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FERTILIZER EXPERIMENTS ON "RUN-OUT" HAY LAND

By FORD S. PRINCE, PAUL T. BLOOD,
T. G. PHILLIPS and G. P. PERCIVAL

Heavily fertilized plot (MLNPK) on left, check plot on right, six years after seeding.

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SUMMARY

Alfalfa

Alfalfa can be grown successfully on adapted worn-out hay lands if the soil fertility requirements of the crop are met.

Manure has given constant and significant increases in the yields of alfalfa hay over a five-year period in this experiment.

Potash appears to be the most necessary element to prolong the life and add to the yield.

Phosphorus exhibits conflicting results but is certainly not as necessary as potash in stimulating yield and maintaining longevity of alfalfa on this soil.

Nitrogen does not seem to be so necessary for alfalfa as the other two elements studied.

The use of more than two tons of *lime* on this soil has not been justified during the period studied.

Excellent crops of alfalfa have been produced from soils with a *pH value* of not more than 5.6.

The yield of alfalfa is influenced directly by the amount of *rainfall* during the spring and summer months.

An analysis of the alfalfa crop for nitrogen content in 1928 revealed no significant differences due to treatment.

Timothy

Nitrogen exerted the greatest influence on the yield of timothy.

Manure benefited the crop, largely because of the nitrogen it contains.

Phosphorus aided in getting a stand on plots where it had been applied and increased the yield markedly the first year. This increase was not maintained, although additional increments of phosphorus were applied.

Lime benefited the timothy crop, indicating that the pH level of the original soil was too low for optimum timothy growth.

Chemical analyses of these soils for nitrogen, phosphorus and potassium indicated relatively large supplies of these elements.

It would appear that worn-out hay fields such as this owe their decline in yield to a lack of available plant food, to a declining supply of rapidly decaying organic matter, and to lessened bacterial activity which would normally render native plant-food stocks available.

This condition is doubtless aggravated by high acidity in the soil.

Fertilizer Experiments on "Run-Out" Hay Land

By Ford S. Prince, Paul T. Blood, T. G. Phillips and G. P. Percival

In 1925 shortly after the passage of the Purnell act, the New Hampshire Experiment Station leased a field on the Whenal farm in the town of Greenland, to experiment with alfalfa and to observe the effect of top dressing on hay yields. The field chosen was "run out" hay land, no part of which had been plowed for about 10 years.

Yields of hay on nearby unplowed land in this field for the six-year period have been as follows:

	Ave. of 6 plots, lbs. hay per A.
1926	379
1927	727
1928	1465
1929	1520
1930	1228
1931	569
Average, six years	981

Yields of hay on this field are dependent largely on the amount and timeliness of spring rainfall, as the soil is somewhat coarse and not well suited to the production of fibrous-rooted grass crops. A mechanical analysis of the soil by the Bouyoucous method gave the following average for four trials: sand, 57.9 per cent.; silt, 20.4 per cent.; clay, 21.7 per cent.

I FERTILIZING ALFALFA

The objects of the experimental work with alfalfa were:

1. To see if the crop could be grown successfully on the worn hay lands of the state without first growing cultivated crops for two or three years.
2. To determine what fertilizer element or combination of elements is most necessary in stimulating yields and adding to the life of the alfalfa crop.
3. To study the acidity changes in the soil after liming and to note the effects, if any, on the composition of the hay produced under different treatments.

Prior to 1925 much demonstrational work had been done with alfalfa over the state. The necessity for using lime and hardy seed and for inoculating the seed at planting time were well established.

In laying out this experiment, therefore, Grimm seed was used. This was inoculated with a pure commercial culture. The plots were limed uniformly at the rate of two tons of ground limestone per acre. This basic application of lime and also a basic treatment of 20 tons of manure should be kept in mind in studying this publication.

The field was plowed in October 1925 and left in the furrow during the winter. Lime and manure, both the basic applications and variables, were applied in April and May 1926. After working the land at intervals to mix the lime and manure thoroughly with the soil, the fertilizer variables were applied, except nitrate of soda. The latter was broadcast on the plots receiving that material about two weeks after seeding.

The seed was sown on June 23, 1926, at the rate of 17 pounds per acre. No other seed was used in the alfalfa area.

No lime or manure has been applied since 1926. On those plots receiving them, fertilizers have been broadcast annually between April 15 and May 1, except in 1927. Five applications of fertilizer have been used to date.

The plots in this experiment are in triplicate, and each is one-twentieth of an acre in extent. There is one check plot for every three treated plots, and 48 plots in all.

The various treatments are here listed:

1.	Check plots, basic treatment			of 20 T. manure and 2 T. ground limestone.
2.	L	"	"	plus 2 T. ground limestone.
3.	N	"	"	plus 100 lbs. nitrate of soda per A.
4.	P	"	"	plus 500 lbs. 16% superphosphate per A.
5.	K	"	"	plus 150 lbs. muriate of potash per A.
6.	M	"	"	plus 20 T. manure per A.
7.	L P	"	"	plus 2 T. ground limestone and 500 lbs. superphosphate per A.
8.	L M	"	"	plus 2 T. ground limestone and 20 T. manure per A.
9.	M P	"	"	plus 20 T. manure and 500 lbs. superphosphate per A.
10.	M L P	"	"	plus 20 T. manure, 2 T. ground limestone and 500 lbs. superphosphate per A.
11.	M L N P	"	"	plus 20 T. manure, 2 T. ground limestone, 100 lbs. nitrate of soda and 500 lbs. superphosphate per A.
12.	M L P K	"	"	plus 20 T. manure, 2 T. ground limestone, 500 lbs. superphosphate and 150 lbs. muriate of potash per A.
13.	M L N P K	"	"	plus 20 T. manure, 2 T. ground limestone, 100 lbs. nitrate of soda, 500 lbs. superphosphate and 150 lbs. muriate of potash per A.

Although the alfalfa on these plots grew to a height of approximately 24 inches in the fall of 1926, no harvest was made. In March 1927 the dead alfalfa tops from the preceding year's growth were raked and carted off the field.

Starting with 1927 and through 1931, two harvests were made annually. In Table I is presented the average yield of each treatment for each cutting.

TABLE I—*Yield of alfalfa in pounds per acre by years and cuttings—Average of each treatment.*

Treatments	1927		1928		1929		1930		1931	
	First Cutting	Second Cutting	First Cutting	Second Cutting	First Cutting	Second Cutting	First Cutting	Second Cutting	First Cutting	Second Cutting
Check plots	4018	2236	4760	2342	2743	848	2228	818	2200	884
L	3836	2133	4447	2313	2550	926	2286	846	2309	1018
P	4090	2242	5151	2313	3519	789	2670	832	2759	1066
N	4340	2249	5005	2425	3096	834	2675	908	2680	1121
K	4576	2391	5283	2818	3966	1218	3342	1472	3468	2083
M	4482	2482	5286	3138	3908	1352	3076	1327	3046	1636
LP	4143	2356	5193	2312	3241	1106	3098	1123	3059	1287
MP	4845	2501	5766	2772	4811	1269	3882	1351	4101	1770
ML	4847	2520	5171	2836	3706	1304	3220	1377	3343	2039
MLP	4602	2496	5898	2959	4594	1433	4264	1616	4401	2385
MLPK	4599	2509	5435	2840	4789	1512	5125	2039	5042	3266
MLNP	4584	2530	5459	2717	4213	1427	4280	1558	4148	2004
MLNPK	4475	2648	5793	3421	5044	1580	5377	2067	5371	3083

In Table II the combined yield of the 10 cuttings is reported, together with the probable error and the difference of the yield of each treatment from the yield of the check plots, with the probable error of the difference.

TABLE II—*Combined yield all harvests (5 yrs., 10 cuttings), Whenal alfalfa 1927-31*

Treatment	Pounds of Hay per Acre					
	Yield		Error	Diff. from Ch.		P. E.* of Diff.
Ch	23077	±	430			
L	22664	±	1204	–413	±	1279
N	25333	±	974	2256	±	1064
P	25432	±	1527	2355	±	1586
K	30616	±	864	7539	±	965
M	29734	±	479	6657	±	644
LP	26918	±	793	3841	±	902
LM	30363	±	1222	7286	±	1295
MP	33069	±	1246	9992	±	1318
MLP	34649	±	1253	11572	±	1325
MLNP	32919	±	174	9842	±	464
MLPK	37155	±	1094	14078	±	1175
MLNPK	38859	±	1128	15782	±	1207

*Probable error (P.E.) was determined by Bessel's formula: $\frac{E\ D_2}{n(n-1)}$ x .6745 in which E D_2 refers to the sum of the squares of the deviation from the mean and n to the number of plots.

In interpreting probable error, we have considered that to be significant a difference must be at least three times its probable error.

See H. H. Love, "The Role of Statistics in Agronomic Experimentation," Sci. Agr. 5: 84-92.

From a study of these data it is evident that all of the differences from the check-plot yields are significant, except those for lime (L), nitrogen (N), and phosphorus (P).

Of the substances used alone, potash (K) and manure (M) gave significant and substantial increases. It is interesting to note that an annual application of 150 pounds of muriate of potash (K) has been slightly more effective in increasing the yield of alfalfa than the additional application of 20 tons of manure (M) applied at the outset of the experiment.

TABLE III—*Increase in yields from potash and manure*

	Increase for Potash—Hay per Acre	Increase for Manure—Hay per Acre
	lbs.	lbs.
1927	713	710
1928	999	1322
1929	1593	1666
1930	1768	1357
1931	2467	1598

From the manner in which the increases from these materials (Table III) parallel each other for the first three years, it seems reasonable to conclude that manure benefited the alfalfa because of the potash it contained. At the end of three years, the response from manure became stationary or declined slightly, while the plots receiving fresh applications of potash gave even greater increases than they had the first three years.

A study of Table III indicates, too, that it is unwise to judge the response for a substance like potash on the basis of one season's results. The increase for 1927, for example, was too small to detect with the eye. As the seasons progressed the differences between the potash plots and the check plots became more marked, the former showing a thicker and more vigorous stand. In 1931 the yield of these potash plots was almost double that of the checks.

With muriate of potash at $50 per ton and alfalfa hay at $20 per ton, each dollar invested in potash returned about four dollars' worth of hay. Manure gave a return of about $3.50 per ton in increased hay yields.

Potash was not used alone with the 20 tons of manure applications. It was used in combination with phosphorus and with nitrogen and phosphorus in the MLPK and MLNPK combinations. Yields of these two series (Table II) show that with manure and other elements, potash stimulated the growth and yield of alfalfa. The average annual yield of the MLNPK plots was 7,772 pounds, or 3.89 tons of hay per acre for the five-year period.

The results for superphosphate (P) are not so encouraging. A study of Table II indicates that the response from this substance is somewhat better when used with lime or manure, or manure and lime, than where used alone. The response for the LP treatment when compared with lime (L) alone gives a significant increase, but none of the other comparisons are significant.

The value of superphosphate as a material for top-dressing is doubtless limited by the fact that after it is applied, it is quickly absorbed or fixed in the first inch or two of top soil. As few of the feeding roots of alfalfa are in this layer, the full effect of the superphosphate is not obtained by the crop.

The soil of this field is quite well supplied with phosphorus, a chemical analysis revealing the fact that in the top soil alone there are almost 1,800 pounds of this element. Liming and manuring may have made these stocks available at a sufficiently rapid rate to supply most of the needs of the crop.

While all of the increases for superphosphate where comparisons are available are positive and indicate that some benefit has been obtained from its use, it does not seem advisable to make such heavy applications of this substance as applied in this test, except at seeding when the material can be worked deeply into the soil.

The results for nitrate of soda (N) are not significant nor encouraging enough to warrant the purchase of nitrogenous fertilizers for top-dressing alfalfa, where an abundance of manure is used prior to or at seeding or for later top-dressings. This statement applies to well established fields and would not hold for young stands that exhibit nitrogen deficiency before the plants become well inoculated.

The application of two tons of ground limestone (L) over the basic application was not justified, at least not during the five years covered. This was the case where lime was used alone or in combination with

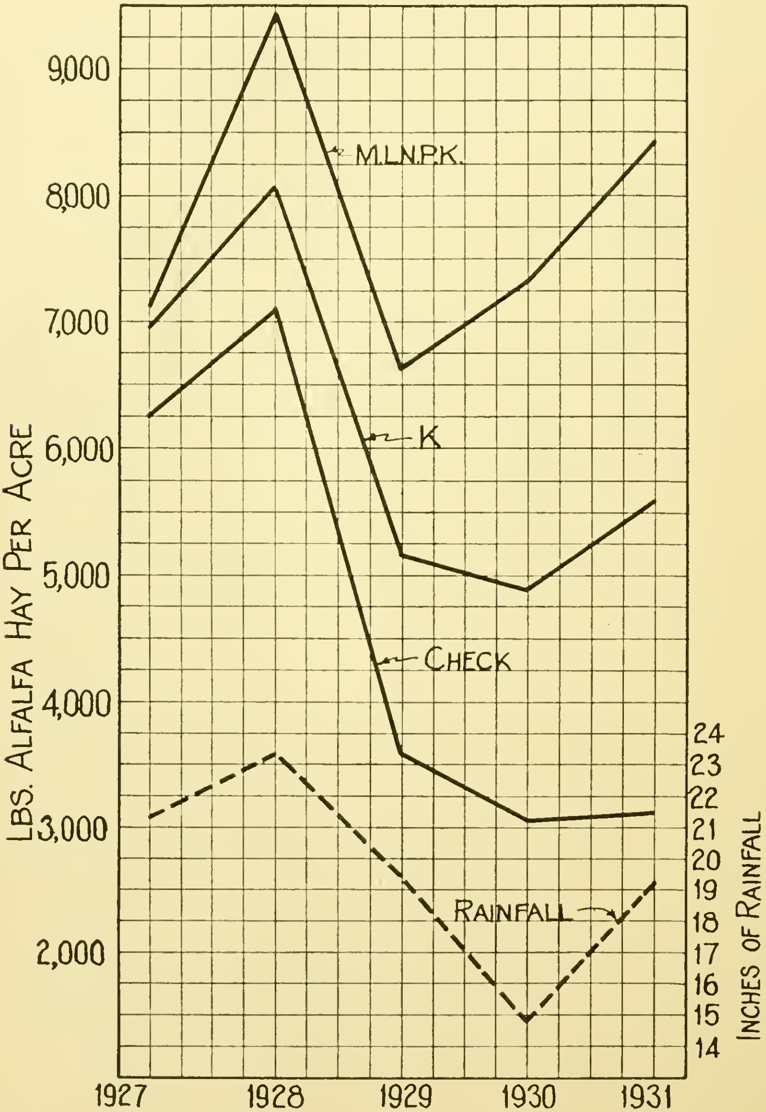

FIG. 1. *Showing mutual relationship between annual rainfall and yields of alfalfa hay*

superphosphate or manure. This is true in spite of the fact that the soils of the plots receiving limestone (L) did not reach a point much above pH 6.1.

It is rather interesting to note, however, that the first five cuttings showed a slight decrease for lime and the last five a slight gain, although these losses and gains are not significant. Future cropping may possibly justify the use of more lime than was applied as a basic treatment, but present farming conditions do not warrant an expenditure which does not begin to pay dividends within a five-year period.

As lime leaches out of a soil in drainage water more readily than any other important substance purchased by farmers for soil improvement, it is probably wise to prevent such loss by using minimum requirements for the crop to be grown. This means two tons of limestone for alfalfa and sweet clover for most New Hampshire soils, and less than this amount in certain sections of the lower Connecticut valley.

For crops other than alfalfa or sweet clover it appears probable that an application of less than two tons of limestone will prove more economical.

Figure 1 presents graphically the correlation between annual rainfall and yields of alfalfa hay in representative treatments. Rainfall records were taken at Durham which is, by airline, eight or nine miles from the field in question. They cover the six months' period from April 1 to September 30 of each year.

On this soil there appears to be a very close correlation between yield and rainfall.

A study of the comparative yields of the three series of plots in the graph reveals, too, that the productiveness of the check plots fell off considerably and the K or potash plots slightly, whereas the yields of the heavily fertilized, limed and manured plots held up well.

This is due, in the main, to the fact that the stand of alfalfa was maintained more fully on those plots receiving potash and other materials over the basic treatment.

In 1928 the crop was sampled by plots for the determination of nitrogen. The samples were taken from the hay in cocks, after curing. Duplicate samples from the same plot agreed fairly well in nitrogen content, but the checks of moisture were, in many cases, far from satisfactory. For this reason, no attempt has been made to calculate the total yield of protein; only the per cent. of protein in the dry sample is reported.

The difficulties in obtaining accurate figures for the total yield of any constituent would make it seem advisable in future samplings to select plants from various parts of the plot while the crop is still standing. This would prevent accidental contamination of the sample with plants other than the main crop, and should yield the most valuable data as to the effects of the treatment on the composition of the particular plant being studied.

The average protein content of the samples from the plots under each treatment and for each cutting are listed in Table IV. It is doubtful if the differences in treatment had any effect on the protein content of

TABLE IV—*Per cent protein of alfalfa, 1928, air-dry basis*

Treatment	First Cutting	Second Cutting
MLNPK	18.00	19.26
MLNP	17.65	20.26
MLPK	17.93	19.34
MLP	17.77	19.80
ML	17.08	19.85
MP	16.87	19.55
LP	16.76	20.33
K	16.57	19.62
P	17.54	20.41
N	17.19	20.54
M	16.51	19.62
L	16.34	20.69
Ch.	16.16	20.08
Av.	16.93	19.97

the hay. The slight differences found are probably without significance. The second cutting is decidedly richer in protein than the first.

Soil samples were taken from each plot before the field was plowed and before any treatments were applied, and then annually in October during the course of the experiment, except in 1926. The quinhydrone electrode was used in determining the pH of each sample.

In Table V are presented the pH values corresponding to the average cH of all the plots receiving similar treatments for each year. The averages of all plots receiving two tons of ground limestone per acre and of those receiving four tons are shown graphically in figure 2.

TABLE V—*pH values of soils*

	1925	1927	1928	1929	1930	1931
Ch	5.35	5.67	5.65	5.58	5.73	5.61
N	5.17	5.62	5.64	5.76	5.80	5.72
P	5.27	5.75	5.57	5.60	5.49	5.61
M	5.28	5.58	5.56	5.52	5.63	5.42
K	5.36	5.71	5.76	5.54	5.59	5.70
MP	5.47	5.78	5.84	5.73	5.87	5.80
Ave.	5.32	5.68	5.65	5.60	5.69	5.62
L	5.17	6.03	6.09	6.22	6.29	6.01
LP	5.00	5.92	5.87	5.92	6.11	6.00
LM	5.33	5.96	6.03	6.20	6.02	6.19
LMP	5.36	5.74	5.95	5.99	6.16	6.08
LMNP	5.30	5.98	5.97	6.20	6.22	6.01
LMPK	5.35	5.92	5.80	6.00	6.02	6.30
LMNPK	5.13	5.88	6.18	5.99	6.15	6.24
Ave.	5.22	5.91	5.97	6.06	6.13	6.11

It should be noted that the maximum pH obtained with four tons of ground limestone per acre is only about 6.1, which is still far from neutrality.

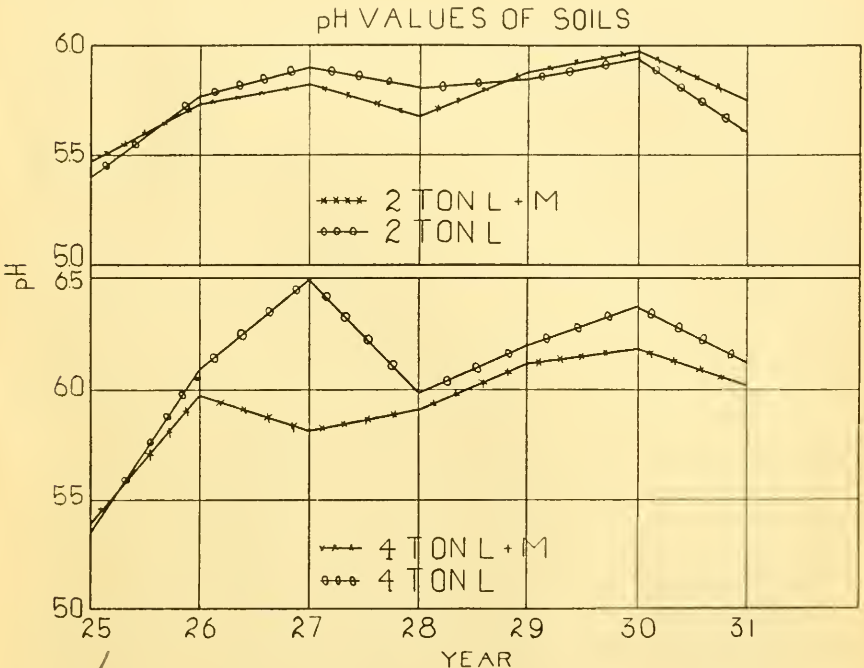

FIG. 2. *Showing average pH value of two groups of plots, 1925-31, one of which received two tons of ground limestone per acre and the other four tons*

Excellent crops of alfalfa have been obtained from soils having a pH value as low as 5.6 resulting from the application of two tons of ground limestone per acre.

The use of an additional two tons of limestone increased the pH of the soils markedly but did not result in a significant increase in yield.

II TOP-DRESSING HAY

A portion of the same field on the Whenal farm where the alfalfa experiment was conducted was plowed in August 1925 and prepared for a fall seeding of timothy. Prior to seeding certain plots were manured and lime applied as a cross treatment at the rate of two and four tons per acre, with an equal number of plots unlimed.

Twelve plots, representing the old sod, were left unplowed, one at either end of each of the six tiers of plots. Beginning in 1926 six of these were top-dressed annually with 100 pounds of nitrate of soda per acre, while the remainder have been left untreated.

In the spring of 1926 nitrate of soda at the rate of 100 pounds per acre and 16 per cent. superphosphate at the rate of 250 pounds per acre were applied as top-dressings to certain specified plots. This has been continued annually during the period studied.

An explanation of the treatments used in this experiment follows:

Unplowed: Ch—Untreated. Td—Top-dressed annually with 100 pounds nitrate of soda per acre.

Plowed and reseeded: No treatment—No manure or fertilizer. M—10 tons manure applied in 1925. MP—10 tons manure applied in 1925 plus 250 pounds 16 per cent. superphosphate annually. MNP—10 tons manure applied in 1925 plus 250 pounds 16 per cent. superphosphate and 100 pounds nitrate of soda*, annually.

P—250 pounds 16 per cent. superphosphate annually. N—100 pounds nitrate of soda annually. NP—100 pounds nitrate of soda and 250 pounds 16 per cent. superphosphate annually. No Lime—Two tiers of plots left unlimed, but treated as outlined above. 2 T. Lime—Two tons of ground limestone per Acre applied on two tiers of plots in 1925 as cross treatment. 4 T. Lime—Four tons of ground limestone per Acre applied on two tiers of plots in 1925 as cross treatment.

The autumn of 1925 was very dry. The seeding made September 8 of that year was successful only on those plots which had been treated with manure. The plots were top-dressed in the spring of 1926 according to the plan of the experiment, but no harvest was obtained from those that had been plowed and reseeded without manure.

In August 1926 the unmanured plots were disked and seeded again. On the plots which were to receive nitrogen, nitrate of soda was applied September 2 at the rate of 100 pounds per acre. The grass on these plots started off better than on those that were untreated. The plots that had an application of superphosphate the preceding spring, also made a better start.

In the spring of 1927, it appeared that a fairly good stand of grass was present on all the newly seeded plots. Top-dressing with nitrate and superphosphate was again done in April 1927 on all plots receiving these materials, except the ones to which nitrate of soda had been applied in September 1926. Since 1927, top-dressing has been practiced annually about April 15 in this experiment.

One harvest has been made each year on all these plots from 1927 to 1931, inclusive. The hay was cut about the last week of June, cured in the field, and weighed there, an effort always being made to have the hay from the plots uniformly dry.

In Table VI the total yield for the five-year period from the unplowed plots is reported, together with the probable error, and the difference between the two series with its probable error.

*Nitrate of soda was used in this experiment largely because it seemed to be the most common nitrogen carrier at the time the experiment was started. There appears to be no reason why calcium nitrate, sulphate of ammonia, cyanamid or other nitrogen carrier could not be used just as well in actual farming.

TABLE VI.—*Total yield cured hay per acre five years, 1927-31*

Unplowed plots	Total Yield	Gain
Ch	5510 ± 199	
T. D.	7030 ± 316	1520 ± 373

From the yields reported in this table it can be seen that the old hay land with which we started was not high yielding, nor was the type of grass* in the stand particularly responsive to applications of nitrogen. The average annual yield on the untreated or check plots was 1,102 pounds of hay per acre, while those top-dressed annually with nitrate of soda averaged 1,406 pounds, an average gain of 304 pounds per acre for each 100 pounds of nitrate of soda applied.

The yields for the plots which were plowed, given various treatments and reseeded, are presented in the following summary:

TABLE VII—*Land plowed and seeded—Total yield cured hay per acre, five years, 1927-31*

Treatment	Total Yield	Gain
No treatment	7840 ± 436	
M	11266 ± 420	3426 ± 605
MP	10900 ± 451	3060 ± 627
MN	15300 ± 511	7460 ± 672
MNP	15390 ± 471	7550 ± 642
P	10119 ± 743	2279 ± 862
N	12724 ± 542	4884 ± 696
NP	13804 ± 616	5964 ± 768

Ten tons manure (M) applied in 1925 showed a total gain of 3,426 pounds of hay over the period studied, or a gain of 342 pounds for each ton of manure applied.

The addition of annual increments of superphosphate to the plots which had received manure (MP) does not seem to have been of benefit to timothy. These plots actually showed a slight decrease from those which had manure alone. The difference is not significant, however.

Nitrate of soda applied annually to certain manured plots (MN) did increase the yield markedly. Compared with the plots which had no treatment, these plots yielded 7,460 pounds more hay during the five-year period, or 1,492 pounds more per annum. Compared with those which had manure alone, the plots getting nitrate of soda in addition yielded 4,034 pounds more hay in five years, which is an increase of 807 pounds of hay for every 100 pounds of nitrate of soda applied.

There is practically no difference in yield between the plots which

*The stand of grass in the old sod was composed mainly of "poverty grass," "Danthonia Spicata."

had an annual top-dressing of 250 pounds of superphosphate in addition to nitrate of soda and manure, and those which did not have this substance. The increase for these plots, then, must have been due entirely to the beneficial effects of the manure and nitrate of soda.

Annual top-dressings of 250 pounds of 16 per cent. superphosphate appear to have stimulated timothy yields more when used without manure or nitrogen. The total increase recorded for these superphosphate plots (P) is 2,279 pounds, although the increase is not significant. When it is understood that 1,617 pounds of this increase came in the 1927 season—the first year after a stand was secured on these plots – it can readily be seen that the effect of the superphosphate was exhibited largely in the germination of the seed and in securing a somewhat earlier stand.

In this connection it is well to remember that the plots were top-dressed in the spring of 1926 before we were certain whether a stand would be obtained. When it appeared later that the stand was meager on all the unmanured plots, the land was re-worked and reseeded. This reworking undoubtedly stirred that application of superphosphate to greater depths and stimulated the early growth there as well as the 1927 yield of hay.

Though additional superphosphate was top-dressed annually on these plots, the 1927 increase was not maintained. This seems to indicate that the material was absorbed or fixed in the soil before it penetrated to the layer in which most of the grass roots feed or that there was sufficient available phosphoric acid through succeeding seasons to supply the needs of the crop.

The behavior of these plots to superphosphate serves to emphasize the importance of using an ample amount of this substance at the time of seeding when it can be drilled or harrowed into the soil to a lower depth than if it is applied later as a top-dressing.

Nitrate of soda (N) on unmanured land gave a slightly better account of itself than where used with manure, the total increase for the five years amounting to 4,884 pounds, or an annual increase of 977 pounds for each 100 pounds of nitrate of soda applied.

Where nitrate of soda and superphosphate were both applied (NP), the increase was slightly larger than for nitrate of soda alone, but here again the increase came largely in the 1927 season as it did on the superphosphate (P) plots.

Since lime was applied as a cross treatment, one group of plots that were manured and top-dressed annually were unlimed, an equal number were treated with two tons in 1925, and a third group of the same size received four tons the same year.

The hay yields for these variables are shown in the following table:

TABLE VIII—*Yield cured hay per acre, 1927-31 inclusive*

Treatment	Yield	Increase
No lime	9698 ± 440	
2 T. Limestone	12793 ± 452	3095 ± 631
4 T. Limestone	13661 ± 444	3963 ± 625

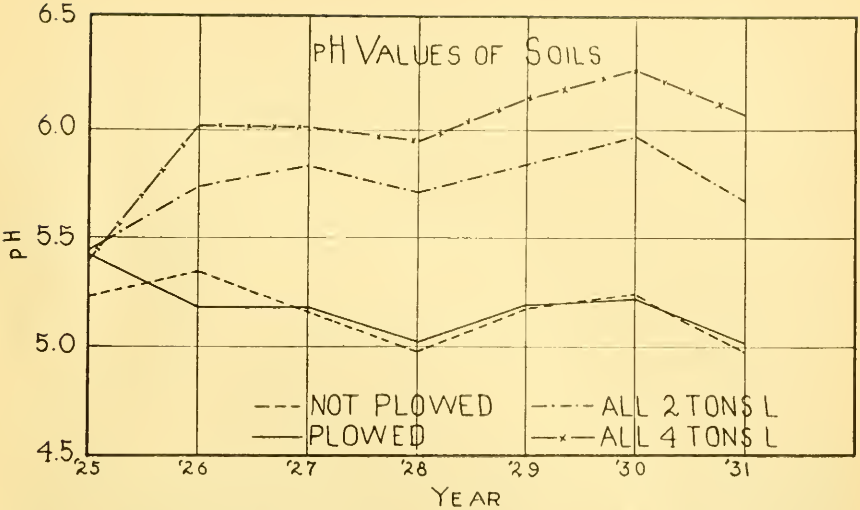

Fig. 3. *Acidity of timothy plots as affected by plowing and by two and four-ton applications of ground limestone per acre, 1925-31*

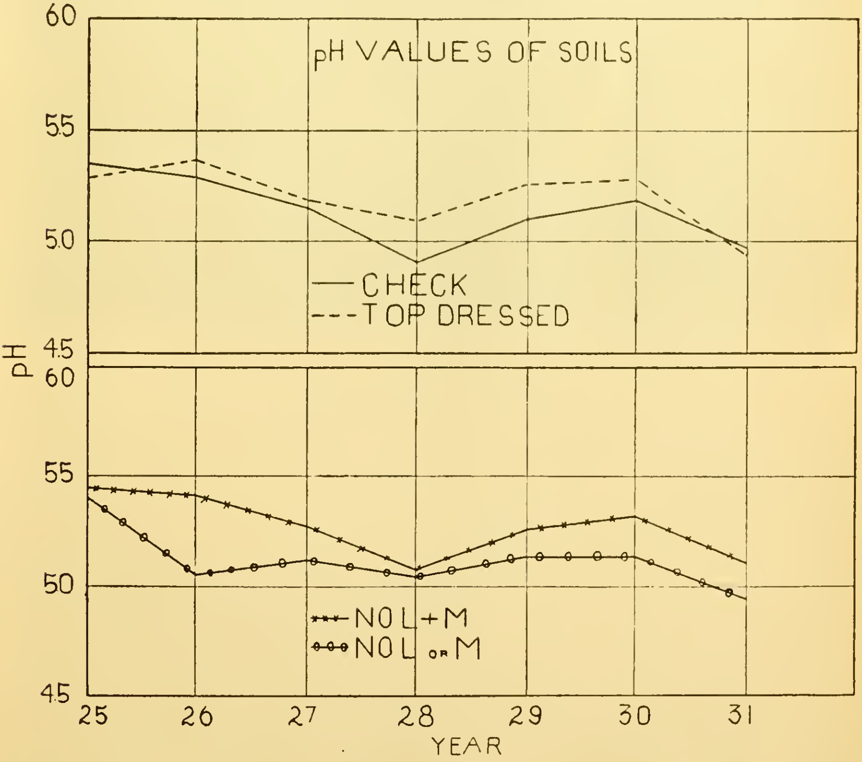

Fig. 4. *Upper section of graph illustrates lessened acidity due to top-dressing with nitrate of soda. Lower part shows that manure decreased acidity on unlimed plots*

That timothy responded to lime on this soil is evidenced by the data presented. The average annual gain for two tons of lime over no lime was 619 pounds of hay per acre per year; for four tons of lime, 793 pounds of hay. As this soil was not much more acid than the average for the state as a whole, the data indicate that lime is often a factor limiting yields, even on grass hay.

Soil samples were taken from each plot before the field was plowed or any treatments applied, and annually in October during the course of the experiment. The quinhydrone electrode was used in determining the pH of each sample.

The pH value for each year corresponding to the average cH values of all plots receiving similar treatments are presented in Figure 3.

It is practically impossible to bring this soil to neutrality by the addition of ground limestone. Starting with an original pH of about

General lay-out of plots. The heavily manured plot at right shows slight lodging.

5.4, the lowest average acidity caused by two tons of ground limestone per acre was 5.97; by four tons per acre, 6.26 (Fig. 3, 1930). In individual plots, these average values for pH are exceeded somewhat, but the highest figure recorded is 6.83.

Plowing alone results in decidedly increased soil acidity the following year (Fig. 3). This increase is prevented by the application of manure (Fig. 4). The whole field was plowed shortly before the 1931 soil samples were taken. This in itself would seem to be sufficient to account for the marked increase in acidity of all plots at this sampling. Limestone and manure had been applied so many years before this sampling that they were no longer able to prevent the increased acidity due to plowing. By the second year the differences in acidity between plowed and unplowed soils had practically disappeared (Fig. 3).

The buffer effect of manure is shown on unlimed soils by the decidedly greater acidity of those plots receiving no manure (Fig. 4). When manure is applied with limestone, it lessens the neutralizing effect of the limestone, especially during the first two or three years. This effect is especially marked with the heavier applications of limestone (Fig. 5).

The effect of top-dressings with nitrate of soda in decreasing soil acidity is shown in Fig. 4. The effect of the dressing, however, does not appear to be markedly accumulative.

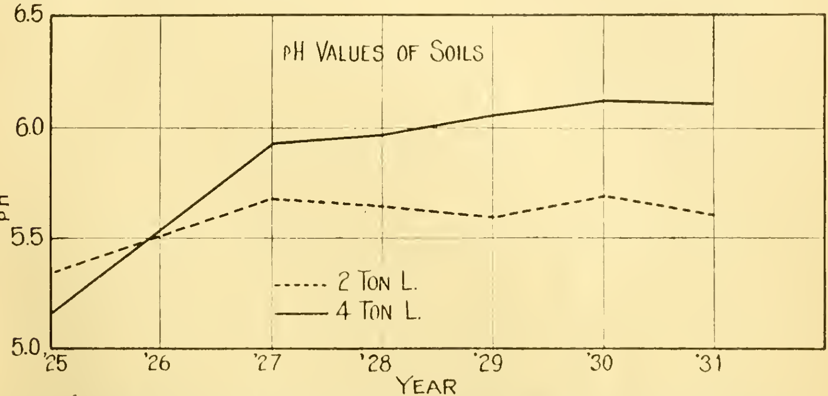

Fig. 5. *Manure in both two and four-ton amounts decreased the neutralizing efficiency of lime when the two were applied together*

III CHEMICAL ANALYSIS OF SOILS

The soils of this field, including the hay and alfalfa experimental areas, are part of a number from various sections of the state that are being subjected to complete chemical analysis. Part of the results for these soils is presented in Table IX.

Table IX—*Chemical analyses of hay and alfalfa soils*

Soil Sample	Depth in inches	Per cent.		
		N	P	K
Hay surface	0 to 7	0.257	0.091	1.390
Hay subsoil	7 to 21	0.142	0.076	1.488
Alfalfa surface	0 to 7	0.252	0.091	1.398
Alfalfa subsoil	7 to 21	0.134	0.071	1.470

Compared with other soils, the total supply of these three elements is fairly large. The lack of fertility in this soil is certainly due in part to the small amounts of these elements present in an available form. This condition is improved considerably by plowing and by the addition of readily decomposed organic matter and lime, all of which tend to increase bacterial activity.