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Kansas Agricultural Experiment Station

SEPTEMBER, 1927 BULLETIN 242

AGRICULTURAL EXPERIMENT STATION
KANSAS STATE AGRICULTURAL COLLEGE

Manhattan, Kansas

ALFALFA PRODUCTION IN KANSAS

PRINTED BY KANSAS STATE PRINTING PLANT
B.P. WALKER, STATE PRINTER
TOPEKA 1927
12-440

Historical Document
Kansas Agricultural Experiment Station

TABLE OF CONTENTS

Historical Document
Kansas Agricultural Experiment Station

FIG. 1.—The side delivery rake, an excellent piece of equipment for making good alfalfa hay.

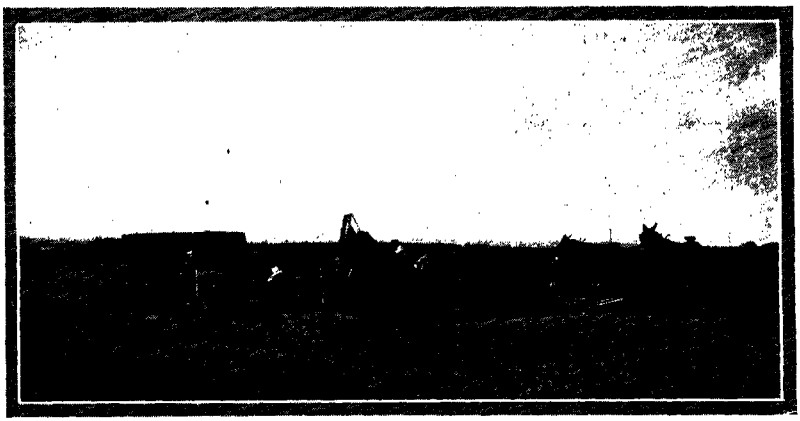

FIG. 2.—Bailing hay from the windrow, one of the most economical methods under proper conditions.

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Kansas Agricultural Experiment Station

ALFALFA PRODUCTION IN KANSAS [1]

R. I. THROCKMORTON AND S. C. SALMON

In many respects alfalfa is the most important crop grown in Kansas. The total value is, of course, greatly exceeded by wheat and corn, but there is no other crop which is so essential in relation to the live-stock industry, so useful to rotate with other crops, or so valuable in proportion to the cost of production. Alfalfa undoubtedly will, in the future as in the past, play an important part in any system of farming that may be considered permanent.

KANSAS AS AN ALFALFA-PRODUCING STATE

Kansas ranks second in the number of acres devoted to alfalfa, and fourth in total production, according to figures collected by the United States Department of Agriculture in 1925. Nebraska ranks first in acreage and second in total production, and California is third in acreage and first in total production. The relative importance of various states in the production of this crop and the average yield per acre are indicated in Table I.

TABLE I.—Acreage, total production, and average yield per acre of alfalfa for the 10 leading states in 1925.

STATE.	Acres.	Total production, tons.	Average yield per acre, tons.
Nebraska	1,300,000	3,016,000	2.32
Kansas	990,000	2,257,000	2.28
California	971,000	4,078,000	4.20
Colorado	870,000	2,001,000	2.30
South Dakota	754,000	1,078,000	1.43
Idaho	709,999	2,694,000	3.80
Montana	604,000	1,208,000	2.00
Utah	495,000	1,732,000	3.50
Wyoming	400,000	880,000	2.20
Michigan	392,000	840,000	2.05

1. Contribution No. 171 from the Department of Agronomy.

Historical Document
Kansas Agricultural Experiment Station

TREND OF ALFALFA PRODUCTION IN KANSAS

Although the acreage of alfalfa in Kansas is relatively high, there has been a general decline during the last twelve years. Thus, in 1915 there were 1,360,000 acres as compared with about 890,000 in 1926.[2] This represents a decline of more than 465,000 acres, or of about one-third of the 1915 acreage. Figure 3 shows this decline graphically.

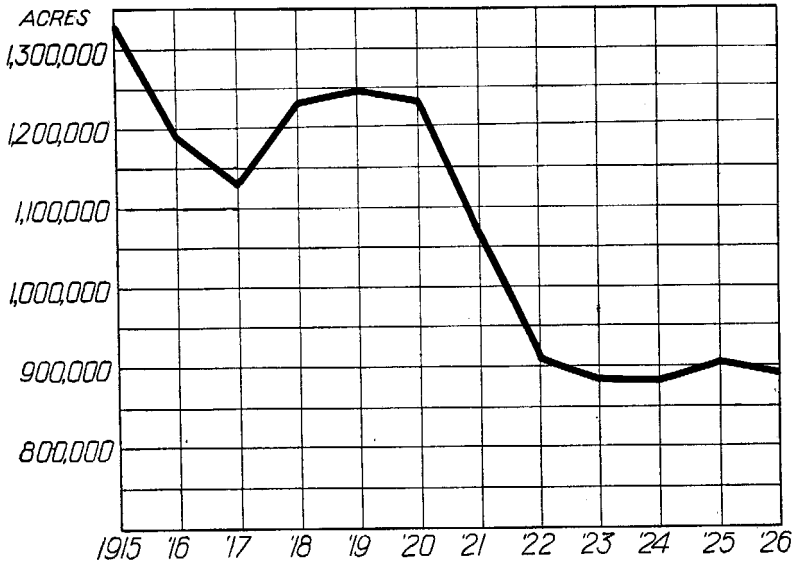

FIG. 3.—Graph showing the trend of alfalfa acreage in Kansas, 1915 to 1926.

WHY THE ALFALFA ACREAGE HAS DECLINED

Considering the value of the alfalfa crop to the state, this decline in acreage of more than one-third calls for an explanation. It will be seen from figure 3 that the decrease has taken place largely during two periods; namely, from 1915 to 1917, and from 1920 to 1922. The first period of decline was probably due to high grain prices during the war, which induced many farmers to break up their alfalfa for grain crops. The decrease during the second period is not so easily explained, but is known to be due, in part at least, to insects and plant diseases and unfavorable seasons. The pea aphid, for example, was responsible for the loss of perhaps one hundred thousand acres in the spring of 1921. Other important factors are decreased fertility of the soil and winterkilling. Diseases, insects,

2. Report Kansas State Board of Agriculture, 1926.

Historical Document
Kansas Agricultural Experiment Station

and soil fertility are discussed later in this bulletin. A brief discussion of winterkilling seems to be desirable here.

Winterkilling of Alfalfa

One of the serious difficulties in growing alfalfa in northern states is winterkilling. This is generally due to low temperatures during the winter, when the ground is not covered with snow. In some

FIG. 4.—Winterkilled plants less than one year old—a condition very common in April and May, 1925. The crowns were girdled at the ground.

cases alfalfa is killed by ice sheets over the fields or by heaving, which is a result of alternate thawing and freezing in the early spring.

Very little difficulty of this sort has been observed in Kansas until very recently. In the past few years numerous complaints have come to the Agricultural Experiment Station with regard to maintaining stands apparently because of winterkilling or winter injury.

Historical Document
Kansas Agricultural Experiment Station

In many cases the difficulty seems to have been due to the use of seed imported from countries having a milder climate, as, for example, South Africa. In other cases the trouble seems to have been due to diseases or to a combination of winter injury and diseases. Information concerning the subject is very meager and the problem is being investigated. In the meantime, it may be said with confidence that the use of Kansas-grown seed from fields that have been established for a number of years will reduce losses of this sort to a minimum, and that no one should hesitate to plant alfalfa in Kansas because of winterkilling or disease if good seed of an adapted variety is used. Some plants killed by low winter temperature are shown in figure 4.

THE EFFECT OF ALFALFA ON OTHER CROPS

The value of alfalfa in maintaining yields of other crops is well illustrated by its effect on the yield of corn and wheat in experimental tests on the Agronomy Farm of the Agricultural Experiment Station, Manhattan, Kan.

In one experiment, corn grown continuously is compared with corn grown in rotation with wheat, and with corn grown in rotation with alfalfa and wheat. In another experiment, the effect of alfalfa on the yield and protein content of wheat grown in rotation with it is studied. The effect of the alfalfa on the yield of corn is shown in Table II, and on the yield and protein content of wheat in Table III.

TABLE II.—Effect of alfalfa on the yield of corn.

(Manhattan, Kan.)

CROPPING SYSTEM.	Average yield per acre, 1911 to 1925.
	Bushels.
Corn continuously	20.0
Corn, corn, wheat	25.7
Alfalfa (4 years), corn, wheat, wheat	31.2

Historical Document
Kansas Agricultural Experiment Station

TABLE III.—Effect of alfalfa on the yield and protein content of wheat.
(Manhattan, Kan.)

CROPPING SYSTEM.	Average yield per acre, 1911 to 1925.	Average per cent of protein, 1916 to 1925.
	Bushels.	
Wheat grown continuously	15.3	14.2
Corn, corn, wheat	14.4	12.7
Alfalfa (4 years), corn, wheat, wheat	19.8	15.1

It is evident that alfalfa in the rotation has a marked influence on the yield of corn and on the yield and protein content of wheat. The net result is an increase of about 11 bushels per acre of corn, 4.5 bushels per acre of wheat, and nearly 1 per cent in the protein content of the wheat, (Tables II and III.) These results emphasize the value of having alfalfa in the rotation wherever possible.

Alfalfa tends to increase the yield of the crops which follow it, largely because it has deep roots and like all legumes is able to secure nitrogen from the air. Its deep roots enable it to penetrate the subsoil and secure food at greater depths. Some of this plant food is left near the surface by the decaying alfalfa roots, where it later becomes available to corn, wheat, and other crops. The rotation of other crops with alfalfa also aids in the control of weeds, insects, and plant diseases.

Comparative yields of wheat obtained in certain rotations in 1928, presented graphically in figure 5, further emphasize the influence of a legume on crop yields.

CROPS TO FOLLOW ALFALFA

It is a mistake, however, to expect an increase every year in the yield of crops grown immediately after alfalfa. As a matter of fact, the alfalfa often reduces the grain yield of the first crop following it. This seems to be due to the low moisture content of the soil and to the large quantity of available nitrogen which the soil contains and as a consequence, the very rank, vigorous growth of the crop grown after it. The result may be lodging if the following crop is wheat and the season a wet one, or burning if the season is dry.

On good soil in eastern Kansas where the rainfall is usually ample, corn is one of the best crops to grow after alfalfa; in central Kansas, kafir is usually better. An early-maturing variety, such as Pink or Dawn kafir, will usually prove most satisfactory. Oats may fre-

Historical Document
Kansas Agricultural Experiment Station

quently be used to good advantage to follow alfalfa in eastern and central Kansas.

It is often difficult to secure a stand of alfalfa immediately after breaking alfalfa sod because the old plants have used all the moisture and left the soil in poor condition for the new plants. Where-

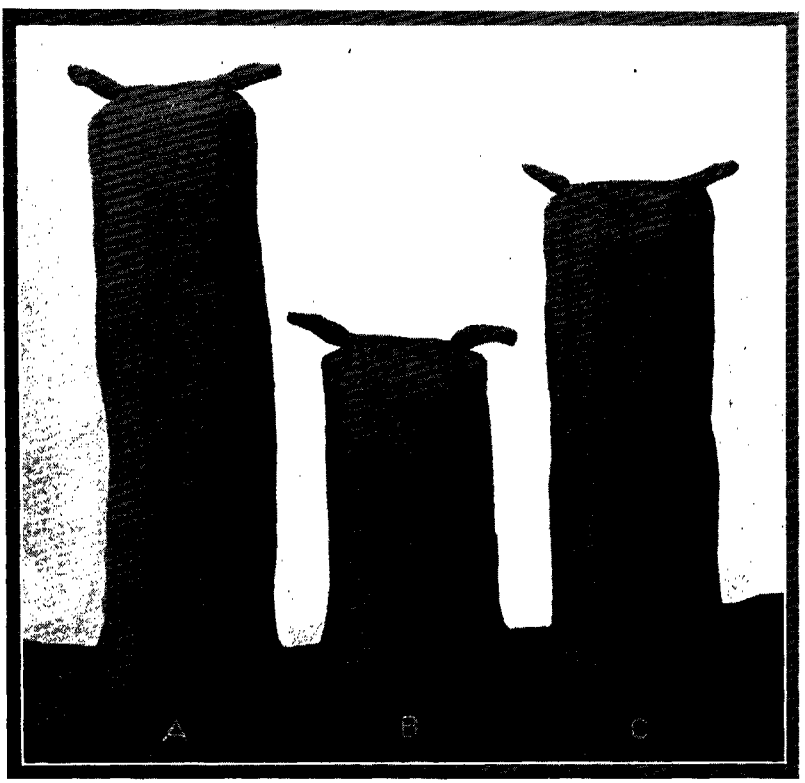

FIG. 5.—Wheat harvested from one-tenth-acre plats, 1922. Treatments: (A) Alfalfa, corn, wheat rotation; yield, 34.4 bushels per acre. (B) Corn 2 years, wheat 1 year; yield, 18.8 bushels per acre. (C) Corn, cowpeas, wheat rotation; yield, 26.7 bushels per acre.

ever possible it is best to grow other crops for a period of four or five years before reseeding to alfalfa.

THE EFFECT OF ALFALFA ON SOIL FERTILITY

Although alfalfa secures nitrogen from the air and increases the yield of the following crops, it should not be assumed that it always increases the fertility of the soil. On the contrary, it may have the opposite effect.

Historical Document
Kansas Agricultural Experiment Station

When alfalfa is grown for hay and the hay removed and sold from the farm, very little plant food is added to the soil and large quantities are removed. Thus four tons of alfalfa remove from the soil nearly 19 pounds of phosphorus, 193 pounds of potassium, and 86 pounds of calcium. In other words, it uses about twice as much phosphorus, five to six times as much potassium, and fifteen to twenty times as much calcium as equivalent yields of other farm crops. While the soils of Kansas are well supplied with potassium, they are, as a rule, low in phosphorus, and some of the soils, especially in eastern Kansas, are deficient in calcium. Four tons of alfalfa also remove 200 pounds of nitrogen, but this is of little importance, since usually this nitrogen has been obtained from the air.

CALCIUM OR LIME REQUIREMENTS OF ALFALFA

Alfalfa and many other leguminous plants such as sweet clover and red clover are very sensitive to acid soils. The nitrogen-fixing bacteria, which develop in the nodules of the roots of these plants, require a neutral or slightly alkaline medium in which to grow and develop. Acid soils not only retard the growth and work of these bacteria, but actually destroy most of them. To correct this condition it is necessary to apply lime.

A deficient supply of lime is indicated by a short weak root system and yellowish-green leaves. The plants have small weak crowns and low-yielding capacity. The stand soon becomes very thin, the alfalfa plants being replaced by weeds and grass.

The value of lime in helping maintain a stand of alfalfa on acid soils is well illustrated by experimental results secured in Allen county, shown in Table IV.

The alfalfa was seeded in the fall of 1914 on land which had received various treatments. It will be seen that by 1920 the alfalfa had disappeared where no lime had been applied. Where lime had been used the stand was retained until the fall of 1923, when the experiment was discontinued. It will be noted that the use of manure did not overcome the deficiency in lime.

Where Lime Is Needed.--The soils of Kansas vary greatly in their lime content. Those in the western part of the state have a high lime content while in eastern Kansas acid soils are common. Upland soils are most likely to be deficient in lime.

About 90 per cent of the upland soils in the eastern three tiers of counties in Kansas are acid. Acid soils, however, are not limited to this area and may be found as far west as the central part of the

Historical Document
Kansas Agricultural Experiment Station

TABLE IV.—Effect of lime on the yield of alfalfa.

(Experimental tests in Allen county, Kansas.)

TREATMENT.	Yield in pounds per acre.									
	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	Average.
None	1,066	1,705	4,969	2,138	1,625	0	0	0	0	1,278
Manure	2,256	3,345	8,969	3,864	2,835	0	0	0	0	2,363
Lime	1,569	2,865	6,699	2,824	3,442	7,042	4,040	3,233	3,010	3,858
Lime and manure	3,238	4,545	9,134	4,388	6,701	9,150	5,840	5,306	5,413	5,968

Historical Document
Kansas Agricultural Experiment Station

state. (Fig. 6.) They are known to occur in Harper, Kingman, Lincoln, and all counties farther east. Because of the wide distribution of acid soils, it is advisable to have lime requirement determinations made when there is any doubt about the need for lime.

Determination of Lime Needs of the Soil.--Since special apparatus and certain chemicals, as well as technical information, are necessary for an accurate determination of soil acidity, it is advisable under most conditions to have the test made by the county agricultural agent or the Department of Agronomy of the Agricultural

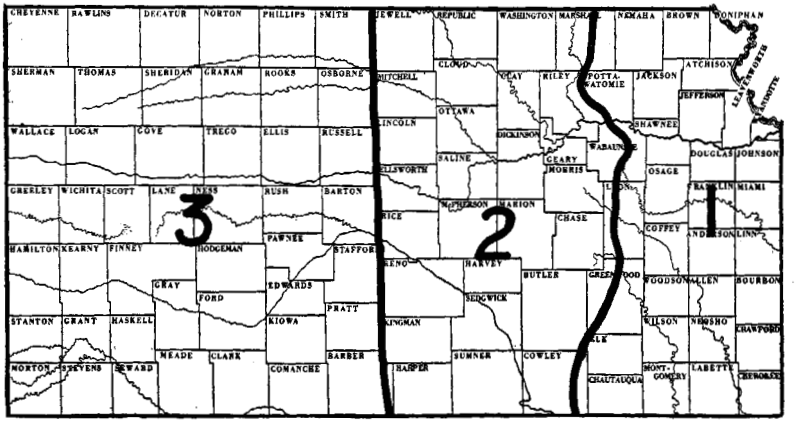

FIG. 6.—Map of Kansas showing where lime is needed for alfalfa. (1) Section of the state in which most upland soils need lime. (2) Section in which upland soils that have been heavily farmed for a long time may need lime. (3) Section in which soils do not need lime at the present time.

Experiment Station at Manhattan. Such tests are made upon request and without charge. As a rule, it is advisable to take several samples of soil from a field because of the wide variation over a given area. These samples should be representative, should be taken to a depth of about six inches, and each sample should consist of about one pint of soil. Each sample should be numbered so the results of the test can be readily applied to the field.

The Form of Lime to Use.--Crushed limestone is the most common and widely used form of lime for agricultural purposes. This form of lime is the most practical under Kansas conditions because of the numerous outcrops of high-grade limestone that are found in practically every section of the state where acid soils are known to exist.

Historical Document
Kansas Agricultural Experiment Station

Limestone must be finely ground if best results are to be obtained. It should be fine enough to pass through a ten-mesh sieve and about 40 per cent should pass through a one-hundred-mesh sieve. This finely ground rock is quickly available, while coarser particles are very slow to take effect. The coarse material will eventually be of value and the ultimate effect beneficial, but it is doubtful if it pays to apply coarsely ground limestone. Crushed limestone should always be purchased and used on the basis of its fineness as well as purity. Mechanical and chemical analyses of samples of limestone will be made by the Agricultural Experiment Station on request.

Other forms of lime include burned or caustic lime, hydrated lime, and air-slaked lime. These forms are much more expensive under practically all conditions than finely-ground limestone, and since they have no significant advantage over the latter there is no reason why they should be used.

Rate to Apply Lime.--The rate of application depends upon the degree of acidity of the soil and the fineness of the limestone. An application varying from one to three tons per acre has been found necessary to neutralize the acidity of most of the soils of eastern Kansas. This wide variation is a very good reason why lime should not be applied without first knowing whether or not the soil is in need of lime, and if so, how much. The average rate of applying pulverized limestone in Kansas is two tons per acre.

When to Apply Lime.--Since the beneficial effects of lime are brought about by close contact between the soil and lime fragments, it is necessary for best results to apply the lime when it can be thoroughly worked into the soil. Lime goes into solution rather slowly, and its movement down through the soil is not rapid enough to be of any great value to the plants, and most of the lime which is dissolved and worked down by drainage water is carried below the surface of the soil. For these reasons surface application of lime to old stands of alfalfa or to newly seeded alfalfa cannot be expected to give satisfactory results. Since lime gradually works downward into the soil it should never be plowed under.

It is preferable to apply the lime at least a month before seeding. When alfalfa is seeded in the fall, the most successful plan is to plow the land early, disk it once and apply the lime immediately after. Additional cultivation during July and August will thoroughly incorporate the lime with the surface soil. Where alfalfa is seeded on disked corn or sorghum land it is desirable to apply

Historical Document
Kansas Agricultural Experiment Station

the lime the spring previous to seeding the alfalfa. Fall-plowed land that is to be seeded to alfalfa in the spring may have the lime applied during the winter months.

Method of Applying Lime.--Lime may be applied with either a lime spreader or manure spreader or by hand with a shovel. The lime spreader distributes the lime more evenly, and where a large area is to be covered will prove more satisfactory and eventually more economical. The ordinary type of end-gate spreader may be used successfully. When a manure spreader is used, the bottom should be covered with manure or fine straw and the lime placed on top at the proper thickness to spread the desired quantity.

FERTILIZERS FOR ALFALFA

The statement that alfalfa enriches the soil is made so often that it is a common belief that a field well established in alfalfa will take care of itself as far as plant food is concerned. This is not the case, because alfalfa, like every other crop, secures a large part of its plant food from the soil.

Fortunately the soils of Kansas are well supplied with potassium, but nearly all are low in phosphorus, and since alfalfa requires this element in fairly large quantities, it is not surprising that applications of this element greatly increase the yield. Some of the soils of the state are already so low in this element that alfalfa is making but a poor, sickly growth on them and is unable to compete with weeds and grass. This has been found to be true especially in the eastern part of the state.

VALUE OF PHOSPHORUS AS A FERTILIZER

During the past 15 years a large number of experiments have been conducted in the eastern part of Kansas to determine the fertilizer requirements of alfalfa. Experiments have also been conducted at Hays on bottom land and at Garden City on irrigated land. The fertilizers have had no appreciable influence on the yield at either of the western points, but experiments in eastern Kansas have shown very profitable returns, especially from the use of phosphorus. Some of these results are given in Table V.

The cost of the fertilizer applied in the tests, the results of which are given in Table V, was about $1.85 per acre. It is evident from the results secured that each dollar expended for fertilizer resulted in an increased return varying from $2 to $7 per acre. In addition

Historical Document
Kansas Agricultural Experiment Station

TABLE V.—Effect of phosphorus on the yield of alfalfa hay.

COUNTY.	Duration of experiment (years).	Yield in pounds per acre.		
		Treatment.		Average annual increase from use of phosphorus.
		No phosphorus.	Acid phosphate.	
Riley	16	4,796	5,454	658
Allen	9	3,736	5,584	1,848
Butler (upland)	8	5,042	6,062	1,020
Butler (bottom land)	5	6,411	8,512	2,101
Nemaha	4	3,989	5,552	1,563
Jackson	2	2,917	4,109	1,192
Greenwood	5	6,519	8,129	1,610
Labette	5	3,961	6,009	2,048
Morris	3	4,507	5,913	1,406

to the increased yields, the phosphorus aided very materially in maintaining the stands against weeds and grass.

Where to Use Phosphorus.--Phosphorus can be profitably used in alfalfa production on most of the soils in the eastern two-fifths of the state, as shown in figure 7, regardless of whether the soil is upland or bottom land. On many of these soils alfalfa can be grown successfully without phosphorus, but it will increase the yield very profitably and will help maintain the stand. The poorer upland

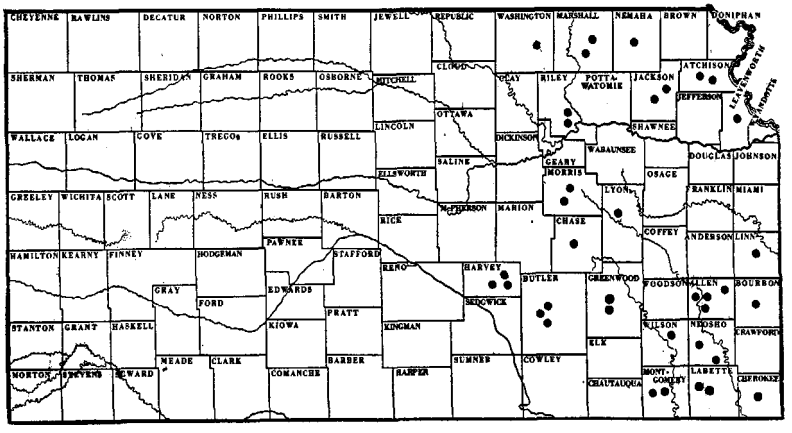

FIG. 7.—Map of Kansas showing where phosphorus has been used successfully on alfalfa. Each dot on the map represents the approximate location of an experiment where phosphorus has given a profitable return on alfalfa.

Historical Document
Kansas Agricultural Experiment Station

soils and many of the bottom land soils that have previously grown alfalfa for many years will not produce paying crops without the addition of phosphorus. When the soil is low in nitrogen and manure cannot be applied previous to seeding, it is advisable to use a fertilizer containing some nitrogen as well as phosphorus, such as a 2-12-0 or 2-14-0 at seeding time.

The Form of Phosphorus to Use.--Phosphorus may be purchased in the form of raw rock phosphate, steamed bone meal, or acid phosphate. The raw rock phosphate is very slowly available and therefore must be incorporated in the soil with some form of organic matter as manure, or a green manure crop, previous to the time of seeding the alfalfa. It cannot be used successfully after the alfalfa is established.

Steamed bone meal is more readily available than rock phosphate and is a fairly good form to use at the time of seeding. It is not readily soluble, however, and for this reason should not be used for top-dressing an established stand.

Acid phosphate is readily available and for this reason is the best form for general use on alfalfa land. It is a satisfactory kind to use at the time of seeding and is the only kind recommended as a surface dressing on an established stand. Contrary to popular opinion, acid phosphate will not make the soil acid.

When to Apply Acid Phosphate.--For a new stand of alfalfa, acid phosphate should be applied just previous to seeding or at the time of seeding, at the rate of about 150 pounds per acre. The application may be made with a fertilizer drill, a combination fertilizer and alfalfa drill, a lime sower, or an old grain drill. After the first year it may be applied to best advantage as a surface dressing in the spring at about the time growth starts. If applied annually the rate should be about 150 pounds per acre. There is no reason, however, why the rate of application should not be doubled and the fertilizer applied every second year.

THE USE OF BARNYARD MANURE

Barnyard manure is an excellent fertilizer to use before seeding alfalfa and as a surface dressing on an established stand. Since manure carries a fairly large quantity of nitrogen it is especially valuable when applied on relatively poor soils previous to seeding. When so used it is desirable to apply it to the crop preceding the alfalfa so that it may have an opportunity to decay and the weed seed may germinate before the alfalfa is seeded. If manure is

Historical Document
Kansas Agricultural Experiment Station

applied just before seeding it should be well decayed, otherwise the seed bed will tend to be too loose and open. It is an excellent practice to apply manure as a top dressing on young alfalfa in the fall after seeding. Such an application will serve as a winter protection to the young plants, will help hold snow on the field during the winter, and will hasten growth the following spring. On well-established stands manure can be used with profit on practically all soils of the eastern half of Kansas. Table VI shows the effect of manure on the yields of alfalfa in experimental tests at Manhattan.

It is evident from the data presented that the application of manure to alfalfa is very profitable. These increased yields amount to from $3.50 to $4.50 for each ton of manure, depending upon the rate and method of application.

TABLE VI.—Effect of manure on the yield of alfalfa.

(Manhattan, Kan.)

TREATMENT.	Yield in pounds per acre, average for sixteen years.	Increase due to manure.
		Pounds.
ALFALFA IN ROTATION:		
No treatment	4,796	.....
Manure, 5 tons per acre every 3 years	5,790	994
ALFALFA CONTINUOUSLY:		
No treatment	2,790	.....
Manure, 2½ tons per acre annually	4,357	1,567
Manure, 5 tons per acre annually	4,757	1,967

PREPARING THE SEED BED FOR ALFALFA

Possibly more failures with alfalfa are due to a poor seed bed than to any other one factor. The essential conditions are a firm, well-settled soil finely pulverized and mellow to the depth to which the seed is to be planted. Such a seed bed enables the seed to take up moisture rapidly and germinate quickly. If, on the other hand, the soil is loose and open it will not retain moisture in the surface layer, the seed will not come in close contact with the soil particles, and germination will be very slow and uneven.

The best implements to use in firming the ground for alfalfa are the cultipacker (fig. 8), the subsurface packer, and the corrugated roller. It is frequently advisable to use a packer both before and after seeding to get the best results, especially when the soil is very loose.

Historical Document
Kansas Agricultural Experiment Station

The soil should also contain an abundance of available plant food and moisture. This requires time and cultivation. Early preparation of the seed bed is, therefore, desirable. Weeds and volunteer grain should be destroyed as soon as they appear.

The methods of handling the soil to bring about these conditions are variable with different sections of the state The methods adapted to western Kansas are not the same as those most successful in eastern Kansas.

FIG. 8.—The cultipacker, one of the most satisfactory implements with which to firm the ground for alfalfa seeding.

PREPARING THE SEED BED IN CENTRAL AND EASTERN KANSAS

In central Kansas and on good alfalfa land in eastern Kansas a very satisfactory seed bed for fall seeding may be prepared by plowing wheat, oats, or barley stubble shallow immediately after harvesting the small grain crop. The ground' should then be worked sufficiently to kill all weeds and volunteer grain and to maintain good tilth until seeding time. The plowing should be only deep enough to cover the stubble well. Deep plowing usually results in a loose seed bed and consequently an uneven stand of alfalfa.

A clean field of wheat, oats, or barley stubble can be put into fairly good condition by disking the stubble ground thoroughly im-

Historical Document
Kansas Agricultural Experiment Station

mediately after harvesting. Additional cultivations are usually necessary to destroy all weeds and volunteer grain. Because of the difficulty of controlling the weeds and volunteer grain and because of the danger of having the volunteer grain smother the young alfalfa, it is usually better to plow. This is especially true when the alfalfa is to be seeded with a drill, because the stubble left after disking will interfere with seeding.

Occasionally it is possible to secure a good stand of alfalfa by seeding in the fall after harvesting a hay crop of cowpeas or soybeans, Under average conditions, however, this method is not dependable, because the seed bed is usually loose and the soil is low in available plant food and moisture. If this is attempted, disking the ground immediately after harvesting and keeping it cultivated until seeding is the accepted practice.

On some of the poorer upland soils of eastern Kansas, it is quite difficult to obtain a stand of alfalfa, and more care must be used in preparing the land. Under such conditions it is usually necessary to allow more time for the liberation of plant food. A good plan is to plow the field to a depth of approximately five inches in the late spring or early summer after weed growth has started, but before it becomes heavy enough to interfere with plowing. The field should then be cultivated frequently enough during the summer to destroy all weeds. If because of a wet season it is not possible to control the weeds by cultivation, the ground should be plowed a second time early in July to a depth of about three inches. An application of manure to the land during the winter preceding the plowing will be profitable. Fertilizers, especially acid phosphate, can also be used to good advantage.

Practically all of the upland soils of eastern Kansas are acid, and it is therefore necessary to use lime before alfalfa can be grown successfully. One of the best times to apply the lime is soon after plowing so it may be thoroughly incorporated into the surface soil while the land is being cultivated. The best system to follow is to plow, double disk, and then apply the lime immediately thereafter.

PREPARING THE SEED BED IN WESTERN AND WEST CENTRAL KANSAS

Alfalfa can be started most successfully in the spring in western and west central Kansas. The best seed bed can usually be prepared by summer fallowing the ground the preceding season. A fallow stores moisture in the soil and aids in the eradication of weeds. A good plan is to plow in the spring after the growth of weeds has

Historical Document
Kansas Agricultural Experiment Station

started but before it becomes so heavy as to interfere with plowing. Summer-fallowed land must be carefully handled to prevent blowing during the winter and early spring. It may be necessary to disk the ground once after plowing, but additional cultivation should be done with a shovel cultivator, spring-tooth harrow, or some other implement which will not pulverize the soil so much as to make it subject to blowing. Disked corn land is often a satisfactory seed bed for alfalfa in this area. It is very essential that the corn ground be kept free from weeds the previous season.

On sandy land where it is difficult to control blowing, a good method is to seed in the spring in standing sorghum or Sudan grass stubble, from which hay has been cut the preceding season leaving a high stubble. The stubble will catch and hold the snow during the winter, prevent soil blowing, and protect the young alfalfa plants. Land of this type is usually free from weeds, and if the alfalfa is not seeded until after a good rain occurs in the spring, a satisfactory stand will usually be obtained.

INOCULATING ALFALFA

Alfalfa, as previously explained, secures nitrogen from the air by means of bacteria which live on its roots. If these bacteria are not present it cannot secure nitrogen in this way, and does not make a satisfactory growth. Many soils are naturally supplied with these bacteria, but others are not, and hence inoculation is necessary.

These bacteria are usually present in overflow lands along the creeks and rivers, and in the soils of north central and western parts of the state, but generally speaking they are lacking in eastern Kansas where alfalfa has not been grown successfully within recent years and especially on soils that need lime. (Fig. 6.)

There is no way of determining whether to inoculate for alfalfa except that inoculation is practically always necessary on acid soils. If there is any doubt it is best to inoculate. It is not an expensive practice, and may mean the difference between success and failure.

There are two common ways of inoculating for alfalfa. One is the soil-transfer method, which is to use soil from an alfalfa or a sweet clover field, and the other is to use commercial cultures of the bacteria. The latter is more convenient and is usually successful if directions are followed and the culture is not too old. Directions for use are always supplied with the cultures.

In the soil-transfer method soil should be obtained from an old field where there are a great number of nodules on the roots of the

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Kansas Agricultural Experiment Station

alfalfa plants. The surface inch of soil should be scraped off and discarded, and the next four or five inches taken for inoculating purposes. This soil should then be broadcast without drying, and as soon as possible, over the field to be inoculated. The field should be harrowed immediately. From 300 to 500 pounds of soil per acre is required to produce good inoculation.

SEEDING ALFALFA

Alfalfa may be seeded either in the fall or spring. In the eastern half of the state fall seeding has certain advantages which should be considered. There is less trouble from weeds, and a fairly good crop is secured the first season. If sown in the spring, practically the entire season is used in getting the plants established and there is very little return for the use of the land. Also weeds compete with the young plants for food and moisture, and if they become too abundant and rank, the young plants will be smothered.

On the other hand, lack of moisture in the fall may prevent seeding at the right time or, as frequently happens, the seed is lost by seeding in ground too dry to insure germination. As a rule, better preparation of the ground and more care in seeding are required for fall than for spring seeding. In central and western Kansas, spring seeding is necessary because of dry weather and grasshoppers.

Fall Seeding.--The best date to seed alfalfa in the fall will depend upon weather conditions. It should be sown late enough to escape the hot summer weather, yet early enough to enable it to make sufficient growth to pass through the winter successfully. A good plan is to have the seedbed ready and to seed soon after the middle of August if weather conditions will permit and there is sufficient moisture to insure prompt germination and a good early growth of the plants. Some growers follow the practice of seeding during the latter part of August when the soil is dry and depending upon rain later to germinate the seed. This practice is not safe because a light rain may supply sufficient moisture for germination of the seed but not enough to keep the young seedlings alive until they make sufficient growth for the roots to reach subsoil moisture. This practice cannot be recommended.

The latest date that alfalfa may safely be seeded in the fall depends upon the soil, the seed bed, and climatic conditions following the time of seeding. Usually the safest plan is to seed not later than September 10, in the latitude of Manhattan, or September 20, in the southern part of the state.

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Kansas Agricultural Experiment Station

Spring Seeding.--Young alfalfa plants are rather sensitive to frost and the seed should not be sown in the spring as early as sweet clover and red clover. It is usually advisable, however, to seed reasonably early so the plants may become established before hot weather. From April 1 to 15 in central Kansas, and correspondingly earlier or later according to latitude is a favorable time. It is good practice to kill one or two crops of weeds before planting, and it is sometimes advisable to delay planting if the delay is for this purpose.

Fig. 9.--An alfalfa drill. A good drill insures an even distribution of the seed and a uniform depth of covering.

Seeding in Western Kansas.--In western Kansas spring seeding of alfalfa is usually more successful than fall seeding because rainfall is so uncertain in the late summer and early fall and grasshoppers are frequently so numerous and hard to control that it is difficult to start alfalfa in the fall. Weeds which cause so much trouble in spring-seeded alfalfa in eastern Kansas are not so important in the western part of the state. In exceptional seasons characterized by unusual fall rains, fall seeding is successful. Grasshoppers must be controlled, however.

The best time to seed in the spring varies from the first of April in southern counties to well into May farther west and north. The crop should not be seeded until after danger of low temperature is past, yet the seeding should be early enough to permit the young

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Kansas Agricultural Experiment Station

plants to become well established before the period of hot, dry weather in midsummer.

Methods of Seeding.--The two common methods of seeding alfalfa are drilling and broadcasting. Drilling with an alfalfa drill (fig. 9) has many advantages over broadcasting. The seed can be placed in firm soil. A good, uniform depth of planting and a good covering, as well as even distribution of the seed, is assured and better germination and a more uniform stand is obtained. A common grain drill may be used, but it is difficult to keep from planting too deep. It also leaves too much open space between the rows, and for this reason the seed should be drilled both ways if possible. If the seed is broadcast it should be covered with a smoothing harrow and the field should be cultipacked or rolled at once.

Rate of Seeding.--The rate of seeding will vary with the quality of the seed, the condition of the seed bed, and the method of seeding. When good seed is used, the seed bed is in good condition, and the seed is planted with a drill, 15 pounds per acre is sufficient. From five to ten pounds more seed should be used if it is broadcast. Heavier seeding will not overcome the bad effects of a poor seed bed, but may help to overcome it to some extent. A good stand is frequently obtained by using only 10 or 12 pounds of seed per acre, but money invested in the additional seed is usually well spent.

Nurse Crops for Alfalfa.--Nurse crops are seldom used in alfalfa seeding in Kansas, and there are not many conditions which make their use advisable. Since fall seeding is preferable in eastern Kansas, there is no necessity for a nurse crop, and such a crop would tend to deplete the soil of moisture during the fall months. In western Kansas, where spring seeding is advisable, a nurse crop is a serious handicap to the young alfalfa because of the competition for soil moisture, which is usually the limiting factor in alfalfa production in that section.

Practically the only condition that justifies a nurse crop is when alfalfa is seeded in the spring in eastern Kansas. For such conditions a nurse crop may help control weeds by occupying the land until the alfalfa plants become well established.

Oats and barley are the best crops for this purpose. They should be seeded at about one-half the usual rate for grain. The crop should be harvested early for hay in order to give the alfalfa plants a better opportunity for growth. Early harvesting is especially necessary in a dry season. In harvesting for hay it is desirable to leave a high stubble.

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Kansas Agricultural Experiment Station

TIME OF CUTTING ALFALFA

Extensive experiments, as well as the general experience of farmers, show that the quality and yield of alfalfa hay depend very materially upon the time the crop is cut and the way it is cured.

It was believed for a good many years that alfalfa should be cut frequently, and that permitting it to go too long without cutting injured the stand, reduced the yield, and produced a poor quality of hay. Recent experiments at the Kansas station and elsewhere have shown conclusively that late cutting does produce a poorer quality of hay, but that the effect on the stand and on the yield is exactly contrary to what it was formerly thought to be. It was found, for example, that cutting each crop in what is known as the bud state, that is, before the plants bloomed or just before the basal shoots appeared, greatly weakened and finally killed the plants. Cutting each crop in full bloom or when the basal shoots were several inches long, however, actually increased the yield, and resulted in a better stand at the end of several years. This shows, if the primary consideration is to maintain the stand, it may be best to delay cutting until the plants are in full bloom or, in those seasons when blossoms do not appear, until the basal shoots are several inches long.

A serious difficulty with this plan, however, is the fact that the quality of hay becomes poorer as the cutting is delayed. Alfalfa cut in full bloom will usually make good hay, but the quality decreases very rapidly after that time. This means that if one does not begin cutting until the crop is in full bloom, or until the basal shoots are four to six inches long, and there are delays in cutting, some of the hay will be very poor. Hence, it is usually desirable to begin cutting somewhat earlier than full bloom so even that which is cut last will be of reasonably good quality.

The effect of cutting at different stages on the yield, encroachment of grass, protein content of the hay, and the amount of hay required to produce a hundred pounds of gain when fed to beef steers is shown in Table VII.

The results show that both extremes should be avoided as a general practice. Late cutting produces a poor quality of hay, except for horses, whereas very early cutting clearly reduces the yield and injures the stand.

The old rule to begin cutting when the field is about one-tenth in bloom is reasonably safe if the same field or the same portion of the field is not cut in the tenth-bloom stage every year. If it is, the

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Kansas Agricultural Experiment Station

TABLE VII.—Relation of time of cutting alfalfa to yield and quality of hay.

STAGE OF GROWTH WHEN CUT.	Grass in hay—eighth year.	Yield per acre, grass-free hay.	Protein content of grass-free hay.	Hay required to produce 100 pounds gain when fed to beef steers.
	Per cent.	*Tons.*	*Per cent.*	*Pounds.*
Bud stage	44	2.65	18.4	1,628
Tenth bloom	53	3.21	17.9	2,086
Full bloom	0.3	3.43	16.2	2,163
Seed stage	0.1	2.91	14.1	3,910

stand is likely to be thinned out after the second or third year, and the alfalfa will be replaced by weeds and grass.

Very recent experiments indicate that fields may occasionally be cut as early as the bud stage without material injury, providing it is not repeated too frequently. This suggests that it may be possible to cut the first or the first and second crops of the season very early and thus avoid the very rank growth that is characteristic of the first crop, and then give the plants an opportunity to recuperate by allowing the later crops of the season to reach full bloom before they are cut. Other possible combinations will suggest themselves to the practical farmer. Keeping in mind the danger to the stand from continued frequent cutting and the loss in quality with late cutting, it should be possible to arrange the time of cutting to meet particular conditions as to weather, distribution of work, quality of hay, etc., better than would be done by following any fixed rule.

When alfalfa is badly infected with leaf spot or is damaged by late spring freezes, it is usually best to cut it at once regardless of the stage of growth, thus permitting the next crop to make a normal growth.

CURING ALFALFA HAY

The most important point in curing alfalfa is to retain as many of the leaves as possible. The importance of this is indicated in Table VIII, which shows analyses of leaves and stems from the same plants.

TABLE VIII.—Per cent of feed constituents in leaves and stems of alfalfa.

	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Leaves	11.07	25.45	15.47	44.50	3.18
Stems	8.17	12.42	38.78	41.09	1.36

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It will be observed that the leaves contain more than twice as much protein and less than half as much crude fiber as the stems. They also contain materially more ash, more nitrogen-free extract, and ether extract (fat) than the stems. Since the leaves are far superior to the stems in every important respect, it follows that any

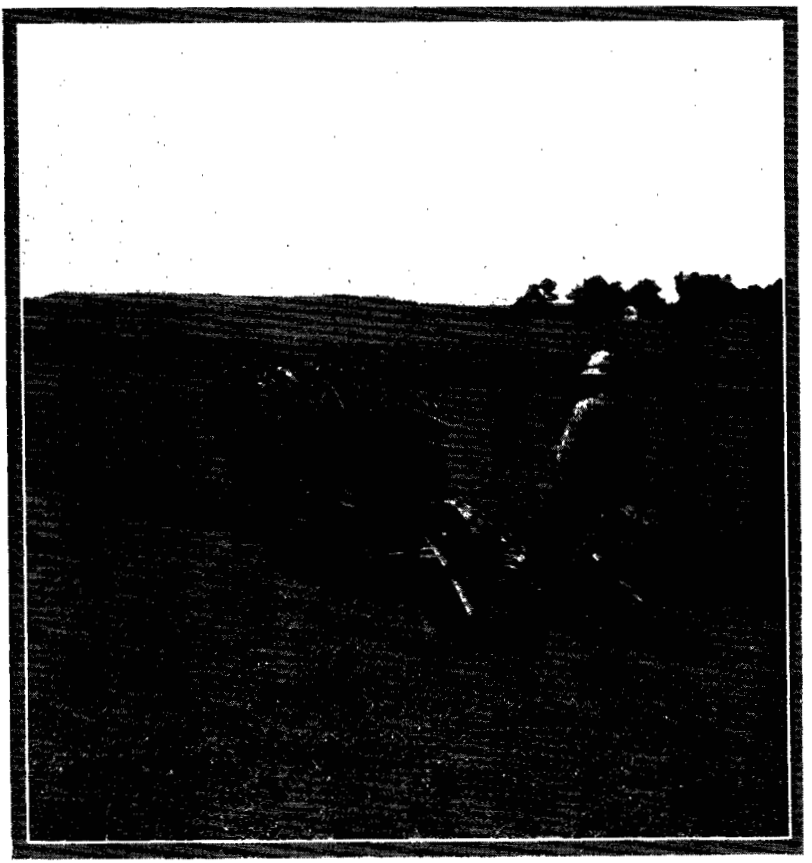

FIG. 10.—Harvesting alfalfa, the best feed crop of Kansas.

method of curing which is most effective in retaining the leaves is likely to be best.

As far as possible, of course, alfalfa should be cut, cured and stacked or put under shelter without rain. All that this means in practice is that haying should not be started when rain threatens, and that when once started it should be completed as quickly as possible. It is worth while to observe that one or two rains do not

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Kansas Agricultural Experiment Station

necessarily ruin the crop, although some damage is the invariable result.

A good plan is to cut in the morning (fig. 10), rake into windrows with a side delivery rake (fig. 1) as soon as the leaves on top of the swath become dry, turn the windrows with the rake the next morning after the dew is off, and stack or bale as soon as the hay is sufficiently dry. (Fig. 2.) It is important to get the hay into the windrows as soon after cutting as possible since drying too long in the swath results in a heavy loss of leaves. When the field is small and a side delivery rake is not available, it is frequently best to bunch the hay for final curing.

The first cutting often cannot be baled directly from the field; in fact, that practice cannot be recommended for any cutting except when weather conditions are very favorable. It should be remembered that baling hay directly from the windrow (fig. 2) is practical only when the hay is thoroughly dry. In eastern Kansas it is usually safer to put the hay in a barn where it may be baled later.

SPOSTANEOUS COMBUSTION

If hay is put in the stack or mow before it is thoroughly cured, it is likely to heat. The temperature may rise until the hay bursts into flame, resulting in what is known as spontaneous combustion. The heat is the result of fermentation of the hay. Hay that is wet with dew or rain is said to be more likely to heat than that which is merely imperfectly cured. Spontaneous combustion often causes the loss of barns and other buildings as well as the hay and, hence, storing damp hay in a barn or near buildings should be avoided.

There appears to be no satisfactory cure once the hay is hot. If heating is detected before it has reached an advanced stage, the hay may be spread out to dry more thoroughly. Opening a stack or mow to the air, however, may cause the overheated hay to suddenly burst into flame and, hence, may be dangerous, especially if no fire-fighting equipment is at hand.

Various means for the prevention of heating, such as salting the hay, have been suggested. The only one known to be effective and practical is to dry the hay thoroughly before it is stacked or mowed.

CULTIVATING ALFALFA

As a general rule cultivating alfalfa in Kansas does not pay if the fields are in good condition. Cultivation may be desirable for the purpose of killing grass or weeds. In such cases the fields may be cultivated in the early spring before growth starts or imme-

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Kansas Agricultural Experiment Station

diately after the first or the second cutting of hay is removed. Early spring cultivation is advised if the field is infested with blue grass or any other grass or weed likely to produce seed before the first crop of alfalfa hay is taken off. Later cultivations are better for foxtail, crab grass, or other annuals which cannot be destroyed by early spring cultivation. When the field becomes so thin that weeds and grass are a serious problem, the best practice usually is to break it up for other crops.

Perhaps the best implement with which to cultivate alfalfa is the spring-tooth cultivator. A disk harrow is sometimes used, but cannot be recommended. It splits the crowns and otherwise injures the plants, thereby permitting the entry of disease organisms. The same objection applies also to alfalfa renovators, and they are less effective in killing weeds.

ALFALFA SEED PRODUCTION

Alfalfa is very uncertain as a seed crop, and it is difficult to estimate with any degree of accuracy early in the growth of the crop what the seed crop will be. Relatively heavy rainfall in the early stages of growth and dry weather during the blooming period are essential for seed production. If heavy rains fall while the alfalfa is in bloom or before the flowers are fertilized, there is little possibility of securing a seed crop. Excessive rain after the seed is formed may prevent uniform maturing of the seed and cause an unprofitable crop. High temperatures and hot winds may injure the bloom and prevent fertilization.

When a field of alfalfa is left for seed, the plants should be examined frequently and carefully immediately after the blooming period to learn if pods are thickly set on the stems. There should be two or more pods in a group to insure a good seed crop. If there is not a good set of pods it is usually more profitable to harvest the crop for hay.

WHEN TO HARVEST THE SEED CROP

The time of harvesting depends upon the uniformity with which the plants bloom and mature seed, and the climatic conditions. In a favorable season when blooming and maturing of the seed have been uniform, it is best to harvest when about two-thirds of the pods have turned brown. At this stage the seed will be sufficiently well matured and there will be a minimum amount of shattering. Under average conditions a part of the seed will be overripe, some will be mature, and some immature. With such a crop it is necessary to harvest when the largest amount of good seed can be saved.

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Kansas Agricultural Experiment Station

METHODS OF HARVESTING THE SEED CROP

In harvesting an alfalfa seed crop the most important factor to consider is the loss of seed due to shattering. A machine for harvesting alfalfa seed should preferably be one that cuts and automatically rakes or bunches the crop. This may be accomplished with the self-rake reaper, the mower with the windrowing and bunching attachments, or the grain binder with the binder attachment removed. If the alfalfa plants are of sufficient height to permit binding, the binder attachment on the machine may be used. Under some conditions, the combine or the header is practicable. However, great care must be used in curing the seed if the combine is used.

After the crop is cut it should be put into small cocks as soon as possible, or at least while it is still damp or tough, as there is less shattering when handled in this condition. If the cocks become wet from rain, they should be turned for complete drying. It usually requires from 5 to 10 days for the crop to become sufficiently dry for threshing and storing. Since the seed is easily injured in the cock by heavy or long continued rains, it is advisable to stack or thresh as soon as possible after the crop becomes dry. If stacked, it should go through the sweat before it is threshed. The stacks must be well covered, as they do not readily shed rain.

Alfalfa and clover hullers are the best machines with which to thresh alfalfa seed, but the later models of grain threshers may be adjusted to do good work.

VARIETIES OF ALFALFA

There are numerous varieties and strains of alfalfa, just as there are of wheat and other grain crops. Some of them may be distinguished or identified by the color of the flowers, the character of the plants, the seed pods, etc., but many of them are so similar that they cannot be distinguished even by a specialist, although differing greatly in productivity. Many of them are named according to the state in which they are grown. Thus there are Kansas Common, Montana Common, Utah Common, etc.

KANSAS COMMON ALFALFA

Of these so-called regional strains, Kansas Common is without doubt the best for Kansas conditions. Most of that grown in the state until very recently descended from fields planted soon after the Civil War. It is natural to expect that those plants best adapted to Kansas conditions would survive the longest and produce the most

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Kansas Agricultural Experiment Station

seed, and hence would gradually increase in number as the years went by. The final result is alfalfa, all or nearly all plants of which are well adapted to conditions which usually prevail. All experiments so far conducted tend to confirm this conclusion. When one is unable to secure Kansas-grown seed, Utah Common can usually be depended upon to give good results. Colorado Common, Nebraska Common, Montana Common, or South Dakota Common are also good, but seed is nearly always scarce and difficult to obtain. Seed from Arizona, California, and from most foreign countries is, in general, not satisfactory.

A variety especially to be avoided is the Peruvian. This variety is extensively grown in the southwestern United States where it gives excellent yields. It is unable to survive Kansas winters as indicated in figure 11.

GRIMM ALFALFA

A relatively new variety that has recently attracted considerable attention is the Grimm. This variety originated in Minnesota and is noted for its winter hardiness. It differs from that commonly grown in Kansas in having flowers of various colors, ranging from yellow and white to dark purple and green. The seed is scarce and expensive, usually selling for about twice as much as Kansas Common alfalfa.

Experimental tests at the Agricultural Experiment Station at Manhattan and also at several points in eastern Kansas, have so far failed to show any marked differences in yield or other qualities in favor of this variety as compared with Kansas Common. There seems to be no good reason at the present time for Kansas farmers to pay the extra price necessary to secure Grimm when seed of Kansas Common of good quality can be obtained.

ALFALFA SEED

One of the factors that has been responsible for many alfalfa failures in Kansas during the last four or five years has been the use of seed that is not adapted to the climatic conditions of the state. Previous to the last few years the state produced a considerable quantity of seed, and was able to supply the needs of the farmers with a good local product. More recently the amount of seed produced has been relatively small and it has been necessary to use supplies from outside the state. As a consequence seed has been imported from other states and countries to meet the demands. Although some of this seed was found to be well adapted, other lots

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Kansas Agricultural Experiment Station

proved to be very unsatisfactory. (Fig. 11.) In securing alfalfa seed, therefore, the point of first importance is to secure seed known to be adapted to Kansas conditions. Kansas-grown seed should have the preference as indicated above.

Imported Seed.--Some Kansas seed is produced in fields that were seeded with imported seed. In order to avoid such seed it will be advisable to secure seed from fields at least ten years old, or from fields the history of which is definitely known. The Kansas Crop

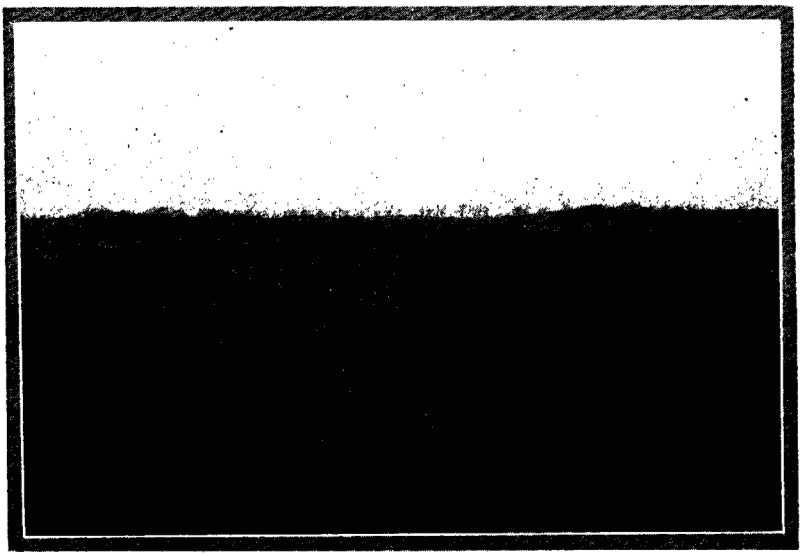

FIG. 11.—A field seeded to alfalfa in the fall of 1925 and photographed in the spring of 1926. The left-hand side of the field was seeded with nonadapted seed and the right-hand side with Kansas Common.

Improvement Association, Manhattan, Kan., usually is able to furnish lists of growers having such seed.

Seed from foreign countries can now be identified by the fact that it is required by law to be stained at port of entry. Thus, seed from Canada is stained approximately 1 per cent violet. Seed from other countries which may be adapted to certain portions of the United States but not to others, is stained approximately 1 per cent green. Seed from South Africa and other countries, which produce seed known to be unadapted for the United States, or seed of unknown origin, is stained 10 per cent red. Canadian seed will undoubtedly give good results in Kansas, but the supply is so limited that none

Historical Document
Kansas Agricultural Experiment Station

is likely to find its way into commercial channels in Kansas. None of the seed imported from other countries can be recommended.

Purity and Viability.--In buying alfalfa seed, considerable attention should be given to purity and viability as well as to origin. A large per cent of brown seed indicates low viability. Good seed has a yellowish-green color, and certain luster or brightness characteristic of all kinds of seed of good germination. Seed containing weed seeds should be avoided, or at least should be examined by a seed analyst for noxious weeds.

Hard Seed.--A considerable proportion of most lots of alfalfa consist of "hard" seed, that is, seeds whose outer coat is so impervious to water that they will not germinate under ordinary conditions. These hard seeds have in general little value unless scarified. A germination test shows the per cent of such hard seeds. The State Seed Laboratory of the Agricultural Experiment Station, Manhattan, makes germination and purity tests free of charge for all residents of the state, and those farmers contemplating the purchase of alfalfa seed will do well to avail themselves of this service.

ALFALFA DISEASES [3]

One of the important factors affecting the production of alfalfa in Kansas is plant diseases. Just how important they are no one can say, but anyone familiar with the situation knows that the loss is tremendous.

The alfalfa crop is subject to several diseases, such as leaf-spot diseases, bacterial wilt, and the various root rots and crown rots. Injuries of this sort are not the direct result of unfavorable weather conditions as is frequently believed. Instead, they are caused by specific germs, either bacterial or fungus, and in order to control them or to reduce the damage it is necessary to understand them.

LEAF SPOTS

Among the important diseases are the so-called leaf spots. The fungi which cause these diseases first kill very small areas of the leaves, and at first cause no noticeable injury. However, these injured areas increase rapidly in number and size, so that eventually the leaves turn yellow, wither, and drop off. The field may have a yellowish or brown tinge and the plants stop growing. There are several different organisms that cause leaf spot, but since the effect is essen-

3. The discussion of this subject was prepared by Prof. L. E. Melchers, plant pathologist of the station.

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Kansas Agricultural Experiment Station

tially the same as far as the crop is concerned, no distinction between them is made in this discussion. As a rule, there is no permanent injury to the plants, so as soon as the crop is cut the new growth comes on as vigorously as though no disease had been present. Damage from leaf spot depends in a marked degree on weather conditions, and there are no practical means of control. If the disease develops to a marked extent it is usually desirable to cut the crop and thus avoid the dropping of the leaves and permit the new growth to get a good start.

BACTERIAL WILT

Alfalfa wilt, or bacterial wilt as it is sometimes called, has become of considerable economic importance. The disease has been reported in many states besides Kansas, and probably will be more common and widespread as time goes on. It attacks the roots, but its effects are most readily seen in the parts above the ground.

A badly diseased plant is dwarfed, with a tendency toward an abnormally large number of short stems, which are spindly and pale green in color, having leaves considerably smaller than usual. The leaves and stems of such plants wilt and eventually die, even though there is plenty of moisture in the soil. The disease is often most apparent in the first crop of the season, although one acquainted with the wilt has little difficulty in detecting diseased plants at any time. A diagnosis may be made by digging up a diseased plant with a foot or more of the root intact, and carefully examining the root. If the bark is stripped back, the woody cylinder will be observed to show a straw-yellow, brownish-yellow, or even dark brown color in the later stages of infection, which is very different from the white or ivory-like cylinder in a healthy plant. A diseased root shows this condition the entire length from the crown of the plant to the root extremity. Plants that go into the winter badly infected are often dead by spring. (Fig. 4.)

Alfalfa bacterial wilt is a recently discovered disease, and very little is known as to methods of control. Investigations are in progress at the Kansas Agricultural Experiment Station to find methods of prevention or control. It seems definitely proved that infection for the most part takes place in the roots through some injury such as may be brought about by insects or certain worms, or as a result of winter injury. There is some evidence that it may be spread in mowing. So far, there is no evidence that wilt is spread by the seed itself.

Historical Document
Kansas Agricultural Experiment Station

Wilt has been found commonly in fields that had been planted with seed from foreign countries. This suggests that the disease attacks varieties not adapted to Kansas conditions, or that because of winter injury it was better able to attack these varieties.

No method of control is known at the present time. The use of adapted seed may safely be recommended, although it cannot be said at present that the use of such seed will prevent all damage. Infested fields should be used for other crops for a few years before seeding back to alfalfa. It has not been proved that failure to follow this practice will result in injury, but it is in line with good farm practice and recognized methods of disease control.

VIOLET ROOT ROT

Violet root rot has been known in Kansas for 28 years. It has not increased to any great extent during that time, although some seasons it is more prevalent than others. Since it is a definite root disease, one's attention is first called to the yellowing of the entire plant, which soon begins to wilt and eventually dies. Plants die in definite areas or spots in a field. These spots gradually increase in size and the fungus spreads in all directions through the soil, killing the plants as it progresses. Each year the spots grow larger until extensive areas may be killed. It seems to be more prevalent in fields where there is inadequate drainage. It is also most noticeable in fields that are six to eight years old or older. It takes its name from the presence of a net of reddish-brown or violet fungous threads on the outside of the bark, which penetrate the root. As the disease progresses the roots begin to decay and the bark sloughs off.

Rotation is the most positive and practical way to control the disease. Since the fungus causing this disease lives over in the soil for a number of years, it is not advisable to replant an infected field to alfalfa for several years. If other crops can be grown for several years before the field is again planted to alfalfa, the fungus will in all probability be eradicated.

CROWN ROTS

Alfalfa plants with badly decayed crowns are frequently found. The cause is not accurately known. The condition is usually found in plants from one to several years old. Injury is believed to be due in some cases to winter injury, disking, too frequent cutting, poor cultivation, or unfavorable soil conditions.

Historical Document
Kansas Agricultural Experiment Station

INSECT ENEMIES OF ALFALFA[4]

Somewhat more than three hundred species of insects are known to obtain their food directly or indirectly from the alfalfa plant. Many of these do no noticeable damage. Some of them are beneficial in that they help in cross-pollination or feed upon insects which, in their turn, obtain food from alfalfa.

Only a few of these three hundred species are really serious pests, Among these may be mentioned especially, grasshoppers, cutworms of various kinds, the pea aphids, army-worms, corn ear-worms, garden web-worms, blister beetles, clover-leaf weevils, and mound-building prairie ants.

GRASSHOPPERS

Grasshoppers are undoubtedly the most important insect enemies of alfalfa, considering the state as a whole. They are most destructive in the western two-thirds of the state, particularly to young fields where they often keep the young plants from making any growth above ground, and thus cause their early death. It is partly for this reason that it has been found impractical to seed alfalfa in the fall in central and western Kansas.

Grasshoppers generally make their first appearance around haystacks and around the border of alfalfa fields. They come in from adjoining pastures and roadsides or from the stacks where they have been hauled with the hay.

Control.--The well-known poisoned bran mash, now often termed "Kansas bait," has proved especially valuable in grasshopper control. It is made as follows:

Bran	20 pounds
White arsenic or Paris green	1 pound
Black strap molasses, sirup, or cheap molasses	2 quarts
Oranges or lemons	3
Water	3 gallons

In preparing the bran mash, mix the bran, white arsenic (not arsenate of lead or calcium arsenate) or Paris green thoroughly in a wash tub while dry. Squeeze the juice of the lemons or oranges into the water, chop the remaining pulp and the peel into fine bits or run them through a meat grinder, and add them to the water. Dissolve the sirup in the water and wet the poisoned bran with the mixture, stirring at the same time so as to dampen the mash thoroughly. More failures are due to imperfect mixing than to any other cause.

The bran mash, or bait, should be sown broadcast in the infested

4. The discussion of this subject was prepared by Dr. Roger C. Smith of the Department of Entomology.

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areas early in the morning, or about the time the grasshoppers begin to move about. It should be scattered sparingly in such a manner as to cover from four to five acres. Since very little of the bran mash is eaten after it becomes dry, scattering it broadcast in the morning places it where the largest number will find it in the shortest time. Sowing it in this manner also makes it impossible for birds, barnyard fowls, or live stock to secure a sufficient quantity of the poison to kill them. In order to secure the best results, it should be applied after a crop has been removed and before the new crop has started. In this case, considerable saving of material and labor can be effected by leaving a strip 20 to 30 feet wide between the strips of mash.

It has been found that sodium arsenate (sometimes called "weed killer") used at the rate of 1/4 pint to 20 or 25 pounds of bran is fully as effective as the regular mash. Sodium arsenate is highly soluble in water, hence it is put into water and poured over the bran. Amyl acetate or "banana oil" can be substituted for the fruit with equally good results, but it evaporates rapidly. This is a liquid, and is used at the rate of 1 to 2 ounces to 20 pounds of bran. It is poured into the water before wetting the bran. Black strap molasses is superior to ordinary molasses for grasshopper bait. The molasses appears to be more important than the fruit flavor.

The hopperdozer is also valuable for grasshopper destruction if the alfalfa is not too tall. It is especially useful during the latter part of June and early July.

CUTWORMS

This group of insects, which includes the army cutworm and the variegated cutworm, occasionally occurs in outbreak proportions and does serious injury.

The army cutworms cause the greatest damage in the early spring on alfalfa sown the previous fall. They may be present in old stands in just as large numbers, but the damage is not so apparent. They are usually first reported in wheat fields in the early spring or in alfalfa fields where there is some volunteer wheat. They migrate as they feed, defoliating or devouring the entire plant to the ground. They are largely nocturnal feeders, but on cloudy or warm spring days they commonly feed in the daytime. On very warm or hot days they remain hidden in the soil around the base of the plants and either feed by cutting off the plants or come out during the evenings or nights and eat the leaves.

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Kansas Agricultural Experiment Station

The variegated cutworms feed on the young growth after the first cutting and may keep it down. They overwinter as young half-grown larvae in alfalfa fields and complete their growth in June, causing the greatest injury at that time.

Control.--There is no better control known for cutworms than the sowing of poisoned bran mash (as made for grasshoppers) in the late afternoon or evening. Best results are obtained by sowing it under the windrows or piles of hay during the first cutting. The worms crawl under the hay for protection and are soon poisoned by the mash. Sowing the mash broadcast on standing alfalfa and on stubble has given satisfactory results in experiments, though under these conditions two sowings are generally necessary.

ARMY-WORMS

There are two kinds of army-worms that cause damage to alfalfa fields, the true army-worm or simply the army-worm, and the fall army-worm. Both eat the foliage, stripping the stalks as they migrate across the field.

Poisoned bran mash (as made for grasshoppers), sown in the afternoon of cool days or early evening of very warm days, is the best means of control. One sowing is sometimes sufficient although two sowings are frequently necessary.

CORN EAR-WORMS

While the corn ear-worm feeds primarily on corn, it nevertheless damages alfalfa sometimes rather severely. These insects can be found during the whole summer in alfalfa fields. They are especially numerous early in the year before the corn is far enough along to attract them.

Excellent control of this insect has been obtained by sowing poisoned bran mash in the afternoon or early evening. It is advised that the alfalfa be cut as soon as injury is observed to save it from destruction. Many of the worms will be destroyed as they search for new sources of food and the young growth will be little or not at all attacked.

PEA APHIDS

The aphid is one of the larger green plant lice which in the last ten years has become one of the most important of the alfalfa insects. The first big outbreak occurred in the spring of 1921, and was the chief factor in the loss of over 100,000 acres of alfalfa in this state. The insect has returned each spring since in certain localities over the state, but especially in the Kaw valley. It is capable of

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Kansas Agricultural Experiment Station

such severe injury that the farmer should watch his alfalfa fields during March and April to determine whether it is present in numbers. If it is, he can destroy it at a great saving of trouble and expense while it is still confined in small areas.

The pea aphid overwinters on alfalfa plants either as aphids or eggs. The first evidence of injury in the spring is the presence of bunchy stalks and of small areas of alfalfa markedly behind the rest in growth. When walking through such spots, one will notice the white molted aphid skins on the ground and the green plant lice on one's shoes. The presence of large numbers of ladybird beetles on the alfalfa is further evidence of the presence of the pea aphids, for the ladybird beetles feed on the aphids.

Pea aphids breed very rapidly, and if March is dry and mild they may become so numerous that they overwhelm the plants by sheer force of numbers. They suck the sap of the plants, causing them to become light green in color and finally die.

Control.--The control of the pea aphids is greatly simplified if they are found in the fields before they have done much damage. They may then be quickly and easily killed by applying calcium cyanide granules at the rate of 25 to 30 pounds to the acre. The material can be applied with a dusting machine or sown by hand. It is not necessary to cover the whole of injured areas. The aphids infest the plants heaviest in a border about six feet wide immediately surrounding the injured area. The calcium cyanide should be spread in this border and rarely will one need to cover as much as an acre. Best results have been obtained when the aphids are knocked to the ground by dragging a pole, or some brush over the area immediately after the sowing or dusting, because the aphids will then come into close contact with the cyanide. The results of the sowing are apparent in 15 minutes. A practically complete kill may be made with one sowing. Calcium cyanide must not be used when the plants are damp or wet, and the temperature should be around 70° F. for best results. If the granules are poorly. distributed or sown too thickly the alfalfa may be burned severely.

Harrowing the infested spots is generally worth while if the ground is not too hard or the alfalfa is not so tall that it prevents thorough cultivating of the ground. Many growers report having controlled these insects by using this method alone, but generally it is much less effective than the cyanide.

Caution.--One should avoid breathing the dust or gas from cal-

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cium cyanide, as it is a violent poison. If the granules are to be sown by hand, gloves should be worn, and one should be careful to keep the material out of cuts.

GARDEN WEB-WORMS

The garden web-worm occasionally occurs in sufficient numbers to destroy or, at least, seriously reduce the quality of the second or third cutting of hay. This is done by the small green or yellowish-black spotted larvae webbing together the upper leaves and branches of clumps and then feeding upon the foliage. The plants are conspicuously webbed and partly or wholly defoliated

There is no very good or practical control for this insect. When the worms are observed doing severe injury, the alfalfa may be cut and thereby saved from destruction. Since the period of greatest damage to alfalfa is the stage just before blooming, this will generally mean cutting the crop rather early. The next crop will practically never suffer from this insect. If it is known that an outbreak is imminent, as when the moths are out in large numbers, it is advisable to delay the previous cutting a week or thereabouts. While the hay may be somewhat reduced in value, the danger of severe injury to the next cutting is materially reduced.

INSECTS OF MINOR IMPORTANCE

Several species of blister beetles, the clover-leaf weevil, and the mound-building prairie ant occasionally cause considerable damage. The clover-seed midge, wheat thrips, and the clover-seed chalcis fly sometimes reduce the seed crop materially. There are at least three species of hay worms that attack the hay in stacks or mows, especially when hay is stacked on old stack bottoms.

Space does not permit a discussion of these insects. In most cases they can be controlled and directions for their control may be secured from the Kansas Agricultural Experiment Station.

POCKET GOPHERS [5]

The pocket gopher is one of the serious pests in alfalfa. If unmolested, pocket gophers will enter a field and eventually make it so unproductive that it must be plowed up. The mounds interfere with mowing and yearly smother a large number of plants.

The best way to control pocket gophers is to poison them with strychnine-treated wheat. Trapping is less effective and more ex-

5. The discussion of this subject was prepared by Prof. George E. Johnson of the Department of Zoology.

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pensive. Treated wheat or directions for preparing it may be secured from the Department of Zoology, Agricultural Experiment Station, Manhattan, Kan.

Poisoning Gophers.--Pocket gophers may be poisoned any time they are active. Especially favorable seasons are late fall when food is being stored and burrows extended, and early spring when new mounds are being thrown up.

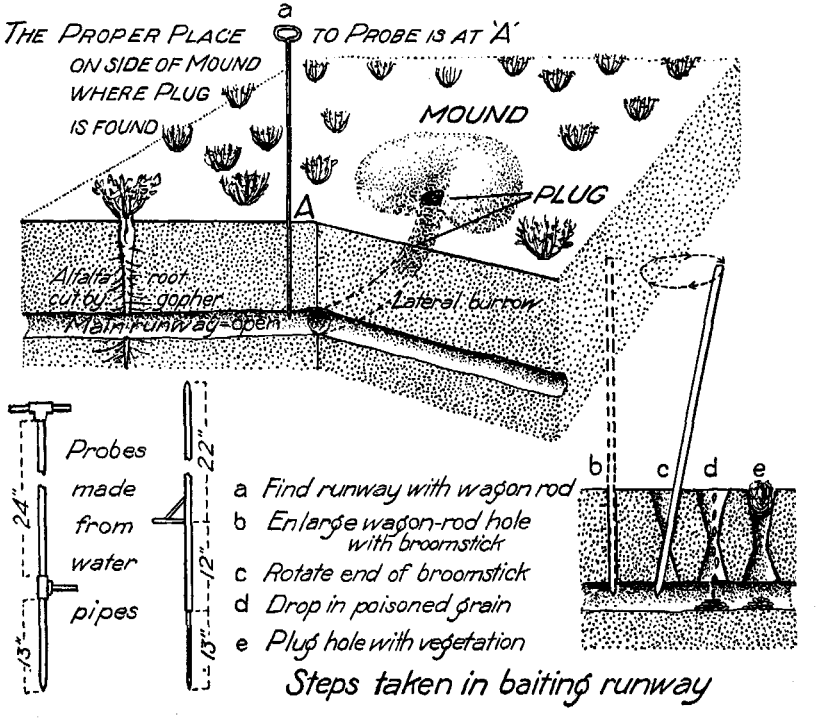

FIG. 12.—Diagrammatic representation of a pocket gopher runway, showing method of placing poison.

In order to poison gophers successfully, one must understand the relation of their runways to the mounds. From its main tunnel, the pocket gopher digs short lateral tunnels to the surface and here pushes out the soil in a mound which has the form of a palm-leaf fan or may be somewhat bean-shaped. (Fig. 12.) It plugs the opening of the lateral and the plug may be seen as a circular area in the mound near the indented side. There is no ridging of the soil above the runway between the mounds as in the case of mole work.

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Placing the Bait.--The main runway is found by probing with a wagon rod *(a)*. This is done 8 to 12 inches from the mound on the side where the plug to the hole is seen, When the rod has been pushed into the ground a few inches and suddenly sinks about three inches more without increased pressure, the runway has been located. The hole made by the rod is enlarged by inserting a sharpened broomstick *(b)*. The broomstick should not be pushed too far in or a depression will be made in the bottom of the runway into which the bait will fall. With the broomstick properly inserted, the top end of it is rotated in a circle to make the hole still larger and make its walls firm so they will not "cave in" *(c)*. The stick is then drawn out, a partly heaping tablespoon of poisoned grain, or two or three pieces of sweet potato or parsnip, are dropped in *(d)*, and the hole is covered *(e)*, care being taken not to let dirt fall in and cover the bait. The mound should be marked by partially kicking it down. Every fourth or fifth mound should be baited, or each system belonging to one gopher should be treated in at least two places.

A probe made by a blacksmith from a water pipe about 34 inches long and a rod about 18 inches long are a help where much baiting is to be done. This probe and another type preferred by some are illustrated in figure 12.

Rebaiting.--If new mounds are thrown up after baiting, they should be treated as before. Thoroughness pays, and as often as necessary retreatment should be made. Whenever possible, it is well to drag down the mounds after each treatment.

Need of Cooperation.--A farmer can keep his fields free from gophers more easily if all his neighbors are likewise working to destroy the gophers, hence the need for a community campaign against these animals.

12-440