RESEARCH BULLETIN 942 JANUARY, 1969

UNIVERSITY OF MISSOURI - COLUMBIA
COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION
ELMER R. KIEHL, *Director*

Fertilizing Hay and Pasture Crops in Missouri

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(Publication authorized July 26, 1968)

COLUMBIA, MISSOURI

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ACKNOWLEDGMENTS

The studies reported were begun under the direction of Dr. G. E. Smith, chairman, department of soils, and completed under the guidance of Dr. C. Merrill Woodruff, chairman, department of agronomy. Assistance with the field work was given by Carl Hayward, Jewel Crabtree, Ray McMeley, and Robert Light at the Southwest Missouri Center; Thomas E. Fisher at the Delta Center; Theo M. Dean at the Columbia and Weldon Spring Research Farms; and L. Earl Barnes at the North Missouri Center. The excellent cooperation of Dr. Norman Justus, Norman Brown, and Larkin Langford, superintendents of the Southwest, Delta, and the North Missouri Centers, is gratefully acknowledged. Appreciation also is expressed for the assistance of Dr. Ted R. Fisher in the choice of treatments and experimental design used in many of the studies and to Dr. Wayne Decker, chairman, department of atmospheric science, for the weather data. The statistical analyses were done by the University of Missouri Computer Center (Howard R. Watts, program manager).

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INTRODUCTION

A large portion of the land area of Missouri is adapted to the production of hay and pasture crops. The topography and types of soils on which these crops can be produced vary from the glacial hills of north Missouri and the loessial hills along the Missouri and Mississippi Rivers to the droughty hills and plains of the Ozark region. Much of the area was formerly utilized for cash crops using horse-drawn machinery. In recent years, this land has become marginal for cash crop production, either because of soil exploitation or small field size, and is being diverted into grazing land for cattle or allowed to be over-run by brush and low value trees.

According to the 1964 Census of Agriculture (8), the number of cattle and calves on Missouri farms increased from 3,833,198 in 1959 to 4,552,108 in 1964. This was an increase of about 700,000 head during the five-year period. According to the 1966 edition of Missouri Farm Facts (5), the number of all cattle on Missouri farms January 1, 1967, was 4,655,000—an increase of approximately 133,000 head in two years. The gradual increase of beef cows in the state is expected as the trend toward larger sized farms continues in areas where cash crop production is becoming uneconomical. For profitable beef production on the marginal soils, economical production of forages is essential. The proper use of lime and fertilizer is a necessary element in the management of soils producing pasture and hay crops.

The production of forage crops has been an item of research by the soils and field crops departments (department of agronomy, September 1, 1968) for many years, but yields of hay crops have not increased appreciably in the last 12 years, nor has the total acreage of hay crops increased during this period (Table 1). The area in alfalfa did increase by about 300,000 acres during the period, evidently a conversion of acres in grass hays to acres of alfalfa-grass mixtures.

Importance of The Problem

The problem of forage crop fertilization can best be approached by delineating the soil areas of the state. These areas are the result of climatic factors which reacted with the natural soil forming materials that produced the specific conditions under which forage crops grow. An area may have similar conditions of

TABLE 1--PRODUCTION OF ALFALFA HAY AND ALL HAY IN MISSOURI 1957-1966*

Year	Alfalfa			All Hay		
	Acres	Production (Tons)	Yield/A	Acres	Production (Tons)	Yield/A
1957	659,000	1,680,000	2.55	3,235,000	4,812,000	1.49
1958	659,000	1,878,000	2.85	3,323,000	5,491,000	1.65
1959	606,000	1,606,000	2.65	2,588,000	4,043,000	1.56
1960	594,000	1,604,000	2.70	2,822,000	4,417,000	1.57
1961	606,000	1,636,000	2.70	2,905,000	4,888,000	1.68
1962	651,000	1,530,000	2.35	2,941,000	4,187,000	1.42
1963	677,000	1,625,000	2.40	2,955,000	4,315,000	1.46
1964	738,000	1,956,000	2.65	3,090,000	5,020,000	1.62
1965	790,000	2,330,000	2.95	3,122,000	5,578,000	1.79
1966	830,000	2,200,000	2.65	2,834,000	4,873,000	1.72

*Missouri Farm Facts 1966. Missouri Department of Agriculture.

TABLE 2--NUMBERS OF ALL CATTLE, COWS MILKING, AND CATTLE OTHER THAN COWS MILKING BY SOIL AREAS JANUARY 1, 1967

Soil Area	All Cattle		Cows Milking		Cows other than Cows Milking	
	Total	Sq. Mi.	Total	Sq. Mi.	Total	Sq. Mi.
1	699,735	102.2	36,430	5.3	663,300	96.9
2	683,760	89.4	55,630	7.3	628,125	82.1
3	688,845	75.1	33,361	3.7	650,624	71.4
4	362,061	65.0	26,010	4.6	341,051	60.4
5	551,100	84.2	46,480	7.1	504,520	77.1
6	385,800	94.7	71,750	17.6	314,051	77.1
7	974,360	44.4	162,890	7.4	811,470	37.0
8	182,680	54.1	16,580	4.9	165,100	49.2
9	127,700	30.9	4,430	1.0	4,430	29.9

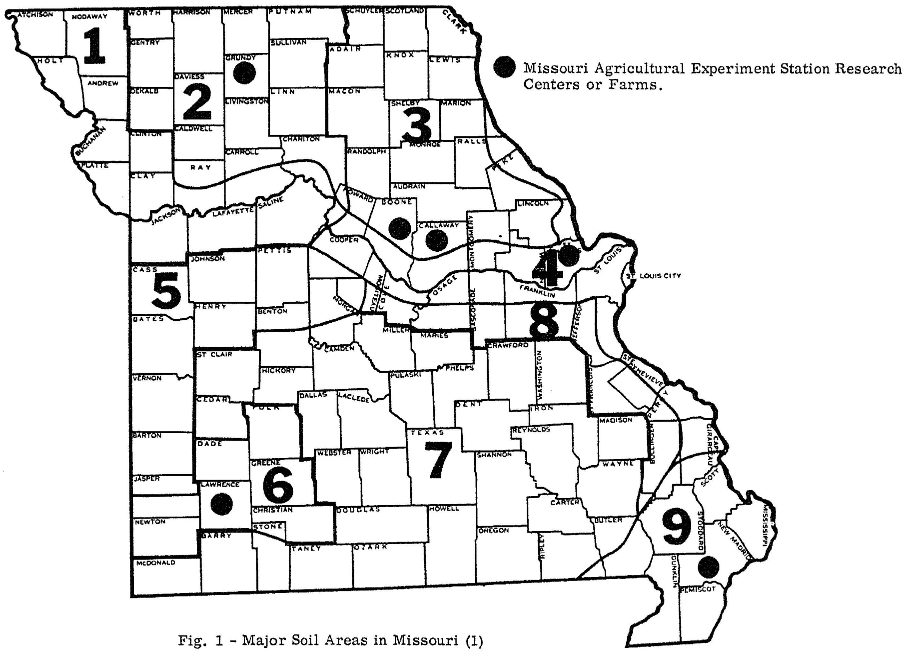

Fig. 1 - Major Soil Areas in Missouri (1)

soil and climate but differ from other areas in some characteristic thereby making it possible that forage crop species and management practices could differ from area to area. The nine major soil areas in Missouri delineated by Scrivener as reported by Christy and Fisher (1) are given in Figure 1.

The pressure for forage in the several soil areas is given in Table 2, which shows the numbers of cattle as of January 1, 1967, by soil areas and concentrations per square mile.[1] The concentration of dairy cattle is low in all areas excepting area 6. On the other hand, beef type animals have a fairly high concentration in all areas with the exception of the southeast Delta region (soil area 9). Even area 7, the central Ozark region, has a surprisingly large number of cattle per square mile. Soil area 6, containing the dairy industry of the state, ranks second to soil area 1 in total number of cattle per square mile.

The sources of forage grazed by Missouri cattle by soil areas and the total acreage grazed per cow are given in Table 3. Many cattle in soil area 1 are feedlot animals, yet a relatively large number of acres in the area are pastured. The average of 1.90 acres grazed per cow is the lowest of the nine soil areas and reflects the fact that many cattle many never do any grazing, but are purchased for feedlot finishing entirely. This is probably the situation in soil area 9. The data in Table 3 shows that a large acreage of woodland in soil areas 6 and 7 is used for grazing. This is also the case in soil areas 4 and 8. That woodland is

[1]Calculated from data secured from county data, Missouri Farm Facts, 1966, Missouri Department of Agriculture; and Official Manual State of Missouri 1963-1964. (6) See Appendix Table 1.

TABLE 3--ACRES OF WOODLAND PASTURE, IMPROVED PASTURE, UNIMPROVED PASTURE, AND CROPLAND USED FOR GRAZING BY SOIL AREAS*

Soil Area	Woodland	Acres/ cow***	Improved Pasture**	Acres/ cow***	Unimproved Pasture**	Acres/ cow***	Cropland Pasture	Acres/ cow***	Total Acres Per cow
1	176,780	0.25	220,317	0.31	511,401	0.73	427,606	0.61	1.90
2	279,162	0.41	190,379	0.28	905,401	1.32	534,909	0.78	2.79
3	503,337	0.73	193,287	0.28	745,341	1.08	539,441	0.78	2.87
4	408,118	1.13	76,297	0.21	217,216	0.60	368,414	1.02	2.96
5	345,267	0.63	209,212	0.38	600,357	1.09	361,794	0.66	2.76
6	347,654	2.81	83,916	0.22	367,481	0.95	449,223	1.22	5.20
7	2,738,194	2.81	244,993	0.25	1,020,097	1.05	1,398,919	1.44	5.55
8	336,229	1.84	42,928	0.24	118,795	0.65	215,562	1.18	3.91
9	67,893	0.53	27,319	0.21	35,323	0.28	122,805	0.96	1.98

* Calculated from county data of the United States Census of Agriculture 1964, Vol. 1., part 17, and estimation of the total acreage in each soil area. See Appendix, Table 1.

** "Improved Pasture" was a census item included in the item, "other pastures." "Unimproved Pasture" is the difference between the two.

*** "Acres per cow" were calculated by using the acres pastured in each soil area and the number of cattle on January 1, 1967, in each soil area as given in Table 2.

TABLE 4--PRODUCTION OF ALFALFA AND ALFALFA MIXTURES AND OF ALL HAY BY SOIL AREAS IN MISSOURI

Soil Area	Acres	Production* (Tons)	Yield/A (Tons)	Acres/ Cow**	Acres	Production*** (Tons)	Yield/A (Tons)	Acres/ Cow**	Tons/ Cow
1	149,665	438,101	2.93	0.21	304,075	729,275	2.40	0.43	1.04
2	160,882	405,401	2.51	0.24	520,225	893,625	1.72	0.76	1.31
3	82,220	197,874	2.41	0.12	431,083	662,543	1.54	0.63	0.88
4	55,092	149,438	2.71	0.15	203,201	349,868	1.72	0.56	0.97
5	59,622	171,558	2.88	0.11	340,995	551,991	1.62	0.62	1.00
6	48,862	140,358	2.87	0.13	234,050	417,800	1.79	0.61	1.08
7	93,109	233,173	2.50	0.10	653,980	967,960	1.48	0.67	0.99
8	35,544	90,201	2.54	0.19	124,236	231,021	1.86	0.68	1.26
9	13,972	44,802	3.21	0.11	50,881	127,700	1.62	0.40	0.65

*Production in 1964 calculated from county data of United States Census of Agriculture 1964. Vol. 1, part 17.

**Calculated using numbers of all cattle January 1, 1967, as given in Table 2.

***Production in 1966 (alfalfa production included). Calculated from county data of Missouri Farm Facts 1966.

an unproductive source of forage is shown by the rather large acreage of cropland that has been diverted to pastures to support the large numbers of cattle in these four areas. Improving the production of pastures would appreciably increase the income from the Missouri cattle industry in all parts of the state, but especially in soil areas 4, 6, 7, and 8.

Hay is another source of forage for cattle, even beef cows are fed considerable hay in some parts of the state. However, the average yield of all kinds of hay are low in all soil areas (Table 4). When the production of alfalfa is subtracted from the all hay figures in Table 4, the average per acre yield of grass hay would be slightly more than 1 ton per acre. To increase the average yield of this hay as well as that of alfalfa would add materially to the income of the Missouri cattle enterprises in all soil areas.

Complexity of the Problem

Diverse soil forming materials and climatic conditions in Missouri have produced the nine major soil areas of the state. Soil characteristics of these areas are given by Scrivner (7) and Krusekopf (3). The weather pattern, especially the quantity and distribution of rainfall, is also of vital importance in forage production. Drought periods are a frequent hazard in Missouri. The extent and frequency of these drought periods have been reported by Decker (2). The type of cattle enterprise influences the management of pasture and hay land and this in turn relates to fertilization practices. The integration of all factors relating to forage fertilization is a complex process involving many disciplines of the Missouri Agricultural Experiment Station.

Opportunities for increased forage production research became available with the acquisition of several new research centers in 1960. The Southwest Missouri Center is especially important because data from this center can be applied to much of the land in soil areas 5, 6, and 7. Fertilizer studies initiated at the Bradford Research Farm near Columbia can supply data applicable to much of the land in soil areas 3 and 4. Similar studies at Weldon Spring would supply data for soil areas 4 and 8, and at the North Missouri Center for soil areas 1, 2, and 3. A study of the lime and phosphorus needs of alfalfa was also started at the Delta Center.

This report gives the results of fertilizer studies initiated since 1960 and for some hay fertilization studies started before 1960.

PART I

Southwest Missouri Center

The Southwest Missouri Center locale was chosen because the soils of the Center represent much of the southwest Missouri area. Two important series on the Center are the Gerald and Baxter silt loams. The Gerald is a prairie clay pan soil while the Baxter is a mature forest derived soil. Both of these soil series are naturally low in fertility and are quite acid. The initial soil test values of the experimental sites are given in Table 5. The Baxter area had received some lime and fertilizer prior to acquisition of the land but the Gerald area had received very little lime or fertilizer, if any, before its purchase.

Weather conditions at the Center had been variable during the period 1960-1967 as indicated by Table 6. This period, according to Myers (4), is representative of the last 25 years at Mount Vernon. Periodic droughts are the rule in southwest Missouri and this fact coupled with the rather low available water capacity of the soils of the area make soil moisture an important factor in forage production and in forage crop fertilization.

PROCEDURES

The studies on fertilization of forage crops at the Southwest Missouri Center were begun in 1961. They included nitrogen, phosphorus, and potassium variables on four major hay and pasture grasses; phosphorus and potassium variables on four major hay and pasture grasses; phosphorus and potassium variables on grass-legume mixtures; and phosphorus and potassium variables on alfalfa and birdsfoot trefoil. All studies were established on both the Gerald and Baxter silt loams. The studies with trefoil were terminated after two years due to loss of stand. Four tons of calcium limestone were applied to all experiments in the summer of 1960 as was any plowdown phosphorus and potassium. One-half of these basic treatments was placed on the plot surface; the plots were disced and then plowed. The remaining half of the treatments was applied and then disced into the plowed surface. This procedure was followed to get thorough mixing of the treatments with the plowed layer as soil samples were to be taken annually from each plot during the period of the study. The complete results of the analyses of these soil samples will be reported as part of another study. Only the results of some tests made in the last year of the study are included in this report. In the case of the pure grass experiments, three additional tons of magnesium limestone were top dressed in 1963.

Where a minor element mixture was used, the following mixture was applied at the rate of 100 pounds per acre: 10 pounds borax, 10 pounds zinc sulfate, 40 pounds copper sulfate, 5 pounds manganese sulfate, 1 pound cobalt sulfate, 1 ounce sodium molybdate, 10 pounds magnesium sulfate, and 25 pounds gypsum.

TABLE 5--REPRESENTATIVE INITIAL SOIL TEST VALUES FOR FORAGE RESEARCH AREAS, SOUTHWEST CENTER

Soil Type	O.M. (%)	P_2O_5*	K (pounds)	Mg	Ca	pH Salt	Me** (H)	CEC
Baxter silt loam	1.8	88	215	313	1960	6.2	1.0	7.6
Gerald silt loam	2.1	24	160	180	585	4.5	4.7	7.2

* Brays strong extracting solution.
** Determined with old buffer solution. The solution developed in 1965 would give about twice this quantity of hydrogen.

TABLE 6--PRECIPITATION RECORD SOUTHWEST MISSOURI CENTER

	Total Precipitation in Inches							
	1960	1961	1962	1963	1964	1965	1966	1967
January	1.00	.02	1.51	.63	.42	1.65	1.56	1.13
February	1.72	2.68	1.83	.48	1.50	2.03	4.04	1.01
March	1.42	5.18	1.45	2.33	4.23	1.99	2.69	1.51
April	2.38	3.37	3.13	1.30	7.29	8.11	4.12	4.88
May	5.51	11.21	4.92	6.11	2.72	6.36	3.14	4.76
June	2.65	2.96	4.97	7.69	6.10	5.90	1.47	7.74
July	4.88	4.51	2.79	2.39	.99	3.94	4.56	3.17
August	3.45	1.69	1.40	2.91	6.12	3.30	5.87	2.23
September	.91	5.81	9.00	2.17	1.53	6.71	2.03	1.42
October	2.59	2.24	1.45	.00	3.07	1.33	1.14	10.92
November	2.90	2.57	1.11	2.16	5.18	1.09	2.60	1.41
December	3.87	2.12	1.69	.89	1.58	3.40	2.09	2.93
Total	33.28	44.36	35.25	29.06	40.73	45.81	35.31	43.11
Yearly Departure from Long-Term Mean	-7.80	3.28	-5.83	-12.02	-0.35	4.73	-5.77	2.03

Dry Periods (all dates inclusive)*

1960--1/18-2/3; 2/6-2/26; 3/15-4/13; 6/14-7/3; 8/19-9/18; 9/20-10/17; 12/12-12/31.
1961--1/1-2/6; 7/23-8/13; 10/14-10/30; 12/17-12/31.
1962--1/15-2/14; 2/28-3/19; 3/26-4/9; 5/10-5/25; 8/11-9/2; 10/1-10/19; 10/29-11/17; 11/28-12/19; 12/21-12/31.
1963--1/1-1/4; 1/6-2/27; 3/12-4/2; 4/28-5/12; 9/8-9/24; 9/26-11/3; 11/23-12/9; 12/12-12/31.
1964--1/1-1/30; 2/16-3/3; 3/20-4/3; 6/14-7/11; 7/24-8/13; 9/5-9/20; 12/11-12/30.
1965--1/23-2/9; 7/15-8/15; 9/23-10/16; 11/15-12/10.
1966--1/3-1/31; 2/12-2/27; 3/24-4/11; 5/19-6/7; 6/15-7/14; 8/23-9/29; 10/1-10/17; 10/19-11/14; 11/11-11/26; 12/29-12/31.
1967--1/1-1/25; 2/3-2/26; 7/29-8/18; 8/24-9/16; 11/4-11/29.

*Dry Period: At least 15 consecutive days with less than 0.25 inches of precipitation.

Experimental plots were 50 feet by 10 feet, being trimmed to 40 feet in length when harvested. Plots were harvested with a five-foot flail type forage harvester. The green material was caught in a large burlap bag and weighed. A sample for moisture determination was taken from each bag and yields were calculated and reported in tons of hay, 15 percent moisture. Data from each study were subjected to analyses of variance statistical procedures and the significant differences among the treatments were evaluated by Duncan's New Multiple Range Test. All yields followed by the same letter in an individual table are not significantly different. The list of treatments for each study are given in the appropriate table.

RESULTS AND DISCUSSION

Studies with Grasses

The objectives of these studies were to determine the response of orchard grass, tall fescue, brome grass, and timothy to varying rates of phosphorus and nitrogen applications when grown on Baxter and Gerald silt loams. Potomic orchard grass, Kentucky 31 fescue, southern brome grass, and common timothy were planted in the spring of 1961. The timothy stand thinned badly so the timothy plots were not harvested after 1966. Average yields of the grasses were disappointingly low. They were cut only once each year because drought periods during the summers of the study did not produce harvestable second growths.

Baxter Silt Loam

The results of the studies on Baxter silt loam are given in Table 7. The data show that 100 pounds N was significantly better than 60 pounds N for all four of the grasses on Baxter silt loam. The 100 pounds N produced an average of 0.5 tons more brome grass, 0.25 tons more orchard grass, 0.3 tons more fescue, and 0.25 tons more timothy than the 60 pound N rate for the period of the study.

The 200 pounds P_2O_5 rate increased yields of all grasses, except brome grass, over no treatment. Four hundred pounds P_2O_5 gave no yield increases over the 200 pound rate with the exception of fescue where the 400 pounds gave a significant yield increase over the 200 pound application. In no case was the 600 pound rate better than the 400 pound rate. Phosphorus soil test values for 1966 are given in Table 8.

Potassium was intended to be a variable in three of the treatments but tests on soil samples showed that potassium levels were low on all plots so 60 pounds K_2O were top dressed in the spring of 1963 and 120 pounds K_2O again top dressed to all plots in the spring of 1966. Potassium should not have been a limiting nutrient in this study.

There was no benefit from applying the minor element mixture in this study.

TABLE 7--RESPONSE OF FOUR GRASSES TO PHOSPHORUS AND NITROGEN APPLICATIONS ON BAXTER SILT LOAM

Treatment*	Brome Grass 6-Year Avg.	Orchardgrass 6-Year Avg.	Fescue 6-Year Avg.	Timothy 5-Year Avg.
1. 200 lbs. P_2O_5 + 60 lbs. N	1.88 c	2.06 bc	1.85 cd	1.87 c
2. 400 lbs. P_2O_5 + 60 lbs. N	2.09 bc	1.98 c	2.04 b	1.96 bc
3. 0 lbs. P_2O_5 + 60 lbs. N	1.74 c	1.76 d	1.63 e	1.66 d
4. 600 lbs. P_2O_5 + 60 lbs. N	2.21 b	2.00 c	1.93 bcd	2.08 ab
5. 400 lbs. P_2O_5 + 100 lbs. N	2.50 a	2.10 ab	2.26 a	2.18 a
6. 600 lbs. P_2O_5 + 100 lbs. N	2.56 a	2.17 a	2.22 a	2.25 a
7. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O	1.85 c	1.84 d	1.78 de	1.89 c
8. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O (minor elements)	1.87 c	1.86 d	1.97 bc	1.85 c
9. 400 lbs. P_2O_5 + 100 lbs. N + 60 lbs. K_2O (topdressed)	2.47 a	2.16 ab	2.24 a	2.16 a
LSD_{05}	0.25	0.13	0.17	0.16

*Phosphorus and potassium treatments were plowed down in August, 1960.

TABLE 8--PHOSPHORUS SOIL TEST VALUES UNDER FOUR GRASSES ON BAXTER SILT LOAM SIX YEARS AFTER TREATMENT

Treatment*	Phosphorus Soil Test Values (Lbs/Acre)			
	Brome Grass	Orchard Grass	Fescue	Timothy
1. 200 lbs. P_2O_5 + 60 lbs. N	78 bc	86 bc	67 cd	57 e
2. 400 lbs. P_2O_5 + 60 lbs. N	127 abc	111 b	135 abc	100 d
3. 0 lbs. P_2O_5 + 60 lbs. N	47 c	40 c	32 d	31 e
4. 600 lbs. P_2O_5 + 60 lbs. N	178 ab	134 ab	180 ab	162 ab
5. 400 lbs. P_2O_5 + 60 lbs. N	169 ab	118 b	102 bcd	139 bcd
6. 600 lbs. P_2O_5 + 100 lbs. N	207 a	194 a	205 a	197 a
7. 400 lbs. P_2O_5 + 60 lbs. N +100 lbs. K_2O	104 abc	135 ab	129 abc	113 cd
8. 400 lbs. P_2O_5 + 60 lbs. N +100 lbs. K_2O +minor elements	151 abc	128 ab	127 abc	150 bc
9. 400 lbs. P_2O_5 + 100 lbs. N +60 lbs. K_2O top dressed	104 abc	104 bc	110 bc	163 ab
LSD_{05}	100	61	71	39

*Phosphorus and potassium treatments were plowed down in August, 1960.

Gerald Silt Loam

The results of the studies on Gerald silt loam are given in Table 9. One hundred pounds N was significantly better than 60 pounds N for all grasses. With the exception of fescue, 200 pounds P_2O_5 was better than no phosphorus and in the case of orchard grass the 400 pound rate was better than the 200 pound rate by only 0.2 ton. In no case was the 600 pounds P_2O_5 better than the 400 pound rate. The phosphorus soil test values for 1966 are given in Table 10. As in the case with the Baxter silt loam, potassium was not a nutrient variable. Potassium had been applied at two different times as a top dressing to all plots in the study.

Studies with Grass-Legume Mixtures

The objectives of these studies were to determine the effectiveness of annual top dressings of phosphorus and potassium in the production of grass-legume mixtures on Gerald and Baxter silt loams with low soil test levels of phosphorus and potassium. All mixtures were established in the fall of 1961 using 15 + 64 + 30 as starter fertilizer banded with a grain drill prior to planting the seed with a brillion seeder. The results of these studies are given in Table 11. Mixtures responded to applications of phosphorus and potassium on both soil types. These nutrients should be applied together as each is ineffective without the other. A greater response to potassium was obtained from the orchard grass-alfalfa than from the other two mixtures. A 0 + 50 + 150 would be better for orchard grass-alfalfa.

Yields of the fescue-lespedeza mixture were surprisingly low. Often half of the yield of a given year would be lespedeza harvested in the fall when good rains came in August or early September. The yellow color of the fescue in the spring indicated insufficient nitrogen so the original study on this mixture was terminated after five years and 30 pounds of nitrogen per acre was added to all of the original treatments. No reason can be given for the consistently lower yields of this mixture on the Gerald silt loam as compared with the Baxter silt loam.

The orchard grass-alfalfa mixture produced well with the application of 0 + 50 + 150 and the stand persisted over the six-year period. In fact, the botanical composition did not vary appreciably with the treatments but remained about the same in all plots of each soil type. The slightly higher yield on the Gerald soil could be due to greater infiltration of rainfall on the level Gerald plots as compared with the more sloping (7 percent) Baxter plots.

Timothy-red clover mixture is questionable for southwest Missouri where yearly drought periods can be expected. It is evident that soil moisture was a seriously limiting factor because applications of phosphorus and potassium had little effect on hay yields of this mixture. The more level topography of the Gerald silt loam plots probably prevented rapid runoff and consequently produced slightly higher yields than the plots on the Baxter silt loam.

TABLE 9--RESPONSE OF FOUR GRASSES TO PHOSPHORUS AND NITROGEN APPLICATIONS ON GERALD SILT LOAM

Treatment*	Brome Grass 6-Year Avg.	Orchardgrass 6-Year Avg.	Fescue 6-Year Avg.	Timothy 5-Year Avg.
1. 200 lbs. P_2O_5 + 60 lbs. N	1.66 d	1.45 c	1.53 cd	1.85 d
2. 400 lbs. P_2O_5 + 60 lbs. N	1.79 cd	1.69 b	1.52 cd	2.04 cd
3. 0 lbs. P_2O_5 + 60 lbs. N	1.16 e	1.25 d	1.32 d	1.46 e
4. 600 lbs. P_2O_5 + 60 lbs. N	1.68 d	1.70 b	1.63 bc	2.09 c
5. 400 lbs. P_2O_5 + 100 lbs. N	2.13 ab	2.05 a	2.10 a	2.34 ab
6. 600 lbs. P_2O_5 + 100 lbs. N	2.22 a	2.06 a	2.24 a	2.48 a
7. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O	1.92 bcd	1.79 b	1.81 b	2.09 c
8. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O +Minor Elements	1.96 abc	1.71 b	1.74 bc	2.14 bc
9. 400 lbs. P_2O_5 + 100 lbs. N + 60 lbs. K_2O Top Dressed	2.18 ab	2.15 a	2.31 a	2.42 a
LSD_{05}	0.84	0.18	0.20	0.22

*Phosphorus and potassium treatments were plowed down in August, 1960.

TABLE 10--PHOSPHORUS SOIL TEST VALUES UNDER FOUR GRASSES ON GERALD SILT LOAM SIX YEARS AFTER TREATMENT

Treatments*	Phosphorus Soil Test Values (Lbs./Acre)			
	Brome Grass	Orchardgrass	Fescue	Timothy
1. 200 lbs. P_2O_5 + 60 lbs. N	50 bc	37 bc	41 de	44 cd
2. 400 lbs. P_2O_5 + 60 lbs. N	85 b	90 b	137 bc	95 b
3. 0 lbs. P_2O_5 + 60 lbs. N	21 c	25 c	25 e	36 d
4. 600 lbs. P_2O_5 + 60 lbs. N	186 a	227 a	219 a	203 a
5. 400 lbs. P_2O_5 + 100 lbs. N	69 bc	86 b	77 cde	89 b
6. 600 lbs. P_2O_5 + 100 lbs. N	190 a	208 a	201 ab	230 a
7. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O	102 b	67 bc	79 cde	95 b
8. 400 lbs. P_2O_5 + 60 lbs. N + 100 lbs. K_2O +Minor Elements	88 b	80 bc	106 cd	81 bc
9. 400 lbs. P_2O_5 + 100 lbs. N + 60 lbs. K_2O Top Dressed	76 bc	78 bc	114 cd	85 bc
LSD_{05}	52	50	70	

*Phosphorus and potassium treatments were plowed down in August, 1960.

TABLE 11--EFFECT OF TOP DRESSING GRASS-LEGUME MIXTURES WITH PHOSPHORUS AND POTASSIUM ON GERALD AND BAXTER SILT LOAMS

Treatment	Gerald Silt Loam			Baxter Silt Loam		
	Orchardgrass-Alfalfa (6-Year Avg.)	Fescue-Lespedeza (5-Year Avg.)	Timothy-Red Clover (4-Year Avg.)	Orchardgrass-Alfalfa (6-Year Avg.)	Fescue-Lespedeza (5-Year Avg.)	Timothy-Red Clover (3-Year Avg.)
1. 0 + 50 + 0	2.19 c	0.97 c	1.79 ab	1.71 d	1.20 c	1.36 a
2. 0 + 50 + 50	3.09 b	0.95 c	2.13 a	2.51 b	1.35 abc	1.55 a
3. 0** + 50 + 100	3.02 b	1.15 a	1.83 ab	2.55 ab	1.43 ab	1.64 a
4. 0** + 1500* + 100	3.15 ab	1.03 abc	1.77 ab	2.46 b	1.25 bc	1.53 a
5. 0 + 25 + 50	2.99 b	0.99 c	1.66 b	2.44 b	1.34 abc	1.46 a
6. 0** + 0 + 100	2.34 c	0.80 d	1.47 b	1.91 c	1.25 bc	1.47 a
7. 0** + 50 + 150	3.40 a	1.15 ab	1.72 ab	2.71 a	1.52 a	1.60 a
LSD_{05}	0.28	0.14	0.35	0.17	0.20	0.24

*1500 pounds of rock phosphate plowed down in 1961.
**One-half of the potash treatments were applied in April, the other half in June.

Studies with Alfalfa

The objectives of these studies were to determine the effect of different rates of phosphorus and the beneficial effects of potassium, nitrogen, and minor elements on the yield of alfalfa on Gerald and Baxter silt loams. Soil tests taken in the fall of 1962 indicated potassium was at a low level on both soil types and 60 pounds K_2O were top dressed in the spring of 1963. One-hundred and twenty pounds K_2O were again top dressed in 1965 on the Gerald soil and in 1966 on the Baxter soil. The stand on the Gerald plots thinned during the winter of 1965-66 and the study was terminated on this soil. The stand on all plots on the Baxter soil persisted satisfactorily through 1967. The results of these studies are given in table 12.

The data show that in the case of the Gerald silt loam which has a very low initial soil test level for phosphorus, 400 pounds P_2O_5 plowed down would be a good rate to apply to maintain yields of alfalfa, although the 400 pound rate is not significantly different from the 200 pound rate. The fact that the 400 pound rate is not significantly different from the 600 pound rate but the 200 pound and 600 pound rate are significantly different would indicate that a higher phosphorus level than that provided by the 200 pound rate would be preferable for alfalfa on this soil. No beneficial effect on yields of alfalfa on the Gerald soil resulting from minor elements or nitrogen could be established in this study.

The initial soil phosphorus level on the Baxter silt loam (88 pounds P_2O_5 per acre) was sufficiently high that the 200 pounds P_2O_5 per acre produced optimum hay yields over the six-year period. This yield was significantly greater than that produced by plots getting no treatment. Other treatments or combinations of nutrients other than phosphorus had no effect on alfalfa yields on this soil. The consistently uniform annual yields in this study were a matter of interest and Myers (4) after a thorough analysis of phosphorus and potassium content of plant tissue, soil test values, individual cutting yields, soil moisture data, and rainfall records, decided that soil moisture as influenced by total rainfall and rainfall distribution was limiting hay yields to the level found in this study. He also concluded that rainfall and rainfall patterns and soil moisture levels should be variables included in crop production studies of this type.

CONCLUSIONS

Southwest Missouri Center

The six years of forage fertilization studies at the Southwest Missouri Center have given data from which the following conclusions can be drawn:

1. Soil moisture is a serious limiting factor in forage production in southwest Missouri.

2. Where grasses are grown for hay in southwest Missouri, at least 100 pounds N per acre applied in the spring would give profitable results, providing phosphorus and potassium were adequate.

TABLE 12--EFFECT OF PHOSPHORUS APPLICATIONS ON YIELDS OF ALFALFA ON GERALD AND BAXTER SILT LOAMS

Treatment	Gerald Silt Loam (4-Year Avg.)	Baxter Silt Loam (6-Year Avg.)
1. 200 lbs. P_2O_5	2.66 c	3.12 d
2. 400 lbs. P_2O_5	3.04 abc	3.28 abc
3. 0 lbs. P_2O_5	1.59 d	2.91 e
4. 600 lbs. P_2O_5	3.07 ab	3.27 bc
5. 400 lbs. P_2O_5 + 100 lbs. K_2O P. D.	3.07 ab	3.38 ab
6. 400 lbs. P_2O_5 + 60 lbs. K_2O T. D. in spring	3.28 a	3.43 a
7. 400 lbs. P_2O_5 + minor elements	2.93 abc	3.24 c
8. 400 lbs. P_2O_5 + 30 lbs. N. T. D.	2.82 bc	3.27 bc
9. 400 lbs. P_2O_5 (NO BORON)	2.80 bc	3.37 ab
LSD_{05}	0.35	0.10

TABLE 13--PHOSPHORUS SOIL TEST VALUES UNDER ALFALFA GROWN ON GERALD AND BAXTER AFTER SEVERAL YEARS OF CROPPING

Treatments*	Gerald Silt Loam (After 4 Years)	Baxter Silt Loam (After 6 Years)
1. 200 lbs. P_2O_5	38 de	50 c
2. 400 lbs. P_2O_5	64 bc	102 b
3. 0 lbs. P_2O_5	22 e	40 c
4. 600 lbs. P_2O_5	128 a	185 a
5. 400 lbs. P_2O_5 + 100 lbs. K_2O Plowed Down	64 bc	105 b
6. 400 lbs. P_2O_5 + 60 lbs. K_2O Top-Dressed in spring	64 bc	104 b
7. 400 lbs. P_2O_5 + Minor Elements	73 bc	99 b
8. 400 lbs. P_2O_5 + 30 lbs. N Top-Dressed in spring	56 cb	115 b
9. 400 lbs. P_2O_5 (No Boron)	77 b	122 b
LSD_{05}	18	44

*Treatments were plowed down in summer of 1960.

3. Two hundred pounds P_2O_5 plowed down on both soil types gave optimum yields of grasses in all but two cases where the 400 pound rate was effective. Six-hundred pounds P_2O_5 gave higher soil test phosphorus values than the 200 and 400 pound rates but did not increase yields over the 400 pound rate in any case.

4. Good yields of grass-legume mixtures can be produced by applications of phosphorus and potassium as top dressings on stands on soil with low test values for phosphorus and potassium. For fescue-lespedeza 0 + 50 + 100 was adequate but for orchard grass-alfalfa 0 + 50 + 150 was more beneficial.

5. Lespedeza apparently does not fix enough nitrogen to greatly influence the growth of fescue in a fescue-lespedeza mixture. Spring top dressings of about 30 pounds N per acre are indicated.

PART II

Southeast Missouri (Delta) Center

Land which became the Delta Center was acquired by the University of Missouri Agricultural Experiment Station in 1960. Treatments for an alfalfa study were applied in the fall of 1961 on Sharkey clay soil but two successive seedings failed. The first successful one was in the fall of 1962. The stand failed in 1965 due to excessive rains and a new stand was established in the fall of 1966. Phosphorus and potassium soil test values for 1967 are given in Table 14.

TABLE 14--PHOSPHORUS AND POTASSIUM SOIL TEST VALUES OF PLOTS IN 1967 RECEIVING VARYING AMOUNT OF FERTILIZER IN 1960

Treatments	Phosphorus (Lbs. P_2O_5/A)	Potassium (Lbs. K/A)
1. 0 + 0 + 0	377 a	420 a
2. 0 + 400 + 0	404 a	418 a
3. 0 + 400 + 200	400 a	420 a
4. 0 + 0 + 200	368 a	410 a
LSD_{05}	33	30

RESULTS AND DISCUSSION

The objectives of this study were to determine the effect of different rates of calcium limestone, phosphorus, and potassium on yields of alfalfa grown on Sharkey clay soil. The results of this study are given in Table 15. The yield data

TABLE 15--EFFECT OF LIMESTONE, PHOSPHORUS, AND POTASSIUM ON YIELDS OF ALFALFA GROWN ON SHARKEY CLAY LOAM

Treatments: Basic* Limestone	Basic* Fertilizer	Top-Dressed 1967	Yields T/A 1963	Yields T/A 1964	Yields T/A 1967
1. None	None	None	4.0	5.9	3.81 e
2. None	0 + 400 + 0	0 + 50 + 0	5.1	6.7	4.52 bcd
3. None	0 + 400 + 200	0 + 50 + 100	5.4	6.9	4.57 bcd
4. None	0 + 0 + 200	0 + 0 + 100	4.6	7.2	4.38 cd
5. 3 Tons	None	None	4.9	6.4	4.26 de
6. 3 Tons	0 + 400 + 0	0 + 50 + 0	4.4	5.8	4.30 de
7. 3 Tons	0 + 400 + 200	0 + 50 + 100	5.0	6.3	4.76 bcd
8. 3 Tons	0 + 0 + 200	0 + 0 + 100	5.3	6.6	4.62 bcd
9. 6 Tons	None	None	5.7	7.2	4.88 bcd
10. 6 Tons	0 + 400 + 0	0 + 50 + 0	5.7	7.5	5.05 bc
11. 6 Tons	0 + 400 + 200	0 + 50 + 100	5.9	7.1	5.10 ab
12. 6 Tons	0 + 0 + 200	0 + 0 + 100	5.9	7.4	5.68 a
				LSD_{05}	0.50

*Basic treatments were plowed down in the fall of 1960.

were statistically analyzed for 1967 only. The data show that applications of either six tons limestone, 400 pounds P_2O_5, or 200 pounds K_2O would have a significantly equivalent effect on yields of alfalfa. In either case an average increase of 0.7 tons per acre was produced. Applying phosphorus alone on unlimed soil, the yield would be increased close to 0.7 tons per acre. Adding potassium to this treatment had no appreciable effect on the yield. Adding potassium alone to unlimed soil would increase yields .57 tons per acre. Applying phosphorus to soil receiving three tons limestone per acre had no benefit over limestone alone. Adding potassium to the fertilizer did not significantly increase this yield. The addition of phosphorus to soil receiving six tons limestone per acre had no effect on yields, nor did added potassium have any effect. However, potassium in combination with six tons limestone did have a significant effect on the yield. The use of a combination of adequate limestone and potassium is indicated by this study. The naturally high soil phosphorus level would appear to be sufficient for alfalfa on this soil.

CONCLUSIONS

Southeast Missouri Center

1. An interrelationship exists between the responses of alfalfa to applications of limestone, phosphorus, and potassium to Sharkey clay soil.

2. Optimum response of alfalfa was obtained from combined applications of six tons of limestone and 100 pounds K_2O as a top dressing in 1967.

3. The yield increases due to applications of phosphorus and potassium did not appear to be related to soil test levels of these nutrients.

PART III

Weldon Spring Research Farm

The Weldon Spring Research Farm was acquired by the University of Missouri in 1955. A dominant soil type on the farm is Weldon silt loam, a soil developed from windblown material under forest vegetation. This series represents much of the hill soils in Soil Areas 4 and 8. Representative initial soil test values for the experimental areas are given in Table 12. Studies of the response of alfalfa to applications of limestone, various phosphate carriers, potash, nitrogen, and minor elements were established in 1955.

RESULTS AND DISCUSSION

Lime and Alfalfa

The response of alfalfa to different rates of calcium limestone are given in Table 16. This study was replanted in 1962 and 1963. There was no increase in yields of alfalfa due to applications of limestone in this study. The pH of the unlimed plots in 1966 was 5.2 while that of the plots receiving limestone ranged from 6.2-6.4, indicating that on this soil alfalfa will produce good yields at a pH 5.2.

TABLE 16--EFFECTS OF LIMESTONE ON YIELDS OF ALFALFA GROWN ON WELDON SILT LOAM

Treatments*	Yields T/A 9-Year Avg.
None	4.7
1. 3 Tons Limestone	4.7
2. 6 Tons Limestone	4.8
3. 9 Tons Limestone	4.9
4. 12 Tons Limestone	4.8
5. 6 Tons Limestone plowed down, 6 Tons disced into plowed surface	4.8

*All plots received 1500 lbs. rock phosphate, 300 lbs. muriate of potash, 20 lbs. Borax plowed down at establishment of the experiment. 30 + 30 + 30 starter disced in at seeding.

Phosphorus and Alfalfa

The objectives of this study were to determine the effectiveness of different sources of phosphorus and fineness of grind of rock phosphate on yields of alfalfa grown on Weldon silt loam. The study was replanted in 1963. The results of this study are given in Table 17.

The data show that: (1) yields of alfalfa were increased by use of phosphorus on this soil regardless of source, (2) Florida and Idaho rock were equally effective in affecting yields of alfalfa, (3) 50 percent of either rock phosphate through a

TABLE 17--EFFECT OF ROCK PHOSPHATE, PHOSPHORIC ACID AND SUPERPHOSPHATE AS SOURCES OF PHOSPHORUS FOR ALFALFA ON WELDON SILT LOAM

Treatments*	Yield T/A 10-Year Avg.
1. 4 T Limestone	3.80
2. 4 T Limestone, 1000 lbs. 85/300 mesh Idaho Rock Phosphate	4.28
3. 4 T Limestone, 1000 lbs. 80/200 mesh Idaho Rock Phosphate	4.27
4. 4 T Limestone, 1000 lbs. 50/200 mesh Idaho Rock Phosphate	4.75
5. 4 T Limestone, 300 lbs. P_2O_5 as superphosphate	5.06
6. 4 T Limestone, 100 lbs. P_2O_5 as superphosphate	5.12
7. 4 T Limestone, 1000 lbs. 50/200 mesh Florida Rock Phosphate	4.74
8. 4 T Limestone, 1000 lbs. 70/200 mesh Florida Rock Phosphate	4.74
9. 4 T Limestone, 300 lbs. P_2O_5 as H_3PO_4 in solution	4.84
10. No Limestone, 2000 lbs. 70/200 mesh Florida Rock Phosphate	4.84
11. No Limestone, 2000 lbs. 70/200 mesh Florida Rock Phosphate + 100 lbs. P_2O_5 as H_3PO_4 in solution	4.86
12. No Limestone, 4000 lbs. 70/200 mesh Florida Rock Phosphate	4.93

*Starter fertilizer 24 + 24 + 24 on all plots.
120 lbs. K_2O and 30 lbs. Borax at seeding and each year after the first cutting. Two replications for each treatment.

200 mesh sieve was adequate, (4) additions of limestone had no effect on yields where rock phosphate was applied, (5) yields produced by superphosphate were slightly higher than those produced by rock phosphate, (6) phosphoric acid was as effective as rock phosphate as a source of phosphorus for alfalfa.

Producing Maximum Yields of Alfalfa

The objective of this study was to ascertain the yields of alfalfa under optimum conditions on Weldon silt loam. The site of this experiment was an old orchard with the soil in good fertility. The soil test levels on this site were as follows: P_2O_5, 150 pounds per acre; K 280 pounds per acre and the pH 5.5-6.0. The results are given in Table 18. Magnesium limestone and starter only produced the lowest yield. A combination of plow down rock phosphate and muriate of potash to soil test with the limestone disced into the plowed surface produced close to the high yield, 6.37 tons per acre, probably not significantly greater than 6.51 tons per acre, the highest average yield of the study. The potassium level produced by the muriate initially plowed down remained adequate for the 11 years of the study because annual applications of potassium as topdressing had no effect on yields. The rock phosphate provided sufficient phosphorus as annual applications of 120 pounds P_2O_5 after the first cutting did not increase hay yields. Even though this soil was initially low in magnesium the use of magnesium instead of calcium limestone did not give a yield increase. Applications of nitrogen or minor elements including boron also did not increase alfalfa yields.

CONCLUSIONS

Weldon Spring Research Farm

The studies at the Weldon Spring Research Farm gave data from which the following conclusions can be drawn:

1. Applications of either calcium or magnesium limestone to Weldon silt loam with a pH of 5.2 did not increase yields of alfalfa.

2. Florida and Idaho rock phosphate were equally effective in influencing yields of alfalfa.

3. Rock phosphate finer than 50 percent through a 200 mesh sieve had no additional effect on yields of alfalfa.

4. Two thousand pounds rock phosphate with four tons limestone did not increase alfalfa yields over 1,000 pounds of rock phosphate alone.

5. Superphosphate was slightly better than rock phosphate as a source of phosphorus for alfalfa in one study and not quite as effective in another, indicating intricate relationships in plant nutrient levels in the soil.

6. Applications of nitrogen and minor elements had no effect on yields of alfalfa on this soil.

TABLE 18--EFFECTS OF VARIOUS PLANT NUTRIENTS ON YIELDS OF ALFALFA GROWN ON WELDON SILT LOAM

	Treatments: Basic	Treatments: Top Dressings	Yields T/A 11-Year Avg.
1.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash	120 lbs. K_2O after 1st cutting	5.85
2.	Mg Limestone, Superphosphate, Borax, Muriate of Potash	120 lbs. K_2O after 1st cutting	5.85
3.	Rock phosphate, Borax, Muriate of Potash plowed down, Mg limestone disced in on plowed surface	120 lbs. K_2O after 1st cutting	6.37
4.	Mg Limestone only	None	5.60
5.	Basic treatments doubled, ½ plowed down, ½ disced in on plowed surface	120 lbs. K_2O after 1st cutting	6.31
6.	Basic treatments doubled, ½ on furrow, ½ disced in on plowed surface	120 lbs. K_2O after 1st cutting	6.17
7.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash	None	6.06
8.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash	120 lbs. K_2O after 1st cutting 33 lbs. N in Spring and after 1st cutting	5.95
9.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash	None	5.83
10.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash	120 lbs. K_2O after 1st cutting	6.18
11.	Ca Limestone, Rock Phosphate, Borax, Muriate of Potash	120 lbs. K_2O after 1st cutting	5.77
12.	Mg Limestone, Rock Phosphate, Borax, Muriate of Potash minor element mixture*	120 lbs. K_2O after 1st cutting	5.88
13.	Basic treatments doubled, ½ plowed 14" deep, ½ disced into plowed surface	120 lbs. K_2O after 1st cutting	6.15
14.	1 Ton Rock Phosphate in furrow in addition to basic treatments and minor element mixture*	120 lbs. K_2O after 1st cutting	6.51

*Trace element mixture: 50 lbs. copper sulfate, 10 lbs. zinc sulfate, 10 lbs. Manganese sulfate, 20 lbs. ferrous sulfate and 2 lbs. cobalt sulfate per acre.

PART IV

Bradford Research Farm

The Bradford Research Farm was acquired by the University of Missouri Agricultural Experiment Station in 1960. The predominant soil type is Mexico silt loam and represents a large percentage of the soils in soil area 3 and could apply to much of the windblown soil in soil area 4. Shortly after acquisition of the farm studies were designed to test the effectiveness of plowing down phosphorus and potassium, top dressing phosphorus and potassium and different particle sizes of calcium limestone on yields of alfalfa. Also a rate of nitrogen study with hay grasses was started in 1961. The initial soil test values for these experimental sites are given in Table 20. During the period of these studies below normal rainfall often occurred and lack of adequate soil moisture was the most important factor in affecting yields. For example the grass plots were harvested twice one year out of the five years of the study reported. The climatic data for the period of the studies are given in Table 19. Soil samples were taken periodically from each plot of the alfalfa studies. Results of tests made on these samples will be reported in another publication.

RESULTS AND DISCUSSION

Plowing Down Phosphorus and Potassium

The objectives of this study were to determine the effectiveness of plowing down varying quantities of phosphorus and potassium on yields of alfalfa grown on Mexico silt loam. The phosphorus was applied by two sources, rock phosphate and 45 percent superphosphate. The results of the study are given in Table 21. The average annual yields of this study ranged from 1.57 tons per acre in 1962 to 6.79 tons per acre in 1965.

The data in Table 21 show there was virtually no effect on alfalfa yields due to treatment. There was no significant effect due to treatment in 1965 when rainfall was near optimum. Even though the initial soil test value for potassium was low (190 pounds per acre) plowing down K_2O at rates of 200 to 400 pounds per acre had no effect on yields. Apparently alfalfa was able to get adequate potassium from the subsoil and loess parent material to supply all its needs. The initial soil phosphorus level of 152 pounds P_2O_5 per acre was also adequate for the phosphorus needs of alfalfa during the six years of the study. The sources of phosphorus were equally ineffective in increasing yields.

Top Dressing Phosphorus and Potassium

The objectives of this study were to determine the effectiveness of top dressing phosphorus and potassium in producing and maintaining yields of alfalfa grown on previously fertilized Mexico silt loam soil. The procedure was to plow down varying quantities of phosphorus and potassium and then apply phos-

TABLE 19--PRECIPITATION RECORD BRADFORD RESEARCH FARM

Months	1961	1962	1963	1964	1965	1966	1967
			Total Precipitation in Inches				
January		.99	.19	.78	2.89	.40	2.16
February		2.04	.28	1.62	1.26	2.23	.70
March		2.88	3.53	3.01	3.53	.99	2.50
April		1.22	2.54	6.05	4.54	4.31	2.93
May		2.42	3.80	5.50	3.02	2.18	4.72
June		1.90	1.86	3.08	9.15	2.42	4.18
July	6.61	1.73	5.92	4.44	2.95	7.01	1.70
August	3.21	1.91	2.78	.99	5.58	.99	.99
September	7.83	5.51	1.46	4.02	8.37	2.34	1.31
October	2.63	3.38	.78	.32	1.55	1.23	6.53
November	3.28	.57	.67	5.07	.45	.94	1.58
December	1.21	.83	.47	1.30	2.24	2.35	1.90
Total		25.38	24.28	36.18	45.53	27.39	31.20
Yearly Departure from Long-Term Mean		-11.58	-12.68	-0.78	+8.57	-9.57	-5.76

Dry Periods (all dates inclusive)*

1961	(Beginning July 1.) 9/25-10/12; 11/22-12/15; 12/23 (Continued next year)
1962	-1/13; 1/15-2/7; 3/21-5/5; 5/7-5/24; 10/20-11/15; 11/17-12/18; 12/20- (Continued next year)
1963	-3/2; 3/12-3/30; 9/26-10/16; 10/18-12/10; 12/12 (Continued next year)
1964	-1/30; 2/16-3/3; 6/15-7/7; 7/29-8/19; 9/27-10/26; 10/28-11/11; 12/3-12/30.
1965	2/12-2/28; 3/17-4/2; 9/25-10/13; 10/17-12/10; 12/25- (Continued next year)
1966	-1/31; 2/10-2/27; 3/4-3/21; 3/23-4/10; 5/18-6/2; 6/27-7/14; 8/11-9/2; 9/4-9/29; 10/19-11/3; 11/5-12/5; 12/9- (Continued next year)
1967	-1/24; 1/29-2/26; 7/10-7/26; 8/19-9/14; 11/3-11/28; 12/10-12/30.

*Dry Period: At least 15 consecutive days with less than 0.25 inches of precipitation.

TABLE 20--INITIAL SOIL TEST VALUES FOR THE EXPERIMENTAL SITES MEXICO SILT LOAM

	OM %	P_2O_5* lbs/A	K lbs/A	Mg lbs/A	Ca lbs/A	Salt pH	H** Me	CEC
Phosphorus and Potassium Studies	1.9	152	190	398	4280	5.6	2.4	16
Size of Limestone	2.8	37	300	628	2850	4.8	6.0	16
Nitrogen on Grasses	2.5	111	166	685	5225	5.4	2.9	19

*Brays Strong Extracting Solution.

**Determined with old buffer solution. The solution developed in 1965 would give about twice this quantity of H.

TABLE 21--EFFECT OF RATES OF POTASSIUM AND RATES AND SOURCES OF PHOSPHORUS ON YIELDS OF ALFALFA GROWN ON MEXICO SILT LOAM

Treatments*	Yield T/A 6-Year Avg.
1. 100 lbs. P_2O_5 + 200 lbs. K_2O	4.63 bcd
2. 200 lbs. P_2O_5 + 200 lbs. K_2O	4.60 cd
3. 0 P_2O_5 + 200 lbs. K_2O	4.84 ab
4. 400 lbs. P_2O_5 + 200 lbs. K_2O	4.66 bcd
5. 800 lbs. P_2O_5 + 200 lbs. K_2O	4.52 d
6. 700 lbs. Rock Phosphate (210 lbs. P_2O_5) + 200 lbs. K_2O	4.63 bcd
7. 1400 lbs. Rock Phosphate (420 lbs. P_2O_5) + 200 lbs. K_2O	4.61 cd
8. 2800 lbs. Rock Phosphate (840 lbs. P_2O_5) + 200 lbs. K_2O	4.86 a
9. 400 lbs. P_2O_5 + 100 lbs. K_2O	4.73 abcd
10. 400 lbs. P_2O_5 + 200 lbs. K_2O	4.71 abcd
11. 400 lbs. P_2O_5 + 0 K_2O	4.75 abc
12. 400 lbs. P_2O_5 + 400 lbs. K_2O	4.74 abcd
LSD_{05}	0.19

*Three tons calcium limestone and 25 lbs. borax were applied to all plots. One-half of each treatment was applied to the plot surfaces disced in, plowed under and the remaining half applied and disced into the plowed surfaces. All treatments were applied in August, 1960. The alfalfa stand was established in August, 1961, the summer 1960 seeding having failed due to dry weather.

phorus and potassium as top dressing in varying amounts. The results of the study are given in Table 22.

Adding phosphorus either as a plow down or as a top dressing did not increase alfalfa yields during the period of this study. On the other hand top dressing 90 pounds K_2O per acre annually or plowing down at least 200 pounds K_2O initially were able to increase alfalfa yields. Yields ranged from an annual average of 4.21 tons per acre in 1967 to 7.29 tons per acre in 1965. In dry seasons plots receiving no boron showed boron deficiency symptoms, but there was no discernible loss in yield due to lack of boron.

Fineness of Limestone

The objectives of this study were to determine the effectiveness of particle

TABLE 22--EFFECT OF TOP DRESSING PHOSPHORUS AND POTASSIUM ON YIELDS OF ALFALFA GROWN ON MEXICO SILT LOAM

	Treatments Plow Down*	Top-Dress	Yield T/Acre 5-year Avg.
1.	100 lbs. P_2O_5 + 100 lbs. K_2O	0 + 0 + 0	5.07 e
2.	100 lbs. P_2O_5 + 100 lbs. K_2O	0 + 30 + 90	5.37 abc
3.	100 lbs. P_2O_5 + 100 lbs. K_2O	0 + 60 + 180	5.34 abcd
4.	100 lbs. P_2O_5 + 200 lbs. K_2O	0 + 0 + 0	5.29 abcde
5.	100 lbs. P_2O_5 + 200 lbs. K_2O	0 + 30 + 0	5.35 abcd
6.	100 lbs. P_2O_5 + 200 lbs. K_2O	0 + 60 + 0	5.38 abc
7.	None None	0 + 0 + 0	5.08 de
8.	None None	0 + 30 + 90	5.28 abcde
9.	None None	0 + 60 + 180	5.51 ab
10.	400 lbs. P_2O_5 + 100 lbs. K_2O	0 + 0 + 0	5.20 cde
11.	400 lbs. P_2O_5 + 100 lbs. K_2O	0 + 0 + 90	5.42 abc
12.	400 lbs. P_2O_5 + 100 lbs. K_2O	0 + 0 + 180	5.36 abc
13.	400 lbs. P_2O_5 + 200 lbs. K_2O	0 + 0 + 0	5.25 abcde
14.	400 lbs. P_2O_5 + 200 lbs. K_2O	0 + 30 + 90	5.43 abc
15.	400 lbs. P_2O_5 + 200 lbs. K_2O	0 + 60 + 180	5.52 a
16.	400 lbs. P_2O_5 + 200 lbs. K_2O-No Boron	0 + 0 + 0	5.32 abcde
17.	400 lbs. P_2O_5 + 200 lbs. K_2O-No Boron	0 + 30 + 90	5.46 abc
18.	400 lbs. P_2O_5 + 200 lbs. K_2O-No Boron	0 + 90 + 180	5.30 abcde
	LSD_{05}		0.23

*Plow down treatments plus 3 ton calcium limestone and 25 lbs. Borax/A were made in August, 1960, one-half being disced into plots plowed and the remaining half disced into the plowed surfaces. Top dressing studies were begun in 1963, applications being made after the second cutting each year thereafter. Additional boron was applied in 1966 to plots having received boron in 1960.

size of calcium limestone on yields of alfalfa grown on Mexico silt loam. The limestone was from St. Genevieve, Mo., screened to give uniform particle sizes. Phosphorus and potassium were brought to soil test levels and maintained by annual top dressings. Soil samples from each plot were taken periodically. Results of tests on these samples will be given in another publication. Average annual yields ranged from 4.13 tons per acre in 1967 to 7.00 tons per acre in 1965. The data are given in Table 23.

The results show that in all cases but one, six tons per acre of any particle size produced optimum yields of alfalfa. The limestone finer than 100 mesh at six tons per acre was not as effective as the coarser material. In general three tons per acre of any material was inadequate. It is interesting to note that in the cases where soil was brought up to soil test by different qualities of limestone, yields were no better than where six tons per acre of the coarsest material was used.

Nitrogen on Grasses

The objective of this study was to determine the effectiveness of different rates of nitrogen on yields of five different species of hay and pasture grasses when grown on Mexico silt loam. The initial potassium soil test values were considered low so applications of 150 lbs. K_2O were made biannually. Because of the unfavorable rainfall pattern soil moisture was a greater limiting factor than soil fertility. The data are given in Table 24.

In three cases out of five, 120 pounds N were better than 60 pounds N. These grasses were brome grass, orchard grass, and tall fescue. The relatively good yields of red top suggest it may have been overlooked as a hay crop for some problem soils.

CONCLUSIONS

Bradford Research Farm

These conclusions can be drawn from soil fertility studies on the Bradford Research Farm:

1. Applications of phosphorus either by plowing down or by top dressing did not increase yields of alfalfa grown on Mexico silt loam with an initial soil test value of 152 pounds P_2O_5 per acre.

2. Applications of 200 pounds K_2O plowed down or 90 pounds K_2O top-dressed annually increased alfalfa yields when grown on Mexico silt loam with an initial soil test value of 190 pounds K per acre.

3. Applications of six tons per acre of 10-20 mesh limestone was as effective as finer fractions or higher rates of varying quality limestone on producing yields of alfalfa on Mexico silt loam with an initial salt pH of 4.8.

4. One hundred and twenty pounds N per acre was better than 60 pounds N per acre on brome grass, orchardgrass, and tall fescue.

TABLE 23--EFFECT OF RATE AND FINENESS OF GRIND OF LIMESTONE ON YIELDS OF ALFALFA GROWN ON MEXICO SILT LOAM

Treatments*		Yields T/A 5-year Avg.
1. No Lime		4.39 g
2. Finer than 10 mesh greater than 20 mesh	3T/A	5.02 def
3. Finer than 10 mesh greater than 20 mesh	6T/A	5.13 abcdef
4. Finer than 20 mesh greater than 40 mesh	3T/A	5.00 ef
5. Finer than 20 mesh greater than 40 mesh	6T/A	5.08 bcdef
6. Finer than 40 mesh greater than 60 mesh	3T/A	5.06 bcdef
7. Finer than 40 mesh greater than 60 mesh	6 T/A	5.25 bcde
8. Finer than 60 mesh greater than 100 mesh	3T/A	5.30 abc
9. Finer than 60 mesh greater than 100 mesh	6T/A	5.40 a
10. Finer than 100 mesh	3T/A	5.03 cdef
11. Finer than 100 mesh	6T/A	4.93 f
12. 200 lbs. Ca/ton to soil test (14T/A)		5.33 ab
13. 400 lbs. Ca/ton to soil test (7T/A)		5.10 bcdef
14. 600 lbs. Ca/ton to soil test (4.7T/A)		5.29 abcd
	LSD_{05}	0.24

*Calcium limestone, 300 lbs. P_2O_5, 200 lbs. K_2O, and 25 lbs. Borax per acre were applied in the fall of 1961. The plots were plowed and wheat planted in October, 1961. Alfalfa was planted in the spring of 1962 with a spring oat cover crop. An annual top dressing of 0 + 60 + 180 was made.

TABLE 24--EFFECT OF RATES OF NITROGEN ON YIELDS OF FIVE GRASSES GROWN ON MEXICO SILT LOAM

Treatment	Yields (T/Acre) 5-Year Average				
	Timothy	Brome Grass	Orchard-grass	Fescue	Redtop
1. No N	2.04 b	1.65 c	1.21 c	1.45 c	1.51 b
2. 60 lbs. N	2.90 a	2.69 b	2.05 b	2.53 b	2.46 a
3. 120 lbs. N	3.09 a	3.57 a	2.53 a	2.90 a	2.61 a
LSD_{05}	0.28	0.42	0.31	0.34	0.38

PART V

North Missouri Center

The North Missouri Center was acquired by the University of Missouri in 1955 and several experiments with rotations were established in 1956 with the first yield data being collected in 1956. Two of these studies were a liming experiment composed of a rotation of corn, soybeans, wheat, three years of alfalfa, and a soil test correlation study composed of a rotation of corn, oats, and two years of grass-red clover mixture. These experiments were established on Edina silt loam. These results could be related to the Grundy and related series of soil area 2. The initial soil test values of these experimental sites are given in Table 25.

TABLE 25--INITIAL SOIL TEST VALUES OF EXPERIMENTAL SITES
EDINA SILT LOAM

	OM %	P_2O_5 Lbs.	K Lbs.	Mg Lbs.	Ca Lbs.	Salt pH	Me* H	CEC
Liming Study	3.2	28	190	800	4400	5.0	5.0	19.5
Soil Test Correlation	3.2	23	208	590	2900	5.0	5.0	15.1

*Determined with old buffer solution. The buffer developed in 1965 would have given about twice this quantity of H.

RESULTS AND DISCUSSION

Limestone and Alfalfa

The plots composing this experiment were brought up to phosphorus and potassium soil tests and then the lime treatments were applied. The phosphorus and potassium levels were maintained by applying superphosphate and muriate of potash before corn each time in the rotation. The quantities of these fertilizers were determined from soil tests taken from the plots to be planted to corn. The results are given in Table 25. Yield increases were obtained from both three and six tons per acre limestone applications. Rates greater than six tons per acre did not increase yields. The pH in 1965 of the soil receiving the three and six tons of limestone per acre was 5.6 and 6.0 respectively.

Effect of Nutrient Applications on Yield of Grass-legume Mixture

The objectives of this study were to determine the effects of varying amounts of phosphorus and potassium as well as different carriers of these nutrients on crop yields in a corn, oats, two-year grass-legume mixture, rotation. The results are given in Table 26.

Both phosphorus and potassium were necessary for good yields on this soil. The initial soil test values for these nutrients were quite low, especially phosphorus. The use of phosphorus and potassium in the starter fertilizer for corn and oats supplied some of these nutrients but applications of at least 200 pounds P_2O_5 per acre and 120 pounds K_2O per acre each rotation before corn were effective in increasing yields of hay. There did not appear to be any real differences between either phosphorus or potassium carriers when applied to give equal quantities of the plant nutrient being compared.

TABLE 26--EFFECTS OF LIMESTONE ON YIELDS OF ALFALFA GROWN ON EDINA SILT LOAM IN A CORN, SOYBEAN, WHEAT, THREE YEARS ALFALFA ROTATION

	Yeilds (Tons/Acre)		
Treatments	1st Yr. Alfalfa (11 Yr. Avg.)	2nd Yr. Alfalfa (10 Yr. Avg.)	3rd Yr. Alfalfa (9 Yr. Avg.)
1. No Lime	3.61	4.11	3.98
2. 3 T Ca Lime	3.90	3.95	4.33
3. 6 T Ca Lime	4.13	4.65	4.55
4. 12 T Ca Lime	3.63	4.63	4.56
5. 3 T Mg Lime	4.02	4.68	4.28
6. Calcium Hydrate	3.95	4.56	4.29
7. 12 T Ca Lime one-half plowed down, one-half on top	3.61	4.11	3.98
8. 24 T Ca Lime one-half plowed down, one-half on top	4.18	4.98	4.60

CONCLUSIONS

North Missouri Center

Conclusions from the soil fertility studies at the North Missouri Center are as follows:

1. Six tons of calcium limestone per acre gave optimum yields of alfalfa on this soil. The pH after 10 years on these plots was 6.0.

2. Phosphorus and potassium applications are necessary for good yields of grass-legume mixtures on Edina silt loam with low phosphorus and potassium soil test values. Starter phosphorus and potassium plus 200 pounds P_2O_5 and 120 pounds K_2O every four years produced good yields of hay. It is questionable whether heavier rates would be necessary.

3. There were no appreciable differences between various phosphorus and potassium carriers as related to hay yields in this study.

TABLE 27--EFFECT OF VARIOUS SOIL TREATMENTS ON YIELDS OF TIMOTHY-RED CLOVER HAY GROWN IN A CORN-OATS-2 YR. TIMOTHY-RED CLOVER ROTATION ON EDINA SILT LOAM

Treatments*		Yields (Tons/Acre)	
Starter	Plowdown	1st Yr. Hay 9-Year Avg.	2nd Yr. Hay 8-Year Avg.
1. 16 + 0 + 16		1.94	2.30
2. 16 + 48 + 16		2.37	2.70
3. 16 + 48 + 16	200 lbs. P_2O_5 (20% Super) 120 lbs. K_2O (KCl)	2.60	2.77
4. 16 + 48 + 16	500 lbs. P_2O_5 (20% Super) 120 lbs. K_2O (KCl)	2.65	2.80
5. 16 + 48 + 16	1100 lbs. P_2O_5 (20% Super) 120 lbs. K_2O (KCl)	2.77	2.87
6. 16 + 48 + 16	200 lbs. P_2O_5 (20% Super)	2.48	2.65
7. 16 + 48 + 16	200 lbs. P_2O_5 (20% Super) 240 lbs. K_2O (KCl)	2.71	2.94
8. 16 + 48 + 16	200 lbs. P_2O_5 (20% Super) 120 lbs. K_2O (K_2SO_4)	2.65	2.92
9. 16 + 48 + 16	200 lbs. P_2O_5 (45% Super) 120 lbs. K_2O KCl)	2.73	2.90
10. 16 + 48 + 16	500 lbs. P_2O_5 (Rock Phosphate) 120 lbs. K_2O (KCl) (each 8 yrs.)	2.81	2.90
11. 16 + 48 + 16	500 lbs. P_2O_5 (Rock Phosphate) 120 lbs. K_2O (KCl) (each 8 yrs. in subsoil)	2.82	3.01
12. 16 + 48 + 16	500 lbs. P_2O_5 (Rock Phosphate) 120 lbs. K_2O (KCl) (each 8 yrs. in subsoil)	2.87	3.26

*Six tons/acre limestone were applied to plots receiving treatments 11 and 12, and 1700 lbs. rock phosphate were applied to plots receiving treatment 11 and plowed 12 inches deep. All plots then received 4 Tons/A limestone and other initial treatments. All plots were again plowed. All treatments were put down in April 1956.

Soil tests were made on samples taken from plots planted to corn each year and phosphorus added in quantities to bring tests up to 100 lbs. P_2O_5/A on plots getting treatments 3, 6, 7, 9, 10; to 200 lbs. P_2O_5/A on plots getting treatment 4; and to 400 lbs. P_2O_5/A on plots getting treatment 8.

100 lbs. N/A as ammonium nitrate were plowed down each year before corn.

The starter was applied on corn and oat crops only.

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TABLE 1--COUNTIES AND PORTIONS OF COUNTIES COMPOSING THE MAJOR SOIL AREAS OF MISSOURI

Soil Area				
1	2	3	4	5
Atchison	Worth	Schuyler	3/10 Howard	Cass
Holt	Gentry	Adair	2/3 Cooper	Bates
Nodaway	De Kalb	Macon	2/5 Boone	Vernon
Andrew	Harrison	Randolph	2/5 Moniteau	1/2 Jasper
Buchanan	Daviess	2/5 Howard	1/2 Cole	Johnson
Clinton	Caldwell	3/5 Boone	2/5 Callaway	Henry
Platte	1/2 Ray	3/5 Callaway	1/2 Osage	Pettis
Clay	Mercer	Scotland	1/5 Montgomery	2/5 Benton
Jackson	Grundy	Shelby	9/10 Warren	3/5 Morgan
Lafayette	Livingston	Monroe	1/3 Franklin	2/5 Moniteau
1/2 Ray	1/2 Carroll	Audrain	St. Charles	1/3 Cooper
1/2 Carroll	Putnam	Clark	1/4 Lincoln	
1/4 Chariton	Sullivan	Lewis	2/5 Pike	
Saline	Linn	5/6 Marion	1/3 Ralls	
1/10 Howard	3/4 Chariton	2/3 Ralls	1/6 Marian	
	1/10 Howard	3/5 Pike	1/3 Jefferson	
		3/4 Lincoln	1/3 St. Genevieve	
		1/10 Warren	2/3 Perry	
		Knox	2/3 Cape Girardeau	
		4/5 Montgomery	St. Louis	
Total Area Square Miles 6,848	7,649	9,114	5,641	6,543

Soil Area				
6	7	7	8	9
1/2 Jasper	La Clede	Shannon	1/5 Moniteau	Pemiscot
Newton	Cedar	Phelps	1/2 Cole	Dunklin
Dade	St. Clair	Dent	1/2 Osage	New Madrid
Lawrence	3/5 Benton	Oregon	1/2 Gasconade	Stoddard
Polk	2/5 Morgan	Crawford	2/3 Franklin	1/2 Butler
Greene	Hickory	Washington	2/3 Jefferson	1/8 Ripley
Christian	Camden	Iron	2/3 St. Genevieve	1/5 Bollinger
1/4 Stone	Dallas	Reynolds	1/3 Perry	1/3 Cape Girardeau
	Webster	Madison	St. Francis	Scott
	Wright	Wayne		Mississippi
	Douglas	Carter		
	McDonald	1/2 Butler		
	Barry	7/8 Ripley		
	3/4 Stone			
	Taney			
	Ozark			
	Miller			
	Pulaski			
	Texas			
	Howell			
	Maries			
Total Area Square Miles 4,075		21,930	3,355	4,129