AGRICULTURAL EXPERIMENT STATION

KANSAS STATE AGRICULTURAL COLLEGE
MANHATTAN, KANSAS

FERTILIZERS FOR ALFALFA IN EASTERN KANSAS

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SUMMARY

1. Alfalfa is the most valuable forage crop grown in Kansas. It can be produced successfully on most of the soils of the eastern part of the state if the crop is rightly handled and the soil properly fertilized.

2. The acreage of alfalfa in Kansas has decreased slightly in the last five years, and it is becoming more difficult to establish new stands in the eastern part of the state.

3. The crowding out of alfalfa by grass and weeds is the result of unfavorable conditions for the alfalfa. A strong healthy stand of alfalfa can successfully combat weeds and grass.

4. Alfalfa will not succeed on acid soil. This condition of the soil may be corrected by the use of lime.

5. Lime increases the value of manure and commercial fertilizer for alfalfa but will not replace them.

6. Kansas soils are lower in phosphorus than in any other plant food.

7. Phosphorus, in the form of acid phosphate, may be used with profit in the production of alfalfa on practically all soils of the eastern fourth of the state.

8. Money invested in acid phosphate returned a profit varying from 200 to over 500 percent when the acid phosphate was used on alfalfa.

9. On established stands of alfalfa, acid phosphate should be applied in the early spring at the rate of about 300 pounds per acre every second year. For new stands the application should be made just before seeding.

10. In establishing new stands of alfalfa a fertilizer containing some nitrogen should be used except when the field has had a recent application of barnyard manure. A 2-12-0 mixture applied just before seeding at the rate of 200 pounds per acre is usually satisfactory.

11. Rock phosphate has not been as profitable as acid phosphate and has not greatly increased the yield of alfalfa except on bottom land in Butler County.

12. Potash has had little influence on the yield of alfalfa and in no case has it been profitable to apply it.

13. Barnyard manure gives very profitable returns when applied to alfalfa but when manure is limited in amount it is usually better farm practice to use the manure on cultivated crops and fertilize alfalfa with acid phosphate.

14. The value of manure for alfalfa in eastern Kansas is increased by the addition of acid phosphate.

TABLE OF CONTENTS

FERTILIZERS FOR ALFALFA IN EASTERN KANSAS[1]

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ALFALFA IN KANSAS

Alfalfa is the most valuable forage crop grown in Kansas. On soils to which alfalfa is adapted no other crop can be produced so cheaply in proportion to its value. Although Kansas is recognized as an important alfalfa state, the acreage of this crop has not increased during the last few years and the crop is not grown as extensively as its value warrants. In 1915 there were 1,359,498 acres of alfalfa in Kansas, while in 1920 there were 1,243,227, or a decrease of 116,271 acres. There was a marked decrease in the acreage in 1916 and again in 1917, but a slight increase in 1918 and 1919 over the two preceding years.

The difficulties of obtaining and maintaining a profitable stand of alfalfa are becoming greater each year. One of the reasons for this trouble is the gradual loss of plant food from the soil where alfalfa is grown and the fact that most all soils under cultivation gradually grow poorer. When the soils of Kansas were new and alfalfa was first introduced into the state it was easy to secure a stand whenever the soil was properly inoculated. This is no longer the case and at present much more care must be used in preparing the seedbed in order to secure a stand, and on many soils, old, well-established fields must be supplied with plant food or the alfalfa soon loses its vigor and is crowded out by weeds and grass.

DOES ALFALFA ENRICH THE SOIL?

The statement that alfalfa enriches the soil is so often made 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. Unfortunately this is not the case. Alfalfa like every other

[1] Contribution No. 138 from the Department of Agronomy.

crop secures a large part of its plant food from the soil and when growing normally uses much larger quantities of some of the elements of plant food than most other farm crops. Table I gives the number of pounds per acre of nitrogen, phosphorus, potassium, and calcium removed by given yields of some of the common farm crops.

TABLE I.—PLANT FOOD PER ACRE REMOVED BY CROPS

Crop	Plant food			
	Nitrogen	Phosphorus	Potassium	Calcium
	Pounds	*Pounds*	*Pounds*	*Pounds*
Wheat—both grain and straw—yield, 30 bus. per acre	57.6	9.6	34.8	6.3
Oats—both grain and straw—yield, 50 bus. per acre	48.5	8.0	34.0	8.5
Corn—both grain and stover—yield, 37.5 bus. per acre	55.5	8.6	26.6	8.4
Alfalfa hay—4 tons per acre	200.0	18.7	193.3	86.7

Alfalfa contains much larger quantities of all four of the most essential elements of plant food—nitrogen, phosphorus, potassium, and calcium—than the other common farm crops. A 4-ton crop of alfalfa contains 200 pounds of nitrogen, nearly 19 pounds of phosphorus, 193 pounds of potassium, and 86 pounds of calcium. The fact, however, that alfalfa contains a large amount of nitrogen is of little importance from a soil fertility standpoint because under normal conditions it secures its nitrogen from the air. In many cases it leaves the soil richer in available nitrogen than before the crop was planted. It is for this reason that alfalfa is often spoken of as a crop that enriches the soil. The fact should not be overlooked, however, that alfalfa requires 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 common farm crops. In other words, alfalfa removes much larger quantities of these other essential elements of plant food from the soil than other crops and is therefore exhausting the soil of these elements more rapidly.

Fortunately the best alfalfa soils of Kansas are well supplied with potassium and it probably will be many years before this element is reduced to a point where increasing the supply will be necessary. Calcium is present in large quan-

tities in the best alfalfa soils of the central part of the state but is present in smaller quantities in the soils of eastern Kansas. In southeastern Kansas the principal reason that alfalfa is not commonly grown is because the soils contain so little calcium that they are sour. The majority of these soils will grow alfalfa successfully if lime is added in sufficient quantities to correct the acidity.

DEFICIENCY OF PHOSPHORUS IN KANSAS SOILS

The element of plant food, however, that is most deficient in Kansas soils is phosphorus. It is also an element that alfalfa requires in fairly large amounts and which the plant can obtain only from the soil. Table II gives the number of pounds per acre of nitrogen, phosphorus, potassium, and calcium found in the surface seven inches of some of the common soil types of Kansas.

TABLE II.—PLANT FOOD PER ACRE IN THE SURFACE SEVEN INCHES OF SOME KANSAS SOILS

Soil	Plant food			
	Nitrogen	Phosphorus	Potassium	Calcium
	Pounds	*Pounds*	*Pounds*	*Pounds*
Marshall silt loam (Northeastern Kansas)	3,620	1,060	38,800	11,200
Oswego silt loam (Riley County)	4,340	1,060	36,400	13,600
Colby silty clay loam (Jewell County)	3,200	920	41,800	14,000
Lincoln silt loam (Jewell County)	4,200	1,240	43,000	46,200
Bates silt loam (Cherokee County)	2,800	700	12,600	7,200
A very fertile soil	6,000	2,080	34,200	11,200

The Lincoln silt loam of Jewell County is one of the best alfalfa soils in Kansas, if not in the United States. It will be seen that this soil contains more than four times as much calcium or lime, and somewhat more potassium, than a very fertile soil. This is one of the reasons why it is such a valuable alfalfa soil. The other soils which contain less calcium are not quite as satisfactory for this crop. It will also be seen from Table II that phosphorus is deficient in all these Kansas soils. Some of them are very deficient in this element. The Colby silty clay loam of Jewell County, a very satisfactory alfalfa

soil, contains less than half as much phosphorus as a good fertile soil, and some of the poorer alfalfa soils, such as Bates silt loam, contain even smaller quantities of phosphorus. Since alfalfa when well established can with the aid of bacteria secure nitrogen from the air, it can readily be seen that if lime is supplied in sufficient quantities to meet the need of the plant, the only element of plant food that probably will be deficient in most Kansas soils is phosphorus. That some of the soils of the state are already so deficient in this element of plant food that alfalfa is making but a poor, sickly growth and is unable to compete with weeds and grass will be shown later.

Unfortunately there is no easy and cheap way of obtaining phosphorus. It is present in small quantities in barnyard manure and is bought in small quantities when commercial feed, such as bran, middlings, and other feed for stock, is purchased. It can be purchased in bone and other by-products of packing plants. The only large source of supply of the element in this country is the deposits of mineral phosphates found in Tennessee, Florida, Arkansas, Idaho, Wyoming, and some other western and southern states. It can be bought in the form of finely ground phosphate rock in which the phosphorus is slowly available or in the form of acid phosphate in which the phosphorus is soluble in water and quickly available.

BARNYARD MANURE VERSUS COMMERCIAL FERTILIZER AS A SOURCE OF PHOSPHORUS FOR ALFALFA

There is a choice, therefore, between barnyard manure and commercial fertilizers as a source of supply of phosphorus for alfalfa. Barnyard manure has the advantage of being a by-product of the farm, while commercial fertilizers, like acid, phosphate, must be purchased at considerable outlay of money. Barnyard manure, on the other hand, has the disadvantage of containing but a small quantity of phosphorus while the nitrogen it contains in large amounts is not valuable as a plant food for alfalfa since this crop can secure its needed nitrogen from the air. Table III shows the amount of nitrogen, phosphorus, and potassium per ton in several different kinds of barnyard manure and in acid phosphate.

It will be seen from the data presented in Table III that all kinds of barnyard manure contain several times as much nitrogen as phosphorus. In fact, in a ton of ordinary cow manure

TABLE III.—PLANT FOOD PER TON IN BARNYARD MANURE AND ACID PHOSPHATE

MATERIAL	Plant food		
	Nitrogen	Phosphorus	Potassium
	Pounds	*Pounds*	*Pounds*
Horse manure	14	2.2	9.1
Cow manure	12	1.3	7.5
Sheep manure	19	3.1	16.6
Hog manure	10	3.1	6.8
Acid phosphate	0	139.7	0

there is less than 1.5 pounds of phosphorus, while in a ton of sheep and hog manure there is but little over 3 pounds of this element of plant food. Because of the low phosphorus content of cow manure it would take 3.5 tons of it to return to the soil the phosphorus removed in 1 ton of alfalfa hay, or to supply the phosphorus removed by alfalfa in a single season if 4 tons of hay were produced, would require an application of 14 tons of cow manure. This information is not presented in order to attempt to underrate the fertilizing value of barnyard manure, but in order to show the tremendous importance of the amount of phosphorus removed from the soil in ordinary crops of alfalfa and the futility of attempting to maintain the supply of phosphorus in a soil deficient in this element by the use of barnyard manure alone.

The fact remains, however, that comparatively small applications of barnyard manure often increase the yield of alfalfa far beyond the increase that would be expected from the quantity of plant food added. This undoubtedly is the result of an increased supply of plant food in the surface soil that increases the vigor of the plant and enables it to push its roots into the subsoil and secure from this source the phosphorus that is not supplied by the manure itself.

The data supplied in Table III also show that nitrogen is present in barnyard manure in fairly liberal amounts. Hog manure contains 10 pounds per ton and sheep manure 19 pounds per ton of this element of plant food. When manure is used on alfalfa the nitrogen in the manure is of course used by the plants, but because of this supply less nitrogen is secured by the plants from the air. Thus, when manure is used on alfalfa the nitrogen in the manure is not used to the best advantage. Alfalfa on the Kansas farm is the best instrument

through which the nitrogen from the air can be collected. It is very important that as much nitrogen as possible be gathered from the air, because it is needed by all kinds of grain crops and they, unlike alfalfa, cannot secure it from the air.

When a limited quantity of manure only is available it would be more economical to use the manure on other crops that must secure their nitrogen from the soil and plan to supply the phosphorus that alfalfa needs from commercial fertilizers that supply only this element of plant food. When barnyard manure is abundant so that the cultivated crops like wheat, corn, and sorghum can be manured liberally and still leave a supply for alfalfa, it should be used on this crop. It will then be the most economical and best fertilizer to use. But when manure is limited so that it is necessary to choose between using the manure on alfalfa or the cultivated crops of the farm it will be the best management from the soil fertility standpoint to use the manure on the other crops and to supply the phosphorus needed by alfalfa from acid phosphate or some other source of commercial phosphorus.

EXPERIMENTAL WORK

During the past 10 years a number of experiments have been conducted in the eastern third of Kansas to determine the fertilizer requirements of alfalfa. These experiments (fig. 1) were conducted on practically all types of alfalfa soils in eastern Kansas. They include bottom land and upland, and also soils of limestone, shale, and glacial origin.

The work was conducted on the Agronomy Farm of the Kansas Agricultural Experiment Station, Manhattan, Riley County, and on six other farms in the eastern third of the state. These farms are located near Vermillion, Nemaha County; Oneida, Nemaha County; Carlyle, Allen County; Altamont, Labette County; Bazaar, Chase County; and Eldorado, Butler County.

ALFALFA FERTILIZER EXPERIMENTS ON THE AGRONOMY FARM

The alfalfa fertilizer experiments on the Agronomy Farm of the Kansas Agricultural Experiment Station are a part of the general soil fertility project. The work consists of two parts; namely, alfalfa in a 16-year rotation and alfalfa grown continuously.

ALFALFA IN ROTATION

The 16-year rotation consists of alfalfa four years, with corn two years and wheat one year alternating for twelve years. The work is being conducted on upland silt loam soil which is in a fairly good state of productivity. Alfalfa was seeded in the fall of 1909 but because of a poor, uneven stand, comparable yields could not be secured until 1911. Five plots of one-tenth acre each, receiving different treatments of manure and commercial fertilizers, and the average yield of check plots are reported in this bulletin. All commercial fertilizer treat-

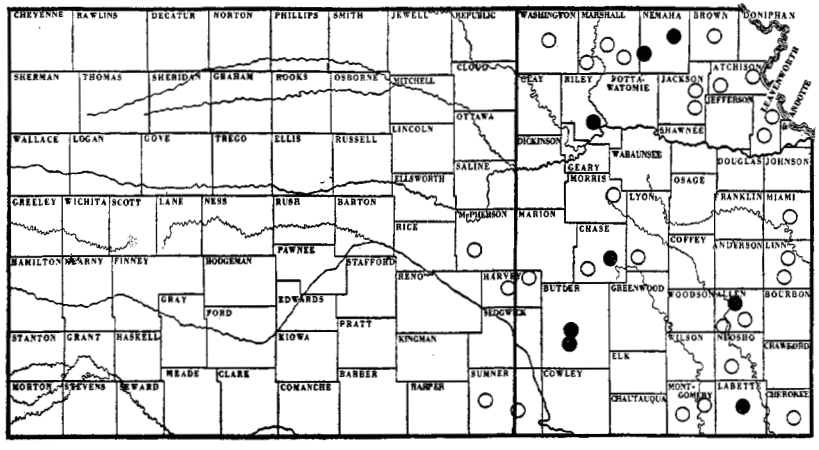

FIG. 1.—Map of Kansas showing location of cooperative experiments where fertilizers and manure have been profitable on alfalfa. The dots indicate the location of the experiments reported in this bulletin. The circles indicate the location of experimental fields which have given profitable returns but are not reported because of short duration. The recommendations contained in this bulletin refer to the area east of the heavy cross line

ments are made annually regardless of the crop being grown, but the rate of application varies with the crop. The commercial fertilizers are applied to alfalfa as a surface dressing in early spring. The applications, of manure are made at the rate of 5 tons every three years. Manure is applied to alfalfa as a surface dressing during the winter between the second and third seasons. Lime is applied to one plot in the form of hydrated lime at the rate of 800 pounds per acre every fourth year.

Table IV gives the treatments and yields of alfalfa from 1911 to 1920, inclusive.

TABLE IV.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA, 1911 TO 1920 INCLUSIVE

(Grown in rotation on the Agronomy Farm, Manhattan)

TREATMENT	Yield in pounds per acre											
	1911	1912	1913	1914 (a)	1915	1916	1917	1918	1919	1920	Average for 10 years	Average increase
None	5,195	4,388	3,633	.....	7,882	9,654	7,244	688	5,690	5,217	4,959	.....
Acid phosphate, 190 pounds annually	6,075	5,268	5,058	.....	8,762	10,751	8,260	736	7,605	6,014	5,853	894
Acid phosphate, 190 pounds and potassium sulphate, 180 pounds annually	6,184	5,326	4,359	.....	9,467	12,610	10,814	726	6,610	5,447	6,154	1,195
Acid phosphate, 190 pounds, potassium sulphate, 180 pounds, and sodium nitrate, 240 pounds annually	6,097	6,560	4,613	.....	9,997	11,885	9,224	1,335	7,525	6,622	6,386	1,427
Manure, 5 tons every three years	4,770	4,806	4,073	.....	10,237	12,293	7,919	763	7,990	7,362	6,021	1,062
Manure, 5 tons every three years; lime, 800 pounds every four years	5,403	5,512	4,503	.....	11,372	12,411	8,789	883	8,262	7,127	6,426	1,467

(a) No yields were secured in 1914 because of failure to obtain a stand of alfalfa in the fall of 1913.

This work includes three different stands of alfalfa. The seedings were made in the fall of 1909, 1913, and 1917. Because of failure to secure good stands, yields are not recorded for 1910 and 1914. The plots seeded to alfalfa in the fall of 1913 were reseeded in the spring of 1914.

The annual application of acid phosphate at the rate of 190 pounds per acre increased the average yield of alfalfa 894 pounds. At $25 per ton for acid phosphate[1] this application would cost $2.37 per acre. With alfalfa hay[2] at $13 per ton this application of acid phosphate increased the returns $5.81 per acre. Each dollar invested in acid phosphate was returned in hay worth $2.51. When acid phosphate and potassium sulphate were used together the average increase was 1,195 pounds, or 301 pounds more than when acid phosphate was used alone. Although this increase is very marked it is not sufficient to pay for the potassium sulphate. A plot receiving acid phosphate, potassium sulphate, and sodium nitrate produced an annual increase of 1,427 pounds, or 232 pounds more than where acid phosphate and potassium sulphate were used. This increase, however, is not sufficient to pay for the sodium nitrate. It will be noticed that the major portion of the increase produced by sodium nitrate was obtained from the increased yields in 1915 and 1918, both of which were the first year after seeding. It is evident that some nitrogen can be used with phosphorus at seeding time very profitably.

The application of manure at the rate of 5 tons every three years caused an average increase of 1,062 pounds of hay per acre, or a total increase of 5.3 tons during the 10-year period. Each ton of manure had a value of $4.15 in increased yields produced. The manure produced an average annual increase of only 168 pounds per acre over the acid phosphate. When the amount of manure available is not sufficient to meet the demands of grain crops and alfalfa, the manure should be used on the grain crops and acid phosphate applied to the alfalfa, or the rate of application may be reduced by reinforcing the manure with acid phosphate. The plot receiving both manure and lime produced an annual increase of 1,467 pounds of hay. This is 405 pounds more than was produced by the plot receiving manure alone. The increase from the use of lime

[1] The average price of acid phosphate for the last seven years has been $25 per ton.
[2] The average price of alfalfa hay for the last seven years has been $13 per ton.

has been very consistent. The figures from this work show very conclusively that acid phosphate, manure, and lime can be used on alfalfa very profitably; that nitrogen can be used profitably at seeding time; and that potassium sulphate or potash cannot be used profitably at the present prices.

ALFALFA CONTINUOUSLY

The soil on which alfalfa is being grown continuously is an eroded upland silt loam which is low in productivity. Alfalfa was seeded in the fall of 1909 but because of a poor stand it was reseeded in 1910. The first yields were secured in 1911. Eight one-tenth acre plots receive different fertilizer and manure treatments, while four plots used as checks receive no treatment. The yields given for no treatment are averages of the four plots. All treatments are made annually except lime, which is applied in the form of hydrated lime at the rate of 1,000 pounds every fourth year. Commercial fertilizers are applied in the spring before growth begins and the manure is applied in late fall or early winter. Table V gives the treatments and yields of alfalfa from 1911 to 1920 inclusive, and the average yields and increases for the same period. Figures 2 and 3 show actual yields of certain plots, first cutting, 1919.

The low average yields from this series of plots are due to the fact that much of the surface soil was washed away before the area was seeded to alfalfa, thus decreasing the producing power of the soil.

An annual application of 190 pounds of acid phosphate increased the average yield of alfalfa 663 pounds. Although this increase is quite profitable, it is not as large as that received where alfalfa was grown in rotation. This difference is due in part at least to the more drouthy condition of the soil on which alfalfa is being grown continuously, thus making moisture rather than plant food the limiting factor, especially after the first cutting. The use of 180 pounds of potassium sulphate in addition to the acid phosphate caused an average increase of 1,081 pounds, or 418 pounds more than the acid phosphate alone. Although this increase is very marked, it is not sufficient to pay for the potassium sulphate. It will be noted, however, that when potassium sulphate was used alone the average annual increase was only 42 pounds per acre, (Fig. 2.)

TABLE V.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA, 1911 TO 1920 INCLUSIVE

(Grown continuously on the Agronomy Farm, Manhattan)

TREATMENT	Yield in pounds per acre											
	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	Average for 10 years	Average increase
None	2,463	920	1,901	2,330	5,570	5,307	5,116	2,330	5,588	2,952	3,448	.....
Acid phosphate, 190 pounds annually	4,043	1,540	2,331	2,725	5,910	6,107	5,986	2,645	6,848	2,982	4,111	663
Acid phosphate, 190 pounds and potassium sulphate, 180 pounds annually	3,538	1,340	2,208	2,740	6,570	8,057	7,036	2,690	7,803	3,306	4,529	1,081
Potassium sulphate, 180 pounds annually	3,375	1,080	1,855	1,730	5,670	5,387	5,306	2,310	5,148	3,037	3,490	42
Acid phosphate, 190 pounds, potassium sulphate, 180 pounds, and sodium nitrate, 240 pounds annually	3,739	1,360	2,873	3,097	7,970	8,122	6,316	2,550	8,368	3,777	4,817	1,369
Manure, 2.5 tons and rock phosphate, 380 pounds annually	4,649	1,800	3,725	4,323	11,530	9,687	7,776	2,590	9,808	4,595	6,048	2,600
Manure, 2.5 tons annually	3,659	1,620	3,041	4,342	11,110	9,027	7,391	3,400	8,373	4,187	5,615	2,167
Manure, 5 tons annually	3,805	1,920	3,366	5,418	13,250	11,254	10,451	4,535	10,447	5,405	6,985	3,537
Manure, 2.5 tons annually; lime, 1,000 pounds every fourth year	3,463	1,680	3,491	4,640	11,470	8,187	7,706	3,345	6,588	4,477	5,505	2,057

A complete fertilizer consisting of 190 pounds of acid phosphate, 180 pounds of potassium sulphate, and 240 pounds of sodium nitrate, produced an average increase of 1,369 pounds per acre, This is an increase of 288 pounds over the yield obtained from the use of phosphorus and potassiurn without nitrogen. Commercial fertilizers have not been as profitable on the continuous alfalfa as they have on the rotation because the soil is lower in organic matter and more subject to drouth injury.

The annual application of manure at the rate of 2.5 tons produced an average increase of 2,167 pounds of hay per acre.

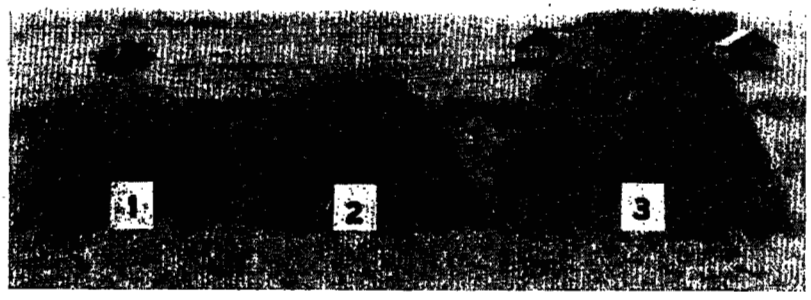

FIG. 2.—Alfalfa hay harvested, first cutting, 1919, from one-tenth acre plots receiving annual treatments as follows:

Treatment	Average yield, 1911 to 1920
1. No treatment	3,448 pounds
2. Potassium sulphate, 180 pounds	3,490 pounds
3. Acid phosphate, 190 pounds, and potassium sulphate, 180 pounds	4,529 pounds

Each ton of manure produced an average of 867 pounds of hay. With alfalfa hay at $13 per ton, the manure used on this plot has been worth $5.64 per ton from the standpoint of crop increase. Manure applied at the rate of 5 tons annually produced an average increase of 3,537 pounds of hay, or each ton of manure increased the yield 707 pounds. With alfalfa hay at $13 per ton, the manure applied at the rate of 5 tons annually was worth $4.60 per ton, or $1.04 less than when applied at the rate of 2.5 tons annually. (Fig. 3.)

An annual application of 2.5 tons of manure with 380 pounds of rock phosphate (fig. 3) produced an average increase of 2,600 pounds of hay. This treatment produced 433 pounds more than manure alone.

The plot receiving an annual application of 2.5 tons of manure and 1,000 pounds of lime every fourth year produced 110 pounds less hay than the plot receiving manure alone.

Although fairly heavy applications of manure are profitable on alfalfa, if the supply is limited it is more profitable to apply that which is available at a light rate over a large acreage rather than to make heavy applications to a smaller area. Heavy applications of coarse manure may lower the market

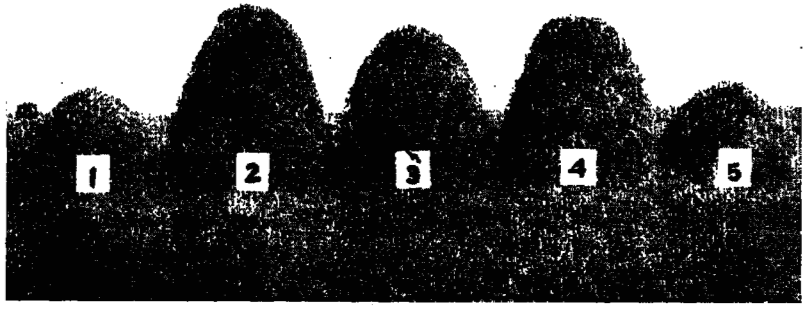

FIG. 3.—Alfalfa hay harvested, first cutting, 1919, from one-tenth acre plots receiving annual treatments as follows:

	Treatment	*Average yield, 1911 to 1920*
1.	No treatment	3,049 pounds
2.	Manure, 5 tons	6,985 pounds
3.	Manure, 2.5 tons	5,615 pounds
4.	Manure, 2.5 tons, and rock phosphate, 380 pounds	6,048 pounds
5.	No treatment	3,006 pounds

value of the hay secured from the first cutting the following season, but will have very little influence on the feeding value of the crop. Coarse manure should be applied as early in the fall as possible so that it will have more time to decay and so that the rain and snow of winter will aid in bringing it in closer contact with the soil where it will be less likely to be disturbed by the rake at harvest time.

OUTLYING FERTILIZER EXPERIMENTS ON ALFALFA

A number of outlying fertilizer experiments were started in 1914 and additional ones in succeeding years. These experiments were conducted in order to secure some information regarding the use of manure, commercial fertilizers, and lime on alfalfa on the various soils throughout eastern Kansas. Two types of experiments were put under way; namely, those in

which the fertilizers were applied and the alfalfa seeded at the beginning of the experiments and those started on established stands of alfalfa.

The outlying experiments were conducted in cooperation with farmers. Each experiment included a series of six to nine one-tenth acre plots variously treated. Every third plot was an untreated or check plot. The yields reported for the no treatment plots in the tables which follow are averages for these two or three check plots.

EXPERIMENTS IN NEMAHA COUNTY

The Nemaha County alfalfa fertilizer experiments were located on the farm of E. H. Woodman in the western part of the county near Vermillion. The soil is an upland type, which is fairly productive and typical of much of the upland in Nemaha and adjacent counties.

The experiments were started in 1914 on a stand of alfalfa which had been seeded in 1907. At the time the experiments were started the stand of alfalfa was uniformly good throughout the area selected for the plots,

The experiments consisted of a series of plots, five of which received treatments of commercial fertilizer, manure, and lime, while the others which were not treated were used as check plots. The fertilizers were applied early in the spring and were worked into the surface soil by disking. Only one application of manure, rock phosphate, and ground limestone was given. The acid phosphate was applied annually. Since the alfalfa was broken up in 1917, results were secured for only four years. The results secured from these experiments are given in Table VI.

The untreated alfalfa averaged practically 2 tons per acre for the four-year period. Acid phosphate increased the average yield 1,563 pounds per acre. With acid phosphate at $25 per ton and alfalfa hay at $13 per ton, the application of acid phosphate cost $3.13 per acre and increased the value of the crop $10.16 per acre. In other words, every dollar invested in acid phosphate returned $3.27 in hay.

Manure applied at the beginning of the four-year period at the rate of 10 tons per acre, produced marked increases in yield every season. The average yield was 1,089 pounds greater than that of the untreated plot. For each ton of

TABLE VI.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA

(Near Vermillion, Nemaha County)

TREATMENT	Yield in pounds per acre					
	1914	1915	1916	1917	Average yield	Average increase
None	4,306	5,354	3,131	3,167	3,989	.....
Acid phosphate, 250 pounds annually.	5,233	7,458	4,654	4,865	5,552	1,563
Acid phosphate, 250 pounds annually; ground limestone, 2,500 pounds and manure, 10 tons in 1914	6,086	8,636	5,110	4,699	6,132	2,143
Rock phosphate, 1,000 pounds and manure, 10 tons in 1914	4,766	7,418	4,127	4,011	5,080	1,091
Manure, 10 tons in 1914	5,080	8,043	3,548	3,636	5,078	1,089
Ground limestone, 2,500 pounds applied in 1914	4,519	6,188	3,309	3,313	4,332	343

manure applied a value of $2.83 was returned in the form of alfalfa hay at $13 per ton. No doubt the manure would have been effective for several more years if the alfalfa had not been plowed up. Manure reinforced with 1,000 pounds of rock phosphate failed to produce as good returns as the manure alone. The rock phosphate caused decreases in the yield the first two seasons, but gave increases the third and fourth years. Evidently this material was too slowly available to have any appreciable influence during the four-year period.

Manure, acid phosphate, and limestone used in combination produced the greatest increase in yield and also the largest profit. The average increase was 2,143 pounds, or 1,054 pounds more than the increase produced by manure alone, Ground limestone increased the average yield 343 pounds per acre.

In 1917 a test similar to the one conducted on the Woodman farm was started on the farm of S. B. Anderson near Oneida. The soil is very similar to that on the Woodman farm. The field in which the plots were located had been in alfalfa for several years. The treatments were the same as those used on the Woodman farm except that lime was applied to one plot only. Because of drouth only one cutting was secured in 1917 and 1918. A normal crop was secured in 1919. The results for the three-year period, 1917 to 1919 inclusive, are given in Table VII.

Acid phosphate increased the average yield 1,207 pounds per acre while manure and acid phosphate together increased

TABLE VII.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA

(Oneida, Nemaha County)

TREATMENT	Yield in pounds per acre				
	1917	1918	1919	Average yield	Average increase
None	2,160	1,438	6,717	3,438	.....
Acid phosphate, 250 pounds annually	2,430	1,875	9,629	4,645	1,207
Acid phosphate, 250 pounds annually; manure, 10 tons in 1917	3,173	2,063	9,581	4,939	1,501
Rock phosphate, 1,000 pounds annually; manure, 10 tons in 1917	2,835	1,965	8,046	4,283	845
Manure, 10 tons in 1917	2,970	1,875	8,219	4,355	917
Lime (air slacked), 1,000 pounds in 1917	2,638	1,688	7,883	4,068	630

the average yield 1,501 pounds, or 584 pounds more than manure alone. Manure and rock phosphate produced less hay than manure alone.

Lime increased the average yield 630 pounds. Acid phosphate has had more effect on the yield than manure, rock phosphate, or lime, but the manure and rock phosphate have not had sufficienttime to produce maximum returns.

EXPERIMENTS IN ALLEN COUNTY

The Allen County alfalfa project is of special interest because farmers in the locality in which the experiments were conducted were positive that alfalfa could not be grown on the upland soils in that part of the state. The plots are located on the farm of A. M. Dunlap near Carlyle. The soil is the Oswego silt loam with a fairly heavy silt loam surface soil and a heavy clay subsoil.

The work was started in 1914. The ground was plowed in the early spring. Two tons of ground limestone per acre were applied to all but two of the plots. The field was plowed again during June when a crop of weeds was turned under. The soil was cultivated frequently enough during the summer to prevent the growth of weeds and to form a good seedbed. Alfalfa was seeded the latter part of August at the rate of 15 pounds per acre. The manure and rock phosphate applications were made in the early summer of 1914 and both materials were worked into the soil. No additional applications of manure or rock phosphate have been made since that time. Bone meal was used as the conveyor of phosphorus until 1916,

after which time acid phosphate was used. The bone meal was applied in advance of seeding in 1914. The applications of acid phosphate have been made annually in early spring.

The fertilizer treatments and the yields in the Allen County experiments are given in Table VIII.

The season of 1915 and the early spring of 1916 were excessively wet. Conditions for alfalfa were about as unfavorable as they ever are in southeastern Kansas. For the remainder of the six-year period growing conditions for alfalfa were probably more favorable than normal, because there was no excessive moisture after 1916.

The average yield per acre for the untreated alfalfa for the six-year period was 1,917 pounds. Under practical farm conditions, this alfalfa would have been plowed up after the third year because of the poor stand. The yields the last three years were very light and the plots were very grassy. Practically the entire stand was gone at the end of the season of 1919 and no alfalfa was produced in 1920.

Lime alone increased the annual yield of alfalfa 1,973 pounds per acre. The total increase from the one application of limestone was 5.92 tons of hay. With hay at $13 per ton, each ton of limestone produced an increase in yield worth $38.48. Undoubtedly the effect of the lime will continue for several years. Although the alfalfa on the plot receiving lime alone made a good growth each season, the yields were always light as compared with those of the other treated plots. Grass and weeds did not appear in the limed plot until the fall of 1919.

Acid phosphate applied annually at the rate of 250 pounds per acre on limed soil produced a marked increase in yield every season and a good thrifty stand remained at the close of the six-year period. The annual increase in yield was 4,507 pounds over the untreated plot and 2,534 pounds over the plot which received lime alone. After deducting the increase due to the lime alone and giving acid phosphate a value of $25 a ton and alfalfa hay a value of $13 a ton, each dollar invested in acid phosphate produced an increase in yield worth $5.27.

The use of potassium sulphate in addition to acid phosphate and limestone decreased the average yield 243 pounds per acre below that secured from acid phosphate and limestone alone.

Manure applied alone at the rate of 10 tons per acre in the summer of 1914 before the alfalfa was seeded resulted in an

TABLE VIII.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA

(Carlyle, Allen County)

TREATMENT	Yield in pounds per acre							
	1915	1916	1917	1918	1919	1920	Average yield	Average increase
None	1,066	1,705	4,969	2,138	1,625	0	1,917	.....
Limestone, 2 tons in 1914	1,569	2,765	5,699	2,824	3,442	7,042	3,890	1,973
Acid phosphate, 250 pounds annually; limestone, 2 tons in 1914	2,013	3,565	8,727	6,032	7,181	11,025	6,424	4,507
Acid phosphate, 250 pounds and potassium sulphate, 50 pounds annually; limestone, 2 tons in 1914	2,132	3,725	8,769	6,262	6,846	9,354	6,181	4,264
Manure, 10 tons in 1914	2,256	3,345	8,969	3,864	2,835	0	3,545	1,628
Manure, 10 tons and limestone, 2 tons in 1914	3,238	4,545	9,134	4,388	6,701	9,150	6,192	4,275
Manure, 10 tons, rock phosphate, 1,000 pounds, and limestone, 2 tons in 1914	2,775	4,255	9,700	4,931	7,149	10,862	6,612	4,695

annual increase in yield of 1,628 pounds per acre. The total increase during the six years was 4.88 tons. With alfalfa hay at $13 a ton, each ton of manure returned a value of $6.34, It will be noted in Table VIII that the yields for the first three seasons were relatively high and that they fell off considerably for the last three years. The stand was practically gone at the end of the season of 1919 and no hay was produced on the plot in 1920. Evidently the manure supplied the necessary plant food required for good yields for the first three seasons, but as soon as plant food became deficient the alfalfa stand deteriorated rapidly, making conditions more favorable for grass and weeds.

Manure with lime was much more effective than manure alone. The average annual yield per acre on the plot receiving manure and lime was 2,647 pounds greater than on the plot receiving manure alone, and the total increase for the six years was 7.94 tons. The average annual increase on the plot receiving manure and lime over the plot receiving no treatment was 4,275 pounds. At the end of the six-year period the alfalfa on this plot was in a thrifty condition and the stand sufficiently strong to successfully compete with grass and to produce maximum yields.

On the plot receiving manure, limestone, and rock phosphate, the rock phosphate caused a decrease in yield for the first two seasons and a slight increase for the last four seasons over the plot receiving manure and limestone. The increase was greater in 1920 than any previous year. The total increase in yield for the six-year period was 1,902 pounds per acre. This increase is more than enough to pay for the rock phosphate but the profit is not so great as where acid phosphate was used. There is a possibility that the rock phosphate will prove effective for several more seasons and may in time return a greater profit. It is evident, however, that this material is not profitable within a period of less than six years.

EXPERIMENTS IN LABETTE COUNTY

The experiments in Labette County supplement those in Allen County. The fertilizer treatments are the same as those in Allen County, with the exception of an additional plot receiving a combination of manure and acid phosphate. The

lime was applied in the form of air-slacked lime at the rate of 1,000 pounds per acre.

The work was conducted in cooperation with the Department of Agriculture of the Labette County High School.. It was started in the fall of 1917. Alfalfa was seeded on summer-fallowed land. The manure, rock phosphate, and commercial fertilizer were applied previous to seeding and were worked into the soil. The application of lime was made in the spring of 1917. The land was inoculated by scattering soil from a sweet clover field over the area. An excellent stand of alfalfa was secured. Because of drouth only one cutting of alfalfa was secured the first season, while three cuttings were secured in 1919 and 1920. The untreated alfalfa was practically a failure the second season. The first cutting for the second year was very weedy, while no alfalfa was produced for the second and third cuttings. No hay was produced on this plot in 1920. The plots receiving manure alone and manure and acid phosphate were very weedy in 1920. The lack of lime has weakened the plants until weeds and grass are crowding the alfalfa out.

The results for the various fertilizer treatments (Table IX) are practically the same as those secured in Allen County.

TABLE IX.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA

(Labette County High School, Altamont)

TREATMENT	Yields in pounds per acre				
	1918	1919	1920	Average yield	Average increase
None	1,575	700	0	758	.....
Lime, 1,000 pounds in 1917	1,440	4,347	3,840	3,109	2,351
Acid phosphate, 200 pounds annually; lime, 1,000 pounds in 1917	2,385	6,857	7,480	5,574	4,816
Acid phosphate, 200 pounds and potassium sulphate, 50 pounds annually; lime, 1,000 pounds in 1917	2,430	6,282	7,420	5,244	4,486
Manure, 10 tons in 1917	3,825	5,052	5,060	4,646	3,888
Manure, 10 tons and lime, 1,000 pounds in 1917	3,510	7,220	6,060	5,597	4,839
Manure, 10 tons in 1917; acid phosphate, 200 pounds annually	3,780	6,570	5,980	5,443	4,685
Manure, 10 tons, rock phosphate, 1,000 pounds, and lime, 1,000 pounds in 1917	3,420	7,668	6,440	5,843	5,085

Lime increased the average annual yield of alfalfa 2,351 pounds per acre. Acid phosphate and lime produced an average increase of 2,465 pounds over lime alone. Manure with lime increased the yield 2,488 pounds over lime alone and 951 pounds over manure alone. Rock phosphate decreased the yield the first year but gave an increase the second and third years. The average annual increase over manure and lime was 246 pounds. A combination of acid phosphate and manure was more effective than manure alone, but not so effective as manure and lime or acid phosphate and lime. Potassium sulphate, acid phosphate, and lime decreased the yield the second and third years and gave an average decrease of 330 pounds during the three-year period as compared with acid phosphate and lime.

EXPERIMENTS IN CHASE COUNTY

The Chase County experiments were started in 1917 on the farm of S. H. Baker, south of Bazaar. The soil occupies a slope and is the Summit clay loam. It contains an abundant supply of lime and for this reason no applications of lime were made. The plots were located in an established field of alfalfa which was seeded in 1915. The fertilizers were applied as a top dressing in the early spring and were disked into the surface soil. Only one application of manure and rock phosphate was made while acid phosphate was applied annually.

Because of drouth only one cutting was secured for each of the first two seasons. Two cuttings were secured in 1919 and one in 1920. During each season the alfalfa was fall pastured and for this reason the yields presented do not represent the total production.

The yields given in Table X show that acid phosphate alone increased the production 813 pounds per acre. It was more effective than manure which increased the average yield only 409 pounds per acre. Manure and acid phosphate applied to the same plot produced an increase of 699 pounds per acre more than when manure was used alone. Rock phosphate used to reinforce manure produced increased yields the second and third years, but the average increase was only 116 pounds per acre. The acid phosphate produced very profitable returns.

TABLE X.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA

(Bazaar, Chase County)

TREATMENT	Yields in pounds per acre					
	1917	1918	1919	1920 (a)	Average yield	Average increase
None	1,094	1,417	2,621	1,536	1,667	.....
Acid phosphate, 250 pounds annually	1,675	1,685	4,782	1,779	2,480	813
Manure, 10 tons in 1917	1,625	1,837	3,178	1,657	2,076	409
Manure, 10 tons in 1917; acid phosphate, 250 pounds annually	2,063	2,214	4,740	2,074	2,775	1,108
Manure, 10 tons and rock phosphate, 1,000 pounds in 1917	1,563	2,059	3,522	1,622	2,192	525

(a) Yields in 1920 are for one cutting only. The plots were pastured during the early part of the season, one cutting was removed in midsummer, and the plots were pastured during the fall.

EXPERIMENTS IN BUTLER COUNTY

The Butler County alfalfa experiments consist of both upland and bottom land fertilizer tests. The plots are located on the farm of J. J. Johnson, five miles north of Eldorado.

Upland Experiments.—The Butler County upland experimental plots are located on red limestone land classified as Crawford silt loam. The soil is deep for this type but nevertheless is very subject to drouth. Acid phosphate was applied annually at the rate of 150 pounds per acre on one plot and 250 pounds per acre on another. Only one application of manure, lime (air-slacked), and rock phosphate was made. They were applied at the time the experiment started. No yields were secured the first year. The yields for the five-year period 1915 to 1919 inclusive, are given in Table XI.

Acid phosphate applied annually at the rate of 250 pounds per acre increased the average yield 1,188 pounds per acre, while an annual application of 150 pounds per acre increased the yield 955 pounds per acre. With alfalfa at $13 per ton and acid phosphate at $25 per ton, each dollar invested in acid phosphate applied at 250 pounds per acre returned an increase in yield worth $2.47, and each dollar invested in acid phosphate applied at 150 pounds per acre returned an increase in yield worth $3.25. While a greater yield resulted from the heavier application, the 150-pound rate returned a greater percent on the investment.

The application of air-slacked lime was not effective. The decreased yield of the limed alfalfa was probably due to a

TABLE XI.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA ON UPLAND

(Eldorado, Butler County)

TREATMENT	Yield in pounds per acre						
	1915	1916	1917	1918	1919	Average yield	Average increase
None	5,900	5,625	2,906	1,668	3,750	3,850	.....
Acid phosphate, 250 pounds annually	6,300	6,450	3,939	2,213	6,287	5,038	1,188
Acid phosphate, 150 pounds annually	6,400	6,100	3,282	2,155	6,087	4,805	955
Lime (air-slacked), 1,000 pounds in 1914	5,400	4,350	2,657	1,668	3,625	3,540	—310
Manure, 10 tons in 1914	8,450	7,225	4,031	2,306	5,462	5,495	1,645
Manure, 10 tons and rock phosphate, 1,000 pounds in 1914	8,175	8,150	3,875	2,156	5,481	5,567	1,717

difference in the natural productiveness of the soil and not to the treatment. It was apparent that the lime has no beneficial effect.

Manure was very effective and increased the average yield 1,645 pounds per acre, or for each ton of manure applied an increase of 822 pounds of alfalfa was received during the five-year period. At $13 per ton for alfalfa each ton of manure applied has returned $5.34. Apparently the manure is still quite effective. Manure reinforced with rock phosphate produced an average annual yield of only 72 pounds more than manure alone.

Bottom Land Experiments.—The Butler County bottom land fertilizer plots are located on productive, deep, alluvial soils exceptionally well adapted to alfalfa. The results are of special interest in that they show what can be expected of the use of manure and commercial fertilizers on the best alfalfa soils in east central Kansas. The treatments are the same as those used on the upland plots except that no lime is used and that the 150-pound application of acid phosphate was not included until the third year. The treatments and results are given in Table XII.

Acid phosphate was very effective and, applied at the rate of 250 pounds annually, increased the average yield 2,101 pounds per acre. During the last three years the 150-pound application produced an average increase of 1,296 pounds over the plot receiving no treatment for the same period. The heavier ap-

TABLE XII.—FERTILIZER TREATMENTS AND YIELDS OF ALFALFA ON BOTTOM LAND

(Eldorado, Butler County)

TREATMENT	Yield in pounds per acre						
	1915	1916	1917	1918	1919	Average yield	Average increase
None	8,400	6,375	6,119	4,237	6,924	6,411	.....
Acid phosphate, 250 pounds annually	8,400	8,675	9,559	5,462	10,468	8,512	2,101
Acid phosphate, 150 pounds annually	.....	.....	6,513	5,294	9,362	a7,056	.....
Manure, 10 tons in 1914	8,350	8,800	6,376	5,700	5,918	7,748	1,337
Manure, 10 tons and rock phosphate, 1,000 pounds in 1914	9,600	9,375	8,676	5,931	9,670	8,650	2,239

(a) Average of three years.

plication of acid phosphate produced a greater yield than manure alone and almost as much as the manure and rock phosphate in combination. Using the values previously given, for every dollar's worth of acid phosphate applied on alfalfa at the rate of 250 pounds per acre there was returned a value of $4.37 in the form of alfalfa hay.

Manure alone increased the annual yield 1.337 pounds per acre or a total of 668 pounds for each ton of manure applied. Rock phosphate was much more effective on the bottom land than on the upland. It was more effective in this experiment than in any other in the state. Manure and rock phosphate used together produced 902 pounds more hay than manure alone. Rock phosphate was very profitable in this experiment.

Results.—The thriftiness, of the fertilized alfalfa and its ability to compete with grass and weeds was an outstanding feature of the Butler County experiments, especially those on the upland. The alfalfa on the untreated plots was usually very grassy for the second and third cuttings. At no time during the five-year period did grass develop sufficiently on the fertilized plots to be injurious. The Butler County work also demonstrated decisively that the fertilized alfalfa did not deteriorate as rapidly as that which was not fertilized, and that proper fertilizing will greatly assist in maintaining a stand.