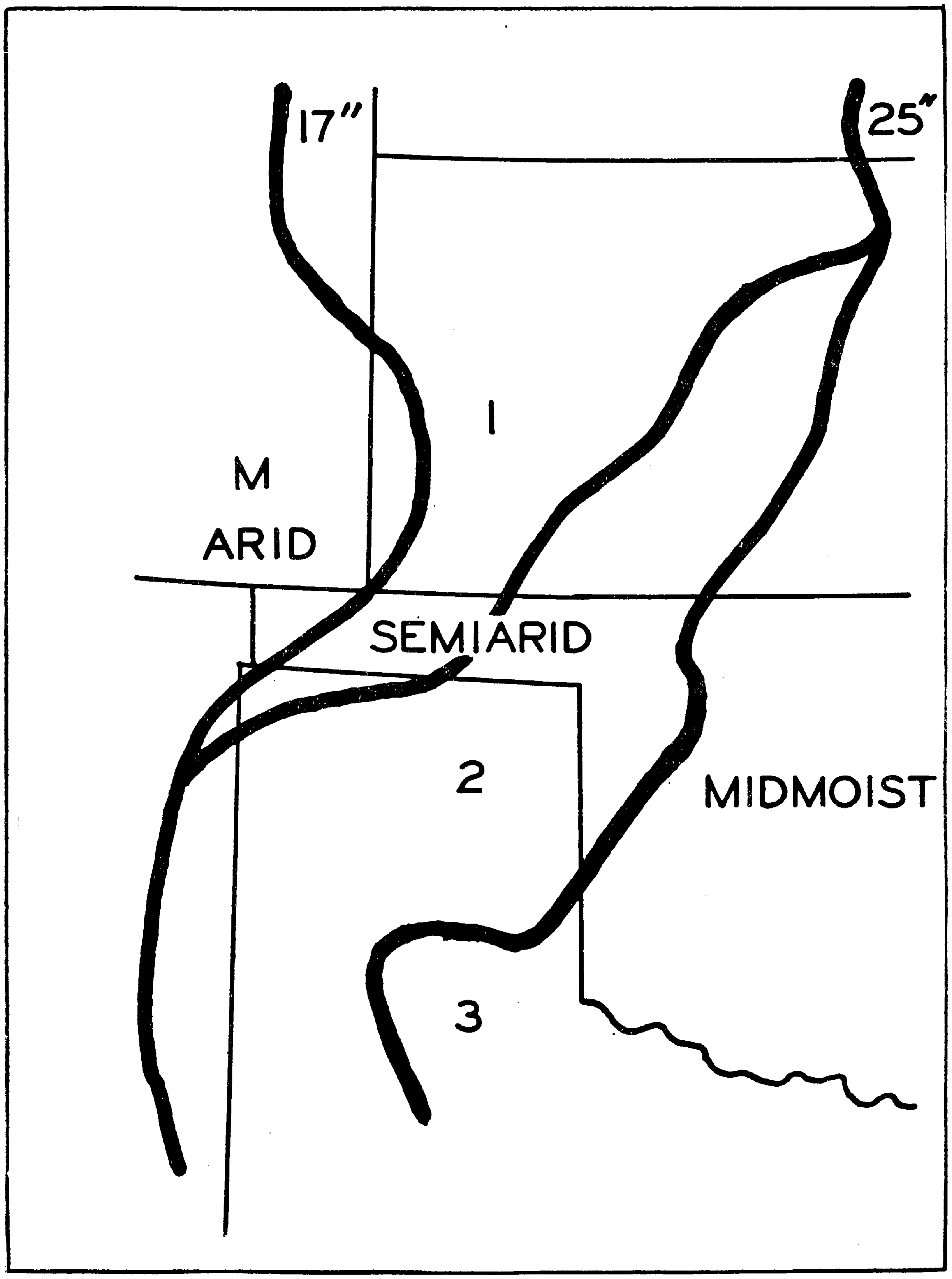

Fig. 3.—Zones of Distinctive Summer Fallow Behavior.

with the natural conditions. In area 2, summer fallowing is recommended as a variable practice embodied in a flexible rotation in which the sequence of both the adapted crops and summer fallow is largely guided by the progress of seasonal and moisture storage trends (7). This is consistent with the natural conditions. In area 3, summer fallowing is little practiced and not generally recommended. This, also, is consistent with the natural conditions. In area "M," grain farming is not recommended because of the recurring difficulty of maintaining a stable agriculture which has been experienced during periods of protracted drouth and low prices.

If the summer fallow practice is used according to its practical possibilities, it will not inject a needless erosion hazard into the cropping system. The ground cover needs for surface protection are consistent with the fertility maintenance needs of the soil, and with the physical water relation of the soil. My conclusion, therefore, is that where good crop residue management is combined with fallow practice it can be safely and profitably practiced within its climatic limitations. The apparent exception which may be noted is in the arid marginal zone, where crop failure wth or wthout summer fallow is sometimes so persistent that crop residues disappear in spite of the farmers' efforts to the contrary.

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The Veterans Agricultural Training Program in Efficient Crop Production

By G. J. DIPPOLD

Teacher Trainer, Veterans Agricultural Training Program

The veteran agricultural training program is a farming program. The farm, therefore, is used as a unit in dealing with all phases of the program. While efficient crop production is one of our major aims, it must be treated in relationship with the other aspects. Crop production, however, is our major concern before we can consider the problems of livestock production. Therefore, I shall call your attention to some of our major purposes before discussing efficient crop production as a challenge in the veterans program.

MAJOR PURPOSES OF THE PROGRAM

The veterans program is based upon a recognized human want, a craving or desire to be successful in life. These men have attained an age at which they are looking ahead in life. They have lost the wanderlust and are anxious to settle down for life. In the last four to six years most of these men have seen much of this country and many other parts of the world. In observing living conditions under a wide range of apparent efficiency, they seem unanimous in their opinions that our country is the best in the world. In this country, however, they wish to settle down and develop into successful farmers.

Wishing to be successful farmers alone will not guarantee them that they will be such. Most young farmers do not know definitely the variations so commonly prevailent in success. They are generally hazy, too, about the specific requirements essential to future success. In the Veterans Agricultural Training Program we hope to combine the basic urges of the individual veteran with a sound understanding of the needs for superior performance or attainment in agriculture. In guiding these trainees we accept the patterns of achievement made available to us by performance records of outstanding farmers within a community and by studies made by the colleges of agriculture. We want our programs to be realistic and true to life. We believe in the old proverb, "Half the fight is won when we know it can be done."

In every community are farmers who have differed greatly in achievements. Trainees should become sensitive to such variations and understand the reasons responsible. They should have some sound judgment in weighing the influence of the economic, biologic, physical and psychological forces which have moulded the lives of farm people who live within their local observation. They should discover the various opportunities which have existed in the past. Unless trainees understand the evolution of local types of farming they will not be able to develop the ideal type for the future.

Most veterans must make a beginning in the business of farming. During the war they were not ready to farm for themselves; or, if they were ready, many of them had to liquidate their holdings. The current high price level has stimulated the urge to get started. In the production of crops or livestock, early attention in the Veterans Agricultural Training program was given to the possibilities for each enterprise. In the constant search for opportunities to succeed, each enterprise had to be appraised so that activities related could be gauged appropriately. The basic philosophy behind the veterans program is that the program must succeed. A good beginning, then, is paramount to a successful end.

TABLE I.—Crop Indexes and Labor Incomes.

Crop Index	No. of Farms	Labor Income
Under 80	104	$ 74.
80-99	173	408
100-119	183	510
120-139	84	612
140-and over	38	977

Penn. Bul. 282, Table 12, pp. 14 (1932).

Farming is not only a business, but a mode of living. Living values obtained from food, fuel, and rent in normal times in this and many other states are worth approximately as much as the cash net farm income. These living values are stressed in our farming programs because not much capital is needed. Certainly no great risk is involved. Such a beginning, too, we believe, will lay a sound foundation for success in later years for a profitable business.

At the beginning of the veterans agricultural training program, considerable attention was given to the government allowance of $65 or $90 per month while the trainee was carrying out the educational program. Strong efforts have been made to create a professional attitude toward the educational opportunities and responsibilities of the program. Today a splendid attitude exists toward this latter point of view.

MAJOR OBJECTIVES OF THE PROGRAM

Many records by farm management investigators show that superior farmers achieve 20 to 30 percent above the average in crop production and as much as 50 percent above average in livestock production. These results are not a matter of fiction; they show what our better farmers actually have done, are now doing, and what they probably will do in the future. These records give us our starting point, our pattern to follow. The following studies support this point of view.

Table I shows that an appreciable number of Pennsylvania farmers were superior crop producers. In fact, some were 40 percent above average. Unfortunately, some farmers were 20 percent or more below the average. The great variation in labor income, from $14 for the poorest crop producers to $977 for the best, is closely related to variations in cropping efficiency. Attention, too, is called to the relatively large number of poor farmers—poor in crop production and in earning ability.

The Nebraska Experiment Station (Table II) also shows that crop production efficiency varies greatly, that some farmers are over 15 percent above average and some the same amount below average. The earning power, too, fluctuates greatly. The lowest labor income was $120 and the highest $675. Every trainee should be aware of such great changes and their causes.

TABLE II.—Crop Indexes and Labor Incomes

Crop Index	Labor Incomes
Under 86	$120
86-95	225
96-105	417
106-115	450
Over 115	675

Neb. Agri. Exp. Sta. Bul. 157, p. 18, Table 10 (1913).

TABLE III.—Crop Indexes and Labor Incomes.

Crop Index	Labor Incomes
86.8	—$500 or less
92.5	— 500 to $0
87.2	0 to $ 200
92.7	$201 to $ 400
103.5	401 to $ 600
106.2	601 to $1000
111.4	$1001 to $2000
124.8	$2000

Mo. Exp. Sta. Bul. 142, p. 19 (1916).

The Missouri Experiment Station (Table III) discovered that farmers with crop yields 25 percent above average earned $2000 or more, while farmers with crop yields 13 percent below average lost up to $500. Earning power, as usual fluctuates relatively much more than crop yields. Why should any trainee be satisfied with low crop production efficiency when such experiences are available to guide future planning.

Studies made during 1908-1928 by the Cornell Station (Table IV) prove that crop yields 30 percent or better than the average are possible. Farmers who have high crop yields invariably earn more than farmers with medium or low yields.

That small increases in crop yields are highly important has been shown by the Indiana Experiment Station in a ten-year study. It found that whenever yields are more than 10 percent above average compared with 10 percent below the average, the labor incomes were $900 higher. These results were obtained from land which averaged 38 bushels of corn, 22 bushels of wheat and 1.3 tons of hay per acre. (Ind. Bul. 452, p. 9; 1929-38.)

The U. S. Department of Agriculture in its 1938 yearbook, p. 99, has this concluding statement on the possibilities of increasing crop production efficiency: "Certainly, taken all together, all of these changes and improvements should have raised acre yields considerably—how much, it is difficult to say exactly—but **we believe an increase of 40 to 60 percent** would have been conservative. There can be but one explanation for the stubbornness with which acre yields have resisted the farmer's efforts to improve them; the natural productive capacity of the land has been deteriorating at a rate almost fast enough to offset all these improvements in soil and crop management. For every step ahead we have slipped back almost, if not quite, as far."

TABLE IV.—Crop Indexes and Labor Incomes.

	Labor Income		
Crop Index	1908	1918	1928
Less than 70	$ 77	$—424	$—618
70-79	103	—308	—230
80-89	453	—116	— 6
90-99	492	69	338
100-109	607	533	723
110-119	802	477	962
120-129	933	368	973
130 or more	1044	869	1244

Cornell Farm Economics, Table 4, p. 1488 (Feb., 1931).

TABLE V.—Livestock Efficiency and Labor Income.

Group	Hog Farms			Dairy Farms		
	Av. Live-stock Eff.	Av. Labor Income	Percent Income	Av. Live-stock Eff.	Av. Labor Income	Percent Income
1	59	−$316	−288.7	65	−$1,105	−889.
2	87	158	94.1	98	50	35.7
3	100	168	100.0	100	140	100.0
4	112	650	387.5	110	888	634.2
5	136	1,170	659.0	124	1,291	922.0
6	----	----	----	146	1,756	1,254.0
1% Efficiency=4.85% Income				1% Efficiency=8.59% Income		

Ind. Exp. Sta. Bul. 453, p. 21, 1930.

The chances for superior efficiency in livestock production are relatively greater than in crop production. For instance, for farmers with hog production as the major livestock enterprise, those who were 30 percent above average, earned $1170 labor income while the average farmer earned $168. On dairy farms those farmers having 46 percent above average efficiency earned $1756 compared with $140 for the average. Very poor efficiency, too, may be expected, as shown in Table V. Some hog producers earned more than six times the average, while some dairymen earned more than twelve times as much.

Whenever farming efficiency is measured by both livestock and crop production, records show that efficiency may be 40 percent above average or as much below. Of course, labor incomes will vary tremendously, as shown in Table VI. Superior performance is very important during hard times.

TABLE VI.—Farm Production Indexes and Labor Incomes.

Number of Farms	Average Production Index	Labor Income
22	62	$ −689
39	75	−508
43	84	−173
63	95	560
66	104	901
46	114	1,073
23	125	1,456
27	140	1,763

Cornell Ext. Bul. 242, p. 38, T. 32 (October, 1932).

Recently the Cornell Experiment Station[1] has shown that rates of production increased greatly during the past 20 years, especially during the war period. From 1919 to 1944 milk per cow advanced 33 percent, eggs per hen 87 percent, wheat 12 percent, beans 40 percent—all in New York. The general index of production for crops and livestock improved 36 percent. These advancements were made with a decrease of 16 percent in the index of labor requirements. Other states undoubtedly have shown similar progress. In Illinois, for instance,[2] corn production used 61 percent less labor and yields increased 78 percent. These achievements certainly must be recognized in planning an agricultural training program if future success is to be attained.

[1] Cornell Farm Economics, Sept. 1946, p. 3911.
[2] *Ibid.*, p. 3913.

There are many reasons why we accept such efficiency indexes as our guides. In the first place, they have a psychological effect upon trainees. Most trainees don't know their possibilities in producing farm products. Such indexes are challenging and give confidence. They develop a sensitivity to the factors related to the attainment of the high efficiency. In the second place, superior crop production efficiency becomes related to other factors indicative of farming success.

Again we go to records[3] which measure farming efficiency. Abundant experiences by farmers, under various economic conditions, within various types-of-farming, prove that farmers who are slightly above average in efficiency in (1) crop production (2) livestock production (3) labor usage (4) size of business and (5) marketing usually have labor incomes two to three times the average. Such outcomes are challenging indeed. Of course, we don't expect every trainee to achieve above average. We do maintain, however that the challenge to achieve in a superior manner is a worthy one.

Every farmer knows that superior crop production is a forerunner to efficient livestock production. Good yields of high quality crops, if produced by a veteran trainee, will start him on the right road to ultimate success. Good crop production affects the quantity and quality of livestock produced. It encourages growth in the size of business. Likewise it makes labor efficiency possible. Without an efficient cropping program the odds against success are great. A veteran trainee, therefore, must learn early how certain economic forces are closely related to the common problems of crop production.

SOME LEVERAGE VALUES

When a man uses a block and tackle, an automobile jack, or a wheelbarrow, he is able to lift heavy loads because he is using leverage power. Such leverages, however, are easily recognized. In farming, the economic leverages made available through small improvements are not easily recognized by most people. Small increases in crop production efficiency in themselves are usually not challenging. When farmers recognize the leverage power associated with these small improvements, they can and should adopt the power made available. In training veterans, it is our plan to capitalize upon such powers in order that maximum labor income may be obtained.

Trainees should be given experience in evaluating the leverage values of small improvements as shown in a local community. They should see how these improvements mean increased earning power, increased livestock efficiency, increased size of business, labor efficiency, etc. They should be sold on the general rule, that successful farmers do the usual things unusually well. Trainees should learn leverage values early in life in order to profit from them over a long period.

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[3] (a) Cornell Extension Bulletin 242, October 1932, page 58: The average labor income was $556, but farmers above average on five factors of success received $2,042.

(b) Pa. Bul. 282, 1932, p. 28: The average labor income was $447, but farmers who were 15 percent above average in efficiency on five factors earned $1,655.

(c) Ky. Bul. 253, p. 61: The average farmer earned $1,029 net farm income while farmers who were above average on four major factors of success earned $2,172.

(d) Ind. Bul. 452, 1940, p. 75: The average labor income was $604, but farmers ranking above average on five or six factors earned $1,624.

(e) Md. Exp. Sta. Bul. 405, 1936, p. 236: The high 25 percent earned $1,379 in labor income, the low 25 percent group $848 (loss) and the average farmer $222.

THE BASIS FOR LEVERAGE VALUES

The following experiment station studies, reflecting relationships between labor income and crop indexes, support the general statement that small improvements in crop production efficiency have relative great leverage value:

1. When Pennsylvania farmers raised their crop index, which is one factor of success, from low to average, or 85 to 102, the labor income rose from $263 to $447, or a 69 percent gain. **For each 1 percent increase in crop production index there was an increase of 3.49 percent in labor income.** (Pa. Exp. Sta. Bul. 282, 1932.)

2. Farmers who raised their crop index from the average to the highest, or from 103.5 to 124.8, or 20 percent, increased their labor income 300 percent, (2000—500=1500 or 300 percent). So **for every 1 percent improvement in crop index, they gained 14.56 percent in labor income. For every 1 percent increase in crop yields, Missouri farmers earned $72.81 more labor income.** (Mo. Bul. 142, 1916.)

3. When Minnesota farmers raised their crop index from 95 to 115, or low to high, or 21 percent, the values of their land rose from $40.18 to $77.46, a rise of $37.28 or 92.78 percent. So **1 percent gain in crop index gave a 4.4 percent gain in the value of land or $1.86.** (115—95=20: $77.46—$40.18= $37.28÷20.) (Minn. Agri. Exp. Sta. Bul. 309, 1934.)

4. Nebraska farmers increased their crop index from 86 to 115, low to high, and the labor income rose from $120 to $765, or a 462.5 percent gain. **For each 1 percent increase in crop index there was an increase of 14.01 percent in labor income.** In dollars, this would mean $13.88. (Neb. Agri. Exp. Sta. Bul. 157, 1913.)

5. Farm Credit Administration records show that as the crop production index is increased, the lower the percent of loans that are foreclosed. **By** increasing the crop index from 90 to 115, (115—90=25) or 27.7 percent, the number of foreclosures decreased from 25 to 5, or 80 percent. **For every 1 percent increase in crop index from 90 there was a decrease of 2.88 percent in foreclosures.** (80÷27.7) (Cir. No. E-4, Oct. 1938, Fig. 9, The Profitable Use of Farm Credit, Farm Credit Administration, Washington, D. C.)

6. The farmer who raised his crop index from 70 to 130, or from low to high, had an 85.7 percent improvement (60÷70) and with this improvement went an improvement of 653 percent, (2418—321÷321) in labor income. Thus by increasing his crop index 1 percent he gained 7.6 percent more labor income which meant, in this instance, $34.95.) (Ky. Bul. 347, 1934.)

7. New York farmers found that if they increased their crop yields from 75 to 100, or from low to average, their labor income would be increased $344 or from $306 to $650, which is an improvement of 112 percent. If 33 percent improvement in crop yields brought about a 112 percent increase in labor income, then only **1 percent improvement caused 3.39 percent increase in labor income.** The farmers who raised their yields from the lowest to the highest, 75 to 125 or 66 percent, raised their income from $302 to $755, a difference of $349, or 146 percent. They gained 146 percent increased labor income for only 66 percent increased yields, so **1 percent yield increase brought about 2.2 percent increase in labor income.** (Cornell Agri. Exp. Sta. Bul. 349, 1914.)

8. In South Carolina the average yield of cotton lint was 499 lbs. per acre compared with 659 lbs. per acre for the highest yield group of farmers. Labor incomes improved from $216 to $436 for the respective groups. On this basis, **each 1 percent improvement in yield was related to 3.14 percent increase in labor income.** S. C. Bul. 340, p. 24, 1940.)

Many other studies show similar relationships between crop indexes and labor incomes. The obvious conclusion is that every veteran trainee should concentrate all of his efforts to increase the crop index of his farm so long as it can be done economically.

In human and livestock nutrition, we often speak of hidden hunger. We have had too much starvation of this kind in this country. On the basis of this analogy, we can safely say that we have also had too much economic starvation in connection with crop production and with livestock production as well. It is our purpose to help the veteran trainees profit by these leverage values.

For many people, a slight improvement in crop production efficiency over the average in the community, or over the current practice on the home farm, would mean little. They are not aware of the potential possibilities for general all-around improvement in farming as a result of such seemingly small changes. To a young farmer, however, such implications should be challenging. Many of these men will make decisions that have lifetime effects. For instance, why should a veteran be allowed to purchase a farm with a low crop index unless the price paid discounts poor opportunities?

Spectacular changes in crop production efficiency would attract attention, for it is normal to be attracted by unusual things and events. Crop improvement, however, happens to change slowly. Some forces are at work reducing crop yields; others are building them up. A young farmer usually isn't aware of the gradual changes taking place on his own farm along these lines. His parents failed to recognize the same changes until it was usually too late. Because of this fact such parents, therefore, were poor teachers of their sons.

For many years, too, we have been enterprise minded instead of farm minded in our points of view toward our farm problems. Our college graduates are taught mostly by specialists. This is necessary under present college programs. Then, too, our farmers have also been enterprise minded, tending to shift special attention from one enterprise to another, without due regard to the interplay of production and management factors affecting the success of the entire farm, both in terms of immediate and ultimate needs. Is there any wonder then why young farmers today have special difficulties in learning to appreciate the tremendous implications of small increases in crop production efficiency.

We can make our oncoming farmers so sensitive to all vital factors affecting crop efficiency that they will react favorably at all times. Why should any farmer grow up immune to the ultimate destructive economic results caused by such undesirable factors as soil erosion, low yielding seed, fertility starvation, and second rate crops not adapted to local needs? Certainly we want our trainees to profit by all small improvements made possible and eagerly remain alert to current programs developed by colleges of agriculture, Soil Conservation Service, etc. By harmonizing farming methods with the basic principles of crop improvement we can assure a young farmer that reasonable success is certain.

Whenever trainees are taught to measure their progress in terms of community of state averages, as they must do whenever they evaluate crop production efficiency in terms of crop indexes, habits of comparing and contrasting are developed. The trainees are encouraged to evaluate their own farm situations in terms of what other farmers have. This procedure brings on further comparisons with the methods used by others.

SOME EDUCATIONAL PROCEDURES

In order to make maximum progress in attaining the ultimate and intermediate objectives of a sound training program, the following steps are being pursued:

1. Every trainee is directed and guided in making a home farm survey to determine the starting point in all farm enterprises, including crops. Home farm data are compared with community, county and State averages for evaluations.

2. Specific objectives are developed for the trainee's farm as a whole. Then objectives for each enterprise, including crop production, as a whole, and then objectives for each crop. Each objective must be justified by valid arguments. **Some suggestive objectives may be as follows:**

   1. To obtain $315 additional labor income by having crop yields above average. (Minn. Bul. 314. 1934.)
   2. To dodge farms, as a long-time investment, with crop indexes below 80. (Ia. Bul. 229, 1921.)
   3. To gain $916 by having crop yields in the upper third group in contrast with the lower group. (Ind. Bul. 453, 1929-38.)
   4. With a crop index of 125 to secure operators earnings which are approximately three times as great as those obtained with a crop index of 75. (Ky. Bul. 347, 1934.)
   5. To avoid trying to farm land with a crop index of 70 or lower. (Cornell Bul. 142, 1910.)
   6. To increase the average total carrying capacity of pastures 142 percent. (Mo. Exp. Circ. 370, 1937.)
   7. To obtain cotton yields 32 percent above the average. (S. C. Bul. 340, 1942.)
   8. To manage soil so that its capacity to produce will be increased 10 percent. (Ohio Bul. 175.)

3. When both the starting point and objectives have been determined, attention is given to the selection of the relatively most important jobs to teach. Each job must make maximum contribution toward the attainment of the objectives. No general crop production problems are discussed, only those having direct bearing upon the success of the program. Meanings and understandings of each job are developed by class and personal discussions, making many relationships between the jobs and the objectives, and with the home farm conditions.

4. Improved practices are finally developed for actual application on the trainee's farm. These practices are put on a calendar for seasonal attention. In the final analysis, three important steps of learning are followed: (1) developing an interest in a sound crop production program; (2) developing an understanding of related information; and (3) applying proper practices.

In order that maximum progress may be made in the Veterans' Agricultural Training Program, instructors are always anxious to use all new knowledge developed by various investigators. The success of the program depends very largely upon the availability of such aid. It is obvious, therefore, that leadership in experimental work is deeply appreciated.

Irrigation Hazards

By H. B. CORDNER
Horticulturist, Vegetables; Oklahoma Agricultural Experiment Station

In most sections of Oklahoma the rainfall during the growing season does not supply sufficient moisture for the crops, and in all sections this rainfall may be poorly distributed. Shortages of moisture during critical periods in the life of the crop greatly limit yields and in turn reduce the net income to the grower. Under favorable conditions, a water supply for irrigation may be developed and used to good advantage in crop production by employing that same good judgment and common sense that makes other farming operations pay dividends. Under less favorable circumstances, it may be impossible or difficult to utilize irrigation water in crop production.

In some areas in Oklahoma it is impossible to develop an adequate supply of water for irrigating crops. In other sections the cost may be too great as an individual enterprise. However, before we give up on this score we should consider the elaborate systems of canals, ditches, and drains that have been constructed through coöperative effort by farmers in some of the Western states.

Before we get too far into this discussion on irrigation, we should make one point clear. There are several factors in the environment of a plant or crop which regulate or control growth, and the substitution of one for the other is impossible. In brief, it is not possible to substitute irrigation water for soil fertility, for an agreeable temperature, or for good cultural practices. If the investment in irrigation water is to pay, the water may be applied to a crop which can reasonably be expected to yield a good acre income and this crop must be grown in a good soil and given good cultural treatment.

The soil should be naturally fertile or adequately fertilized and supplied with organic matter. Irrigated crops can effectively utilize more fertilizer or plant nutrients than those not irrigated. Good sub-soil drainage is an essential characteristic of irrigated fields. Some of the fine textured soils found in arid regions are not adapted to irrigation. With a high sodium and alkali content, these soils are not porous enough to allow proper penetration and drainage of the water applied in irrigations.

Artificial drainage may be a necessary complement to the irrigation system. In most irrigated sections it is natural for bogs to be formed in low places and localized areas may become water logged in association with perched water tables. Water logging of fields adjacent to irrigation canals is common in areas where the surface soil is porous. The installation of artificial drainage for farm land is an expensive operation. Drainage channels range five feet to eight feet in depth and are made at 500 to 1,000 foot intervals, depending on sub-surface conditions. At additional expenses, tile is sometimes used to eliminate the open drainage ditches.

The water from surface streams, ponds, or lakes, and from underground supplies, may be of questionable quality for irrigation purposes. Some streams in Oklahoma may have 2500 to 5700 ppm of dissolved solids and are unfit for use on farm land. However, it is difficult to set a limit for the soluble solids content of irrigation water, since the kind and ratio of certain minerals in the water (e. g. calcium to sodium) and the composition and drainage of the soil are determining factors. The composition and quality of the water in Oklahoma streams may vary from one week to the next according to the area or watershed that contributes to the flow.

Irrigation water has been used to a good advantage in vegetable growing at the Oklahoma Experiment Station Farm at Perkins. Many crops have been grown with wide variations in the irrigation program to discover the most economical and effective way to apply water to the growing crops.

Irish potatoes respond very well to the additional water supplied by the irrigation supplement. As an average for four years, the irrigated crop averaged 223 bushels of No. 1 potatoes per acre, an increase of 73 percent over the unirrigated potato crop. Generally, four to six acre inches of irrigation water in two to four irrigations are sufficient; and, in terms of increased yield, these irrigations individually were worth 12 to 48 bushels of potatoes. The best time to irrigate potatoes is during the period from May 15 to June 10. A uniformly high moisture supply is desirable during this time while the tubers are developing, and the quality of the crop may be greatly lowered by delaying the first irrigation or by irregular irrigations. Second growth (knobby potatoes) and growth cracks result when the soil moisture supply shifts from low to high. Late irrigating, within a week or two of harvest, may prove harmful. Two weeks should be allowed for the soil to get in shape for harvesting the crop. Rain, coupled with irrigation late in the season, may delay harvesting and induce decaying of the tubers.

Irrigated tomatoes produced 49 percent more tomatoes than those not irrigated, with a four-year average of 4.56 tons of marketable tomatoes per acre. Irrigation water is not a remedy for blossom drop, but it can be used to grow large vines and in this way increase the total fruit produced. Two to four irrigations during the preharvest period will develop a good plant, while two to three applications of water during the harvest season keeps the foliage up to provide shade for the fruit. Sunscald and blossom end rot were materially reduced by proper use of irrigation water on tomatoes, while fruit-set and yields were greatly reduced by irregular and light applications of water.

Sweet corn responded most to irrigations made during the time the ears are developing (post-silking period). Pre-silking applications increased plant growth to a great extent (grew more stover), but increased the yield of green ears very little. Irrigated sweet corn in a four-year test averaged 4.71 tons of marketable ears per acre. This represented a 46 percent increase over the unirrigated crop. Ordinarily, about three irrigations were sufficient to induce good production in this crop.

The cantaloupe crop, which matures during July and August, is greatly benefited by irrigation water. In some seasons, the production of marketable fruits was increased by 400 to 500 percent. As an average for four years, irrigated cantaloupes produced 388 crates of marketable fruits per acre, with an average increase in production of 116 percent over unirrigated cantaloupes. Irrigating greatly improved the size and quality of the fruits of this crop.

These examples of improvement of crop yields by irrigating could be extended, but the above are sufficient to demonstrate that the natural moisture supply in Oklahoma is not sufficient for maximum production in crops.

There is a need for some pioneering in the field of irrigation in Oklahoma. This problem should be approached in an intelligent manner with some knowledge of the quantity of water required and how to use a limited amount of water effectively in crop production. In areas where the irrigation supplement is needed most, the hazards of quality of water and soil conditions are greatest. However, the success attained by farmers in irrigated sections of other states indicated that these are not entirely insurmountable. There are supplies of water in many sections of Oklahoma which could be used for irrigating crops, and a good dividend awaits the grower with sufficient enterprise to develop and utilize this natural resource.