THE FERTILITY LEVEL OF A SOIL UNDER THIRTY-SEVEN YEARS OF CONTINUOUS ALFALFA CULTURE

By

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INTRODUCTION

It is well known to students of soil science that the continuous growing of grain crops decrease the fertility of the soil on which they are grown. Also it is known that the growing of legumes, such as alfalfa, in a measure helps to restore this fertility. To what degree this takes place is not so well known (14).[1]

There is not too much information to be found in the literature concerning the effect on soil fertility of the long continued growing of alfalfa on the same land.

Located on the Agronomy Farm of the Oklahoma Agricultural and Mechanical College are plots which have been growing alfalfa continuously since 1913, except for two years when the stand died. Each time the stand thinned or died out the land was prepared and reseeded to alfalfa.

These plots presented an excellent opportunity for research on the fertility level of a soil which has been producing alfalfa continuously for a long period of time. It was thought that an investigation of the fertility level of these plots would give worthwhile information.

The main problem of the present study is this: When alfalfa, which has received various fertilizer treatments for several years, has been grown continuously on a piece of land and all the crop harvested as hay, what has been the effect on the soil fertility elements.

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[1] The numbers in parentheses refer to the "Literature Cited" on page 37.

REVIEW OF LITERATURE

Alfalfa and Nitrogen Fixation

According to Swanson and Latshaw (14), Russel mentions the classic instance of the restoration of the nitrogen content of the soil of the Schultz-Lupitz estate in Germany as an example, of the power of legumes to restore nitrogen to worn-out soil. This estate was once a barren sand. Lime and fertilizers containing phosphorus and potassium were used but no nitrogenous manures. The land was cropped alternately to lupines and cereals, the former being either plowed under or fed. The barren sand after a time became a rich soil capable of producing a large variety of crops. As shown by Russel the enrichment in nitrogen of soil by legumes is dependent upon available phosphorus and potassium.

Bracken and Larson (2) reported an investigation which was started for the purpose of measuring changes in nitrogen content of soil planted to alfalfa for varying number of years following wheat. Accounting for the nitrogen in the hay, adding this to that accumulated in the soil, and dividing by the years of cropping gave the average yearly increase of nitrogen per acre of 246 pounds. Fields which had been in alfalfa 10 to 13 years showed as much recovery of nitrogen in the first foot of soil as those that had been in alfalfa 15 to 30 years. The nitrogen equilibrium level for land in alfalfa following wheat is considered to be approximately 7 per cent below adjacent virgin areas.

Lucas, Scarseth, and Sieling (9) found that the nitrogen content in Crosby silt loam soil on a plot which had its residue returned and was fertilized with phosphate and potash, was 500 pounds per acre above the untreated plot. This increase in nitrogen occurred even though the nitrogen removal had been greater with the greater legume hay yield on the treated plot than on the untreated plot.

Lipman and Blair (8) point out that while it is not possible to determine directly just how much nitrogen the alfalfa was able to get from the air, the results as given by them seem to justify the assumption that the crop on two plots in 1916, calculated on the acre basis, secured not less than 150 to 175 pounds of its nitrogen from the air. If the lower figure be taken, it would mean nitrogen equivalent to nearly 1,000 pounds of 16% nitrate of soda.

This indicates that alfalfa is especially efficient in the accumulation of atmospheric nitrogen, and points to the desirability of a wider use of this crop as a means of maintaining the nitrogen supply of the soil.

In a field experiment conducted by Roberts and Olson (12), there was an estimated difference in the nitrogen content of fertilized and unfertilized plots in some cases as high as 800 pounds of nitrogen per acre. The bulk of this nitrogen gain is associated with the use of phosphorus, although there is evidence of gain due to potassium.

Alfalfa and Minerals

Very little work has been done relating to the effect of legumes on the mineral elements of the soil. Certain work has shown that some elements, particularly phosphorus, have decreased. Other work fails to show any appreciable change. This is partly due to the inherent difficulties of the problem (14).

As stated by Blair and Prince (1), it is well known that alfalfa draws heavily upon certain of the mineral elements in the soil, especially calcium and potassium. Less is known of its phosphorus requirements.

It was concluded by Hinkle (6, 7) that fertilization of alfalfa with phosphates may increase the phosphorus content of hay as much as 30 per cent if the soil is deficient in available phosphorus.

Pittman (10) of the Utah Station has shown that there is a direct correlation between yields resulting from the application of manure or superphosphate and the phosphorus content in the hay.

Almost without exception, a deficiency of either phosphate or potassium decreased the absolute amount of nitrogen fixed by soybeans in a greenhouse experiment (12). In all cases large increases in growth and in the amount of nitrogen fixed resulted from the use of phosphorus. Alsike clover and alfalfa also responded to potassium if an adequate supply of phosphorus were available.

Under Utah conditions, Pittman and Burnham (11) showed that alfalfa responded to phosphorus, but not to nitrogen or potassium. These investigators stated that this was expected, since alfalfa is a legume and has the ability to obtain its nitrogen supply from the air; and because most Western soils are well supplied with available potassium.

HISTORY OF PLOTS

The soil on which these plots are located has been classified in the 1916 soil survey by the United States Department of Agriculture as Kirkland silt loam. A description of this soil follows (3).

> The Kirkland silt loam consists of 6 to 15 inches of brown, grayish-brown, or dark-brown silt loam, underlain abruptly by a tenacious, heavy clay, which is plastic when wet and very hard and compact when dry. The clay subsoil is brown or dark-brown in the upper part, and brown usually mottled with yellow, gray, and red in the lower part. Where the heavy "hardpan" or "claypan" lies more than 12 or 15 inches from the surface the soil immediately above it is usually as heavy as a silty clay loam, but in the areas of shallower surface soil the transition from the silt loam soil to hard clay subsoil is more abrupt.
>
> In some places the lower subsoil is yellow and brown mottled, and in others it is dull red mottled with brown or gray. The reddish subsoil color occurs in slightly elevated situations within or bordering more nearly level areas. In some depressed areas, especially south of Stillwater, the subsoil is extremely plastic and nearly black in the upper part, but gradually becomes lighter colored with increase in depth, generally being mottled with rusty brown or yellowish gray in the lower part of the 3-foot section.
>
> The Kirkland silt loam is derived largely from the finer grained sandstones and shales of Permian age. It owes its comparative absence of red color to comparatively poor drainage resulting from the nearly level surface and relatively low position. On account of the prevailing lack of surface relief the soil has not been subject to erosion such as has been constantly carrying away the old material from the Vernon soils and allowing them to be renewed by weathering of the underlying rock. Drainage is frequently rather poor, but in many places the slope is steep enough for adequate drainage, and some areas occur in comparatively elevated places at the heads of draws. The type is encountered mostly in the central part of the county.

The Kirkland silt loam on which this experiment is located fits the general description as given above. The claypan was encountered at a depth of approximately 12 inches. Calcium carbonate concretions were encountered in the 24 to 36 inch horizon. Surface drainage is adequate.

This land was first planted to alfalfa in the Spring of 1913. The history of the soil area is not known prior to the time when the alfalfa was planted. It is known that the land where the plots are located had been producing row crops for several years before 1913, but there are no records of the particular crops that were grown on this area.

In the Winter of 1912-13 the land was plowed and the seedbed was prepared. Alfalfa was seeded in the Spring of 1913. Fig. 1 shows a diagram of the plots at the beginning of the experiment. The manured plot received an application of twelve tons of manure per acre.

The two original plots were divided equally in 1916 (see Fig. 2) and the south one-half of each of the original plots received an application of agricultural limestone at the rate of two and one-half tons per acre.

By the Summer of 1922 the stand had deteriorated badly so the land was plowed in the Winter of 1922-23. The seedbed was prepared and the alfalfa was reseeded in the Spring of 1923. The stand deteriorated again so that the alfalfa had to be reseeded again in May, 1929. The growth in 1929 was very limited and no yield data were taken. The alfalfa was clipped and the clippings were left on the plots.

The plan of the experiment was changed in the Summer of

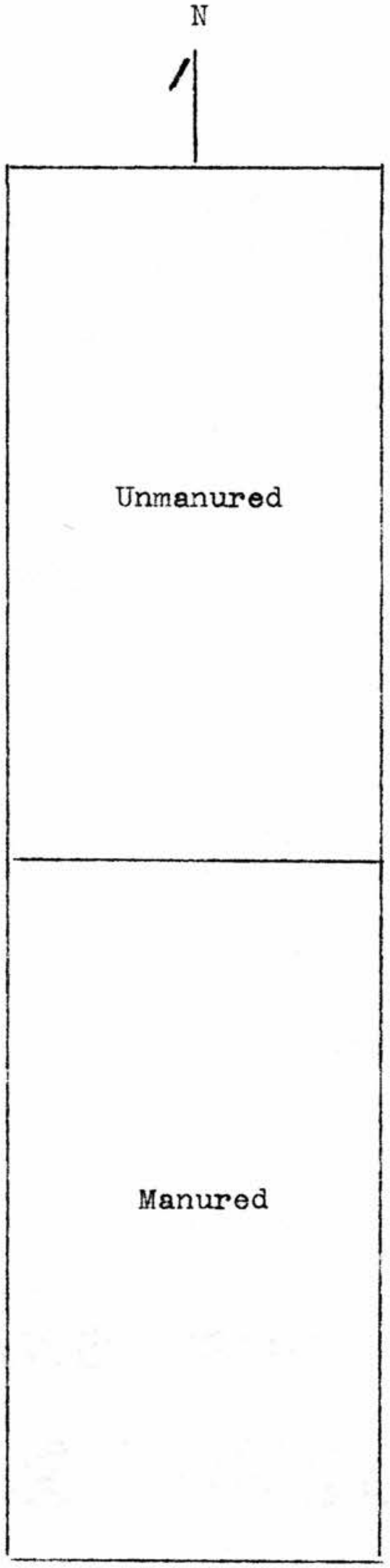


Fig. 1. Plots as of 1913.

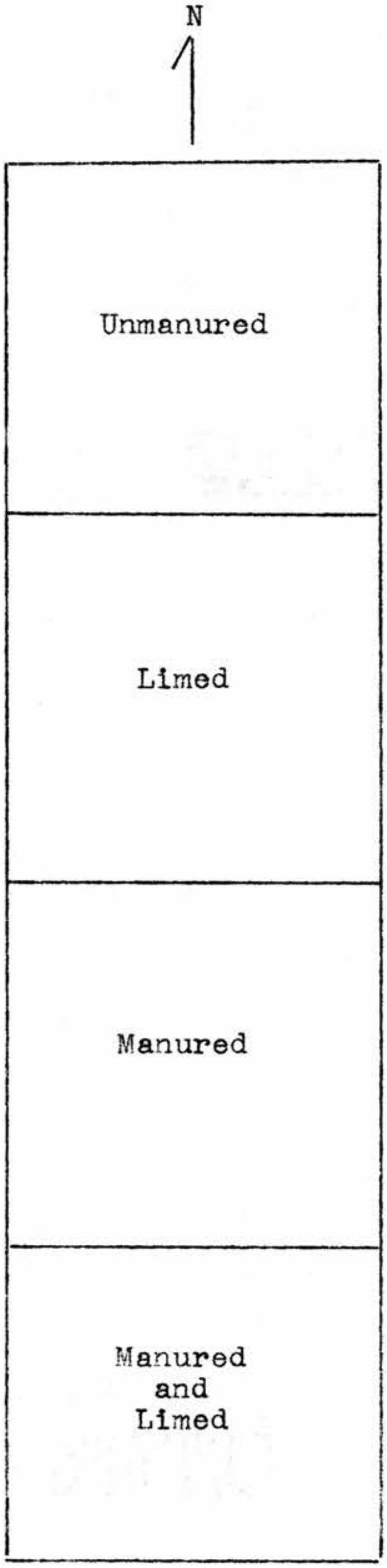


Fig. 2. Plots as of 1916.

1929 to include the use of commercial fertilizers. Each of the four plots shown in Fig. 2 were divided into five strips with a border strip left on the east side (see Fig.3). The first application of commercial fertilizer was made on June 11, 1929.

Nitrate of Soda at a rate equivalent to sixteen pounds of nitrogen per acre was applied annually to the N plots. Superphosphate at a rate equivalent to forty-eight pounds of P_2O_5 per acre was applied annually to the P plots. Muriate of Potash at a rate equivalent to thirty-two pounds of K_2O per acre was applied annually to the K plots.

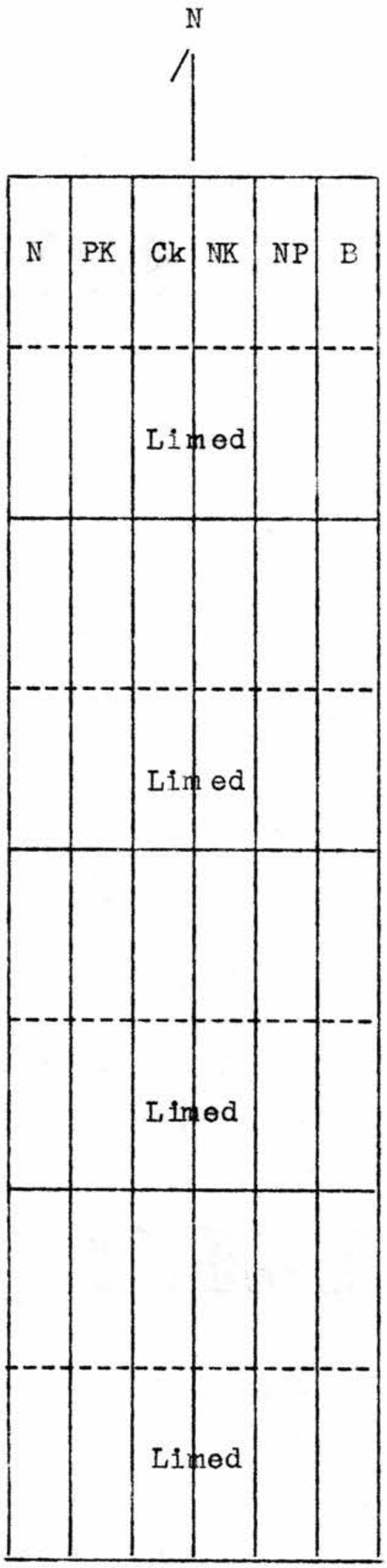
The drought of 1939 severely thinned the stand of the alfalfa. On June 1, 1940 the land was plowed and a seedbed prepared. Alfalfa was reseeded in the fall of 1940.

In the Spring of 1944 the alfalfa was attacked by a heavy infestation of aphids (<u>Macrosiphum</u> <u>pisi</u> Kltb.). It did not recover from this attack. The land was plowed during the latter part of June and left fallow during the summer. Alfalfa was reseeded in the Fall of 1944.

Fertilizer was applied to the plots in February, 1949, but the stand of alfalfa was not sufficient for yield data. The stand of alfalfa was especially thin on plots which had received no lime and no phosphorus.

In the Spring of 1950, it was decided to terminate the experiment, and soil samples were taken from the plots designated as Area A in Fig. 4. The present study has been limited to this area.

The plot numbers are given at the top of Fig. 4. Each



LEGEND

N = Nitrate of soda

P = Superphosphate

K = Muriate of potash

Ck = Check

B = Border

Fig. 3. Plots as of Summer 1929.

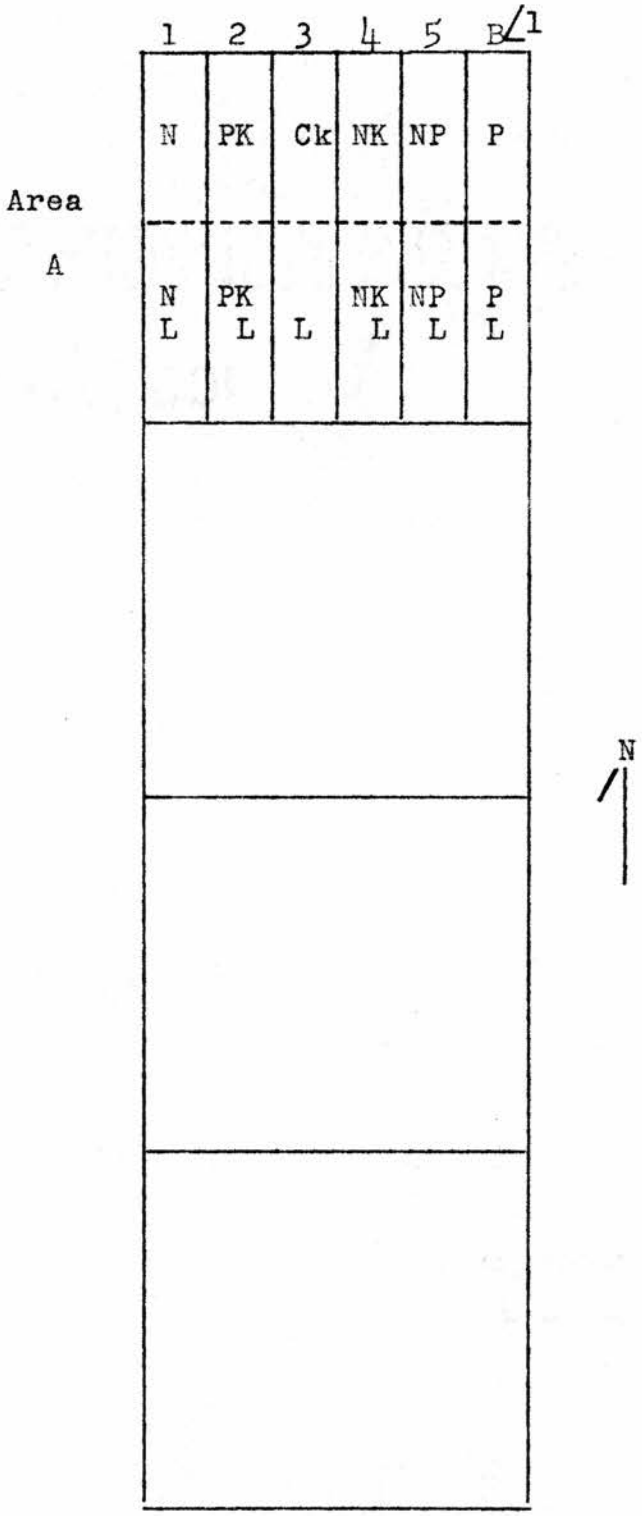


Fig. 4. Area A.

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[1] In the Spring of 1937 this border strip was treated with Superphosphate and Superphosphate and Lime. The superphosphate was applied at the rate of 240 pounds per acre and limestone at the rate of 2 tons per acre. These plots are not discussed in this paper.

plot consists of an area 16.5 feet by 71 feet.

Area A was the original check plot. No yield data are available for the years 1913 to 1915 inclusive, for this plot. From 1916 to 1928 inclusive (13 years), the average yield was 1,704 pounds of hay per acre.

Two tons of agricultural limestone per acre were applied to the limed plots during each of the following winters: 1929-30, 1933-34, 1937-38, 1941-42, and 1945-46.

It should be noted that Area A had received no soil treatment prior to 1930.

EXPERIMENTAL WORK

Collecting and Preparing the Samples

In collecting soil for analysis, five samples were taken by means of a soil tube from each plot at depths indicated and composited. The samples were generally taken at four different depths, namely 0 to 4 inches, 4 to 12 inches, 12 to 24 inches and 24 to 36 inches.

The soil samples were put in paper bags and carried to the laboratory. When thoroughly air-dry, the whole sample was pulverized with a brass roller until it would pass through a 20-mesh sieve. The sample was thoroughly mixed and a small subsample was then ground in a Braun pulverizer. This subsample was placed in a small manila envelope and a total nitrogen analysis was made on it. The portion of the 20-mesh soil that would pass through a 60-mesh sieve was placed in small cardboard cartons. This soil was used for the determinations of easily soluble phosphorus, exchangeable potassium, soluble calcium, and pH. The portion of the 60-mesh soil that would pass through a 100-mesh sieve was used for the determination of total phosphorus.

Methods of Soil Analysis

The total nitrogen was determined by using the Standard Kjeldahl procedure (4). Easily soluble phosphorus was determined by using the acetic acid method (5). A colormetric procedure with slight modifications was used for the determination of total phosphorus (13). The exchangeable potassium was extracted by using neutral normal ammonium acetate at 70° C and the amount determined by using the flame photometer (4). The soluble calcium was determined using the same extractant as for potassium. The flame spectrometer was used instead of the flame photometer in determining the amount. The pH was determined electrometrically with a glass electrode (4).

RESULTS

The average weight of an acre of soil for the different depth horizons was calculated from apparent specific gravity data. These acre weights were as follows: 1,217,000 pounds for 0 to 4 inches; 2,575,000 pounds for 4 to 12 inches; 3,913,000 pounds for 12 to 24 inches; and 4,024,000 pounds for 24 to 36 inches. These weights of soil per acre for the different depth horizons were used in the calculations of Tables 1, 5, 6, 7, and 9. The pounds of the different elements per acre for the different depths were calculated using the analytical data (see Appendix, Tables 11, 12, 13, 14, and 15) and the average weight of an acre of soil for the different depth horizons.

The tables which follow give the various data for the several plots.

Table 1.--Pounds of nitrogen per acre[1] at different depths in July, 1950.

Depth in inches	Treatment				
	N	PK	Check	NK	NP
			Unlimed		
0-4	1,406	1,458	1,329	1,497	1,380
4-12	2,477	2,312	1,831	2,093	2,462
12-24	2,551	2,594	2,426	2,300	2,176
24-36	1,851	1,541	1,634	1,678	1,203
0-36	8,285	7,905	7,220	7,568	7,221
			Limed		
0-4	1,269	1,496	1,483	1,586	1,483
4-12	2,143	2,119	2,037	2,119	2,176
12-24	2,176	2,508	1,503	2,502	2,176
24-36	1,376	1,806	1,545	1,762	1,545
0-36	6,964	7,929	6,568	7,969	7,380

[1] The pounds of total nitrogen per acre were secured by using the average weight of soil per acre and the percentages of nitrogen (see Appendix, Table 11) in the respective horizons.

Table 2.--Nitrogen balance sheet. Data are in pounds per acre.

	N	PK	Treatment Check	NK	NP
			Unlimed		
Nitrogen in profile 1950	8,285	7,905	7,220	7,568	7,221
N removed in hay	810	1,493	752	735	1,526
Total N for system	9,095	9,398	7,972	8,303	8,747
N furnished by fertilizer	304	0	0	304	304
N balance	8,791	9,398	7,972	7,999	8,443
			Limed		
Nitrogen in profile 1950	6,964	7,929	6,568	7,969	7,380
N removed in hay	950	1,843	1,029	1,230	1,789
Total N for system	7,914	9,772	7,597	9,199	9,169
N furnished by fertilizer	304	0	0	304	304
N balance	7,610	9,772	7,597	8,895	8,865

Table 3.--Pounds of nitrogen, phosphorus, and potassium[1] added in fertilizers to the different plots during 1930-49 inclusive.

	Treatment N	PK	Check	NK	NP
			Unlimed		
Nitrogen	304	0	0	304	304
Phosphorus	0	398	0	0	398
Potassium	0	505	0	505	0
			Limed		
Nitrogen	304	0	0	304	304
Phosphorus	0	398	0	0	398
Potassium	0	505	0	505	0

[1] These data were secured by multiplying the pounds of each element added per acre by the number of applications made during the period.

Table 4.--The total pounds of hay[1] and the total pounds of nitrogen, phosphorus, potassium, and calcium[2] in the hay harvested from the different plots during 1930-49 inclusive.

	Treatment				
	N	PK	Check	NK	NP
			Unlimed		
Total lbs.	34,156	62,997	31,707	31,011	64,382
Total N	810	1,493	752	735	1,526
Total P	82	151	76	74	155
Total K	700	1,291	650	636	1,319
Total Ca	502	926	466	456	946
			Limed		
Total lbs.	40,093	77,762	43,436	51,897	75,521
Total N	950	1,843	1,029	1,230	1,789
Total P	96	187	104	125	181
Total K	821	1,593	890	1,063	1,548
Total Ca	589	1,143	639	762	1,110

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[1] Unpublished data from the Agronomy Department, Oklahoma Agricultural and Mechanical College.

[2] Using percentage composition for different nutrient elements in alfalfa hay as given in Morrison's, Feeds and Feeding, 21st Ed., 1948, p. 1087.

Table 5.--Pounds of easily soluble phosphorus per acre[1] at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	6	39	4	6	51
4-12	0	15	0	3	21
12-24	0	0	0	0	0
24-36	0	0	0	0	0
0-36	6	54	4	9	72
			Limed		
0-4	6	39	4	7	51
4-12	8	13	8	5	26
12-24	0	0	0	0	0
24-36	0	0	0	0	0
0-36	14	52	12	12	77

[1] The pounds of easily soluble phosphorus per acre were secured by using the average weight of soil per acre and the ppm of easily soluble phosphorus (see Appendix, Table 12) in the respective horizons.

Table 6.--Pounds of total phosphorus per acre[1] at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	168	268	176	186	304
4-12	389	407	355	360	430
12-24	509	446	446	458	493
24-36	418	418	443	406	447
0-36	1,484	1,539	1,420	1,410	1,674
			Limed		
0-4	168	235	173	186	220
4-12	366	360	353	343	353
12-24	430	493	477	446	430
24-36	414	418	406	459	358
0-36	1,378	1,506	1,409	1,434	1,361

[1] The pounds of total phosphorus per acre were secured by using the average weight of soil per acre and the ppm of total phosphorus (see Appendix, Table 13) in the respective horizons.

Table 7.--Pounds of exchangeable potassium per acre[1] at different depths in July, 1950.

Depth in inches			Treatment		
	N	PK	Check	NK	NP
			Unlimed		
0-4	35	49	41	68	33
4-12	62	77	70	77	64
12-24	168	133	129	188	149
24-36	129	125	117	121	121
0-36	394	384	357	354	367
			Limed		
0-4	37	52	39	55	39
4-12	62	88	77	72	62
12-24	137	153	176	149	164
24-36	129	141	133	129	125
0-36	365	434	425	405	390

[1] The pounds of exchangeable potassium per acre were secured by using the average weight of soil per acre and the ppm of exchangeable potassium (see Appendix, Table 14) in the respective horizons.

Table 8.--Exchangeable potassium balance sheet. Data are in pounds per acre.

	N	PK	Treatment Check	NK	NP
			Unlimed		
K[1] in profile 1950	394	384	357	354	367
K removed in hay	700	1,291	650	636	1,319
Total K for system	1,094	1,674	1,007	990	1,686
K furnished by fertilizer	0	505	0	505	0
K balance	1,094	1,169	1,007	485	1,686
			Limed		
K in profile 1950	365	434	425	405	390
K removed in hay	821	1,593	890	1,063	1,548
Total K for system	1,186	2,027	1,312	1,468	1,938
K furnished by fertilizer	0	505	0	505	0
K balance	1,186	1,522	1,315	963	1,938

[1] Exchangeable K.

Table 9.--Pounds of soluble calcium per acre[1] at different depths in July, 1950.

Depth in inches	Treatment N	PK	Check	NK	NP
			Unlimed		
0-4	2,356	3,365	2,275	1,775	1,992
4-12	5,262	5,974	4,574	6,704	5,907
12-24	16,300	15,860	14,560	18,880	18,420
24-36	19,320	18,680	19,290	18,060	16,300
0-36	43,238	43,879	40,719	45,419	42,619
			Limed		
0-4	3,728	4,153	2,757	4,643	3,008
4-12	6,757	9,378	9,270	6,892	5,584
12-24	14,370	17,170	18,970	12,780	15,500
24-36	19,500	17,220	19,500	19,010	16,510
0-36	44,355	47,921	50,497	43,325	40,602

[1] The pounds of soluble calcium per acre were secured by using the average weight of soil per acre and the ppm of soluble calcium (see Appendix, Table 15) in the respective horizons.

Table 10.--pH at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	5.9	5.4	5.8	6.1	5.8
4-12	6.5	6.1	6.3	6.5	6.0
12-24	7.5	7.5	7.9	7.0	7.3
24-36	8.5	8.5	8.6	8.5	8.5
			Limed		
0-4	7.4	7.3	7.6	7.5	7.4
4-12	7.4	7.2	7.5	7.5	7.2
12-24	7.7	7.6	7.7	7.7	7.1
24-36	8.6	8.5	8.6	8.5	8.5

DISCUSSION OF RESULTS

In discussing the results of this study, unless otherwise stated, it will be assumed that the pounds of an element per acre will be that which is in or removed from the 0 to 36 inch depth. It is assumed that all of the plots were at approximately the same fertility level at the beginning of the fertilizer treatments since the entire area had received no previous fertilizer treatment and had been continuously in alfalfa for 17 years.

Losses from leaching, nitrogen in rainwater, and denitrification were not considered.

Nitrogen

Any increase or decrease in nitrogen is assumed to have been brought about by the addition of nitrogen fertilizer, nitrogen fixation, and usage by the alfalfa crop.

Table 2a.--Summary of nitrogen fixation by treatments above any fixation in untreated soil.

	Pounds of nitrogen fixed per acre				
Treatment:	N	PK	Check	NK	NP
Without Lime	819	1,426	---	-27	471
With Lime	-362	1,800	-375	923	893

Slightly more nitrogen has been removed in the hay from the N plot as compared to the check plot. Considering the nitrogen removed in the hay, the amount furnished by the fertilizer and the amount present in the profile, there has been a gain of 819 pounds of nitrogen per acre in the N plot over that in the check plot.

Approximately twice as much nitrogen has been removed in the hay from the PK plot as from the check plot. The nitrogen balance for the PK plot is 1,426 pounds per acre more than the check plot.

There has been slightly less nitrogen removed in the hay from the NK plot as from the check plot. The nitrogen balance for the NK plot was approximately the same as for the check plot.

From the NP plot there has been twice as much nitrogen removed in the hay as from the check plot. The nitrogen balance for the NP plot is 471 pounds per acre more than the nitrogen balance for the check plot.

From the NL plot there has been 198 pounds more nitrogen removed in the hay as from the check plot. The nitrogen balance for the NL plot is 362 pounds per acre less than the nitrogen balance for the check plot.

There has been 1,091 pounds more nitrogen removed in the hay from the PKL plot than the amount removed from the check plot. The nitrogen balance for the PKL plot is 1,800 pounds per acre more when compared to the nitrogen balance for the check plot.

In the hay removed from the L plot there has been 277 pounds more nitrogen than in the hay removed from the check plot. The balance of nitrogen for the L plot is 375 pounds per acre less than the balance of nitrogen for the check plot.

The highest nitrogen fixation was in the PK and PKL plots.

Phosphorus

In both the unlimed and limed plots there was no soluble phosphorus in the 12 to 36 inch depth. All soluble phosphorus was in the 0 to 12 inch depth.

The check plot contained only 4 pounds of easily soluble phosphorus per acre. All of this was located in the 0 to 4 inch depth. The N plot contained 6 pounds of soluble phosphorus per acre, which is one and one-half times the amount in the check plot. The PK plot contained 50 pounds more or thirteen and one-half times as much soluble phosphorus per acre as was found in the check plot.

The NK plot contained 5 pounds of soluble phosphorus more per acre or slightly more than twice the amount in the check plot. The NP plot contained eighteen times as much soluble phosphorus per acre as the check plot.

The NL plot contained 10 pounds more per acre or three and one-half times as much soluble phosphorus per acre as the check plot.

There was thirteen times as much soluble phosphorus per acre in the PKL plot as in the check plot. The L plot contained 8 pounds more soluble phosphorus per acre or three times as much as was present in check plot. The same amounts of soluble phosphorus per acre were found in the NKL and L plots.

There was 73 pounds of soluble phosphorus per acre more in the NPL plot when compared to the amount present in the check plot.

The efficiency of the phosphate fertilizer applied with nitrogen or potassium on the unlimed soil amounted to approximately 19 per cent, assuming no difference in the composition of the hay. If one assumes a 30 per cent increase in the phosphorus content of the hay (6, 7) on the phosphated plots, the efficiency would be approximately 31 per cent. For the limed area these figures would be 20 per cent and 32 per cent respectively. Liming increased the yield of hay sufficiently to increase the removal of phosphorus approximately 37 per cent.

Potassium

The data on potassium are given in Tables 7 and 8.

There has been 50 pounds more potassium removed in the hay from the N plot than in the hay removed from the check plot. The potassium balance for the N plot was 87 pounds per acre higher than the potassium balance for the check plot.

In the hay removed from the PK plot there has been approximately twice as much potassium as in the hay removed from the check plot. There were 162 pounds per acre more in the potassium balance for the PK plot than in the potassium balance for the check plot.

Slightly less potassium has been removed in the hay from the NK plot as compared to the amount removed in the hay from the check plot. The potassium balance for the NK plot was 512 pounds per acre less than the potassium balance for the check plot.

Approximately twice as much potassium has been removed in the hay from the NP plot when compared to the amount removed in the hay from the check plot. The balance of potassium for the NP plot was 679 pounds per acre higher than the balance of potassium for the check plot.

From the NL plot there has been 171 pounds more potassium removed in the hay than in the hay removed from the check plot. The potassium balance for the NL plot was 179 pounds per acre higher than the potassium balance for the check plot.

There has been 943 pounds more or approximately two and one-half times as much potassium removed in the hay from the PKL plot when compared to the amount removed in the hay from the check plot. The potassium balance for the PKL plot was 515 pounds per acre higher than the potassium balance for the check plot.

The hay removed from the L plot contained 240 pounds more potassium than the hay removed from the check plot. For the L plot the potassium balance was 308 pounds per acre more than the potassium balance for the check plot.

In the hay removed from the NKL plot there has been 413 pounds more potassium than in the hay removed from the check plot. The balance of potassium for the NKL plot was 44 pounds per acre less than the potassium balance for the check plot.

From the NPL plot there has been approximately 900 pounds more potassium removed in the hay than the amount of potassium removed in the hay from the check plot. The potassium balance for the NPL plot was 931 pounds per acre above the potassium balance for the check plot.

The availability of the potassium has been higher for the limed than for the unlimed plots.

A high percentage of the potassium applied with nitrogen both on unlimed and limed plots apparently was changed to a non-exchangeable form in the soil because in each case the potassium balance was less than that of the check plot.

Soluble Calcium

The amounts of calcium removed in the hays from the different plots are given in Table 4. Data pertaining to soluble calcium at the various depths in the different plots are presented in Table 9.

In the hay removed from the N plot there has been 36 pounds of calcium more than the amount removed in the hay from the check plot. There were 2,519 pounds of soluble calcium per acre more in the N plot than in the check plot.

From the PK plot there has been approximately twice as much calcium removed in the hay as has been removed in the hay from the check plot. The PK plot contained 3,160 pounds of soluble calcium per acre more than the amount present in the check plot.

Approximately the same amount of calcium has been removed in the hay from the NK plot and the check plot. In the NK plot there were 4,700 pounds of soluble calcium per acre more than the amount found in the check plot.

Twice as much calcium has been removed in the hay from the NP plot as was removed in the hay from the check plot. In the NP plot there were 1,900 pounds of soluble calcium per acre more than that present in the check plot.

From the NL plot there has been 123 pounds more calcium removed in the hay than in the hay removed from the check plot. The amount of soluble calcium per acre in the NL plot was 3,636 pounds more than the amount present in the check plot.

In the hay removed from the PKL plot there has been 677 pounds of calcium more than the amount removed in the hay from the check plot. In the PKL plot there were 7,202 pounds of soluble calcium more than the amount present in the check plot.

The hay removed from the L plot contained approximately the same amount of calcium as was present in the hay removed from the check plot. In the L plot there was 9,778 pounds of soluble calcium per acre above the amount present in the check plot.

There has been 296 pounds more calcium removed in the hay from the NKL plot when compared to the amount removed in the hay from the check plot. The amount of soluble calcium per acre in the NKL plot was 2,606 pounds more than the amount present in the check plot.

From the NPL plot there has been 644 pounds more calcium removed in the hay than in the hay removed from the check plot. The amount of soluble calcium per acre in the NPL plot was approximately equal to the amount present in the check plot.

There was an average of 43,175 pounds of soluble calcium per acre in the unlimed plots. The average for the limed plots was 45,340 pounds per acre. Liming has increased the soluble calcium, particularly in the 0 to 12 inch horizon. The average soluble calcium for the unlimed plots for the depth is 8,037 pounds per acre compared to 11,233 for the limed plots.

pH

The pH of the 0 to 4 inch depth and the 4 to 12 inch depth of the unlimed plots ranged from 5.4 to 6.5. This range was from strongly acid to slightly acid. In the 12 to 24 inch depth and the 24 to 36 inch depth the pH ranged from 7.0 to 8.6. This range was from neutral to moderately alkaline.

Throughout the different depths of the limed plots the pH ranged from 6.9 to 8.6. This range was from neutral to moderately alkaline.

Generally with an increase in depth there was in increase in pH in both the unlimed and limed plots.

SUMMARY

Located on the Agronomy Farm of the Oklahoma Agricultural and Mechanical College are plots which have been producing alfalfa since 1913. These plots presented an excellent opportunity for research on the fertility level of a soil which has been producing alfalfa continuously for a long period of time.

The history of the area on which the plots were located was given as far as it was known. Diagrams were presented which showed how the original plots were subdivided and the various treatments given the different plots during the period of years since the original seeding of alfalfa.

Soil samples were collected in July, 1950 and allowed to thoroughly air-dry. They were prepared and analyzed for total nitrogen, easily soluble phosphorus, total phosphorus, exchangeable potassium, soluble calcium, and pH.

The calculated results and analytical data were given in Table form. In discussing the results, the check plot was used as a standard and all other plots were compared to it.

The highest nitrogen fixation was in the PK and PKL plots.

The efficiency of the phosphate fertilizer applied with nitrogen or potassium on unlimed soil amounted to approximately 19 per cent, assuming no difference in the composition of the hay. If one assumes a 30 per cent increase in the phosphorus content of the hay on the phosphated plots, the efficiency would be approximately 31 per cent. For the limed area these figures would be 20 per cent and 32 per cent respectively. Liming increased the yield of hay sufficiently to increase the removal of phosphorus approximately 37 per cent.

The availability of the potassium has been higher for the limed than for the unlimed plots.

A considerable amount of the potassium when applied with nitrogen either on the unlimed or on the limed plots apparently was changed to a non-available form in the soil.

There was an average of 43,175 pounds of soluble calcium per acre in the unlimed plots. The average for the limed plots was 45,340 pounds per acre. Liming has increased the soluble calcium, particularly in the 0 to 12 inch horizon.

Generally with an increase in depth there was an increase in pH in both the unlimed and limed plots.

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APPENDIX

Table 11.--The percentage of nitrogen at different depths in July, 1950.

Depth in inches	Treatment				
	N	PK	Check	NK	NP
			Unlimed		
0-4	.1155	.1198	.1092	.1230	.1134
4-12	.0962	.0898	.0711	.0813	.0956
12-24	.0652	.0663	.0620	.0588	.0556
24-36	.0460	.0383	.0406	.0417	.0299
			Limed		
0-4	.1043	.1230	.1219	.1304	.1219
4-12	.0832	.0823	.0791	.0823	.0845
12-24	.0556	.0641	.0384	.0641	.0556
24-36	.0342	.0449	.0384	.0438	.0384

Table 12.--Easily soluble phosphorus in ppm at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	5	32	3	5	42
4-12	0	6	0	2	8
12-24	0	0	0	0	0
24-36	0	0	0	0	0
			Limed		
0-4	5	32	3	6	42
4-12	3	5	3	2	10
12-24	0	0	0	0	0
24-36	0	0	0	0	0

Table 13.--Total phosphorus in ppm at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	138	220	145	153	250
4-12	151	158	138	140	167
12-24	130	114	114	117	126
24-36	104	104	110	101	111
			Limed		
0-4	138	193	142	153	181
4-12	142	140	137	133	137
12-24	110	126	122	114	110
24-36	103	104	101	114	89

Table 14.--Exchangeable potassium in ppm at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	29	40	34	56	27
4-12	24	30	27	30	25
12-24	43	34	33	48	38
24-36	32	31	29	30	30
			Limed		
0-4	30	43	32	45	32
4-12	24	34	30	28	24
12-24	35	39	45	38	42
24-36	32	35	33	32	31

Table 15.--Calcium soluble in neutral normal ammonium acetate in ppm at different depths in July, 1950.

Depth in inches	N	PK	Treatment Check	NK	NP
			Unlimed		
0-4	1,936	2,766	1,870	1,459	1,637
4-12	2,044	2,320	1,776	2,603	2,294
12-24	4,166	4,052	3,722	4,824	4,708
24-36	4,800	4,644	4,794	4,490	4,051
			Limed		
0-4	3,064	3,412	2,266	3,816	2,472
4-12	2,624	3,642	3,600	2,676	2,168
12-24	3,674	4,388	4,848	3,268	3,960
24-36	4,848	4,280	4,848	4,726	4,104

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