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Some factors affecting the flora of pastures

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SOME FACTORS AFFECTING THE FLORA OF PASTURES

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A. INTRODUCTION

"Grass is the forgiveness of Nature--her constant benediction . . Its tenacious fibers hold the earth in its place and prevent its soluble components from washing into the wasting sea. It invades the solitudes of the desert, climbs the inaccessible slopes and forbidden pinnacles of mountains, modifies climates, and determines the history, character and destiny of nations. Unobtrusive and patient, it has immortal vigor and aggression. Banished from the thoroughfare and the field, it bides its time to return, and when vigilance is relaxed, or the dynasty has perished, it silently resumes the throne from which it has been expelled, but which it never abdicates. It bears no blazonry of bloom to charm the senses with fragrance or splendor, but its homely hue is more enchanting than the lily or the rose. It yields no fruit in earth or air, and yet, should its harvest fail for a single year, famine would depopulate the world." John J. Ingalls.

Fifty five percent (17) of the 1,903,000,000 acres making up the entire land area of the United States is pasture land in some form or other; of this immense grazing area 29% is plowable, 19% is in woodland, the remainder or 52% is open range. In New England, (10) 17% of the total land area and 43% of the land in farms is classified as pasture of which 11% is plowable, 54% is in woodland and the balance or 35% is called other pasture land. On the basis of acreage, the average New England farm has 19.5 acres of pasture; varying from 41 acres per farm in Vermont to 11.8 acres per farm in Massachusetts.

The average number of acres per farm per cow is 2.8, which area should more than furnish sufficient pasture for one cow during the summer months. However, pasture (from the Latin pasturare--to feed) is grassland used for feeding livestock. This definition automatically eliminates from the above much overgrown woodland which furnishes the cattle with excellent shade and a means of brushing off flies, but no feed; rocky hillsides on which young stock develop an agility and sense of balance second only to that of the goat and antelope; and finally, those verdant slopes of moss and cinquefoil which receive the weary bodies of the milking cows at the end of their daily jaunt in search of feed which is not there.

When properly managed, pasture, and by the term pasture we mean grass and clover produced on land well supplied with all the essential fertilizer elements, furnishes carbohydrates, fats, proteins, minerals and vitamines i. e. a balanced ration, in a palatable, easily digestible, and easily assimilable form, in quantity sufficient to maintain dry cows; to grow out young stock; and to produce milk and prime beef with a minimum amount of expensive concentrates. It supplies the animals with moderate exercise, fresh air, sunlight and nature's own food in the form that was intended for them. It markedly reduces the labor required in caring for and feeding the herd during the summer months. In short, good pasture is the ideal feed for livestock during the summer months, a complete ration in itself, yet in too many cases it has been and still is the most neglected crop on the farm.

In fact until very recently, it received but scant recognition from the farmer and even less from the colleges and experiment stations. The

present active interest in pastures is due to a combination of several factors:

1. Probably of paramount importance is the fact that after years of depletion of their mineral and organic reserves, the pastures have reached a point where they no longer provide adequate feed for dairy cows. By adequate feed, to quote J. B. Abbott, (2) we mean "enough grazing of the right quality at the right time and in the right place."

2. At present with all New England facing an overproduction of milk and dairy cattle, with a decreased consumption as a result of widespread business depression, with constant danger from tuberculosis and contagious abortion in the herds, there is greater need than ever for economies in production if dairying is to remain a profitable farm enterprise.

3. The high cost of barn feeding, which during the winter months in many cases actually exceeds the value of the product, has been a contributing factor.

4. Changing economic conditions and the high price of labor have forced the farmer to recognize the worth of a feed which the cows themselves can harvest.

5. The replacement of the draft horse with the truck in the city and the tractor on the farm has eliminated a profitable market for grass hay thus making available for pasture purposes many acres of former hayland.

6. The rapid development of synthetic nitrogen production following the world war with a corresponding decrease in the cost per unit has upset all former relationships between cost of fertilizer and value of crop.

7. The development in Germany (22) of an intensive system of grassland management based on heavy fertilization and rotational grazing, which has been demonstrated to be adaptable to our New England conditions, has induced many farmers to attempt to improve the productivity of their pastures.

B. OBJECTIVES — NEED FOR INVESTIGATION.

The introduction of several new factors in the pasture problem; namely, the increasing use of nitrogen fertilizers, the adoption of rotational grazing, and the combination of grazing and hayland presents many perplexing problems and some of the conclusions reached in previous investigations may have to be modified in the light of the newer developments. Since up to the very recent past the use of nitrogen on pastures has been impractical from the economic viewpoint, very little data based on actual grazing trials is available regarding its effects on the flora, and where data is available the amounts of nitrogen applied were too low for optimum results.

The conversion of hay fields into permanent pastures presents many problems as to seeding and succession. It is a question of considerable economic importance whether to plow and reseed or establish a sod by top dressing, what grasses to choose and what fertilizers to apply, and in what amounts. The increasing tendency to combine grazing and hayland brings up the question of duration of life of meadow and pasture plants and pressing problems in management. The widespread adoption of rotational grazing provides an entirely new set of conditions under which fertilizers act upon grasses and wherein grasses compete with one another.

Thus, today in the field of pasture improvement there is a real need for a renewed study of pasture grasses, their adaptations and ecological relationships. In the pages which follow, the author will

attempt to analyze in the light of these newer developments the effect of liming, fertilization and management on the flora of pastures, stressing particularly the role of nitrogen, the influence of rotational grazing and the adaptability of various seeding mixtures for semi-permanent pasture on tillable land.

C. A REVIEW OF PREVIOUS WORK BEARING UPON THE PROBLEM.

Lime

1883 Russell(33) reported that on plots which were well supplied with potash, the lime gave an increase of crop and brought about a great increase in the proportion of leguminous plants. "The effect of lime obviously had been mainly due to the bringing into action of the residues of potash accumulated from the previous manuring."

1913 White (76) states that the limit of acidity for clover seemed to vary with the fertility of the soil; high clover yields were associated with heavy applications of limestone.

1922 Cook (12) found that lime alone was of doubtful value in bringing in clover.

1926 Wiggans (78) writes, "Lime on the poorer areas gave very positive results tho the increase in production was of less importance than the change in vegetation showing an increase in grass and clovers with a corresponding decrease in weeds."

1927 Lanphear's (42) work indicated that "determination of lime requirement seems to be of little value as a guide to pasture treatments. Determination of the hydrogen-ion concentration on the other hand may indicate whether an application of lime will be" beneficial or not.

1929 Several years work at Connecticut Agricultural College (7) indicated that calcium, in one of the several forms of lime, has generally increased the productivity of pastures, sometimes alone but more frequently when applied in conjunction with a carrier of phosphorus.

1930 Odland (54) found that for each dollar invested in pasture improvement, the lime probably yielded the greatest return and seeding the least. It increased the response of all treatments over the unlimed in every case.

Summary: Many years experience with lime on permanent pastures has indicated that it is almost universally beneficial, that it is a prerequisite to fertilization on strongly acid soils and that the application of lime is usually followed by an increase in the vigor and abundance of white Dutch clover. However, most of the applications were made with the idea of neutralizing the soil, whereas it is possible that a smaller application which would supply the necessary available calcium to the clover would have been as successful. Furthermore, it was generally applied with minerals only i. e. on a lower plane of fertility and may or may not be as necessary in connection with a complete fertilizer.

Phosphorus

1905 Hall (33) reporting on experiments at Rothamsted carried on since 1856 states: "Plot 4-1 which has received superphosphate only, now presents a very impoverished appearance and is giving very little more crop than the unmanured plots." "It is not uncommon to find cases where the application to grassland of a purely phosphatic manure like superphosphate or basic slag, is followed by a great increase of crop, the addition of the phosphoric acid to the dormant nitrogen and potash of the soil having supplied the missing element in a complete plant food. The result, however, of this plot shows how disasterous a continuation of such one sided manuring may become."

1923 Russell (33) reported in 1923; "basic slag produces excellent results on many pastures, especially on boulder clay where there is much bent grass and little wild white clover. Failure to act may be due to soil acidity or insufficient potash."

1926 Wiggans (78) found that acid phosphate gave significant increases in total vegetation under each of the three conditions studied. A second effect, particularly on the poorer acres, was that the increase was almost wholly due to the favorable change in the vegetation, resulting in a larger proportion of grass and clover with a corresponding decrease in the proportion of weeds.

1928 Brown (7) states "of the elements commonly deficient in the soil for optimum plant growth, phosphorus is the one most needed in pastures."

1929 Mortimer (51) makes the following statement regarding his work at Wisconsin. "In this experiment no increase whatever was obtained from phosphate alone, yet phosphorus and potash without lime increased the yield 154 percent. (i. e. Potash not lime is the limiting factor)."

Summary: The previous work with phosphoric acid on pastures which has covered a long period of years, which has been carried out on all types of soils in all parts of Europe and North America and which has given excellent results in some cases and failed to make a showing in others, still leaves room for doubt as to its exact status. The case for phosphorus is admirably presented in the following concise statement by J. B. Abbott (1). "The results of pasture fertilization

experiments started by Dr. Sir William Somerville at the Northumberland County Experiment Station at Cockle Park in England in 1897 plus the known general phosphorus deficiency of most upland soils in America had led to the more or less stereotyped recommendation to top-dress pasture land with phosphates. Lime and superphosphate brought in a satisfactory stand of white Dutch clover and produced a satisfactory increase in total yield and protein content on clay soils and loams, not too badly exhausted. Lime and phosphorus gave no results, but lime, phosphorus and potash were satisfactory on sandy and light loam soils and heavy loams low in fertility. Thus it can be seen that the effectiveness of the phosphorus treatment depends upon the presence of a certain amount of potash necessary for the clover and a good growth of white Dutch to supply nitrogen for growth of the grasses. The mineral clover system of pasture management appears to be limited to moderately heavy soils with a rather dependable moisture supply."

Potash

1912 Russell (33) writes concerning an experiment at Rothamsted begun in 1861: "The omission of potash from a complete mineral mixture on plot 8 has caused a very striking difference both in the crop and the character of the herbage. The poor results on this plot as compared with plot 7 must be put down to its poverty in leguminous herbage, the development of which seems to depend on a free supply of potash.

1922 Osmun and Haskell (56) found that potash and phosphorus were most effective in changing the vegetation from moss and cinquefoil to white Dutch clover.

1926 Wiggans (78) found that applications of potash on one set of plots failed to give conclusive results. The increases on the unlimed areas consisted mostly of weeds, whereas the results on the limed areas seemed to indicate an improvement in the quality of the product. "The inconsistency of the results makes the value of the potash as a fertilizer for pasture very doubtful."

1926 Haskell (35) states: "On the relatively coarse grained, depleted granitic soils of the Station Farm, potash was the plant food most needed."

1927 Lanphear (42) reported that success with applications of potassium varied somewhat with the area under consideration. It was especially beneficial on light soils.

1929 Brown and Slate (7) found that the results from potash were conflicting. "Experiments on the heavier soils show little if any response to potash but on the lighter soil types--those less suitable for permanent pastures, potash has been of benefit. On the same soils, potash seems to be of much less importance for pastures than for meadows."

1930 Sprague and Evaul (66) at New Jersey showed that clover is favored by the use of fertilizers containing phosphates and potash and that liming is beneficial on acid soils.

1930 Mortimer and Richards (51) reached the following conclusions. "Perhaps the most significant observations to be made from these results is that the largest yields are associated with the use of potash. How extensive the need is for potash in pasture fertilization is only a

matter that can be decided by a more extended use of it. In all plots where potash was used the feed contained from 40-60 per cent of white and alsike clovers. A second trial on another pasture seemed to warrant its use for maximum production of feed through its encouragement of clover." Thus here again, we find conflicting results and a need for further research.

Summary: Briefly, the effectiveness of potash seems to vary with the soil series and its success to depend upon the presence of white Dutch clover.

Nitrogen

1912 The following observation was made in 1912 at Rothamsted (33). "The aspect of the plots receiving only a nitrogenous manure shows very characteristic differences, a very dark green unhealthy color, and leguminous plants are practically absent from both plots. There has been a gradual decline in production and an encroachment of weeds."

1922 Cook (12) found that an application of complete fertilizer, along with three other treatments, produced sufficient growth of clover to effect a marked improvement.

1926 Wiggans (78) reported that nitrate of soda was used on the Bald Hill plots and gave, on the whole, a significant increase in total vegetation largely by increases in grass and weeds, with an actual decrease in the proportion of clover. "These results therefore indicate that nitrogen might better be added to pastures thru a stimulation of legume production, rather than by the use of nitrogenous fertilizers."

1926 Lamphear (42) concluded that nitrogen was significant in determining pasture succession to a minor extent as compared with phosphorus and potassium.

1929 Brown and Slate (7) reported:- "In this country, some benefit has usually been obtained from including nitrogen with the minerals, but there have been very few clear-cut comparisons under real pasture conditions.

1930 Sprague and Evaul (66) found that white clover on golf greens was held in check by close cutting combined with the use of soluble nitrogenous fertilizers. Growth of bluegrass was favored by the use of a complete fertilizer.

1930 J. B. Abbott (2) discovered that clipping the grass with shears as often as it reached a height of four to six inches failed to simulate grazing conditions on the plots receiving nitrogen since there was a marked suppression of clover on the clipped area as compared with the corresponding grazed area and a tendency for the sod to become thinner and coarser. This tendency was less marked with more frequent clipping and was more marked with less frequent clipping.

1930 Mortimer and Richards (51) conclude-- "On a soil impoverished in mineral fertility, nitrogen alone cannot produce economical returns; on soils low in minerals, little clover persists and with the use of nitrogen under such conditions what little clover there may be present is decidedly depressed. On pastures rich in mineral fertility and having a medium clover-grass ratio, nitrogen fertilization may be used in single applications as high as thirty to fifty pounds of elemental nitrogen without suffering a serious suppression of the clover."

Summary: The use of nitrogen also seems to have given conflicting results on pastures and its effect on the growth and vigor of white Dutch clover is still an open question. Probably much of the disagreement can be traced to the different methods used in measuring the results since nitrogen may cause the grasses to shade out the clovers if not kept grazed down.

D. FIELD INVESTIGATIONS — METHOD OF PROCEDURE.

Fortunately, there was an abundance of material at hand with which to pursue a study of pasture flora in the experimental pasture plots of the Agronomy department. These represent a broad, fundamental research covering all the important fertilizer elements and their combinations and range in age from the older Hobart* series laid out in 1924 through the new Hobart series begun in 1930. Changes in flora are gradual transitions, they cannot be brought about instantaneously by top-dressing, and the study becomes one of determining general trends in succession over a period of years under a given treatment on similar soils. All the experiments studied were well supplied with check areas, showing the former type of flora, and detailed records concerning fertilization and management have been kept. Thus the problem resolved itself into that of determining by botanical analysis the present composition of the flora on the various plots, of correlating this data with the fertilizer elements supplied, and from the whole, to draw general conclusions regarding the effect of various elements and methods of management on the flora of pastures.

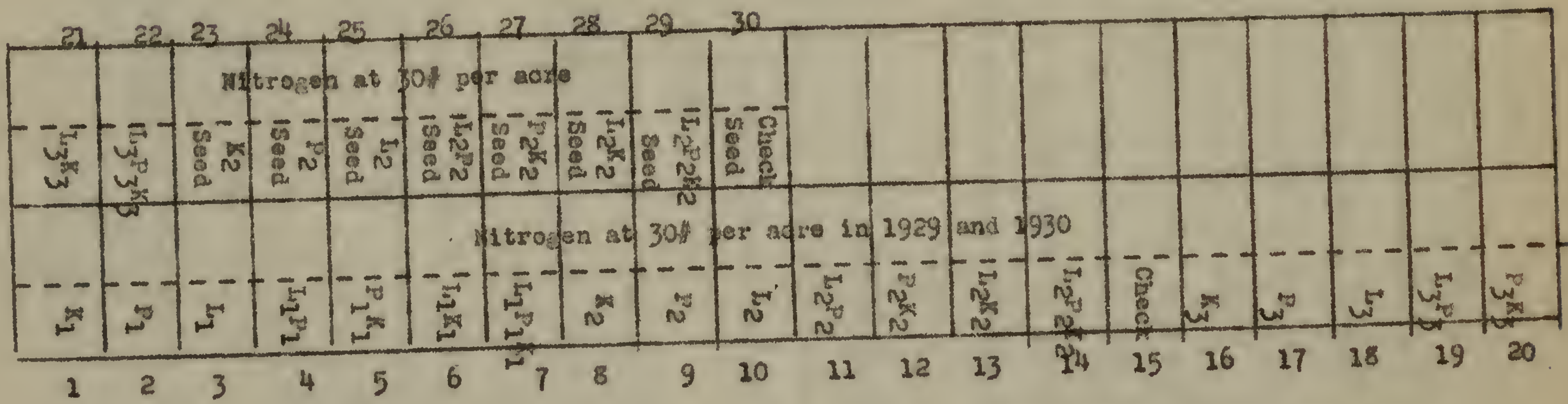
The method of procedure in determining the botanical composition is, of course, extremely important. It must be accurate and yet sufficiently rapid to allow for a reasonable number of analyses upon which to base general conclusions. After consideration of the problem and several trials,

*Note. Experiments A and B begun on Tillson pasture by Osmun and Haskell in 1921 and 1922 respectively, have been discontinued or altered.

the following method was chosen and used thruout the experiment. In June, clippings were taken from several areas of three square feet each scattered on representative areas over the plot (the number varying from 2-6 depending upon the size of plot), thoroughly mixed and carefully sub-sampled, and while still fresh, separated into Kentucky bluegrass, white Dutch clover, timothy, redtop, other grasses, weeds and moss. The separates were oven dried (60°-70°), weights determined in grams for each species and the percentage composition of the herbage calculated from the data. On some series this procedure was repeated in August but on the remainder it was necessary to base the August figures on a careful estimate of the composition after studying the herbage on the plot as a whole. It is realised that there is a certain amount of unavoidable error in sampling and sub-sampling and for convenience in analyzing the results, percentages are calculated to the nearest five percent in the tables which follow.

Figure 1 - Hobart Experiment C-1

Arrangement of Plots



Soil Series Cheshire

Size of plot 10 feet square

Soil Type Stony Sandy Loam

This series runs North and South

Fertilizer Treatments per Acre

K_1 108# Muriate of Potash	P_1 435# Superphosphate	L_1 1740# Ground Limestone
K_2 216 "	P_2 1470 "	L_2 3480 "
K_3 435 "	P_3 5220 "	L_3 10875 "

Seed: Kentucky bluegrass and white Dutch clover seed applied only in 1924.

1. HOBART PASTURE.

A. Experiment C-1 (1924).

This experiment was laid out in 1924 by M. O. Lanphear in connection with his graduate work in pasture ecology. The mineral treatments were repeated in 1929 and for the last two years (1929 and 1930) the east half of all plots has received a nitrogen top-dressing (Chilean nitrate) at the rate of 30 pounds of nitrogen per acre. This series has been studied as a basis for conclusions regarding the more complex treatments on Tillson and Hohenheim and to note the effect upon the flora, particularly the percentage of clover and bluegrass, of two years nitrogen fertilization.

Table 1 - The Check Area

Plot	Am't per Acre	pH	Ky.Blue	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
15	0	4.70	0	0	5	5	15	75

1. The flora consisted largely of a healthy, vigorous growth of moss and cinquefoil.

2. Other grasses included poverty grass and bent grass.

3. The soil was very acid.

Table 2 - Lime Alone

Plot	Am't per Acre	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
3	1740#	6.05	15	15	5	15	60	50	10	10	10	10	0	0*
10	3480	5.80	10	10	5	10	55	50	20	15	10	15	0	0
18	10875	7.40	20	20	0	5	60	45	10	15	10	15	0	0
25	3480 Seed		20	20	5	15	45	35	15	10	15	20	0	0
Average Composition of the flora			16		8		50		13		13		0	

*Moss which amounted to 1-2% is included under weeds.

Comparing the average composition of plots 3, 10, 18 and 25 with that of the check area we may assign the following influences to lime:

1. Lime killed out the moss almost completely.

2. Lime reduced the proportion of cinquefoil and weeds slightly.

3. Lime increased the percentage of grasses.

4. Lime raised the pH.

The moss was replaced largely by redtop and bent grasses. Apparently the presence of soluble calcium and probably the increased bacterial activity permitted the growth of white Dutch clover which in turn supplied the nitrogen for the bent grasses and a small amount of Kentucky bluegrass.

Table 3 - Phosphorus Alone

Plot	Am't per Acre	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
2	435#	4.85	5	5	0	0	60	50	5	5	15	15	20	20
9	1470	5.10	5	5	0	0	65	55	10	15	15	20	5	5
17	5220	5.20	20	20	0	0	55	55	10	10	15	15	0	0
24	1470 Seed		5	5	0	5	60	50	10	15	15	20	10	5
Average composition of the flora			9		1		56		10		16		8	

1. The superphosphate acted somewhat as an amendment in killing out the moss and reducing the acidity.

2. Phosphorus encouraged a better sod, composed largely of redtop and bent grass.

3. It did not bring in any white Dutch clover and showed less Kentucky bluegrass than the lime plots. All plots showed a lack of available nitrogen in a very stunted growth.

Table 4 - Potash Alone

Plot	Am't per Acre	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
1	108#		0	0	0	0	50	40	10	10	20	25	20	25
8	216	5.20	0	0	0	0	50	40	10	20	20	20	20	20
16	435	4.80	0	0	5	0	50	40	5	15	20	25	20	20
23	216 Seed		0	0	5	5	55	50	5	15	20	20	15	10
Average composition of the flora			0		2		46		11		22		19	

1. Potash alone did not affect the moss as much as did the two previous elements.

2. It did not encourage the clover particularly, though the average is slightly higher than that for phosphorus.

3. The sod as a whole was weaker and more weedy than for lime or phosphorus.

Table 5 - Lime and Phosphorus

Plot	Am't per Acre L	Am't per Acre P	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
4	1740	435	15	15	5	10	65	55	5	10	10	10	0	0
11	3480	1470	15	10	8	10	60	45	7	15	10	20	0	0
19	10875	5220	5	10	5	8	70	55	10	15	10	12	0	0
26	Seed 3480	1470	23	20	12	20	50	35	5	10	10	15	0	0
Average composition of the flora			14		9		55		9		13		0	

1. Lime and phosphorus together tended to encourage white Dutch clover and Kentucky bluegrass though the latter showed a lack of nitrogen and the clover was not very vigorous.

2. The composition is very similar to that of the lime alone plots.

Table 6 - Lime and Potash

Plot	Am't per Acre L	Am't per Acre K	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
6	1740	108	12	15	13	20	55	45	5	10	10	10	0	0
12	3480	216	15	20	15	10	45	30	5	15	20	25	0	0
21	10875	435	25	25	20	25	40	30	5	10	10	10	0	0
28	3480 Seed	216	10	10	20	20	50	35	10	15	10	20	0	0
Average composition of the flora			16		18		42		9		15		0	

1. The lime and potash treatment stimulated the clover more, in most instances, than did the lime and phosphorus treatment with the proportion of Kentucky bluegrass remaining approximately the same.

2. It was, however, slightly more weedy and the sod was not quite as strong as that which received the phosphorus.

Table 7 - Phosphorus and Potash

Plot	Am't per Acre P	Am't per Acre K	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
5	435	108	22	15	3	3	50	37	5	15	10	20	10	10
13	1470	216	15	10	5	8	60	50	5	17	15	15	0	0
20	5220	435	25	25	3	0	55	45	7	20	10	10	0	0
27	1470 Seed	216	20	20	10	25	55	35	5	10	10	10	0	0
Average composition of the flora			20		7		50		10		11		2	

1. These plots with the exception of plot 27 showed very little white Dutch clover.

2. Under the combined influence of the minerals, the plots showed a fair proportion of Kentucky bluegrass.

Table 8 - Lime, Phosphorus and Potash

Plot	Am't per Acre L	P	K	Ky.Blue June	Aug	Wh.Dutch June	Aug	Redtop June	Aug	Other Grasses June	Aug	Weeds June	Aug	Moss June	Aug
7	1740	435	108	10	10	20	20	58	50	5	10	7	10	0	0
14	3480	1470	216	45	30	20	30	20	20	5	10	10	10	0	0
22	10875	5220	435	15	15	30	50	40	15	10	10	5	10	0	0
29	3480	Seed 1470	216	15	20	20	25	45	35	10	10	10	10	0	0
Average composition of the flora				20		26		36		9		9		0	

1. This treatment gave the most vigorous growth of clover, plot 22 averaging 40% on the two clippings.

2. The percentage of Kentucky bluegrass was variable but averaged as high as in any of the previous treatments.

3. The proportion of clover seemed to vary inversely with the amount of Kentucky bluegrass present and vice versa.

Table 9 - Summary

Treatment	Ky.Blue	Wh. Dutch	Redtop	Other Grasses	Weeds	Moss
K	0	2	46	11	22	19
P	9	Trace	56	10	16	8
L	16	8	50	13	13	0
LP	14	9	55	9	13	0
LK	16	18	42	9	15	0
PK	20	7	50	10	13	0
LPK	20	26	36	9	9	0

1. Lime is the first limiter on this soil as regards the growth of a desirable pasture flora. It killed the moss, to a large extent, and encouraged the growth of white Dutch clover and Kentucky bluegrass.

Figure 2 Showing typical cover on the Hobart check area. Note that moss and cinquefoil are very much in evidence.

Figure 3 The other extreme was reached on the $L_3P_3K_3$ plot where the white Dutch clover is vigorous and abundant.

2. Potash apparently, by its stimulation of the clover, comes next after lime and is necessary for a really vigorous growth of the clover.

3. Phosphorus is low in this soil and additional amounts are necessary for optimum growth of the grass and clovers.

4. Conclusions drawn from the above data in regard to pasture flora will be presented at the end of the thesis.

THE EFFECTS OF THE ADDITIONAL NITROGEN

Check Area

The nitrogen caused a slight improvement in the sod by killing out the moss and stimulating what redtop and native grasses were present.

Lime Plots

No detailed analyses were made (by the author) but in addition to a marked increase in growth, the east halves of the plots showed fewer weeds and cinquefoil. The nitrogen apparently caused a slight reduction in the proportion of clover on the east half of those plots containing a considerable proportion of Kentucky bluegrass. The bluegrass made rapid growth and there is a question whether the decrease in clover was due to the presence of the soluble nitrogen or to a secondary shading effect resulting from the increased height and density of the bluegrass.

Phosphorus or Potash Plots

The addition of nitrogen to phosphorus or potash alone gave a denser sod but did not affect the clover since very little was present.

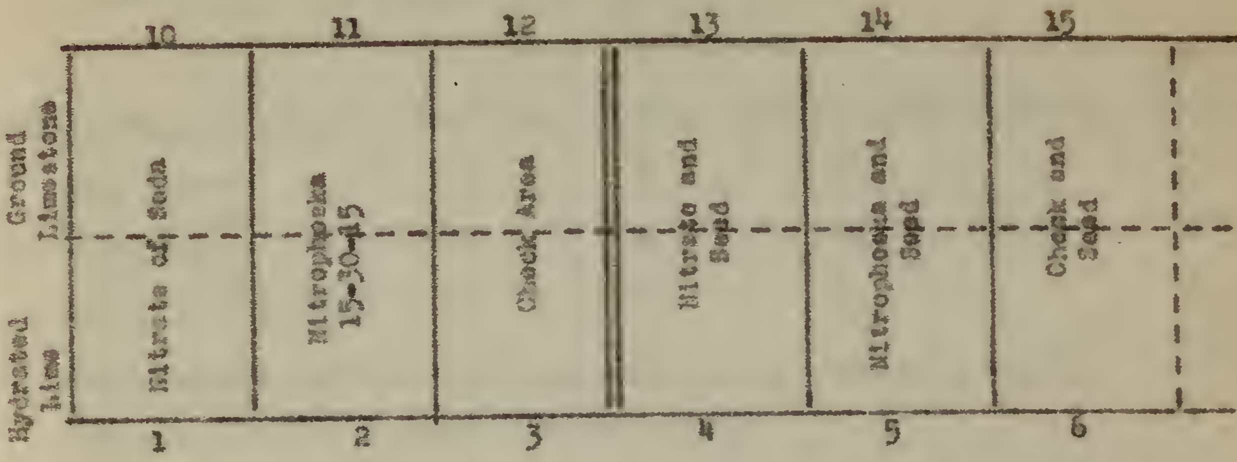
Lime, Phosphorus and Potash in Combination

The addition of nitrogen to the various combinations resulted in a marked increase in yield and a stronger, denser turf of the grasses. The influence of the nitrogen on white Dutch clover was variable. In general the decrease on the east half as compared with the west was slight, and it seemed that the most marked decreases occurred on those plots containing the most bluegrass. On plot 22 which showed the best stand of clover, there was no line of demarcation between the two halves. On this plot there was more redtop than Kentucky bluegrass and due to the vigorous growth of the clover, the latter was not shaded very much by the grasses.

B. Experiment C-2 (1930).

Figure 4 - Hobart Experiment C-2

Arrangement of Plots



The above experiment which was begun in 1930 on an area adjacent to Experiment C-1 consists of six plots duplicated and treated as follows:

1. The east half of all plots received 2000# of ground limestone in the spring while the west halves were treated with 1500# of hydrated lime per acre.

2. The first plot in each series received nitrate of soda (193.5 per acre) while plot 4 received $NaNo_3$ plus 5# of Kentucky bluegrass and 5# of white Dutch clover seed.

3. The second plot in each series received 200 pounds per acre of a complete fertilizer (15-30-15) while plot 5 received Nitrophoska plus seed.

4. The third plot in each series served as a check while plot 6 received seed but no fertilizer.

This experiment was laid out with several objects in view: First, it was desired to compare the two forms of lime for use in pasture top-dressing; secondly, to study the effectiveness of seeding without cultural treatment, and finally, to determine the value of nitrogen alone and in combination

with the minerals in establishing a pasture sod on a mossy worn-out area. The results of the first season were striking and analyses made in July yielded the data presented in the following tables.

Table 10 - Check Area

Plot	Lime	pH	Seed	Wh. Dutch	Redtop	Other Grasses	Weeds	Moss
3	1500 Hyd.	--	--	0	15	15	30	40
12	2000 Gr.L.	-	--	0	10	10	30	50*
6	1500 Hyd.	5.30	Seed	5	15	15	25	40
15	2000 Gr.L.	5.00	Seed	2	10	8	30	50

*Moss still alive on ground limestone strip.

1. The hydrated lime seemed very much superior to the ground limestone for spring application with seed.

2. The hydrate almost entirely destroyed the moss.

3. The hydrate permitted a few clover plants to start but they were scattered and lacking in vigor.

Table 11 - Nitrate of Soda

Plot	NaNo3	Lime	pH	Seed	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss*
1	200	1500 Hyd.	--	--	0	20	10	30	40
10	200	2000 Gr.L.	-	--	0	20	10	30	40
4	200	1500 Hyd.	5.80	Seed	15	20	10	20	35
13	200	2000 Gr.L.	5.65	Seed	5	20	10	30	35

*The moss plants were thoroughly killed out in this series on both the ground limestone and hydrated lime strips but of course were still present and made up a considerable portion of the cover.

1. The nitrate of soda thoroughly killed out the moss.

2. It stimulated the bent grasses, including redtop, that were present but did not encourage much of a sod up to time of analysis.

3. On the seeded plots, it apparently helped the young clover plants to get started since they were more vigorous than on the lime alone areas.

Table 12 - Complete Fertilizer

Plot	Nitro-phoska I	Lime	pH	Seed	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
2	200	1500 Hyd.	--	--	0	20	20	25	35
11	200	2000 Gr.L.	-	--	0	20	15	25	40*
5	200	1500 Hyd.	5.00	Seed	30	10	15	15	30
14	200	2000 Gr.L.	4.80	Seed	10	15	15	25	35

* Moss not completely killed on the ground limestone strip.

1. The complete fertilizer did not affect the moss as markedly as did the nitrate but did encourage a slightly denser turf.

2. It brought about a thicker, more vigorous stand of white Dutch clover on the seeded plots.

3. The vegetation was apparently more palatable to the cattle, these plots being grazed most closely of the series.

Table 13 - Summary

Plot	Lime	Seed	Wh. Dutch	Redtop	Other Grasses	Weeds	Moss
Check	1500 Hyd.	Seed	5	15	15	25	40
NaNo3	"	"	15	20	10	20	35
Nitrophoska	"	"	30	10	15	15	30

Assuming that the best basic treatment for the land in the experiment was an application of 1500 pounds of hydrated lime plus seed, the addition of nitrate of soda and a complete fertilizer brought about the following changes:

1. Ground limestone had caused but a slight change in flora at the time of analysis. The addition of seed produced only two per cent clover.

2. Hydrated lime destroyed a larger proportion of the moss and encouraged slightly more clover when seed was supplied in addition to the lime.

3. The nitrate of soda was more effective than the lime in destroying the moss and stimulated the grasses which were present. It enabled the clover plants to start even in the absence of a mineral application.

4. The complete fertilizer produced a thicker sod than did the nitrate alone and caused a greater reduction weeds. With seed, it brought in a healthy, vigorous growth of white Dutch clover.

5. The NPK plot seemed to be the most palatable since the cattle grazed it very closely.

Figure 5 Gr. Limestone and seed failed to establish the clover.

Figure 6 Gr. Limestone, seed and $NaNO_3$ stimulated the grass.

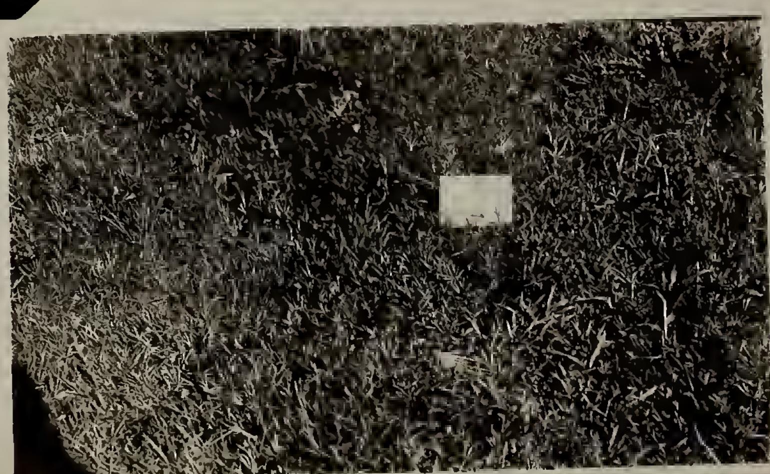


Figure 7 A complete fertilizer, gr. limestone and seed encouraged some clover and closer grazing.

Figure 8 Hydrate alone differed little from gr. limestone alone.

Figure 9 $NaNo_3$, hydrated lime and seed caused this change.

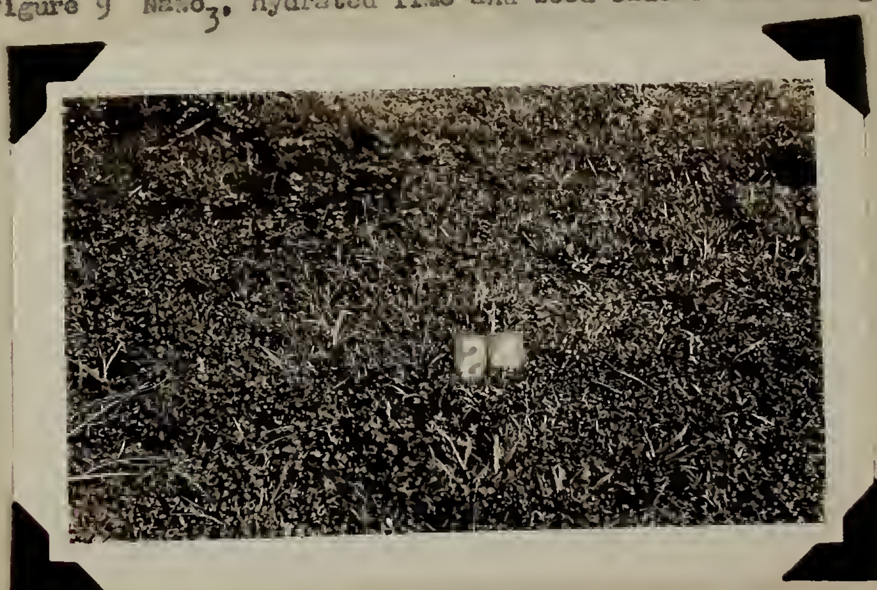


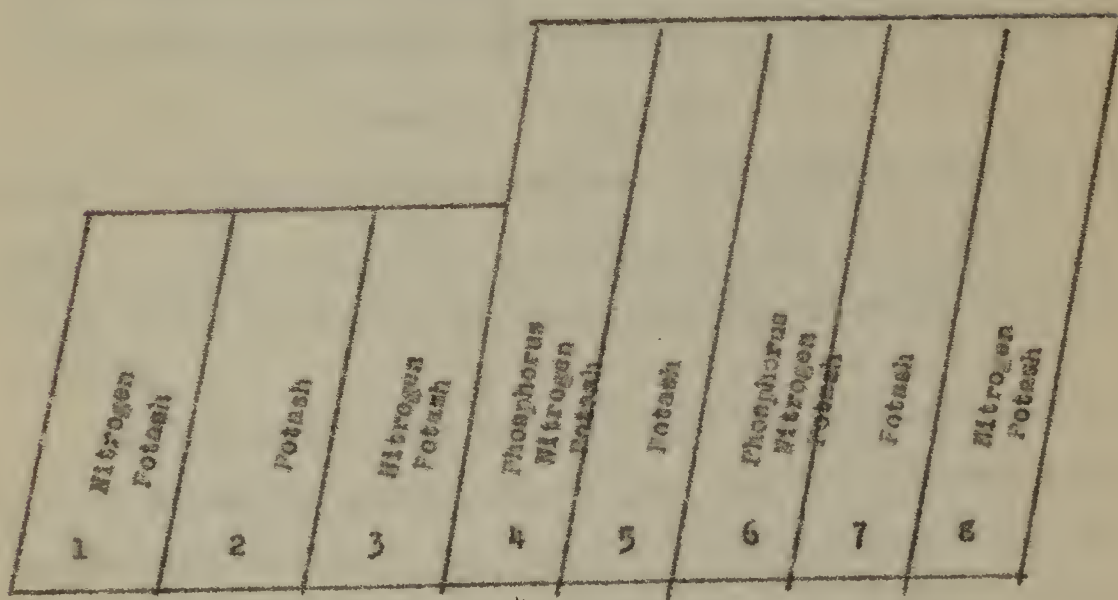
Figure 10 A complete fertilizer, hydrate and seed established this dense clover sod in one season.

2. TILLSON PASTURE.

A. Experiment U (1927).

Figure 11 - Tillson Experiment U

Arrangement of Plots



Soil Series (Cheshire)

Size of plot Approx. .5 acre

Soil Type Stony Sandy Loam

Entire area limed at rate of 2000# ground limestone per acre.

Fertilizer Treatments per Acre

Potash applied at the rate of 80 pounds K_2O per acre

Nitrogen applied at the rate of 46 pounds N per acre

Phosphorus applied at the rate of 58 pounds P_2O_5 per acre

Except for minor differences the above amounts have been applied each year since 1927 i. e. 1927, '28, '29 and '30.

The plots are grazed by the Hereford herd of the College farm during the six pasture months (May--October). These larger plots showed much more variation in herbage than did the small plots in the preceding experiments but an effort was made to secure representative samples for analysis. In the following tables except the first, the left hand columns represent actual analyses made of the herbage in June, while the right hand columns represent the estimated percentage composition of each plot in August.

Table 14 - Check Area

Treatment	Ky.Blue	Wh. Dutch	Redtop	Other Grasses	Weeds	Moss
Lime	0*	0	10	25	60	5

*This plot showed no change in flora. Therefore, the second column was omitted.

The application of lime to the above area had pretty thoroughly taken care of the moss but running cinquefoil was very much in evidence as the dominant weed, and other grasses consisted largely of poverty grass and sweet vernal. In addition, the following weeds were present in varying proportions: sorrel, yarrow, buttercup, and thistle.

Table 15 - Potash Alone

Plot	pH	Ky.Blue		Wh.Dutch		Redtop		Other Grasses		Weeds		Moss	
		June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
2	5.45	10	15	15	15	30	25	10	10	35	35	0	0
5	5.05	25	25	20	20	25	25	10	10	20	20	0	0
7	5.10	20	20	22	25	28	20	10	15	25	25	0	0
Average composition of the flora		17	20	19	20	28	23	11	12	25	25	0	0

1. This series, particularly plot 2, was quite weedy with buttercup, hardhack, dandelion, plantain, yarrow, Juncus, Carex, hawkweed and some moss on the hummocks.

2. These plots showed solid mats of white Dutch clover on the closely grazed portions, particularly in the wetter areas at the south end.

3. At the lower ends of the plots (north) which were drier and not as well grazed, clover was not as abundant.

4. The distribution of the Kentucky bluegrass followed that of the clover.

Table 16 - Potash and Nitrogen

Plot	pH	Ky.Blue		Wh.Dutch		Redtop		Other Grasses		Weeds		Moss	
		June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
1	5.35	30	25	15	15	25	25	15	15	15	20	0	0
3	5.10	25	25	10	15	25	25	15	15	25	20	0	0
8	5.75	30	25	15	18	18	20	15	15	22	22	0	0
Average composition of the flora		28	25	13	16	23	23	15	15	21	21	0	0

1. The Nitrogen-Potash series showed a better grass sod with more Kentucky bluegrass than did the plots receiving potash only. The weeds were not quite so much in evidence.

2. The average percentage of clover was slightly less but here again it is not clear whether this reduction is due to the direct effect of the nitrogen on the clover or whether it is a secondary shading effect of the better growth of the grasses.

3. On the closely grazed areas the growth of the white Dutch clover was comparable with that on the plots receiving potash only.

Table 17 - Complete Fertilizer

Plot	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
4	5.35	30	30	22	25	20	20	13	10	15	15	0	0
6	5.25	35	35	25	30	20	15	10	10	10	10	0	0
Average composition of the flora		32	32	23	28	20	18	13	10	12	12	0	0

1. The NPK plot showed both the largest percentage of Kentucky bluegrass and the greatest proportion of clover.

2. This plot showed the fewest weeds and the strongest sod.

3. The complete fertilizer here again, apparently added to the palatability for these plots were much more even in appearance after grazing than were the others in the experiment.

Table 18 - Summary

Treatment	Ky.Blue	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
(L) K	17	19	28	11	25	0
(L) NK	28	13	23	15	21	0
(L) NPK	32	23	20	13	12	0

1. After the reduction in acidity on these plots by the lime applied in 1927, yearly applications of potash encouraged the growth of white Dutch clover which furnished nitrogen for the development of some Kentucky bluegrass. However, the sod was somewhat open and very weedy.

2. The addition of nitrogen to the potash resulted in a stronger sod containing 28 per cent of Kentucky bluegrass and reduced the weeds slightly. The percentage of clover was somewhat depressed.

3. The addition of phosphorus as well as nitrogen to the potash gave a slight increase in Kentucky bluegrass and a marked increase in white Dutch clover. The proportion of weeds was considerably reduced and the sod as a whole presented a well-balanced mixture of grasses and clover.

Figure 12 The check area.

Figure 13 Lime, potash and nitrogen accomplished this change.

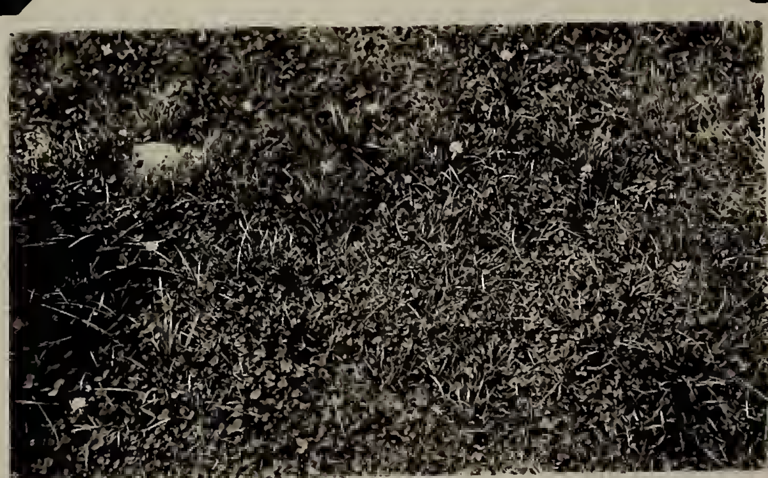
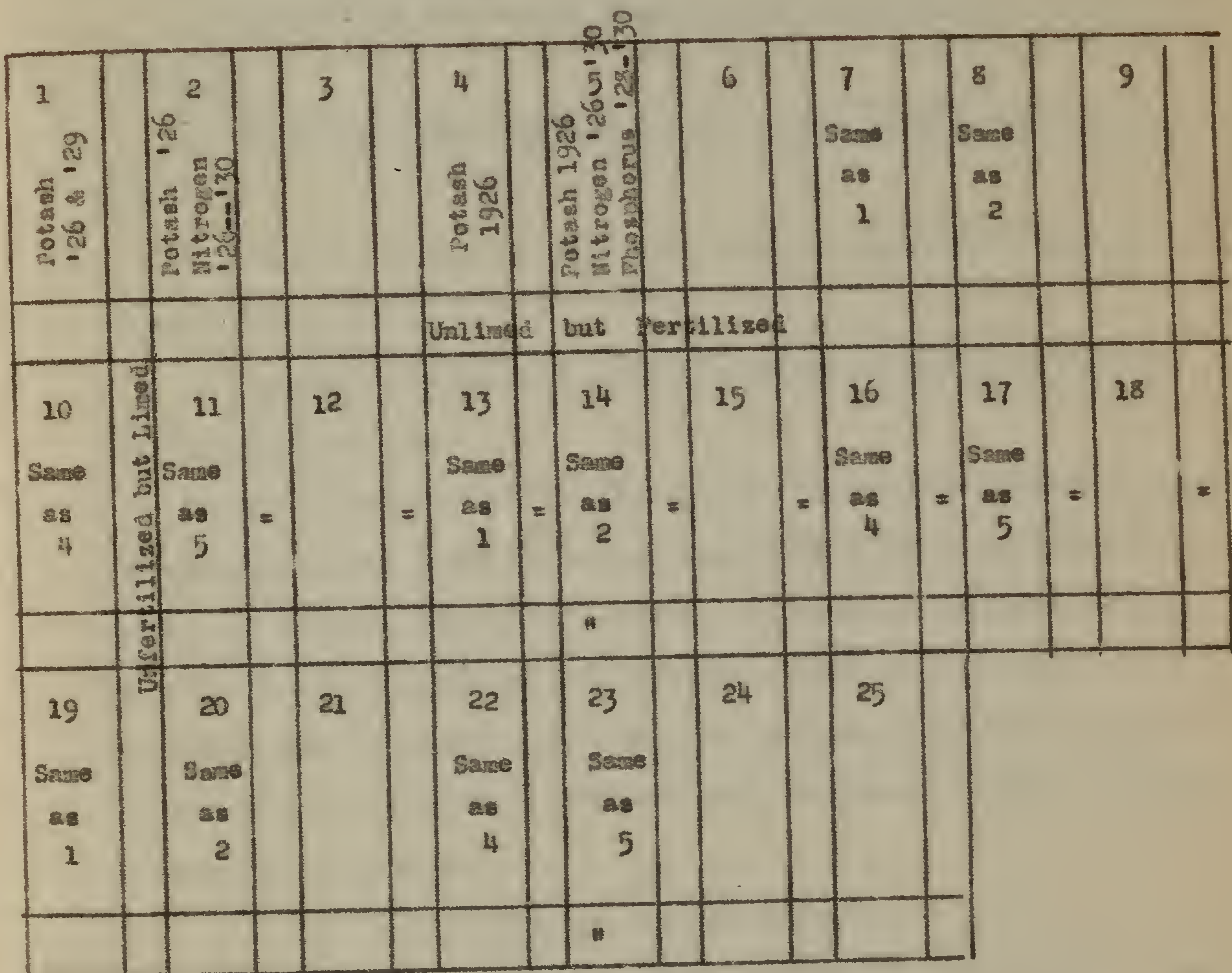


Figure 14 Lime plus a complete fertilizer has brought in a dense Kentucky bluegrass-white Dutch clover sod.

B. Experiment G (1926)

Figure 15 - Tillson Experiment G

Arrangement of Plots



Note: Plots 26--29 are omitted in this diagram.

Soil Series (Cheshire) Soil Type Stony Sandy Loam

Size of Plot 2 X 6 rods Strip 1 rod wide between plots

Fertilizer Schedule

1. The entire area was limed in 1926 except a strip one rod wide at the east end of each series.

2. The unlabeled plots in the above diagram (3, 6, 9, 12, 15, 18, 21, 24) received phosphorus and nitrogen and since potash is apparently the first limiter on this soil, there was little or no clover present. These plots were not analyzed.

3. The strip (1 rod) at the north side of each plot was unfertilized but limed.

4. Potash was applied as muriate at the rate of 150 pounds K_2O per acre.

5. Nitrogen was applied in various synthetic carriers at rate of 23 pounds per acre.

6. Phosphorus was applied in Diammonphos at rate of 57 pounds of available P_2O_5 per acre.

7. The treatments in the above experiment were replicated five times; the series starting at the top of the slope next to the C. V. railroad tracks and extending down into the swamp. Since the fifth series was on very low land and not grazed in keeping with the rest of the series it is omitted in the following tables. The June analysis represents clippings handled as in the previous experiments while the August analysis is based on estimated percentages.

Table 19 - Check Area

Treatment	Ky.Blue	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
None	0	0	15	25	45	15

Note: The check area showed no change from June to August and the two analyses were combined.

The check areas were very poor and open, showing much bare soil and what vegetation was present consisted largely of weeds and native grasses, even these making but little growth.

Table 20 - Lime and Potash

Plot	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
5	5.95	40	35	0	7	45	40	10	8	5	10	0	0
11		30	25	18	30	35	30	10	10	7	5	0	0
17	5.95	30	25	25	35	28	25	10	10	7	5	0	0
23		28	25	20	25	30	30	10	10	12	10	0	0
Average composition of the flora		29	25	21	30	31	28	10	10	9	7	0	0

1. The potash brought about a marked change in flora, encouraging a satisfactory proportion of white Dutch clover and Kentucky bluegrass.

2. The sod was excellent on all four plots; the chief variables being the percentages of weeds and white Dutch clover.

3. It is interesting to note that, in general, the percentage of white Dutch clover increased as the plots descended the hillside i. e. as the moisture supply increased.

Table 21 - Lime and Potash

(2 applications)

Plot	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
1	6.50	30	20	8	15	45	45	7	10	10	10	0	0
7		25	20	10	12	48	51	5	5	12	12	0	0
13		30	25	15	15	33	38	10	10	12	12	0	0
19		28	25	12	20	40	30	10	15	10	10	0	0
Average composition of the flora		28	22	11	15	41	41	8	10	12	12	0	0

1. The two applications of potash had practically the same effect as did the single application but with somewhat less clover and more redtop on the average. The fact that two of the plots in the series were along the

top of the hill, while plot 19 was not as well grazed as was plot 23, may have had something to do with this rather surprising result.

Table 22 - Lime, Potash and Nitrogen

Plot	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
2	5.65	40	35	3	10	40	35	10	10	7	10	0	0
8	6.05	30	35	1	10	50	35	9	10	10	10	0	0
14		38	35	5	15	45	35	5	5	7	10	0	0
20		31	30	4	12	45	35	10	13	10	10	0	0
Average composition of the flora		35	34	3	12	45	35	8	9	9	10	0	0

1. The addition of nitrogen on these plots increased the percentage of Kentucky bluegrass slightly and brought about a considerable decrease in the average percentage of clover.

2. This was most marked in the June analysis and on the plots at the upper end of the series. The August estimate showed a normal percentage of clover as compared with the plot receiving potash alone.

3. The presence of an excellent growth of clover on the closely grazed areas and the increased proportion of Kentucky bluegrass on this plot might indicate that the reduction in clover was a secondary effect of the bluegrass.

Table 23 - Complete Fertilizer

Plot	pH	Ky.Blue June	Ky.Blue Aug	Wh.Dutch June	Wh.Dutch Aug	Redtop June	Redtop Aug	Other Grasses June	Other Grasses Aug	Weeds June	Weeds Aug	Moss June	Moss Aug
5*	5.95	40	35	0	7	45	40	10	8	5	10	0	0
11		30	25	18	30	35	30	10	10	7	5	0	0
17	5.95	30	25	25	35	28	25	10	10	7	5	0	0
23		28	25	20	25	30	30	10	10	12	10	0	0
Average composition of the flora		29	25	21	30	31	28	10	10	9	7	0	0

Note: Plot 5 is omitted in the average for this treatment since it differs so markedly from the other three plots in botanical composition. In accordance with previous observations it would seem that this plot was too deficient in moisture to grow white Dutch clover to advantage.

1. The complete fertilizer resulted in the best sod. The herbage showed 30% Kentucky bluegrass and an excellent proportion of white Dutch clover and, in all cases but one, a reduced percentage of weeds. Plot 17 which was so situated that it received somewhat more moisture than the others presented a solid mat of white Dutch clover on certain portions.

2. These plots, except plot 5, showed slightly more uniform grazing than did the others.

Table 24 - Summary

Treatment	pH	Ky.Blue	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
(L) K-26	6.00	32	18	27	9	14	0
(L) K-'26,'29	6.50	28	11	41	8	12	0
(L) NK	5.80	35	3	45	8	9	0
(L) NPK	5.95	29	21	31	10	9	0

1. The application of lime and potash to a run-down pasture sod, encouraged a satisfactory growth of Kentucky bluegrass and white Dutch clover.

2. The addition of nitrogen to the above treatment increased the bluegrass slightly, reduced the proportion of weeds and showed a tendency, somewhat variable, to reduce the percentage of clover.

3. The application of a complete fertilizer brought about a marked increase in white Dutch clover without upsetting the balance of the vegetation i. e. clover was not stimulated at the expense of the grasses.

The Relative Need for Lime

The presence of the fertilized but unlimed strips at the east end of each plot and of the unfertilized but limed areas along the north side of the plots enabled the observer to note the relative need for lime on this land, under the various treatments.

The unfertilized but limed areas in all cases showed a poor, open sod, very weedy with cinquefoil and Carex. The grasses consisted largely of poverty grass, sweet vernal and the bents. The plots were not well grazed; clover was present only in urine spots; and in a few cases live moss was present.

The unlimed areas receiving potash only, showed no significant difference from the check areas.

The unlimed areas receiving potash and nitrogen were variable in herbage but in general showed a fair bent grass sod, some redtop, and occasionally a trace of clover. Moss and cinquefoil were still present in spots.

The unlimed areas receiving the complete fertilizer (i. e. potash plus phosphorus and nitrogen) showed an excellent grass sod with most of the moss and cinquefoil driven out. A small proportion of Kentucky bluegrass was present and there were traces of white Dutch clover on some of the plots.

Thus, the above observations would seem to indicate that the need for lime varies somewhat with the plane of fertility, being least important where a complete fertilizer is used.

TILLSON PASTURE - EXPERIMENT C

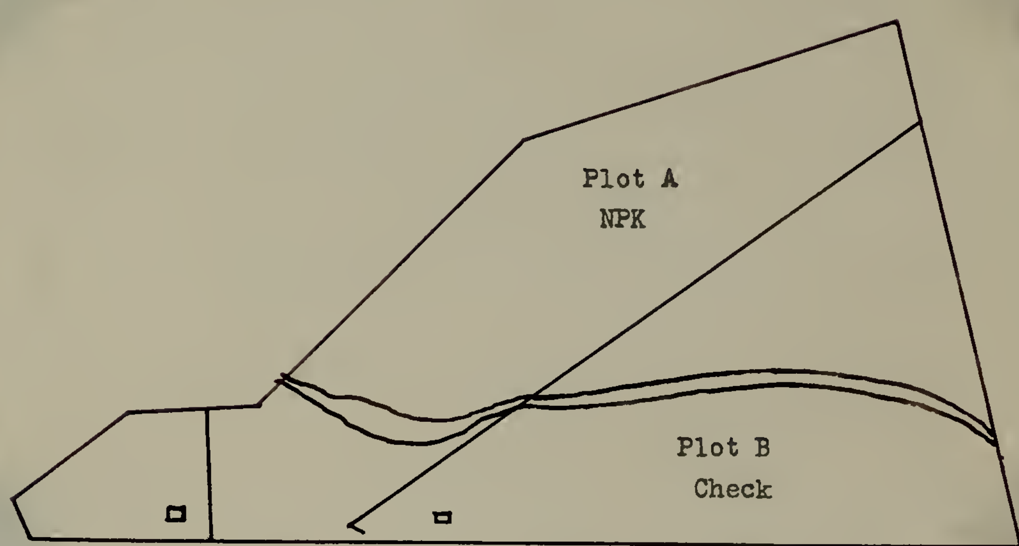
Figure 16 The check area - unfertilized.

Figure 17 This plot has received a complete fertilizer (limed) for three years.

3. ANGUS PASTURE.

Figure 18 - Angus Pasture

Layout of Plots



Soil Series Cheshire   Soil Type Stony Sandy Loam

Size of Plot 3.85 acres   (Slightly heavier than Tillson)

Fertilizer Treatments per Acre

	Plot A	Plot B
1928	85# N - 55# P_2O_5 - 67# K_2O	Unfertilized
1929	76# Nitrogen	"
1930	85# N - 33# P_2O_5 - 43# K_2O	

This experiment was begun in 1928 on an area which had been in permanent pasture for many years but which was in better condition than either Hobart or Tillson pastures. It was divided into two fields of 3.85 acres

each and one half (Plot A) received a complete fertilizer plus two additional summer applications of nitrogen while the other half (Plot B) remained unfertilized.

The two fields were grazed in rotation by young stock from the College farm and an effort was made to regulate the grazing at the optimum, both from the standpoint of the cattle, and the pasture. Thus this experiment differs from the preceding ones in two important aspects. First, rotational grazing was practiced on the Angus pasture, whereas the Hobart plots were allowed to head out, and the Tillson plots have been grazed continuously, except during the last year. Secondly, much heavier applications of nitrogen were made on this field than on the others previously considered.

Table 25 - Angus B - Check Area

Treatment	pH	Ky.Blue		Wh.Dutch		Redtop		Other Grasses		Weeds		Moss	
		June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
None	5.5	40	25	2	3	26	25	25	37	12	10	0	0

It will be noted that the June analysis (actual) was high for Kentucky bluegrass and low for other grasses as compared with the August estimate. This lack of correlation is probably largely due to the fact that since Kentucky bluegrass predominates in certain areas and not in others, the samples selected for clipping contained an abnormally large percentage of bluegrass. The fact that the bluegrass was heading out tended to emphasize its presence in the flora. In August the Kentucky bluegrass was dormant and the other native grasses were much more in evidence.

The excellent condition of the sod on this field, in spite of a lack of fertilizer treatment for three years, can probably be attributed in part at

least to the benefits derived from rotation which prevented over-grazing and permitted the plants to make adequate top growth and root development. Other grasses included sweet vernal, the bents, poverty grass, crab grass with a small proportion of orchard grass. Weeds consisted largely of Juncus, Carex, buttercup, dandelion, thistle, plantain and chickweed.

Table 26 - Angus A - Complete Fertilizer

Treatment	pH	Ky.Blue		Wh.Dutch		Redtop		Other Grasses		Weeds		Moss	
		June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
NPK	5.00	75	50	2	6	10	15	10	25	3	4	0	0

A similar lack of correlation between the two analyses is seen on this area, which is probably to be explained in the same manner as suggested for Plot B.

1. The complete fertilizer increased the proportion of bluegrass very markedly at the end of the three years and brought about a considerable reduction in the proportion of weeds.

2. The percentage of white Dutch clover in the field as a whole was quite low though in the moist area at the center of the plot the proportion of clover averaged considerably higher. Although no analyses were made, the percentage of clover, by observation, was much higher in 1928 and in 1929. Two factors probably contributed to the reduction evident in 1930. The heavy application of nitrogen in the spring of 1929 caused such rapid growth of the grasses that the feed got ahead of the animals and this undoubtedly exerted a deleterious shading effect on the clover. Secondly, the extremely dry summer of 1929 injured the shallow rooted clover plants on the hillside and they failed to revive the following spring.

Table 27 - Summary

Treatment	pH	Ky.Blue	Wh.Dutch	Redtop	Other Grasses	Weeds	Moss
None	5.50	33*	2	25	29	11	0
NPK	5.00	61	4	13	18	4	0

Note: Although the advisability of averaging an actual analyses with an estimate is questionable, the author feels in this case that the above percentages approximate the actual composition of the two fields more closely than either of the separate analyses.

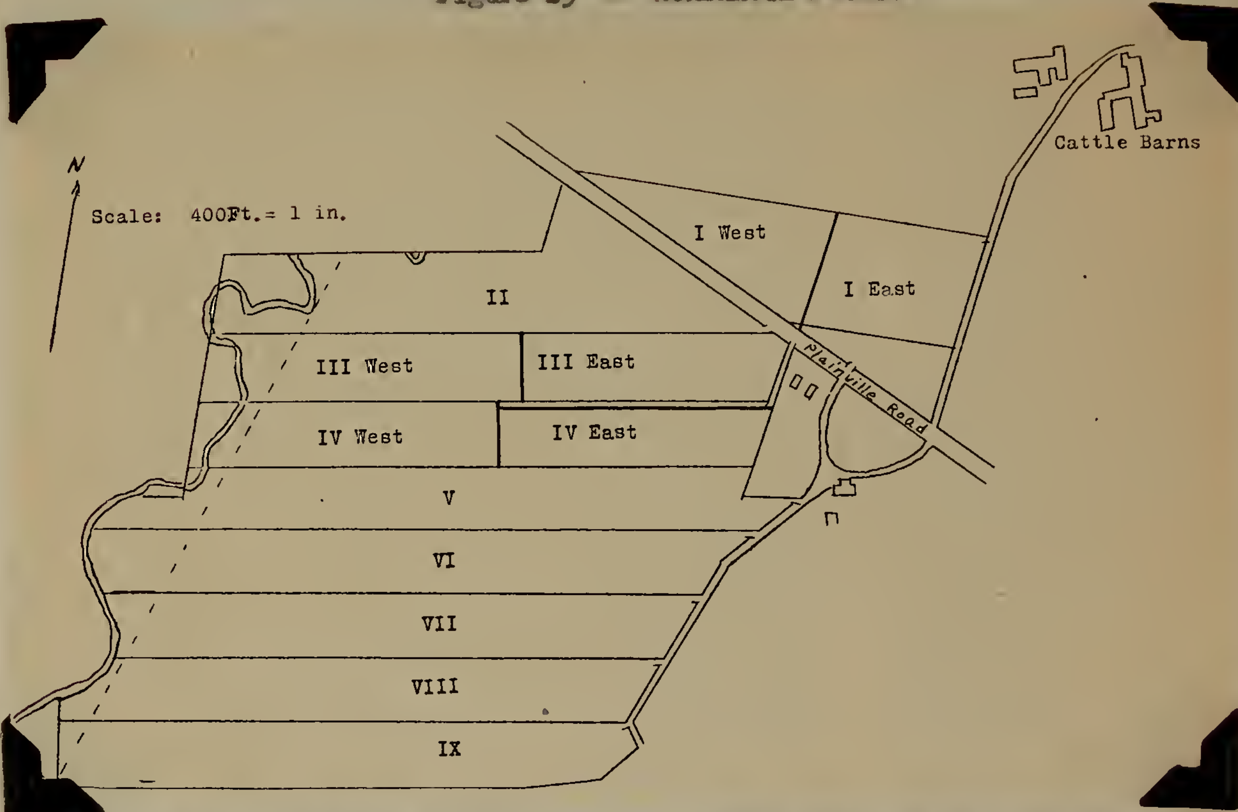
1. The effect of three years application of a complete fertilizer on a permanent pasture which was rotated was to improve the sod thru the increase of Kentucky bluegrass with a decrease in native grasses and weeds.

2. The low percentage of white Dutch clover on this field can as logically be ascribed to management and moisture conditions as to the nitrogen. Further work is indicated.

The tendency for the hillside to dry out during July and August except in very wet years leaves some doubt as to the desirability of trying to encourage a large proportion while Dutch clover on this type of land since due to its shallow root system, it is bound to be injured by drouth. A similar objection, of course, can be raised in the case of a straight blue-grass sod. In other words, a mixture of several grasses and clovers is always to be preferred to a sod made up wholly of one species.

4. HOHENHEIM DEMONSTRATION.

Figure 19 - Hohenheim Pasture



Soil Series Agawam

Soil Type Silty Clay Loam

Size of Plot 8.25 acres

Seeding Trials 2 acres

Figure 20. A view of the high producing group. Note height of the grass.

The following experiment differs from those discussed in the preceding pages in that the land is all plowable and was formerly a part of the regular College farm rotation. Various grass and clover mixtures have been used in seeding down but the methods of fertilization and management have been more or less standardized. For the last three years, the entire area has formed the intensive grassland management demonstration on the College farm and all plots with the exception of plots IV and VI have received a complete fertilizer plus additional summer applications of nitrogen.

Plots III and IV were seeded to the same mixture in 1924 and received identical treatment up to 1928. Since that time the former has received heavy applications of nitrogen, phosphorus and potash while the latter has remained unfertilized.

Plots V and VI were seeded to the same mixture in 1925, fertilized and managed in the same way through 1929, but for the last two years plot V has received a complete fertilizer while plot VI has received only minerals.

Plot I is composed of three different seedings dating 1922, 1925 and 1926.

Finally, plots VII, VIII and IX contain a series of seven seeding trials begun in 1926 in an effort to determine the most desirable seeding mixture for pasture.

Thus, the above layout makes it possible to study the effect on the flora of three years of heavy fertilization with a complete fertilizer (85# nitrogen, 43# phosphoric acid and 53# potash) as compared with the effect of the minerals without the nitrogen. The seeding trials on I, and VII, VIII and IX will furnish a considerable amount of data on the

longevity, adaptability and palatability of the various pasture grasses under the new system of rotational grazing plus heavy nitrogen applications. In the following tables the percentage composition of the flora is based on an actual analysis of clippings from six representative areas scattered over the plot in the case of the June figures while the August percentages represent the estimated average composition after a careful survey of the plot as a whole.

Table 28

No Treatment vs. Complete Fertilizer

Seeded 1924 | Pounds Seed per Acre 27

Timothy	12	White Dutch Clover	1
Redtop	3	Medium Red Clover	3
Meadow Fescue	3	Alsike Clover	3

Kentucky Bluegrass 2

Plot	Treatment	pH	Timothy		Redtop		Ky.Blue		Wh.Dutch		Other Grasses		Weeds	
			June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
4	Check	6.25	7	7	45	50	25	15	0	3	8	5	15	20
3	NPK	5.90	22	16	17	26	52	48	0	1	5	5	4	4

1. The timothy had practically disappeared on the check area and redtop was the dominant grass.

2. There was a fair amount of timothy on plot 3, with an equal proportion of redtop; Kentucky bluegrass was the dominant grass.

3. The percentage of clover was very low on both of these fields.

4. The check plot was very weedy in comparison with the field receiving a complete fertilizer.

Table 29

Minerals vs. Complete Fertilizer

Seeded 1925 Pounds Seed per Acre 26

Timothy	10	White Dutch Clover	1
Redtop	3	Medium Red Clover	3
Meadow Fescue	3	Alsike Clover	4

Kentucky Bluegrass 2

Plot	Treatment	pH	Timothy		Redtop		Ky.Blue		Wh.Dutch		Other Grasses		Weeds	
			June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
6	PK	5.90	21	20	32	37	30	25	7	7	5	5	5	6
5	NPK	5.80	14	10	19	30	60	50	2	1	3	6	2	3

1. The complete fertilizer plot showed less timothy and redtop and double the percentage of Kentucky bluegrass as compared with the plot which received minerals only.

2. The percentage of clover was slightly higher on the mineral plot, but the proportion was very low on both fields. On plot V, which made very rapid growth in June, the bluegrass had smothered out any clover that was present. The clover on Plot VI was not sufficiently abundant to promote optimum growth of the grasses and the plot as a whole showed a lack of available nitrogen.

Table 30 - Seeding Mixtures on Plot I

1922 Seeding				1925 Seeding		1926 Seeding	
Timothy	10	Wh. Dutch Clover	1	Timothy	15	Timothy	15
Redtop	3	Med. Red Clover	3	Redtop	3	Redtop	3
Ky. bluegrass	2	Alsike Clover	3	Med. Red Clover	5	Med. Red Clover	5
Meadow Fescue	3			Alsike Clover	4	Alsike Clover	4

It will be noted that the two later seedings are the same and differ from the '22 seeding mixture in that they contained no Kentucky bluegrass or white Dutch clover and had five pounds more timothy.

Treatment	pH	Timothy		Redtop		Ky.Blue		Wh. Dutch		Other Grasses		Weeds	
		June	Aug	June	Aug	June	Aug	June	Aug	June	Aug	June	Aug
Seeded '22 NPK	5.70	14	15	14	15	64	58	2	0	2	5	4	7
Seeded '25 NPK	6.10	30	35	32	25	18	14	15	16	3	5	2	5
Seeded '26 NPK	6.15	36	40	35	20	12	15	12	15	2	7	3	3

The _'22 seeding_ represents the oldest sod in the demonstration. It is also the strongest sod and has been outstanding in carrying capacity under the new system. The dominant grass is Kentucky bluegrass and unfortunately this seemed to be less palatable to the milch cows than was timothy. Other grasses included meadow fescue and orchard grass and weeds consisted largely of dandelion and plantain.

The _'25 seeding_ contains a larger proportion of timothy and redtop and the increased percentages of white Dutch clover has been very noticeable. The proportion of Kentucky bluegrass is relatively low.

The _'26 seeding_ contains approximately 6% more timothy and 6% less Kentucky bluegrass as compared with that seeded the year previous.

Conclusions regarding these seedings will be found at the end of this thesis.

b. Seeding Mixture Trials on Plots VII, VIII and IX

The east portion of this experiment was seeded in oats in 1926; the west portion seeded in corn two months later. Six different mixtures of

pasture grasses and clovers were seeded in a series of two acre plots running north and south, while a seventh combination was used on the balance of the field down to the brook. When cut for hay the first year (1927) the plots showed marked differences in the proportions of red and alsike clover. Since 1928 the plots have formed part of the Hohenheim system, receiving a complete fertilizer in April plus supplementary nitrogen applications.

They have been cut for hay early in June, top dressed with a nitrogen carrier, then grazed during the latter part of the season. No appreciable differences in flora were noticed in 1928 and 1929. However, in 1930 there were marked differences in the proportions of bluegrass in the hay crop on the various seedings and after the cattle were turned onto the plots for grazing significant differences in the intensity of grazing by the milking groups appeared on the different seedings.

In the following discussion, the amounts of clover in the various mixtures are unimportant since the red and alsike clovers are biennials and did not appear after the first two years. Likewise, since the plots were allowed to produce a crop of hay each year, before being grazed, the percentages of white Dutch clover present were very low. The pounds of redtop per mixture are relatively constant so that the two important variables in these trials are the amounts of timothy in the mixture and the presence or absence of Kentucky bluegrass seed. Plots 3, 4 and 6 had no bluegrass in the original seeding.

Table 31 - Seeding Mixtures on Plots VII, VIII and IX

Seeding	1	2	3	4	5	6	7
Timothy	14#	10#	15#	15#	10#	5#	10#
Redtop	4	4	4	4	5	8	4
Ky. bluegrass	5	2	0	0	5	0	4
Wh. Dutch clover	3	1	1	0	2	2	2
Med. Red "	4	4	4	3	0	0	3
Alsike clover	3	3	3	5	5	7	5
Total	33	24	27	27	27	22	28

The above table contains the seeding mixtures used in the trials, giving the pounds per acre for each species. In the following table, the percentage composition of the plots represents the average of two botanical analyses of clippings. One was taken in June just before haying and the second was taken in August before the cattle were turned on the plots to graze the aftermath.

Table 32 - Botanical Composition of the Seedings

Plot	1	2	3	4	5	6	7
Timothy	16%	15%	30%	36%	9%	41%	21%
Redtop	28	28	42	48	25	45	33
Ky. Bluegrass	48	46	12	2	55	1	37
Wh. Dutch clover	0	0	1	4	0	1	0
Weeds	8	11	15	10	11	12	10

Plots 1 and 2, differing in seeding, by a slight change in the amounts of timothy and Kentucky bluegrass, showed approximately the same composition in herbage four years later. The eastern end of plot 1 was covered with

quack grass which was not included in the analysis. Weeds included a considerable proportion of Juncus which was present on those areas where the grass had been killed out under the windrows during the wet season of 1928. Note that Kentucky bluegrass makes up almost fifty percent of the herbage on these plots.

Plot 3 For some reason, (possibly it was in the seeding mixture) this plot was very weedy. It contained a good percentage of timothy and about 12 per cent of Kentucky bluegrass though there was none in the seeding mixture.

Plot 7 This large plot was somewhat variable in herbage but showed about an equal proportion of the three major grasses on the average.

Plots 4, 5 and 6 The most interesting comparison lies between these plots. In June, just previous to haying, a clearly marked line formed by the heads of the bluegrass separated plot 5 from those on either side of it. Later in the season, a similar line was apparent, due to the closer grazing by the milch cows on plots 4 and 6 with a tendency to pass over the bluegrass plot. Plot 5 which had 5 pounds of Kentucky bluegrass in the seeding mixture analyzed 55 per cent in the flora, while plots 4 and 6 without Kentucky bluegrass in the seeding showed but a trace of bluegrass on their respective areas. Apparently the bluegrass had replaced most of the timothy and part of the redtop in the fifth seeding.

It is of interest also to note that the two plots (4 and 6) having no Kentucky bluegrass were the only ones in the entire series to show white Dutch clover in their analyses. As on plot I, the timothy lasted much better in the absence of bluegrass in the seeding mixture. It did not seem to depress the clover as much as did the bluegrass.

SEEDING TRIALS - PLOTS VII, VIII and IX

Figure 21 This picture brings out the difference of intensity in grazing. Seeding six (without Ky. bluegrass) is in the foreground, seeding five (with Ky. bluegrass) is in the background.

Figure 22 Another view of the above with seeding five (with Ky. bluegrass) in the foreground and seeding four (without Ky. bluegrass) in the background.

E. DISCUSSION OF RESULTS.

LIME:

The author raised the question as to relative need for lime under varying planes of fertility, particularly in connection with the use of a complete fertilizer on pastures.

Hobart C-1.

It was indicated that on this type of soil, (fine sandy loam, drumloid in topography, with pH's from 4.5 to 5.0) it required the addition of lime with the mineral treatment to obtain a satisfactory growth of white Dutch clover.

Hobart C-2.

This series substantiated the author's premise when the addition of a complete fertilizer and seed to the area receiving ground limestone (pH 4.80) resulted in a fair stand of clover in the August analysis.

Tillson G.

A study of the fertilized but unlimed areas on this experiment revealed that there was a gradual improvement in sod with the addition of each fertilizer element to a point where the areas receiving a complete fertilizer without lime showed a fine grass sod, largely bent grasses but with some Kentucky bluegrass and traces of white Dutch clover.

Conclusion:

It is indicated that the need for lime varies with the plane of fertility, being less pronounced with a complete fertilizer than with minerals only, on lands of equal acidity. Lime reduces the moss permitting the

desirable grasses and clovers to make a firm sod and reduces the percentage of weeds slightly. Lime raises the pH and thus encourages Kentucky bluegrass and white Dutch clover to replace the bent grasses. White Dutch clover is seriously handicapped at pH's below 5.00.

PHOSPHORUS:

The author, in attempting to determine the reasons for the conflicting results following applications of phosphorus, and its relationship to the presence of white Dutch clover in the flora secured the following results.

Hobart G-1.

Phosphorus was not particularly beneficial in the absence of potash.

Tillson G.

Phosphorus, in the absence of potash, brought in no white Dutch clover and the sod was rather weak and quite weedy. The soils in the above experiments were Cheshire stony sandy loams on which potash was a limiting factor in the growth of clover. Therefore, phosphorus could not be of benefit until the need for potash was met. The Connecticut experiment which showed a marked response to phosphorus is situated on a Charlton loam, which contains more organic matter, a higher percentage of both silt and clay and is fairly high in available potash (43) (49). In both the Hobart and Tillson experiments the addition of phosphorus to potash increased the percentage of clover over potash alone.

Conclusion:

The response to phosphorus will depend upon the supply of available potash, being more pronounced on the heavier soils and less pronounced as the proportion of sand increases. Both phosphorus and potash are necessary for an abundant and vigorous stand of white Dutch clover.

POTASH:

In spite of conflicting experimental results with potash, observation of urine spots in any pasture will show a marked response to the nitrogen and potash supplied and the presence of white Dutch clover can hardly be attributed to the nitrogen.

Hobart G-1.

Lime and potash brought in twice as much white Dutch clover as did lime and phosphorus while the addition of potash to lime and phosphorus tripled the average percentage of clover in the herbage.

Tillson U.

Potash alone, on land which had been previously limed, brought in a very satisfactory proportion of white Dutch clover.

Tillson G.

The plots receiving potash and lime average 15% clover in the flora.

Conclusion:

On soils similar to those in the above experiments, i. e. Cheshire and Ludlow series, potash will improve the sod, particularly the proportion of white Dutch clover.

MINERALS:

The so-called "mineral system" of pasture fertilization is based upon the theory that a good stand of white Dutch clover in a pasture will furnish sufficient nitrogen for a satisfactory growth of the grasses. Thus, the success of this system is based upon the ability of the phosphorus and potash to encourage the clover.

Hobart C-1.

With lime, the mineral treatment gave an excellent response on this series, bringing in a good stand of clover which supplied the nitrogen for a large percentage of bluegrass.

Hohenheim Plot VI.

Here the minerals did not establish a satisfactory proportion of clover and the carrying capacity was low on this plot in comparison with plot V which received nitrogen. The percentage of clover was somewhat higher in 1929 than in 1930.

Conclusion:

Phosphorus and potash encourage white Dutch clover where moisture conditions are satisfactory, unless its growth is hindered by managemental or seasonal factors. Kentucky bluegrass will do well under similar conditions if the clover supplies sufficient nitrogen.

COMPLETE FERTILIZER:

The impression seemed to be quite generally held, that the effect of a complete fertilizer on pasture flora was practically the same as the effect of nitrogen alone i. e. a pronounced stimulation of Kentucky bluegrass and other grasses and a marked depression of the clover. The author felt that part, at least, of this change could be attributed to management and season.

Hobart C-1.

The effect of the nitrogen on the east half of all plots was variable, and marked depression of the clover occurred only on those plots where the dominant grass was Kentucky bluegrass and it had made sufficient growth to

shade the clover. The plot (22#) analyzing forty per cent white Dutch clover had an equal proportion where the nitrogen was supplied.

Hobart C-2.

The nitrogen was helpful in getting the young clover plants started from seed on a poor sod.

Tillson U.

The six per cent reduction in the proportion of clover on the nitrogen-potash plots may have been due to a shading effect of the grass; on closely grazed areas the clover was equal to that on the potash plots. The complete fertilizer plots averaged 23% clover and 32% Kentucky bluegrass.

Tillson G.

The rather marked reduction in clover on the nitrogen-potash plots in this series may possibly be explained by Fudge's work in connection with the availability of potash. He found that the availability of this nutrient was markedly reduced following application of nitrogen carriers with an alkaline reaction. It is of interest to note that these plots showed the highest percentage of Kentucky bluegrass. The NPK plots averaged 21% clover and 29% Kentucky bluegrass.

Angus Pasture.

The low percentage of clover on this area has been explained previously.

Conclusion:

When the feed is kept properly grazed, a complete fertilizer does not suppress white Dutch clover. The complete fertilizer encouraged Kentucky bluegrass to become the dominant grass and reduced the proportion of weeds in the flora. The complete fertilizer plots showed the strongest sod and the most desirable mixture of grasses and clovers.

MANAGEMENT:

a. Methods of Grazing.

In this group of experiments, three systems of grazing were followed in harvesting the yields, and each method had certain specific effects on the data obtained regarding the flora. It is fairly obvious that where the grass is allowed to mature and is then harvested as hay in small plot trials, there will be a marked suppression of the clover by the grasses. This, of course, will be most pronounced on the completely fertilized plots. The Hobart series was fenced off from the cattle and allowed to reach a considerable height before being grazed down. This method permitted the grasses to make adequate root growth, and enabled them to compete with the weeds, but where Kentucky bluegrass was the dominant grass, tended to depress the clover.

On Tillson where continuous grazing was practiced, the clover was encouraged on the closely grazed plots but thru selective grazing of the better areas the weeds were allowed to become much more widespread. Finally, on Angus pasture, rotational grazing is followed and here the percentage of weeds is very low and the sod is the strongest of those studied. The low percentage of clover has been explained previously.

Conclusion:

It is realized that there were other variables involved in the above comparison but this fact seems evident. Rotational grazing results in a more desirable balance between clover and grasses than on Hobart where the clover is suppressed, and in better weed control than on Tillson where the weeds are not suppressed.

b. Seeding.

The preceding discussion has been confined to permanent pasture land (non-tillable) and the effectiveness of various fertilizer treatments and grazing systems in controlling weeds and establishing a strong Kentucky bluegrass-white Dutch clover sod. This conception of the ideal pasture sod has grown up in the northeastern states along with the lime and superphosphate method of pasture fertilization, depending upon the legume to furnish the necessary nitrogen for the growth of the bluegrass. This system has been carried over into semi-permanent pastures on tillable land and an attempt is made by seeding and mineral fertilization to obtain a bluegrass-clover sod. Such a pasture will supply early spring and late fall feed but dries out badly in July and August; it will be permanent and form a strong turf, but the yield is only medium; and while it is high in feeding value, its palatability has been questioned of late.

There are several other objections. First, white Dutch clover seems to be subject to great seasonal variations and this in turn affects the bluegrass. We speak of "clover years" when the legume is widespread and abundant, often to be followed by its total disappearance the following season. For example, 1929 was considered a good clover year, but 1930 was a very poor one. The prevalence in 1929 may be attributed to the favorable moisture conditions in 1928, a very wet season. The preceding experiments having indicated that moisture supply is the most important factor affecting the distribution of white Dutch clover. The disappearance in 1930 might be explained by the death of the shallow rooted clover plants during the drouth in 1929 and a lower percentage of seeds germinating under the adverse conditions.

Secondly, there is constant danger of the bluegrass crowding out the creeping clover plants if grazing cannot be properly controlled. On the other hand, where the clover is very abundant, it may temporarily displace the grass resulting in a considerable decrease in yield. Such a pasture is unbalanced in feeding value according to Orr; the ration being high in protein and calcium but very low in phosphorus. With these points in mind, the seeding trials described under the Hohenheim system were studied and yielded the following conclusions.

Conclusions:

1. The seeding mixture used has a pronounced effect on the composition of the flora of tillable pasture land.

2. A complete fertilizer encourages Kentucky bluegrass to become the dominant grass when it is present in the seeding mixture.

3. Under similar management, white Dutch clover is most depressed in the seedings containing Kentucky bluegrass. Timothy and redtop do not have this pronounced effect.

4. Timothy stands up well under pasturage where rotational grazing is practiced and is a very palatable and desirable grass under intensive management.

5. Redtop is helpful in building up a dense pasture sod and is palatable to the milch cows.

6. The seedings without Kentucky bluegrass are most palatable to the milch cows and conversely the bluegrass plots appear to be less palatable and are not as closely grazed by the milch cows.

F. GENERAL CONCLUSIONS.

1. Lime, phosphorus and potash will establish a Kentucky bluegrass, white Dutch clover sod on permanent pasture land sufficiently moist to grow the clover. Potash may be unnecessary on heavy soils but will usually be beneficial on run-out pastures situated on Cheshire, Ludlow or Gloucester series.

2. The addition of nitrogen to the above treatment speeds up the succession, results in better weed control and encourages a more evenly balanced mixture of grasses and clover.

3. The use of a complete fertilizer on permanent pasture encourages Kentucky bluegrass to become the dominant grass but does not drive out white Dutch clover when grazing is properly controlled.

4. Kentucky bluegrass and white Dutch clover will not flourish on strongly acid soils but the effect of acidity is less pronounced as the plane of fertility is raised.

5. Moisture is the most important single factor affecting white Dutch clover. Season, intensity of grazing, and the presence of available phosphorus and potash are other important factors.

6. Rotational grazing makes for a better balance in pasture flora and better weed control.

7. On tillable land, timothy, redtop and white Dutch clover are the most desirable species for pasture from the standpoint of yield and palatability.

8. Further work with these grasses and with orchard grass as a substitute for Kentucky bluegrass under intensive management is desirable.

GLOSSARY

Kentucky Bluegrass	Poa	pratensis L
Annual "	"	annua L
Canada "	"	compressa L
Fowl Meadow Grass	"	palustris L
Rough Stalked Meadow Grass	"	trivialis L
Timothy -- Herd's Grass	Phleum	pratense L
Redtop	Agrostis	alba L
R. I. Bent Grass	"	vulgaris L
Orchard Grass	Dactylis	glomerata L
Meadow Fescue	Festuca	elatior L
Tall Oat Grass	Arrhenatherum	elatius L
Quack Grass	Agropyron	repens L (Beauv)
Sweet Vernal	Anthoxanthum	odoratum L
Poverty Grass	Danthonia	spicata L
Med. Red Clover	Trifolium	pratense L
Alsike	"	hybridum L
White Dutch Clover	"	repens L
Buttercup	Ranunculus	acris L
Dandelion	Taraxacum	officinale L
Ox-eye Daisy	Chrysanthemum	leucanthemum L
Wild Carrot	Daucus	carota L
Shepherd's Purse	Capsella	Bursa-pastoris L
Common Plantain	Plantago	major L
Hawkweed	Hieracium	aurantiacum L

GLOSSARY (Continued)

Yarrow	Achillea	millefolium L
Canada Thistle	Cirsium	arvense L
Bull Thistle	"	lanceolatum L
Sorrel	Rumex	hastalus Baldw.
Crab Grass	Syntherisma	sanguinale A
Broom-sedge	Andropogon	virginicus P
Broom-sedge	Carex	
Cinquefoil	Potentilla	canadensis
Moss	Polytrichum	commune

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