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Permanent Pasture Studies on Upland Soils

By
E. L. MAYTON

AGRICULTURAL EXPERIMENT STATION
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Permanent Pasture Studies on Upland Soils

By

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Permanent Pasture Studies on Upland Soils

THERE is perhaps no phase of agriculture in Alabama which has received less attention than the problem of permanent pastures. This is rather striking in view of the fact that according to the 1930 census report the acreage devoted to all types of pastures in the State was approximately one fourth of the total acreage in farms, or an acreage larger than that devoted to any other single crop or enterprise.

The lack of interest in pastures has been due largely to the farming system in the State. Alabama has been primarily a cotton-producing state in the past, but in recent years there has been an increased interest in livestock. The resulting development of the livestock industry has emphasized the need for better pastures.

Studies have been made at the Alabama Experiment Station to determine the possibilities of various grasses and legumes as pasture plants on a typical upland soil. The results obtained in these experiments are reported in this bulletin.

DESCRIPTION OF EXPERIMENTAL AREA

The area on which these studies were conducted was typical upland Norfolk sandy loam soil very low in natural fertility. It had been planted to clean-cultivated crops for a period of at least thirty years before these investigations were begun.

The area was divided into five sections of twenty-one plots each and three sections of ten plots each on which the different experiments reported herein were conducted. Duplicate sections were separated by two-foot alleys and unlike sections were

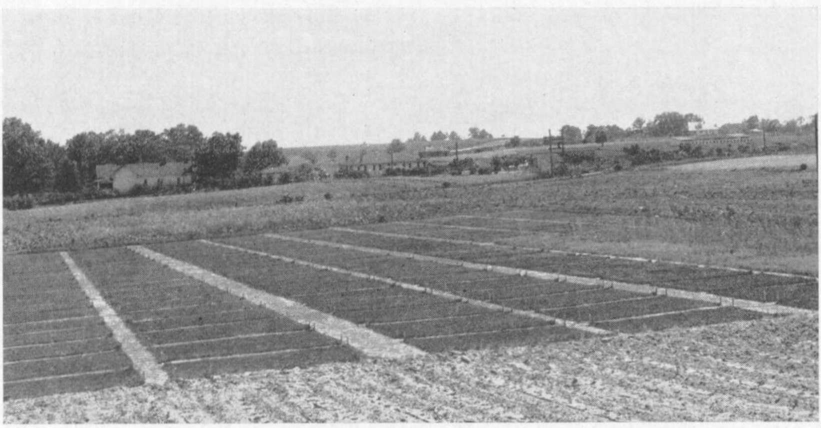

FIGURE 1.—General view of upland pasture experiment.

separated by four-foot alleys. Each plot was 9 by 12 feet; an area of 1/403 acre. A general view of the area is shown in Figure 1 on the preceding page.

PASTURE FERTILIZER EXPERIMENT

An experiment to study the effect of various fertilizer treatments on pasture plants was begun in the fall of 1925 and has been continued since.

Plan of Experiment

Fertilizer Treatments.—The fertilizer treatments in this experiment are shown in Table 1. The different treatments were in duplicate on unlimed land and on land which received ground limestone at the rate of 2 tons per acre at the beginning of the experiment. Fertilizer treatments varied from applications of

TABLE 1.—Fertilizer Treatments and Yields of Plots in Pasture Fertilizer Experiment.

Plot No.	Fertilizer treatment[1]	Pounds of green and dry material per acre—six-year average 1927-1932[2]			
		Unlimed		Limed[3]	
		Green	Dry	Green	Dry
1	O—Check	3,257	1,008	3,359	1,039
2	N	5,017	1,466	5,037	1,455
3	N P	6,584	1,884	7,866	2,187
4	N P K	6,976	1,967	8,751	2,393
5	O	3,153	989	3,830	1,185
6	N P K (N as ammonium sulfate)	5,476	1,579	8,237	2,299
7	N P K (P as basic slag)	7,053	2,007	7,835	2,193
8	2N ⅓P ⅓K	6,445	1,862	7,830	2,193
9	O	2,288	707	3,311	1,023
10	P	3,795	1,091	5,000	1,413
11	P K	4,323	1,254	6,031	1,657
12	N 1/6P 1/6K (Top dressed yearly)	6,694	1,912	8,395	2,343
13	O	2,570	815	3,529	1,070
14	N P K (N in two equal applications)	6,289	1,792	8,663	2,360
15	2N P K (N in two equal applications)	8,645	2,416	11,206	3,093
16	3N P K (N in three equal applications)	10,366	2,930	13,035	3,597
17	O	2,666	797	3,581	1,104
18	½N 2P 2K	5,694	1,633	9,548	2,569
19	½N P K	5,881	1,685	8,136	2,248
20	2N 2P 2K	9,553	2,703	12,240	3,329
21	O	3,493	1,096	4,243	1,307
Average of check plots		2,905	902	3,642	1,121

[1]N=200 pounds of nitrate of soda per acre annually.
P=600 pounds of superphosphate per acre every five years.
K=150 pounds of muriate of potash per acre every five years.
On Plot 12 all materials were applied annually.
[2]Each figure is the average yield of two duplicate plots.
[3]Limed at the rate of 2 tons of ground limestone per acre in the fall of 1925.

single salts of nitrogen and phosphorus to different complete fertilizer mixtures. The treatment which consisted of 200 pounds of nitrate of soda, 600 pounds of superphosphate, and 150 pounds of muriate of potash (NPK) per acre will be, for convenience of discussion, referred to as the standard application. There were variations from this standard application to include treatments with a high-nitrogen and low-phosphorus and -potash content, and a low-nitrogen and high-phosphorus and -potash content.

Phosphate and potash fertilizers, with one exception (Plot 12), were applied at five-year intervals. Two such applications of these materials have been made, one in the fall of 1925 when the phosphate and potash fertilizers were worked well into the soil in the preparation of the seed bed, and one in January 1931 when these materials were applied as a top dressing. The nitrogen fertilizers were applied annually as top dressings and on Plot 12 all fertilizer materials were applied annually as a top dressing.

Seeding of Plants.—In the fall of 1925 bur clover (Medicago arabicca Huds.), and a mixture composed of one part of each of Common and Ladino white clovers (Trifolium repens L.), and two parts of black medic (Medicago lupulina L.) were seeded on each plot in this experiment. Bur clover was seeded at the rate of 27 pounds per acre and the mixture of legumes at the rate of 9 pounds per acre. Inoculated soil was scattered over the area to insure inoculation. In March 1926, Dallis grass (Paspalum dilatatum Poir.) and the Common (Lespedeza striata (Thunb.) H. & A.) and Korean (Lespedeza stipulacea Maxim.) varieties of lespedeza were sown on these plots and covered lightly with a weeder. Dallis grass and Common lespedeza were each seeded at the rate of 20 pounds per acre, and Korean lespedeza at the rate of 10 pounds per acre.

To insure a thick stand of plants another seeding was made in September 1926 with the addition of Carolina clover (Trifolium carolinianum Michx.) and hop clover (Trifolium procumbens L.). The Dallis grass seeding was repeated in the spring of 1927 at the rate of 12 pounds per acre. An abundance of lespedeza seed was produced during the 1926 season so that it was not necessary to reseed this plant.

In July 1928, six plants of centipede grass (Eremochloa ophiurodes (Munro) Hack.) were set on each plot in the experiment. These plants were set to determine whether or not centipede grass could become established in competition with other pasture plants which were already established.

The rates at which plants were seeded was undoubtedly higher than would be practical in pastures; however, for the purpose of the experiment it was desired to get a sod established as quickly as possible.

Harvesting.—Plants which were seeded in the fall of 1925 and in the spring of 1926 were harvested only once, in 1926, on August 27. Systematic harvesting was begun in the spring of 1927 and has been continued throughout each season since. Harvesting was done with a lawn mower, having a basket attachment, as often as the plants had made sufficient growth. Since the growth of plants was the factor governing harvesting, the time of harvesting and the number of harvests each season were largely dependent on seasonal conditions, especially rainfall. The cutter bar of the lawn mower was set as low as practicable in order to simulate heavy grazing. The material when cut was immediately weighed to obtain the green weight. The amount of dry material was calculated from representative samples taken from check and fertilized plots and dried in an oven at approximately 35° to 40° C. for a period of three days to one week.

The yields obtained by harvesting pasture plants in this manner could not be used to calculate accurately the pounds of milk or pounds of beef that would have been produced had animals grazed the plants. The manner of harvesting, however, did seem comparable to grazing as far as the effects on plant yields were concerned, and it had one evident advantage, namely, the plants were harvested much more uniformly than would have been possible by grazing. It was believed that the method employed therefore gave more accurate comparisons of the amounts of grazing material produced by the use of different fertilizers than would have been obtained by grazing the plots.

Results and Discussion

Flora.—The reaction of the different pasture plants to fertilizer materials and weather conditions has been very striking.

Lespedeza was the predominant pasture plant on all plots in this experiment in 1926. Dallis grass was rather slow in becoming established except on the plots which received a high-nitrogen fertilizer. The stand of Dallis grass was also slightly thicker on the limed than on the unlimed plots. There were some bur, white, and Ladino clovers and black medic on the plots during the early part of the 1926 season; there were more of these plants on the limed than on the unlimed section. Black medic continued to grow and mature seed until well into July; however, this plant was not observed in the material cut on August 27. Weeds were rather abundant during the 1926 season. A considerable portion of the material harvested was weeds, although on only a few of the fertilized plots was the percentage of weeds greater than the percentage of pasture plants; whereas, on the check plots the harvested material was almost entirely weeds.

In the early spring of 1927, weeds, principally buckhorn (Plantago lanceolata L.), evening primrose (Oenothera biennis L.), and sheep sorrel (Rumex acetosella L.) were abundant on all plots; but they were more abundant on the unlimed plots. These weeds constituted approximately fifty per cent of the material cut from the low-yielding fertilized and unfertilized plots at the time of the first cutting on April 7. Weeds were prevalent on this experiment, especially on the unlimed section during the first three years. As the pasture plants became more firmly established the percentage of weeds in the harvested material decreased. There were decidedly fewer weeds after the first year on the limed than on the unlimed plots. This decrease of weeds on the limed plots was clearly shown by a comparison of the material harvested from the check plots of the two series. On the limed series the material from check plots was composed almost entirely of the desirable pasture plants; whereas, on the unlimed checks the cut material was largely weeds.

Bur clover was predominant over Carolina, hop, Ladino and white clovers, and black medic on the limed plots during the early spring. On the unlimed plots all of the above-named plants were present, no one being predominant over the others. Dallis grass had made very little growth at the time of the first cutting on April 7. The stand of this grass was still rather thin particularly on the check plots and on those on which the fertilizer treatment contained no nitrogen or a low percentage of nitrogen. At the time of the second cutting on May 18, there were very few clover plants on the unlimed plots. On the limed section the material harvested was largely clovers, with more Dallis grass and fewer weeds than on the unlimed plots. Dallis grass was the predominant plant on all treated plots for the remainder of the 1927 season. Weeds predominated on the unfertilized check plots. The percentage of lespedeza increased throughout the season so that this plant constituted a considerable portion of the material harvested after July 1. By December 1927 young plants of hop clover, bur clover, and black medic were developing on the plots, but a severe freeze early in January 1928, when a low temperature of 8° F. was recorded, killed practically all of the young plants of bur clover and black medic. Some hop clover plants survived this low temperature, but their growth was severely checked. Since that time the amounts of bur and white clovers and black medic in this experiment have been negligible. A few scattered plants of each of these were observed at the first cutting in 1928, but none have been observed since.

Hop clover has withstood two other low temperatures since the one referred to above. Its growth was severely checked by cold in March 1932 when freezing or sub-freezing temperatures were recorded at Auburn over a period of ten days; the lowest temperature recorded was 17° F. The weather previous to this low temperature was unseasonably warm so that hop clover was in a very succulent condition, and was about one to two inches in height. No killing of plants was observed. On February 8, 1933, a low temperature of 11° F. was recorded, but there was no apparent injury to hop clover aside from a checking of its growth. Its period of most vigorous growth extends from about March 1 until May 15. The length of its period of growth depends largely on weather conditions, since it matures seed and dies very quickly with the advent of hot weather.

The flora of plots from 1928 through 1931 was composed of hop clover, Dallis grass, lespedeza, and weeds. Dallis grass has been the predominant plant from about May 15 until the end of the season each year. This grass has proved quite resistant to drouth under the conditions of this experiment. Although very little leafy growth is produced during severe drouths, it recovers quickly from the effects of drouth as was observed during the season of 1931 when, after a rain on July 20 which broke a drouth of approximately two-months duration, it had made sufficient growth to be harvested by July 29. Lespedeza grew well in this experiment in 1928 and 1929 except for a short period of drouth in 1929, and constituted a considerable portion of the harvested material after May 15. The seasons of 1930 and 1931 were unusually dry at the time lespedeza usually makes its best growth so that there was very little lespedeza high enough to be in the harvest material from any plot. So many of the plants died from the effects of drouth that few seeds were produced. Consequently, there was no lespedeza in this experiment in 1932. Another possible explanation of the disappearance of lespedeza is the competition offered by hop clover. Hop clover was usually at the peak of its growth when lespedeza seed was germinating and thus the young plants were apparently smothered before they became well established. The effect of this competition by hop clover on the stand of lespedeza will be studied more fully in the future. There was more lespedeza in 1930 and 1931 on the unlimed than on the limed plots.

Centipede grass which was set on the plots in 1928 had spread until by the middle of the summer of 1933 this grass predominated on most plots. On some plots as much as 90 per cent of the cut material was centipede grass at some harvests in 1933. Although centipede grass is vigorous enough to crowd other grasses out of a sod it seems to reduce rather than increase the yields of harvested material wherever it replaces Dallis grass in the sod. This reduction in yield is due in part to the failure of the cutter bar on the mower used to cut low enough to reach a large percentage of the creeping stems of this plant.

Plant Response to Fertilizers.—The response of the pasture plants to fertilizer treatments has been interesting in that the different plants have shown a marked difference in their response to the materials used.

The percentage of Dallis grass in the sod and the growth of this plant was increased by nitrogen and lime, with the greater response to nitrogen. This grass became established much sooner on plots which received a high-nitrogen fertilizer than on those which received a low-nitrogen fertilizer. The effect of lime was shown by a comparison of the material harvested from limed and unlimed check plots; on the limed plots Dallis grass has been predominant in the harvested material, whereas the material from the unlimed ones has been predominantly weeds. The various clovers have shown a direct response to phosphorus and, with the exception of lespedeza, to lime. There was some apparent increase from the use of potash; however, the extent of this increase could not be determined since there was no plot which received potash alone. It was possible to identify the heavy, light, and no-phosphate treatments in the spring of 1931 by the direct response of hop clover to phosphorus after the second application of this material. This was also true for bur clover and black medic as long as they were present. The best balanced sod of clovers and grasses was obtained on those plots which received lime and a complete fertilizer.

Yields from Fertilizer Treatments.—In studying the yields from the experiment it should be kept in mind that it was located on a sandy upland soil where moisture was often the limiting factor in the growth of the various plants. Because of this unfavorable condition returns from fertilizer treatments were less than might have been expected had the experiment been located on land with a more plentiful supply of moisture.

The six-year average yields of green and dry material per acre are shown in Table 1. The yields of dry material per acre are also shown graphically in Figure 2, where the different treatments are grouped for convenience of discussion. In Figure 2 the cross-hatched columns represent the yield from unlimed plots and the solid columns represent the increased yield from the same fertilizer treatment on limed plots. In only one case (Plot 2 which received the N treatment) was the yield greater from unlimed plots than from limed plots. In this case the difference was only 11 pounds of dry material per acre. The unfertilized check plots are included in Group 1, Figure 2. There were six such plots on each section so that the yield shown is the average of twelve check plots on the unlimed and limed sections, respectively. It may be seen from Table 1 that the increase due to lime alone on the checks was 219 pounds of dry material per acre.

The plots included in Group 2 received either one or two fertilizer materials as shown. The N P treatment produced the

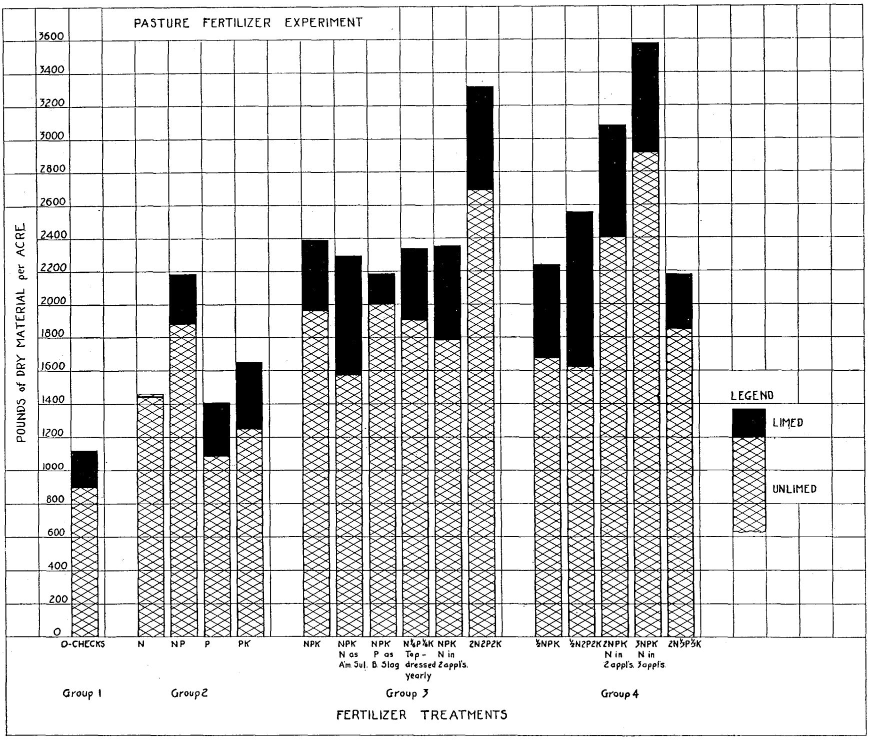

FIGURE 2.—Six-year average acre yield of dry matter of plots in Pasture Fertilizer Experiment. The cross hatched section of each bar represents the yield on unlimed plots, while the colored section represents the increase in yield on limed plots.

largest yield of all treatments included in this group. The N treatment produced the largest yield for a single material; this was due to the predominance throughout the greater part of each season, of Dallis grass which has shown a direct response to nitrogen. Potash in combination with phosphate gave a slight increase over phosphate alone. A comparison of the N P treatment with the N P K treatment in Group 3 also shows a small increase due to potash.

Group 3 includes six sets of duplicate plots. Five sets of these plots received the fertilizer equivalent of N P K. One set of these five received the standard N P K treatment; another N as ammonium sulfate; a third P as basic slag; a fourth N P K divided into six annual applications; and in the fifth N in two annual applications, one in April and a second in June. The sixth set of plots received 2N 2P 2K. This set produced the largest yield of all treatments in this group and the second largest of all treatments used. The second increment however did not produce as large an increase as the first increment of N P K. On the limed section the five sets of plots receiving N P K or its equivalent produced approximately the same yields, thus showing that ammonium sulfate when used in combination with lime was as good a source of nitrogen as nitrate of soda. On the unlimed section, however, the plots which received nitrogen as ammonium sulfate and those on which the nitrogen application was split produced smaller yields than plots of the other three sets.

The beneficial effects of lime are shown by a study of the yields produced by treatments in Group 3. The average increase due to lime when used in combination with treatments which included only the standard materials was 475 pounds of dry material per acre. The lime increase on the ammonium sulfate plot was 720 pounds per acre of dry material. The limed basic slag plot, however, produced only 186 pounds of material per acre more than the unlimed plot. This shows that when ammonium sulfate was used as the source of nitrogen the yields were greatly increased by lime. When basic slag was used as the source of phosphorus the lime content of this material was practically enough to take care of the lime needs of the plants.

The difference in yield between the limed and unlimed ammonium sulfate plots was due largely to the response of hop clover to lime. There was a very thin stand of this plant on the unlimed plots but a very thick stand on the limed plots. The stand of Dallis grass was also thicker on those plots which were limed.

The plots which received two applications of nitrogen produced smaller yields on both limed and unlimed sections than those on which the same total amount of nitrogen was used in one application.

The plots included in Group 4 received complete fertilizer treatments, the ratio of which varied from the ratio of the standard application. Nitrogen was used in this group at one-half, double, and triple standard ratio. Phosphate and potash were applied at standard, double standard, and one-third standard ratio.

The plots which received the 3N P K treatment produced the largest yields of all plots in the experiment on both limed and unlimed sections. The yields on the unlimed section of this group with low nitrogen were not materially affected by varying the phosphate and potash. Where the high nitrogen (2N) was used, yields were materially increased by increases in phosphate and potash. On the limed section the ½N 2P 2K treatment produced 321 pounds of dry material more per acre than the ½N P K treatment. This increase from phosphate and potash as compared with practically no differences from variations of these materials on the unlimed section was due largely to differences in the stand and growth of hop clover. There was a thicker stand of this plant on limed than on unlimed plots. Since hop clover responds well to phosphorus, the increase of this material on limed plots where the stand was thick stimulated the growth of this plant and, therefore, increased the yield of dry material.

A comparison of the two extremes, low nitrogen with high phosphate and potash and high nitrogen with low phosphate and potash, with the unfertilized check plots in Figure 2 shows that both of the two treatments made substantial increases in yields over the checks. The high-nitrogen treatment gave the greater increase on the unlimed section; whereas, the high-phosphate and -potash treatment gave the larger increase on the limed section. Although the yields from these two treatments did not differ greatly in quantity, there was an important difference in the composition of the harvested material from the two. The harvested material from the high-nitrogen treatment on the unlimed section was made up largely of grasses while that from the high-phosphate and -potash treatment on the limed section, particularly in the spring, was composed largely of legumes.

Cost and Returns from Fertilizer Treatments.—It was not the objective of this experiment to go into a detailed study of the economics of pasture fertilization; however, the variations in the acre cost of the different treatments and the fertilizer cost per ton of material produced by these treatments are interesting. These data are presented in Table 2. The dry material produced on treated plots was estimated to be equal in feeding value to a good grade of grass hay. The average market price of grass hay in Alabama over the six-year period, 1927-1932, was approximately $13.40 per ton, which gives a basis of comparison between the cost of hay on the market and the cost of the dry material produced by the fertilizer treatments used in this experiment. The fertilizer cost per ton of increase in dry material produced by the different treatments was calculated from the acre costs. The annual acre costs of N, P, and K were $4.68, $1.03, and $0.66, respectively, which gives $6.37 as the cost of the standard application. Nitrogen was by far the most expensive element used in these treatments. The cost of treatments on unlimed and limed plots is shown in columns 2 and 3, respectively, of Table 2. The acre cost on limed plots is greater in each case by $0.90 than that on unlimed plots.

A study of Table 2 shows that with the exception of the N treatment the cost per ton of increase was lower on the limed than on unlimed plots. An average of the cost of material from all treatments shows that the cost per ton was $2.88 less when lime was used in the treatment than when no lime was used. On unlimed plots eight treatments out of fifteen produced ma-

TABLE 2.—Cost of and Returns from Various Fertilizer Treatments Over Six-Year Period, 1927-1932.

Fertilizer treatments	Annual cost of fertilizer treatments in dollars per acre[1]		Pounds of dry material increase due to fertilizer treatments		Fertilizer cost in dollars per ton of increase	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
Group 1						
O—checks	0	0.90	0	219	0	8.22
Group 2						
N	4.68	5.58	564	553	16.60	20.18
N P	5.71	6.61	982	1,285	11.63	10.29
P	1.03	1.93	189	511	10.90	7.55
P K	1.69	2.59	352	755	9.60	6.86
Group 3						
N P K	6.37	7.27	1,065	1,491	11.96	9.75
N P K (N as ammonium sulfate)	4.94	5.84	677	1,397	14.59	8.36
N P K (P as basic slag)	6.18	7.08	1,105	1,291	11.19	10.97
N 1/6P 1/6K (Top dressed yearly)	6.09	6.99	1,010	1,441	12.04	9.70
N P K (N in two equal applications)	6.37	7.27	890	1,458	14.31	9.97
2N 2P 2K	12.74	13.64	1,801	2,427	14.15	11.24
Group 4						
½N P K	4.03	4.93	783	1,346	10.29	7.33
½N 2P 2K	5.72	6.62	731	1,667	15.65	7.94
2N P K (N in two equal applications)	11.05	11.95	1,514	2,191	14.60	10.91
3N P K (N in three equal applications)	16.16	17.06	2,028	2,695	15.51	12. 66
2N ⅓P ⅓K	9.92	10.82	960	1,291	20.67	16.76

[1]The average cost of fertilizer materials was as follows:
Nitrate of soda, $46.80 per ton
Superphosphate, $17.00 per ton
Muriate of potash, $44.00 per ton
Ground limestone, $4.50 per ton

terial at a cost greater than the average market price of hay; whereas, on limed plots the cost per ton was greater than the market price of hay in the case of only two treatments. Thus lime lowered considerably the cost per ton of material produced with all fertilizers except with nitrogen alone.

The efficiency of lime in combination with the different treatments is shown in Table 3. These data show that the increase due to lime was produced at the lowest cost when this material was used in combination with the low-nitrogen and high-phosphate and -potash treatment. These data also show that lime was more efficient when used in combination with other materials, except where basic slag was used as the source of phosphorus, than when used alone. The lime in basic slag, as was previously stated, was practically enough to satisfy the lime requirements of plants. Lime was usually more efficient when used with a complete fertilizer than when used with one or two materials.

TABLE 3.—Increase in Yields Due to Lime and the Cost Per Ton of Increase.

Fertilizer treatments	Annual acre cost of lime—$	Pounds of dry material per acre			Lime cost per ton of increase —$
		Unlimed	Limed	Increase due to lime	
Group 1					
O—Checks	0.90	902	1,121	219	8.22
Group 2					
N	0.90	1,466	1,455	-11	
N P	0.90	1,884	2,187	303	5.94
P	0.90	1,091	1,413	322	5.59
P K	0.90	1,254	1,657	403	4.47
Group 3					
N P K	0.90	1,967	2,393	426	4.23
N P K (N as ammonium sulfate)	0.90	1,579	2,299	720	2.50
N P K (P as basic slag)	0.90	2,007	2,193	186	9.68
N 1/6P 1/6K (Top dressed yearly)	0.90	1,912	2,343	431	4.18
N P K (N in two equal applications)	0.90	1,792	2,360	568	3.17
2N 2P 2K	0.90	2,703	3,329	626	2.88
Group 4					
½N P K	0.90	1,685	2,248	563	3.20
½N 2P 2K	0.90	1,633	2,569	936	1.92
2N P K (N in two equal applications)	0.90	2,416	3,093	677	2.66
3N P K (N in three equal applications)	0.90	2,930	3,597	667	2.70
2N ⅓P ⅓K	0.90	1,862	2,193	331	5.44

The efficiency of N, P, and K when used in combination with other materials in the same amounts as in the standard application is shown in Table 4. A study of results recorded in this table shows that nitrogen was more efficient when used in combinations with phosphorus, that phosphorus was most efficient when used in combination with nitrogen and lime, and that potassium was most efficient when used in combination with phosphorus and lime.

The data in Table 2 show that the P K, ½N P K, and P treatments in the order named produced material at the lowest cost per ton on both limed and unlimed plots; the cost was approximately $3 per ton less on limed than on unlimed plots in each treatment. An analysis of the data presented in Tables 2, 3, and 4, in so far as comparisons can be made, shows that

TABLE 4.—Efficiency of N, P, and K When Used in Combination With Materials as Indicated.

Materials	Increase due to N Lbs.	Cost per ton of increase due to N —$	Increase due to P Lbs.	Cost per ton of increase due to P —$	Increase due to K Lbs.	Cost per ton of increase due to K —$
O	564	16.60	189	10.90	——	——
L	334	28.02	292	7.05	——	——
P	793	11.80	——	——	163	8.10
P K	713	13.13	——	——	——	——
P L	774	12.09	——	——	244	5.41
P K L	736	12.72	——	——	——	——
N	——	——	418	4.93	——	——
N L	——	——	732	2.81	——	——
N P	——	——	——	——	83	15.90
N P L	——	——	——	——	206	6.41

nearly all fertilizer materials were more efficient when used in combination with other materials than when used alone. The exception to this is noted in the case of the nitrogen and lime combination and the lime and basic slag combination. When single materials were used alone the highest returns per dollar invested were from lime, superphosphate, and nitrate of soda, respectively. The cost per ton of dry material produced by these materials when used alone was less than the average market price of hay in the case of lime and of superphosphate, and greater in the case of nitrate of soda.

Seasonal Distribution of Yields.—The average seasonal distribution of yields from the limed series of plots over the six-year period, 1927-1932, is presented in Figures 3, 4, and 5. It is shown that material was harvested from these plots over a period of approximately 200 days, April 1 to October 20, each season. The yields calculated by ten-day periods from the average seasonal yields of plots are presented as pounds of dry material produced per acre per day. It may be seen from a comparison of the data that there was a marked fluctuation in yields throughout the season but that the yields from all plots irrespective of fertilizer treatment followed the same general seasonal distribution. The yields declined during April, increased slightly the first ten days in May, and again declined sharply until June 10. There was a decided increase in yields from June 10 to July 1, which was followed by a slight decrease to July 10 after which there was an additional increase to July 20. Over the period, July 20 to September 10, the yields were maintained at a fairly constant level and was followed by a sharp decline to a low point on October 1 which was approximately the same as the low point in June. There was an in-

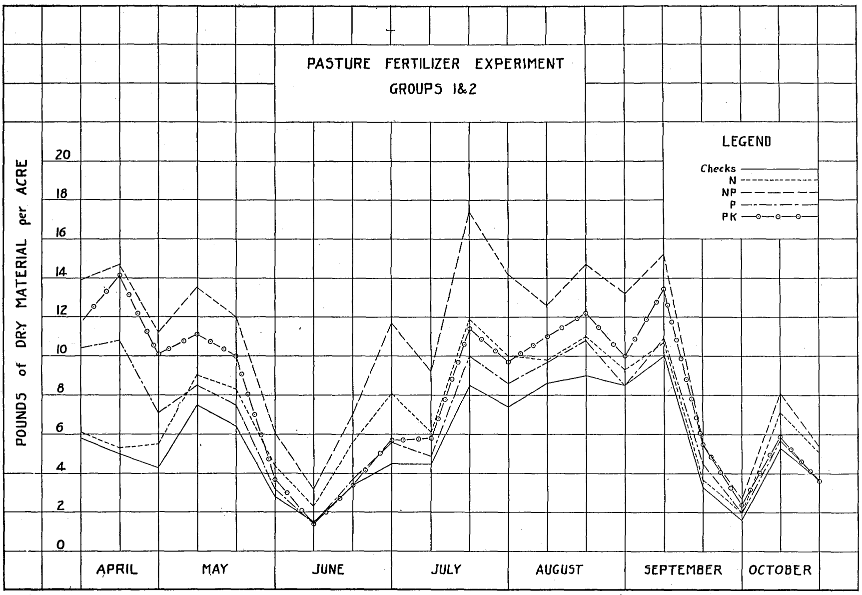

FIGURE 3.—Average daily acre yields of dry matter from limed plots in Groups 1 and 2, calculated by ten-day periods from the six-year average yields of plots.

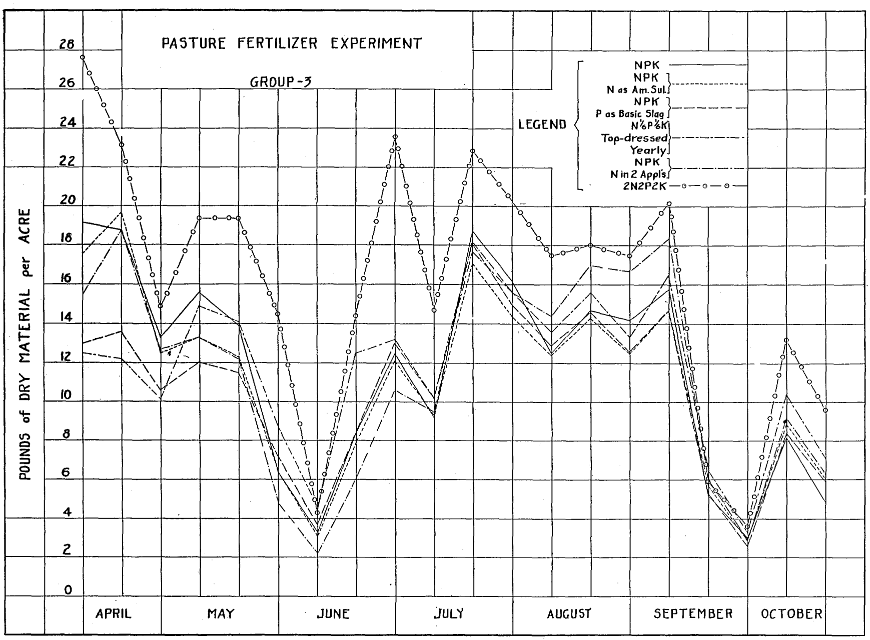

FIGURE 4.—Average daily acre yields of dry matter from limed plots in Group 3 calculated by ten-day periods from the six-year average yields of plots.

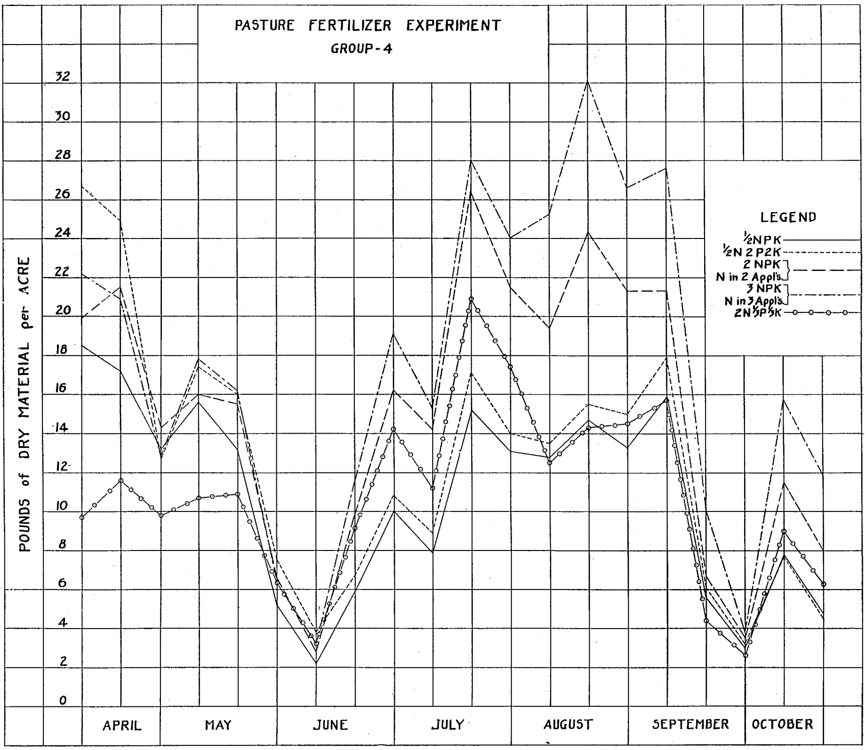

FIGURE 5.—Average daily acre yields of dry matter from limed plots in Group 4, calculated by ten-day periods from the six-year average yields of plots.

crease from this low point to October 10 which was followed by a decrease to October 20.

The seasonal yields of both limed and unlimed plots which received the N P K treatment and the six-year average distribution of rainfall for the period 1927-1932, by ten-day periods throughout the pasture season, are shown in Figure 6. Since it was shown in Figures 3, 4, and 5 that the yields from all plots followed the same general seasonal distribution, the plot which received the standard application was used as a representative plot. It was observed that the seasonal yields correlated very closely with the distribution of rainfall throughout the season with an approximate twenty-day time interval between rainfall and yields. Therefore, in Figure 6 this time interval of twenty days is adjusted so that the rainfall during any particular period and the yields produced by this rainfall are plotted on the same ordinate in order that the correlation may be more easily followed.

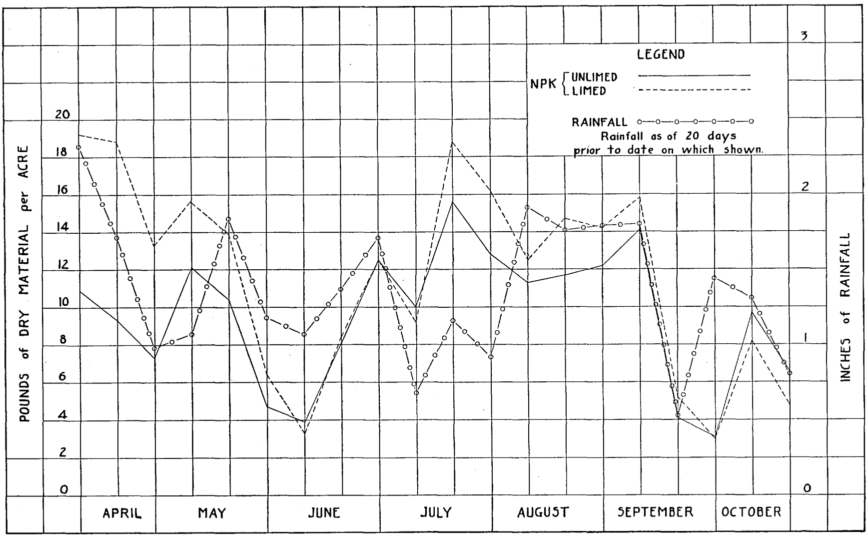

FIGURE 6.—Average rainfall and average daily acre yields of plots receiving the N P K treatment for the six-year period, 1927-1932.

These data show that with few exceptions a decided change in rainfall caused a corresponding change in the yields. An exception is noted in the case of an increase in rainfall over the period April 20-30 for which there is shown a decrease in yield for the period May 10-20. This exception is accounted for by the fact that hop clover during the period May 10-20 had passed its peak of production and was maturing seed and dying out on these plots. The dying out of hop clover in May together with a decrease in rainfall over the period May 1-20 largely accounts for the low production of these plots around the first of June. Each spring since 1928 plots in this experiment were so covered with hop clover that other plants had little chance to make any considerable growth until hop clover died. Since there was no plot in the experiment on which hop clover was not seeded, it was impossible to determine if this extremely low level of production around June 1 could have been avoided by the use of Dallis grass seeded alone or in combination with lespedeza. However, Dallis grass or a combination of Dallis grass and lespedeza could hardly be expected to produce as high a yield in the early spring as hop clover.

The effect of lime on the yield at various times during the season is clearly shown in Figure 6. It may be seen that the greatest difference between the yields from limed and unlimed plots was during April when hop clover was the predominant plant. As this plant died out the yields from limed and unlimed plots became practically the same for a period of approximately

35 days or until Dallis grass reached its peak of production when the yields from limed plots were again greater than the yields from unlimed plots. The yields were again practically the same after the sharp decrease around September 10, with the limed plots showing a smaller yield in October than unlimed plots. The seasonal distribution of yields from limed and unlimed plots which received the same treatment show the same general distribution as illustrated by the yields from the N P K treatment.

According to data obtained by the Animal Husbandry Department of the Alabama Experiment Station in a steer-feeding experiment, approximately 20 pounds of Johnson grass hay per day were required to maintain an animal unit. Using this as a basis, since the cost of increase due to fertilizers was compared with the average market price of hay, the average number of days in each month and in a season one acre under the different treatments used would maintain an animal unit is shown in Table 5.

A study of the data presented in this table shows that the treatments which had a high-nitrogen content produced grazing for the greatest number of days, and that the material produced was more uniformly distributed throughout the season than that from any other treatment. The treatments which had a high-nitrogen content produced material, as was shown in Table 2, at a higher cost per ton of material than treatments with a low-nitrogen content. Hence the data indicate that of the treatments used those containing low nitrogen or no nitrogen would be most profitable where the land for permanent pastures was unlimited. On the other hand, with a limited amount of land available for pastures, treatments with a high-nitrogen content used in combination with lime might be more profitable because of the larger number of animal units that could be maintained on a smaller acreage.

PASTURE MIXTURE EXPERIMENT

Mixtures of different pasture plants with various complete fertilizer treatments were studied on an area adjacent to the pasture fertilizer experiments during the seven-year period, 1926-1932.

Plan of Experiment

Mixtures Used.—This area was seeded in the fall of 1925 to Southern bur clover at the rate of 27 pounds per acre and a mixture of one part of common white clover, one part of Ladino clover, and two parts of black medic at the rate of 9 pounds per acre on a well-prepared seed bed. Inoculated soil was sown along with the seed to insure inoculation. In the spring

TABLE 5.—Average Number of Days per Season One Acre Under Different Treatments Would Support One Animal Unit Over the Period 1927-1932.

Fertilizer treatments	Days per month														Total per season	
	April		May		June		July		August		September		October			
	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]	Ul[1]	L[2]
Group 1																
O—Checks	5	8	7	8	4	5	10	10	10	13	5	7	4	5	45	56
Group 2																
N	7	9	11	11	10	8	15	14	14	15	8	8	6	6	71	71
N P	12	20	14	16	13	11	19	20	17	20	10	12	8	7	93	106
P	9	14	7	10	5	5	10	12	12	15	6	9	4	5	53	70
P K	10	18	8	12	6	6	12	13	14	17	7	11	5	5	62	82
Group 3																
N P K	14	26	14	18	13	12	19	22	18	21	11	12	9	7	98	118
N P K (N as ammonium sulfate)	9	25	11	16	10	12	16	20	16	19	8	12	6	7	76	111
N P K (P as basic slag)	15	19	13	15	13	13	20	22	20	20	10	11	7	7	98	107
N 1/6P 1/6K (Top dressed yearly)	10	17	14	19	15	15	19	22	18	21	9	13	8	9	93	116
N P K (N in two applications)	12	24	11	16	10	9	18	22	20	24	10	14	6	8	87	117
2N 2P 2K	16	33	18	27	23	21	27	29	25	27	13	15	9	11	131	163
Group 4																
½N P K	12	24	13	17	10	9	17	18	16	20	9	12	7	6	84	106
½N 2P 2K	11	32	12	20	10	11	15	20	17	22	9	14	6	6	80	125
2N P K (N in two applications)	14	28	14	19	15	14	26	31	28	33	14	16	8	10	119	151
3N P K (N in three applications	17	28	14	20	17	17	28	34	37	42	18	21	12	14	143	176
2N ⅓P ⅓K	10	16	11	14	12	13	22	25	19	21	9	11	8	8	91	108

[1]Unlimed
[2]Limed

of 1926 this area was divided into sections and different grasses or mixtures of grasses were sown on each section. One section was seeded to Dallis grass at the rate of 18 pounds per acre; one to carpet grass at the rate of 9 pounds per acre; one to Bermuda grass at the rate of 9 pounds per acre; and a fourth to all three of the grasses at their respective rates. Common and Korean lespedeza were seeded on each section along with the different grasses at the rate of 15 and 10 pounds per acre, respectively. Very few of the Bermuda grass seeds germinated and, therefore, sod was set in May 1926. In the fall of 1926 the seeding of the previous fall was repeated on all sections. Dallis grass and carpet grass were again seeded on their respective sections at the rate of 12 pounds per acre in the spring of of 1927. Hop clover was not seeded in this experiment; however, it scattered from the Pasture Fertilizer Experiment and by 1929 there was a scattered stand on the Dallis grass and carpet grass sections of this experiment. By the spring of 1930 there was a good stand of hop clover on the Dallis grass and carpet grass sections and some on the Bermuda section. There has been a thick stand of hop clover on these sections each year since 1931.

Fertilizer Treatments.—Each section was divided into plots on which the fertilizer treatments shown in Table 6 were duplicated. The phosphate and potash materials were applied periodically as the plants showed a need for them. These materials were applied and worked into the soil in the preparation of the seed bed in 1925. A second application as a top dressing was made in

TABLE 6.—Fertilizer Treatments and Yields of Plots in Pasture Mixture Experiment.

Plot No.	Fertilizer treatment[1]	Pounds of material per acre, six-year average yields 1927-1932[2, 3].							
		Dallis grass section		Carpet grass section		Bermuda grass section		Dallis, carpet, and Bermuda grass mixture section	
		Green	Dry	Green	Dry	Green	Dry	Green	Dry
1	O—Check	2,568	769	2,216	644	1,313	415	1,662	494
2	N P K	5,854	1,649	5,263	1,439	3,834	1,173	3,926	1,095
3	N P K L	7,697	2,115	6,745	1,784	5,765	1,651	5,174	1,452
4	½N 2P 2K L	8,142	2,208	7,348	1,917	6,254	1,735	4,680	1,276
5	2N ⅓P ⅓K	7,479	2,155	5,610	1,607	4,507	1,399	5,488	1,587

[1]N=200 pounds of nitrate of soda per acre annually.
P=600 pounds of superphosphate per acre every five years.
K=150 pounds of muriate of potash per acre every five years.
L= 2 tons of ground limestone per acre applied at the beginning of the experiment in 1925.
[2]Each figure is the average yield of two duplicate plots.
[3]The legume mixture was the same on all sections.

January 1931. Nitrogen has been applied annually as a top dressing. Lime was applied to the plots which receive it along with the phosphate and potash in the fall of 1925; since that date no lime has been applied.

Results and Discussion

Since the plan of this experiment was very similar to the one discussed previously, and the method of harvesting was the same, the results obtained are in many instances very similar. As in the Pasture Fertilizer Experiment, bur, and the common and Ladino white clovers, and black medic were killed by the low temperature of January 2, 1928. There has been practically none of these plants on the area since that date. Also lespedeza failed to mature enough seed to propagate itself during the two dry seasons of 1930 and 1931 so that there were only a few plants on any plots in 1932. The responses to the different fertilizers have been in general the same as reported under the Pasture Fertilizer Experiment, namely, the grasses have shown a direct response to nitrogen and the clovers a direct response to phosphate and potash, and to lime.

Resulting Flora of the Different Sections.—The pasture plants on the Dallis section in 1932 included only hop clover and Dallis grass, the other plants seeded having disappeared as stated above. Hop clover seemed to grow better in combination with Dallis grass than with either carpet or Bermuda grass. This is probably because of the fact that Dallis grass is a bunch grass growing in clumps, rather than forming a continuous sod over the surface of the ground as do carpet and Bermuda grasses. During each season previous to 1930 lespedeza constituted a considerable portion of the harvested materials from plots of this section.

Carpet grass and hop clover were the only pasture plants on Section 6 in 1932. The growth of hop clover on this section has been smaller and somewhat later than on the Dallis grass section. Carpet grass did not become established as quickly as Dallis grass or Bermuda grass. It has proved very susceptible to drouth and is much slower in recovering from drouth effects than Dallis grass. Lespedeza constituted a considerable portion of the harvested material from the carpet grass section each season previous to 1930, though there was not as much lespedeza produced as on the Dallis grass section.

On the Bermuda grass section Bermuda grass and hop clover were the only plants which survived. Bermuda grass seed did not germinate to give a good stand, so sod was set. From this sod the grass became established sooner than either carpet or Dallis grass which were seeded. The sod at the one harvest in August 1926 was practically all Bermuda grass, whereas the sod on the other sections was principally lespedeza. Although Bermuda was established sooner than either Dallis or carpet grass it has not grown as well since 1928 as the other two grasses. Lespedeza seemed to grow better in combination with Bermuda than with carpet or Dallis grass. The flora of harvested material throughout the seasons of 1928 and 1929 was approximately half Bermuda and half lespedeza on all plots.

On the section that was originally seeded to a mixture of the three grasses in combination with the other plants, carpet and Dallis grass now predominate. The seed of hop clover have not scattered to this section. Only a small percentage of the Bermuda grass seed germinated so that there were only a few plants of this grass on these plots. The reaction of carpet and Dallis grass to different moisture conditions has been clearly demonstrated on this section. In seasons when the amount and distribution of rainfall has been adequate carpet grass was the predominant plant; whereas, in years of lighter rainfall Dallis grass has been predominant.

Yields.—The yields from plots in this experiment are given in Table 6 as pounds of green and dry material per acre. They are also shown graphically in Figure 7 as pounds of dry material per acre.

All fertilizer treatments produced larger yields on the Dallis grass section than on any other. The second highest yields from each treatment were produced on the carpet grass section. The third highest yields were produced on the Bermuda grass section with the exception of the 2N ½P ½K treatment which produced higher yields on the section on which all three of the grasses were seeded than the yields from Bermuda grass alone. The lower production on the mixture section is in part accounted for by the absence of hop clover from this section. Also, yields throughout the season as compared with the yields from other sections indicate that the competition between carpet grass and Dallis grass has lowered the yields of both. The ½N 2P 2K L treatment produced the largest yield on all sections except the mixture section where the 2N ⅓P ⅓K treatment produced the largest yield. This again emphasizes the fact that clovers, especially hop, have been a decided factor in the yields of plots in this experiment.

CENTIPEDE GRASS FERTILIZER EXPERIMENT

In March 1926 one section of ten plots which received the same fertilizer treatments as plots in the Mixture Experiment was set out to centipede grass. These plots adjoined those of the two experiments previously reported. This grass became

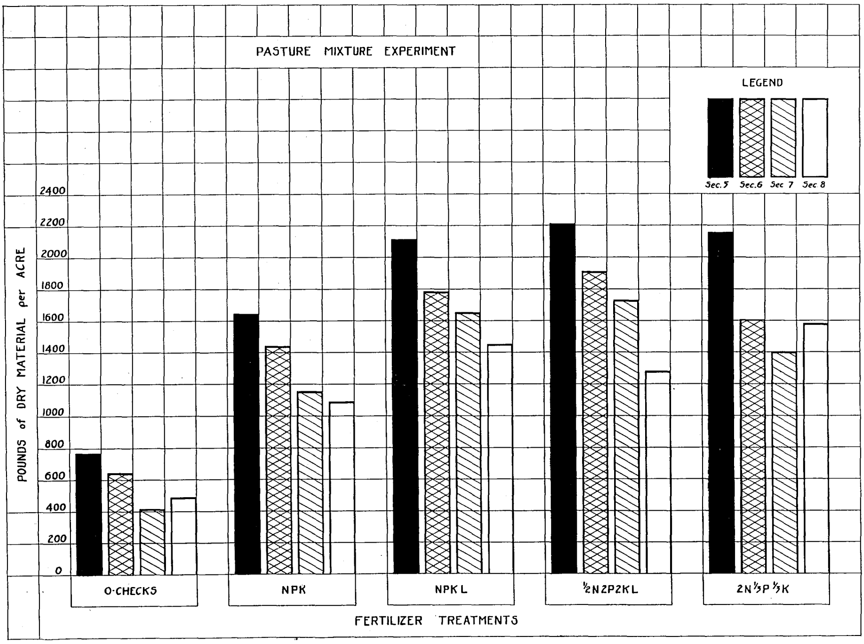

FIGURE 7.—Six-year average acre yields of dry matter from plots in Pasture Mixture Experiment. Basic grasses were as follows: Section 5, Dallis; Section 6, carpet; Section 7, Bermuda; and Section 8, a mixture of Dallis, carpet, and Bermuda.

sufficiently established by 1928 that harvesting with a lawn mower was begun.

The yields from these plots in 1928 and 1929 were considerably smaller than yields from plots which received the same fertilizer treatments but were seeded to a different grass. In 1930 the nitrogen treatment of one plot was increased to 800 pounds of nitrate of soda per acre applied in two equal applications. The fertilizer treatments and average yields of plots in this experiment are presented in Table 7.

A comparison of the yields of centipede grass with the yields from like fertilized plots in the Mixture Experiment shows that fertilizers produced much smaller increases when applied to centipede grass than when applied to Dallis, carpet, or Bermuda grass. These smaller increases are in part due to the method of harvesting since centipede grass makes very little upright growth except under very heavy nitrogen fertilization. It forms a very thick sod which seems to inhibit its growth to some extent.

TABLE 7.—The Effect of Different Fertilizer Treatments on the Yields of Centipede Grass.

Plot	Fertilizer treatment[1]	5-year average yield of pounds of material per acre	
		Green	Dry
1 and 6	None	969	382
2 and 7	N P K	2,022	773
3 and 8	N P K L	2,180	835
4	½N 2P 2K L	1,877	704
9	4N 2P 2K L (N in two equal applications)	6,288[2]	2,453[2]
5 and 10	2N ⅓P ⅓K	2,848	1,095

[1]N=200 pounds of nitrate of soda per acre annually.
P=600 pounds of superphosphate per acre every six years.
K=150 pounds of muriate of potash per acre every six years.
L= 2 tons of ground limestone per acre applied at the beginning of the experiment in 1926.
[2]Three-year average. The fertilizer treatment of this plot was changed in 1929.

SUMMARY

Results of studies on the effects of fertilizer treatments on pasture plants on upland Norfolk sandy loam soil at Auburn over the seven-year period, 1926-1932, are reported in this bulletin.

Dallis grass, carpet grass, hop clover, and lespedeza proved to be the most promising pasture plants for sandy upland soils under the conditions of these experiments. Dallis grass was the most promising plant when moisture was a limiting factor.

In these studies black medic, bur, white, Ladino, and Carolina clovers proved susceptible to cold as was indicated by their being killed at a temperature of 8° F. Hop clover successfully withstood this and other low temperatures.

Hop clover grew better in combination with Dallis grass than with carpet or Bermuda grass; lespedeza grew better in combination with Bermuda grass.

Centipede grass almost crowded Dallis grass out of an established sod over a period of five years. This plant produced considerably smaller yields than Dallis grass by the method of harvesting used.

Summer drouths and the competition of hop clover seriously affected the stand of lespedeza on plots of these experiments.

On limed and on fertilized plots pasture plants became established more quickly than on untreated plots; also there were fewer weeds on the limed and on fertilized plots.

Dallis grass and carpet grass when used together produced smaller yields than when used separately as basic grasses.

The grasses, Dallis, carpet, centipede, and Bermuda, showed a direct response to nitrogen and the clovers a direct response to phosphorus. Dallis grass and hop clover also showed a marked response to lime.

Lime in combination with all fertilizer treatments, except with nitrogen alone, materially reduced the cost per ton of increased yields.

Plots which received a high-nitrogen fertilizer produced larger and more uniformly distributed yields than was produced by any other treatment but at a greater cost per ton of material. At the prevailing prices of hay and nitrogen over the period 1927-1932 the same amount of feedstuff as was produced by nitrogen could have been bought as hay at a lower cost.

The P K, ½N P K, and P treatments in the order named produced material at the lowest cost per ton of increase on both limed and unlimed plots.

The average seasonal yields of plots for the period 1927-1932 were found to be correlated very closely with the average distribution of rainfall with an approximate twenty-day time lag.

Yields from all plots regardless of fertilizer treatments followed the same general seasonal distribution, thus showing that periods of low production could not be avoided by the use of fertilizers.

The low production around the first of June was due in part to the competition of hop clover with young plants of Dallis grass.