NITROGEN AND PHOSPHORUS FERTILIZATION OF ORDINARY UPLAND BLUESTEM RANGE

by

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INTRODUCTION

Intensive research has been conducted on nitrogen and phosphorus fertilization of tame, cool-season grasses. However, much less work has been done on fertilization of native, warm-season grasses.

In Kansas there are about $3\frac{1}{2}$ million acres of bluestem range made up primarily of warm-season grasses. Kansas farmers and ranchers often have warm-season hay meadows. Considerable interest has been shown by them in the possibility of increasing yield of hay by nitrogen fertilization.

Quality of the forage produced is also of interest in a fertilization program. Fertilization may cause an increase in the protein content of the forage which makes the forage more palatable and nutritious for the animals consuming it. This increased palatability has been used to attract animals to remote parts of the range.

In addition to yield and protein content of the forage, other factors must be considered. Native bluestem range is composed of many species of grasses and forbs. If the favorable species respond to fertilization better than less desirable ones, fertilization might be profitable. If not, fertilization may cause an unwanted shift in the vegetation of the range.

With these facts in mind this study was undertaken at Manhattan, Kansas, to determine the feasibility of fertilization of Flint Hills bluestem range. The effect of nitrogen and phosphorus fertilization on yields of forage, protein content of the most abundant grass, big bluestem (Andropogon gerardi Vitman), and recovery of the vegetation 5 to 9 years after a previous fertilization program were studied.

This study will be carried on in subsequent years to observe possible yield differences and any change that might occur in the botanical composition due to the fertilization treatments.

REVIEW OF LITERATURE

Range fertilization has not been studied so thoroughly as fertilization of tame pastures. Most cases of fertilization of range composed of warm-season grasses have proven to be economically unsound. Relatively few cases can be found where phosphorus and potassium fertilization increase production. Generally, the warm-season grasses respond to nitrogen fertilization to some extent.

In his studies at Manhattan, Kansas, Mader (1956) stated that forage yields of native bluestem range were increased in all cuttings where nitrogen fertilizer had been applied except in some aftermath cuttings. Using rates of 50 and 100 pounds of nitrogen per acre, he found that the second 50-pound increment of nitrogen increased hay yields almost as much as the first, but that potassium and phosphorus were relatively ineffective in increasing forage yields. He found in his experiment that the stand of Kentucky bluegrass (Poa pratensis L.) increased considerably in the plots that received nitrogen. In 1954, after 4 years of fertilization, Kentucky bluegrass made up 87% of the vegetation on the plots receiving 100 pounds of nitrogen plus phosphorus and only 16 to 18% on the check plots. Big bluestem, little bluestem (Andropogon scoparius Michx.), and indiangrass (Sorghastrum nutans (L.) Nash), all decreased under fertilization, the greatest decrease occurring at the highest nitrogen level. He also found that applications of nitrogen significantly increased the crude protein content of the forage, but phosphorus and potassium had no such effect.

These same experimental plots were fertilized annually with 32 pounds of nitrogen per acre which was split into 3 applications, and with one application of 16 pounds of nitrogen per acre. The average yields from 1928 to 1943 showed that the 16-pound rate of nitrogen did not increase forage production. The 32-pound rate of nitrogen produced a yield increase of 665 pounds of air-dry vegetation per acre. The greatest increase came from the application of 3 tons of manure in alternate years. However, the manured plots tended to become more weedy. It was concluded that fertilizers did not appear to have stimulated bluestem grasses sufficiently to be profitable, but manure could be used if it were available (Anderson, 1943).

Aldous (1935), reporting on a 5-year experiment in upland bluestem pastures at Manhattan, Kansas said that 200 pounds of ammonium sulfate per acre applied annually increased the grass yield about 33% and 100 pounds increased it 20%. He also found that grass on fertilized plots had about 20 to 25% more crude protein than that on nonfertilized ones. He got very little response to phosphorus and potassium. The Flint Hills vegetation responds to nitrogen fertilization but it is seldom profitable.

Launchbaugh (1962) fertilized reseeded vegetation at Hays, Kansas, on range sites which had erosion varying from none to severe. He obtained response to nitrogen on both kinds of sites and a response to nitrogen and phosphorus in combination was obtained on sites low in organic matter. Cool-season annual bromes responded more to nitrogen than did the warm season grasses. He could detect increased protein in vegetation from plots receiving nitrogen only during the early growing season in 1959.

Klipple and Retzer (1959) reported that corral manure applied at 10 tons per acre was the most effective treatment in their experiment on central

Great Plains range. Manuring increased the herbage yields 15 to 50% while yields from plots treated with 80 pounds of nitrogen, 100 pounds of phosphorus, and 200 pounds of potassium per acre seldom exceeded those of the untreated plots. Both the manure and phosphorus treatments improved the protein content of blue grama herbage.

In Oklahoma studies Elder and Murphy (1958) reported that under favorable moisture conditions in June, nitrogen fertilization increased yields but was not profitable. No change was noted in botanical composition, but the crude protein level in the forage was increased by fertilization.

Elwell and Daniel (1953), also in Oklahoma, found that switchgrass (*Panicum virgatum* L.) fertilized with 300 pounds of superphosphate and 33 pounds of nitrogen per acre for two successive years produced up to 1800 pounds of additional forage. Almost 60% more beef was produced on fertilized, cleared brushland and 54% more was produced on fertilized, abandoned cropland than on similar unfertilized areas.

In Oklahoma Huffine and Elder (1960) fertilized cleared, unplowed brushland and abandoned cropland that had been allowed to return to native grass over a period of 20 years. Using 300 pounds of superphosphate (0-20-0) in 1952 and 1955 and annual applications of 100 pounds of ammonium nitrate (33-0-0), they found that fertilization increased the weed populations significantly in both types of pastures. The total yield of grass for a 2-year period, 1957 to 1958, was slightly higher from the nonfertilized pastures. Two to 5 times more weeds by weight were produced in the fertilized pastures.

In other work conducted in Oklahoma (anonymous) forage production was increased 35 and 52% by the use of 40 and 80 pounds of nitrogen, respectively. Nitrogen fertilization increased the crude protein content of the forage. The 80 pound application increased the crude protein over the 40 pound treatment which in turn produced forage with a higher protein level than from the plots receiving no nitrogen.

In fertilizing native prairie in Gage county, Nebraska, Conard (1956) obtained an increase in yield of prairie hay as he varied the nitrogen from 0 to 135 pounds per acre. In 1953 and 1954 he increased yield by adding 60 pounds of P_2O_5 per acre. In 1953 he reported crude protein contents ranging from 5.45% in plots receiving no nitrogen to 7.88% in plots receiving 80 pounds of nitrogen per acre. In 1954 he also increased crude protein by the addition of nitrogen. Phosphorus did not change the crude protein content significantly.

In his studies at Lincoln, Nebraska, Williams (1953) stated that ammonium nitrate-treated plots yielded 4.5, 3, and 2 times as much dry matter as the nonfertilized plots in the May, June, and August harvests, respectively. The nitrogen treatments produced significantly higher protein percentages in the May and June cuttings than in late cuttings.

On subirrigated meadows in Nebraska, Brouse and Rhoades (1958) reported significant responses to nitrogen and phosphorus fertilization. A carry-over effect was present on 50 to 75% of the meadows. They stated that application of nitrogen may or may not increase the protein content of subirrigated hay due to the presence or absence of legumes, to soil factors, to growing conditions, and to rate and time of application.

Smika et al. (1963) found that northern Great Plains native grass responded to nitrogen fertilization, but phosphorus applied gave no additional yield even though soil tests indicated that the phosphorus level was low. Crested wheatgrass responded to phosphorus only when applied in combination with nitrogen.

Rauzi and Smika (1963) found in a northern Great Plains experiment that plots receiving nitrogen had more of the mid grasses and less blue grama than other plots. They also said that there was no consistent influence of nitrogen fertilization on water intake.

The effects on native range production from annual applications of 30 and 90 pounds of nitrogen per acre were studied at the Northern Great Plains Field Station by Rogler and Lorenz (1957). Western wheatgrass (Agropyron smithii Rydb.) responded most favorably. Ninety pounds of nitrogen per acre applied annually on a heavily grazed pasture produced an average of 2271 pounds of dry forage per acre compared with 1326 and 748 pounds of forage for the 30-pound and the zero rate respectively. On a moderately grazed pasture the results were similar. The greatest return in pounds of hay per pound of nitrogen was obtained from the 30-pound rate. They reported that the crude protein level was highest in the herbage from the plots receiving 90 pounds of nitrogen per acre.

Lodge (1959) reported a significant increase in yield of northern Great Plains forage with 32 pounds of nitrogen per acre and a highly significant increase with 20 tons of manure per acre in 1952 while in 1951 there was no increase from the fertilizer application. In 1951 increases in crude protein resulted from all of the treatments. In 1952 the percent of crude protein in the forage was not increased except by the addition of manure or 32 pounds of nitrogen per acre.

In Arizona Honnas et al. (1959) reported that the growth response of sideoats grama (Bouteloua curtipendula (Michx.) Torr.), hairy grama (Bouteloua hirsuta Lag.), and blue grama (Bouteloua gracilis (H.B.K.) Lag. x Steud.) were extremely varied when fertilized with 100, 250, and 500 pounds of ammonium phosphate per acre. The date of range readiness was advanced and the length of the green-feed period was increased in hairy grama and blue grama but were unaffected in sideoats grama except for a reduction of the green-feed period under medium and high fertilization. They found that all species in the fertilized areas initiated flowering earlier and remained in flower longer than those in unfertilized areas. Forage production was increased except in hairy grama and sideoats grama fertilized at the medium rate.

Eastern Oregon studies on mountain meadows by Cooper and Sawyer (1955) showed that nitrogen applied at 20, 40, and 60 pounds per acre increased hay yields. An increase on one ton per acre occurred with the 60-pound application. Phosphorus increased hay yields 1/3 of a ton per acre in the year of application and 1/5 of a ton in the year following application. No additional benefits were obtained from fertilizing with phosphorus at rates greater than 40 pounds of P_2O_5 per acre. Both nitrogen and phosphorus fertilization proved to be profitable.

Hall and Altona (1952) reported that nitrogen increased the carrying capacity of South African veld while phosphorus alone did not, although it did improve palatability. The phosphorus had not altered botanical composition after 15 years, but plots receiving 63 pounds of nitrogen per acre annually had very little grass of the original species left after 4 years. In another experiment, veld hay yields were increased 3.6 tons per acre in plots receiving 2000 pounds of ammonium sulfate and 600 pounds of superphosphate per acre annually.

MATERIALS AND METHODS

The experiment was established at Manhattan, Kansas, on an area in Kansas State University pastures that has not been grazed since 1927. The plots are located at the crest of a north-south ridge on a deep Loveland loess soil. A complete description of the soil is given in Table 1. The plots are laid out in a randomized block design and each plot is 20 feet long and 6 feet wide. The experiment is replicated 4 times.

The plots were fertilized from 1951 to 1954 with nitrogen at 0, 50, and 100 pounds per acre, phosphoric anhydride (P_2O_5) at 0 and 100 pounds per acre, and potash (K_2O) at 0 and 50 pounds per acre annually. Three other treatments were included, a single 25-pound application of nitrogen with phosphorus and potassium and two split applications of 25 and 50 pounds of nitrogen in each application with phosphorus and potassium. The results of this experiment including yields, protein content of the hay, and the change in botanical composition were reported by Mader (1956).

No fertilizer was added from 1954 to 1963. In 1963 a new fertilization program was introduced. Soil samples, taken to a depth of 6 inches were tested for pH, percent organic matter, pounds of available phosphorus per acre, and pounds of potassium per acre. These tests revealed significantly more phosphorus on plots that had received phosphorus in the 1951 and 1954 treatments than on plots that had received no phosphorus. The plots were divided into two groups, those that had received phosphorus previously and those that had not. On each group of plots nitrogen at 0, 33, and 67 pounds per acre and phosphoric anhydride at 0 and 45 pounds of P_2O_5 (19.6 pounds of P) per acre were applied in all possible combinations, making a total of 6 treatments for each group.

Nitrogen fertilizer was applied as ammonium nitrate (33.5% nitrogen) and the phosphorus was applied as triple superphosphate (45% available P_2O_5). The fertilizer was spread uniformly over the plots by hand on May 7, 1963.

Forage was harvested July 10 to 18. A random half of each plot was chosen and 2, one ten-thousandths-acre quadrats were randomly selected and

Table 1. Soil Profile Description of Soil on the Experimental Area

This a moderately developed, moderately fine textured, well drained, Reddish Brunizem (Prairie), soil of loessial origin which occurs on the uplands, and on the oldest alluvial terraces in the vicinity of the Kansas river, and its major tributaries, the Republican and the Smoky Hill rivers.

Soil Profile:[1]	_________ Silt Loam. (SW ¼, Sec. 6, T10S, R8E). This soil occurs on the ridge crest, and is on a convex slope of 1%.
A_1 0 - 5"	Dark Grayish brown (dry) to very dark gray (moist) silt loam; Slightly hard, friable; moderate medium and fine granular structure; abrupt lower boundary.
AB 5 -12"	Brown (dry) to dark brown (moist) silty clay loam; very hard, very firm; weak coarse prismatic structure breaking into weak coarse blocky structure; clear lower boundary.
B_{21} 12 -18"	Brown (dry) to dark reddish brown (moist) silty clay; very hard, very firm; weak medium blocky breaking into moderate fine blocky structure; abrupt lower boundary.
B_{22} 18 -32"	Brown (dry) to reddish brown (moist) silty clay; very hard, very firm; weak medium blocky breaking into moderate fine blocky structure; clear lower boundary.
B_3 32 -48"	A mixture of pink and light brown (dry) to brown (moist) silty clay; very hard, firm; massive structure; gradual lower boundary.
C 48 -60"	A mixture of brown and light brown (dry) to brown (moist) silty clay loam; very hard, firm; massive structure. The horizon contains abundant very fine sand grains.
Vegetation:	Natural vegetation consisted of bluestem prairie.
Root Distribution:	Abundant in the A horizon; plentiful to 18 inches, few below. (Water removal indicates that roots penetrate at least 5 feet)[2]
Note:	This soil, when described was completely dry to 3 feet, and very slightly moist below that depth.

Described 9-17-55, by Dr. O.W. Bidwell, Kansas State University, Manhattan, Kansas

[1] Soils of this type in Kansas have not been given an official name at this time.

[2] Modified from O.W. Bidwell's description.

harvested by hand clipping. The vegetation was separated into grasses and forbs. Each component was placed in a separate sack and oven-dry weights were obtained. Total yields were reported because the forbs constituted only a small percentage of the vegetation. The remaining vegetation on the harvested half of the plot was mowed and the hay removed. The other halves of the plots were harvested in like manner September 21 to 28.

A sample of big bluestem was taken from each plot and a nitrogen determination made using the Kjeldahl method. Percent nitrogen was multiplied by 6.25 to approximate crude protein.

Botanical composition of the plots was studied from 1959 to 1963 to observe the vegetation's recovery from the 1951 to 1954 fertilization program. A modified line transect consisting of a one-meter rod 3/16 inches in diameter was inserted into the vegetation and plants touching it were recorded. Six of these meter rods were recorded for each plot.

The soil moisture data used came from the check plots of an adjacent burning experiment which has identical soil and vegetation. These plots were less than 20 yards from the fertilization experiment.

The yield and protein data were subjected to a factorial analysis with the assistance of H.C. Fryer. The other data were subjected to analysis of variance according to methods given by Snedecor. The plant census data were not analyzed statistically. Summaries of the analysis are presented in the appendix.

PRECIPITATION AND TEMPERATURE FOR 1963

The average annual precipitation for Manhattan, Kansas, is 32.00 inches. Nearly 3/4 of it occurs from April through September.

The precipitation for the 1963 growing season was below normal and the temperature was above (Tables 2 and 3). Rainfall was 9.89 inches below normal during the period from May through August. These records of temperature and precipitation are from the Manhattan Agronomy Farm which lies approximately 3/4 mile west of the fertilized plots.

The soil moisture level of this area was above average at the beginning of the 1963 growing season but fell more rapidly than normal when the plants started to grow and remained below normal for the rest of 1963 (Fig. 1).

The temperatures immediately preceding and during the 1963 growing season were much higher than the long time average. Despite the limited amount of rainfall, the plants started growth readily in the spring due to the high temperatures and the stored soil moisture. As long as the soil moisture was adequate, they could absorb the fertilizer. Possibly more response to fertilization might be expected under more desirable climatic conditions.

The vegetation deteriorated after mid-July due to the excessively high temperatures and small amount of rainfall. July and August had 2.83 and 2.17 inches less rainfall than normal, respectively. The average maximum temperature for these months was approximately 13 degrees above normal. July had 9 days and August had 7 days with maximum daily temperatures of 100 degrees or more (Table 3). Yields taken in September were on the average somewhat less than those of the June harvest due to some deterioration of the vegetation.

Table 2. Precipitation record, Kansas State University Agronomy Farm, Manhattan, Kansas, September 1, 1962, to September 30, 1963.

	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
1		.25	.03							.25			.08
2	.01	.28	.02						.05				.28
3		.27						.13					
4	.06						1.07						.01
5	.12				.09		.07		.02				
6		1.40							.05		.02	.10	
7													.02
8	.57												
9	.34												
10	.72							.05		.08		.04	
11					.05		.24				.21		
12					.09					.64	.51		
13							.02		.50		.10	.02	
14													
15	.03								.07	.97	.02		
16			.56					.14	.08	.18			1.61
17									.38		.21	.09	
18												1.06	
19	.10		.05		.09		.16		.08	.21		.67	
20		.16		.01	.01				.23				
21	.15			.14	.03						.02		
22	1.32			.02							.03		
23					.02								
24									.06	.10			
25				.12					.35				.09
26									.04	.10			
27			.57		.03			.49	.02				
28		.29						.01			.02	.03	
29	.93							.65	.13		.01		
30													
31	.21						.48				.02		
Total	4.56	2.65	1.23	.29	.41	.00	2.04	1.47	2.06	2.53	1.17	2.01	2.09
Normal	3.71	2.32	1.24	.94	.86	.96	1.71	2.60	4.37	5.11	4.00	4.18	3.71
Deviation	+.85	+.33	-.01	-.65	-.45	-.96	-.33	-1.13	-2.31	-2.58	-2.83	-2.17	-1.62

Table 3. Maximum daily temperature record, Kansas State University Agronomy Farm, Manhattan, Kansas, April 1, to September 30, 1963.

Month	1931 - 1960 Average	1963	Deviation	No. days 100°F or over
April	55.3	69.5	+14.2	0
May	65.0	75.6	+10.6	0
June	75.4	88.6	+13.2	2
July	80.7	94.0	+13.3	9
August	79.7	92.7	+13.0	7
September	70.6	83.8	+13.2	0

RESULTS AND DISCUSSION

Yield of Forage

Total yields were measured because the grasses present were all of the true prairie type and there is natural variation in bluestem range which causes yield of each species on small plots to be meaningless in some cases. Forbs comprised only 6.4% of the total yield in the July harvest and 5.1% of the total September harvest. There was no apparent difference in the yield of forbs which could be attributed to the 1963 fertilization program.

Nitrogen increased forage yields as shown in Tables 4 and 5. The yield of oven-dry forage increased significantly with each 33-pound increment of nitrogen that was added. The adequate soil moisture and the limited rains permitted the plants to absorb nitrogen early in the growing season which accounted for the yield increase.

Figure 1. Soil moisture in an adjacent area with similar vegetation during the period September 1, 1962 to September 30, 1963.

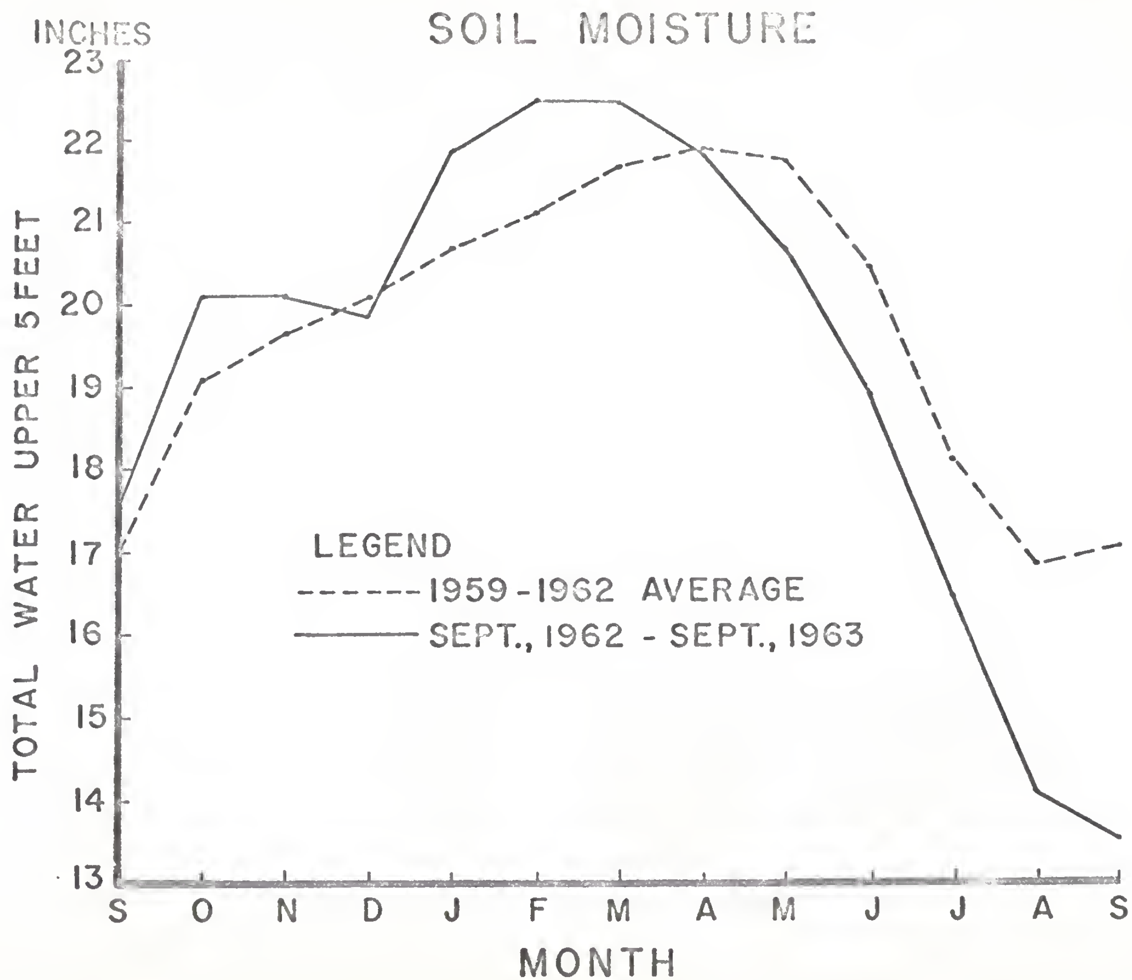
SOIL MOISTURE
INCHES
23
22
21
20
19
18
17
16
15
14
13
TOTAL WATER UPPER 5 FEET
LEGEND
1959-1962 AVERAGE
SEPT., 1962 - SEPT., 1963
S O N D J F M A M J J A S
MONTH

Figure 1

Table 4. Effect of nitrogen levels on yields of hay from two dates of harvest at Manhattan, Kansas, 1963.

Lbs. N/Acre	July Harvest	Sept. Harvest
	lbs./acre	lbs./acre
0	4054	4176
33	4816	4772
67	5529	5074

Table 5. Effect of fertilizer treatments on total forage yield at 2 cuttings at Manhattan, Kansas, 1963.

Treatment, lbs./acre of N	P_2O_5	July Harvest P_r 1/	July Harvest no P_r	July Harvest Av.	Sept. Harvest P_r	Sept. Harvest no P_r	Sept. Harvest Av.
		lbs./A	lbs./A	lbs./A	lbs./A	lbs./A	lbs./A
0	0	4054	4067	4061	3982	4031	4007
0	45	3960	4131	4046	4155	4535	4345
33	0	4516	4697	4607	4411	4598	4505
33	45	5239	4934	5087	5189	4887	5038
67	0	6336	4802	5569	5308	4656	4982
67	45	5574	5404	5489	5772	4560	5166

1/ P_r refers to the presence of residual phosphorus from the 1951 to 1954 fertilization program.

There was no response in yield either to the 45 pounds of phosphoric anhydride (P_2O_5) applied or to the presence of residual phosphorus. Residual phosphorus refers to that detected in plots that had received 100 pounds of P_2O_5 annually from 1951 to 1954 (Table 8).

The statistical analysis indicated that there was a highly significant difference among replications. It was noticed that replication 4 appeared to have less forage present than the other replications.

The interaction between residual phosphorus and linear nitrogen was barely significant at the .05 level. The residual phosphorus appeared to speed up the response of the vegetation to the added increments of nitrogen somewhat and to make the response more linear. The fertilizer effects on the vegetation can be noticed in Figs. 2 through 6.

July Harvest

The yield response to nitrogen in July was nearly a perfectly linear one. The 33-pound nitrogen level increased the yield an average of 762 pounds when compared to the check plots and the 67-pound rate increased the yield an average of 713 pounds over the 33-pound rate of nitrogen.

The highest yields in the July harvest came from the plots that received 67 pounds of nitrogen per acre and had residual phosphorus present. The increase is attributed to the effect of nitrogen. The lowest yields were from the plots receiving no nitrogen.

Figure 2. Vegetative growth on a check plot and one receiving 67 pounds of nitrogen and 45 pounds of phosphoric anhydride (P_2O_5) per acre. Note the color contrast. Notice that there is no difference due to phosphorus. Compare with Fig. 3. Photographed in early July, 1963.

Figure 3. A contrast between a check plot and a plot receiving 67 pounds of nitrogen per acre. Photographed in late July, 1963.

Figure 2

Figure 3

Figure 4. A contrast between a check plot and a plot receiving 33 pounds of nitrogen per acre. Photographed in late July, 1963.

Figure 5. Vegetative growth differences between a plot receiving 33 pounds of nitrogen and 45 pounds of phosphoric anhydride (P_2O_5) and a check plot. There is no difference between this 33-45-0 treatment and the 33-0-0 treatment. Compare with Fig. 4. Photographed in late July, 1963.

Figure 4

Figure 5

Figure 6. A comparison between a plot treated with 33 pounds of nitrogen and one treated with 67 pounds of nitrogen per acre. Photographed in late July, 1963.

Figure 6

September Harvest

The yields of the September harvest were not significantly different from those of the July cutting. There was a 596-pound and a 302-pound difference between the 0 and 33-pound rate of nitrogen, and the 33 and 67-pound rate respectively. The highest yields in this harvest were from plots receiving 67 pounds of nitrogen and 45 pounds of phosphoric anhydride (P_2O_5) per acre, while the lowest yields came from the unfertilized plots. In some treatments the yields were slightly lower due to the deteriorating effect the hot, dry summer of 1963 had on the vegetation. Lodging also occurred on some of the high nitrogen plots resulting in excessive decomposition of the forage which may account for the nonlinear response in this harvest. The forage from the high nitrogen plots apparently deteriorated most since the date and linear response to nitrogen interaction indicated that the rate of increase in yield was less for the September harvest than for the July harvest.

The interaction among date of harvest, applied phosphorus, residual phosphorus, and linear response to nitrogen can be seen by graphing the respective components of the data. Since there were only three levels of nitrogen, making only three points on the graph, exact trends of certain lines were not clear. It was not thought to be useful to interpret this interaction.

The regrowth after the July cutting was not harvested in 1963 because there was very little due to the exceptionally dry summer.

Crude Protein

Since big bluestem was the most abundant grass on the experimental plots it was selected for protein determination. Samples were analyzed for nitrogen by the Kjeldahl method. The values were multiplied by 6.25 in order to express the data as percent crude protein. Big bluestem was found to contain around 5 to 6% crude protein in the July harvest and approximately 3 to 4% in the September one (Tables 6 and 7).

Table 6. The effect of nitrogen fertilizer on crude protein content of big bluestem harvested at Manhattan, Kansas, on two dates in 1963.

lbs. N/Acre	July Harvest	Sept. Harvest
	%	%
0	5.1	3.3
33	5.4	3.7
67	5.8	4.0

Table 7. The effect of fertilization on the crude protein content of big bluestem harvested on two dates at Manhattan, Kansas, in 1963.

Treatment, lbs./acre of N	Treatment, lbs./acre of P_2O_5	July Harvest P_r 1/	July Harvest No P_r	Sept. Harvest P_r	Sept. Harvest No P_r
		%	%	%	%
0	0	5.0	4.9	3.3	3.3
0	45	5.1	5.2	3.2	3.5
33	0	5.3	5.5	3.5	4.0
33	45	5.5	5.3	3.6	3.5
67	0	5.8	5.7	3.7	4.0
67	45	5.6	6.2	3.9	4.3

1/ P_r refers to the presence of residual phosphorus from the 1951 to 1954 fertilization program.

There was a highly significant linear response in protein percentage to the nitrogen fertilizer, however the increase was not large. This increase in crude protein with added increments of nitrogen was present in both the July and September harvests (Table 6). In both harvests the highest levels of protein occurred in big bluestem treated with 67 pounds of nitrogen in combination with 45 pounds of phosphoric anhydride (P_2O_5) per acre (Table 7). However, the phosphorus applied alone had no effect on the level of crude protein.

There was a highly significant difference between the protein levels of big bluestem from the July and the September harvests. There was a general reduction of about 2% in crude protein in the September cutting. The statistical analysis indicated that the big bluestem harvested from plots without residual phosphorus contained significantly more protein than that from plots with residual phosphorus, but the difference is too small to have any practical importance. This indicates that the presence of residual phosphorus does not increase the protein content of big bluestem.

The interaction among applied phosphorus, residual phosphorus, and quadratic response to nitrogen can be seen when the data are graphed but they were not intrepreted because it was thought to be of no value.

Residual Effects of the 1951 to 1954 Fertilization Program

Botanical Composition

The fertilization program conducted on these same plots by Mader (1956) caused a considerable change in the plant population. Kentucky bluegrass increased considerably during fertilization from 1951 to 1954, especially on plots that had received 100 pounds of nitrogen per acre. In 1954 there was as much as 87% Kentucky bluegrass on some of the high-nitrogen plots. The dry years in the mid-fifties caused nearly all of this bluegrass to die leaving open areas. When normal rainfall started again in 1957 forbs filled the bare areas. These were replaced by annual grasses, mostly Japanese brome (Bromus japonicus Thunb.), during the next two years. By 1959 the plots that had received 100 pounds of nitrogen per acre had much annual grass, and the population of forbs was about normal. From 1959 until 1961 the annual grass decreased from 30 to 1.4% of the total plant population (Fig. 7) and also the number per transect decreased similarly. They have remained low to date on all plots. This decrease was also accompanied by an increase in perennial grasses.

On plots that had received 0 and 50 pounds of nitrogen per acre the vegetation had essentially returned to normal by 1959. The annual grasses increased on these plots in 1960 and then virtually disappeared in the following years (Fig. 7).

The increaser grasses consist primarily of Kentucky bluegrass, sideoats grama, tall dropseed (Sporobolus asper (Michx.) Kunth.), and scribner panicum (Panicum scribnerianum Nash.). On the plots fertilized by 100 pounds of nitrogen per acre the percent of these grasses increased rapidly from 1959 to 1960, increased more slowly from 1960 to 1961, and later decreased slowly (Fig. 8). There was a similar change in the increaser grasses on the plots that received 50 pounds of nitrogen per acre in the early fifties, but it was not so great as the change on the high nitrogen plots. The increaser grasses on plots that had received no nitrogen exhibited only normal fluctuations in population during the period of 1959 to 1963.

The decreaser grasses include big bluestem, little bluestem, indiangrass, switchgrass, and prairie junegrass (Koeleria cristata (L.) Pers.). There has been an increase in percentage of the decreaser grasses each year since 1959 in plots that had received 100 pounds of nitrogen per acre in 1951 to 1954. The largest increase was from 1962 to 1963 (Fig. 9). This trend is due mostly to the increase of big bluestem since it is the most abundant grass. This can be noticed by comparing Figs. 9 and 10. The other decreaser grasses are not abundant enough to study separately. The decrease in the 0 and 50-pound plots in 1960 is due primarily to a decrease in little bluestem and indiangrass. The percentage of decreaser grasses was about the same for 1963 as for 1959 in the 0 and 50-pound nitrogen plots, and this was taken to indicate that the vegetation in these treatments had returned to near normal by 1959. Little bluestem is not very abundant on these plots. It did not appear to re-establish itself after the 1951 to 1954 fertilization program during which time it had dropped from 19.9 to 7.5% of the total ground cover.

Forbs were of no significance in the recovery of the plots from 1959 to 1963.

The trends in the grass population of the plots recovering from the nitrogen treatment of 100 pounds per acre fit into a normal pattern. The years of favorable rainfall, 1959 to 1962, caused a decline in annual grasses in favor of the increaser and decreaser grasses. The annuals were nearly eliminated by 1961, and few have been noticed since then. The increaser grasses began to decline after 1961, while the decreaser grasses became more numerous as would be expected in a series of years of good rainfall.

The forage was harvested from the plots in 1961, and at that time there was no significant difference in the yields due to the 1951 to 1954 fertilization program.

Figure 7. The trend of annual grasses on the experimental plots from 1959 to 1963. The rates of nitrogen refers to annual application from 1951 to 1954.

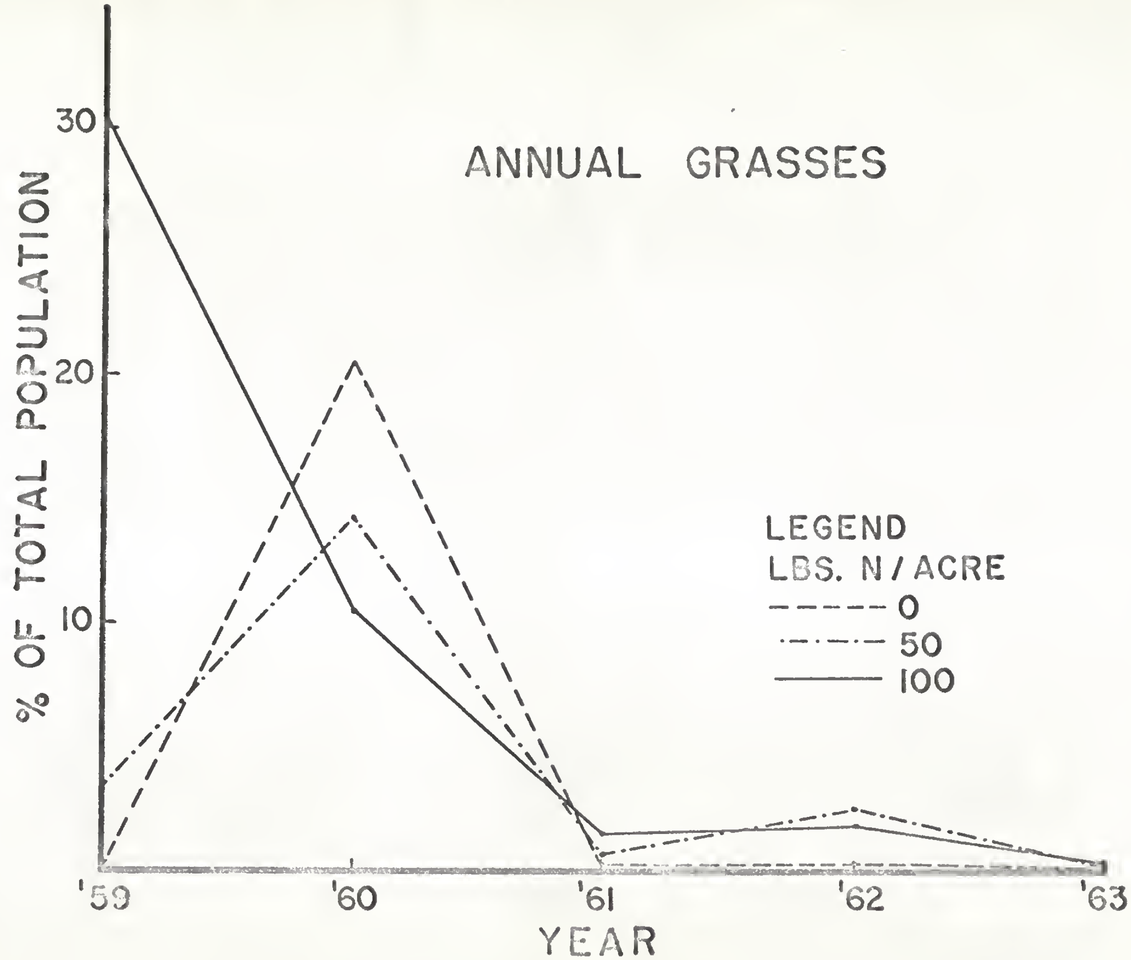
ANNUAL GRASSES
% OF TOTAL POPULATION
30
20
10
LEGEND
LBS. N / ACRE
0
50
100
'59
'60
'61
'62
'63
YEAR

Figure 7

Figure 8. The trend of grass increasers; primarily Kentucky bluegrass, sideoats grama, tall dropseed, and scribner panicum, on the plots from 1959 to 1963. The rates of nitrogen refer to annual applications from 1951 to 1954.

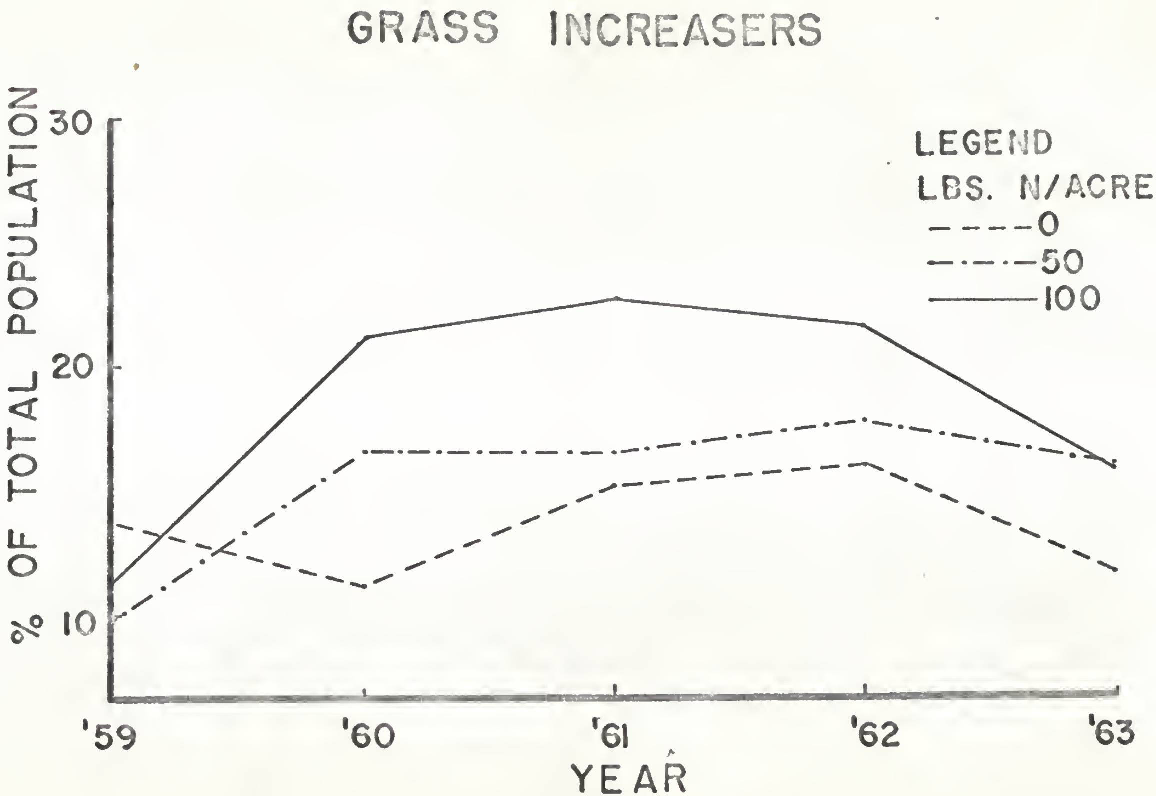
GRASS INCREASERS
% OF TOTAL POPULATION
30
20
10
LEGEND
LBS. N/ACRE
0
50
100
'59
'60
'61
'62
'63
YEAR

Figure 8

Figure 9. The trend of grass decreasers; primarily big bluestem, little bluestem, indiangrass, switchgrass, and prairie junegrass, on the plots from 1959 to 1963. The rates of nitrogen refer to annual applications from 1951 to 1954.

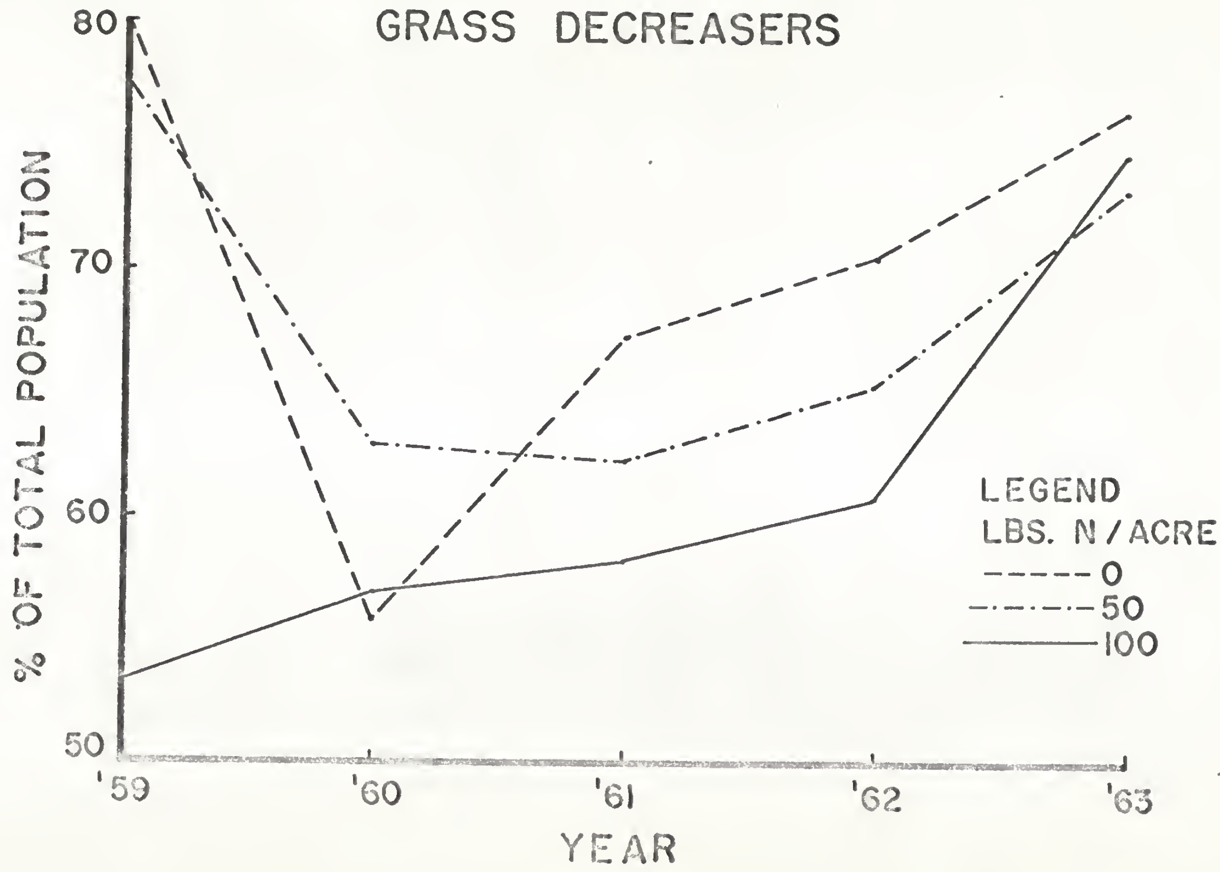
GRASS DECREASERS
80
70
60
50
% OF TOTAL POPULATION
'59
'60
'61
'62
'63
YEAR
LEGEND
LBS. N / ACRE
0
50
100

Figure 9

Figure 10. The trend of big bluestem, the principal decreaser in these plots, from 1959 to 1963. The rates of nitrogen refer to annual applications from 1951 to 1954. Compare this with Fig. 9.

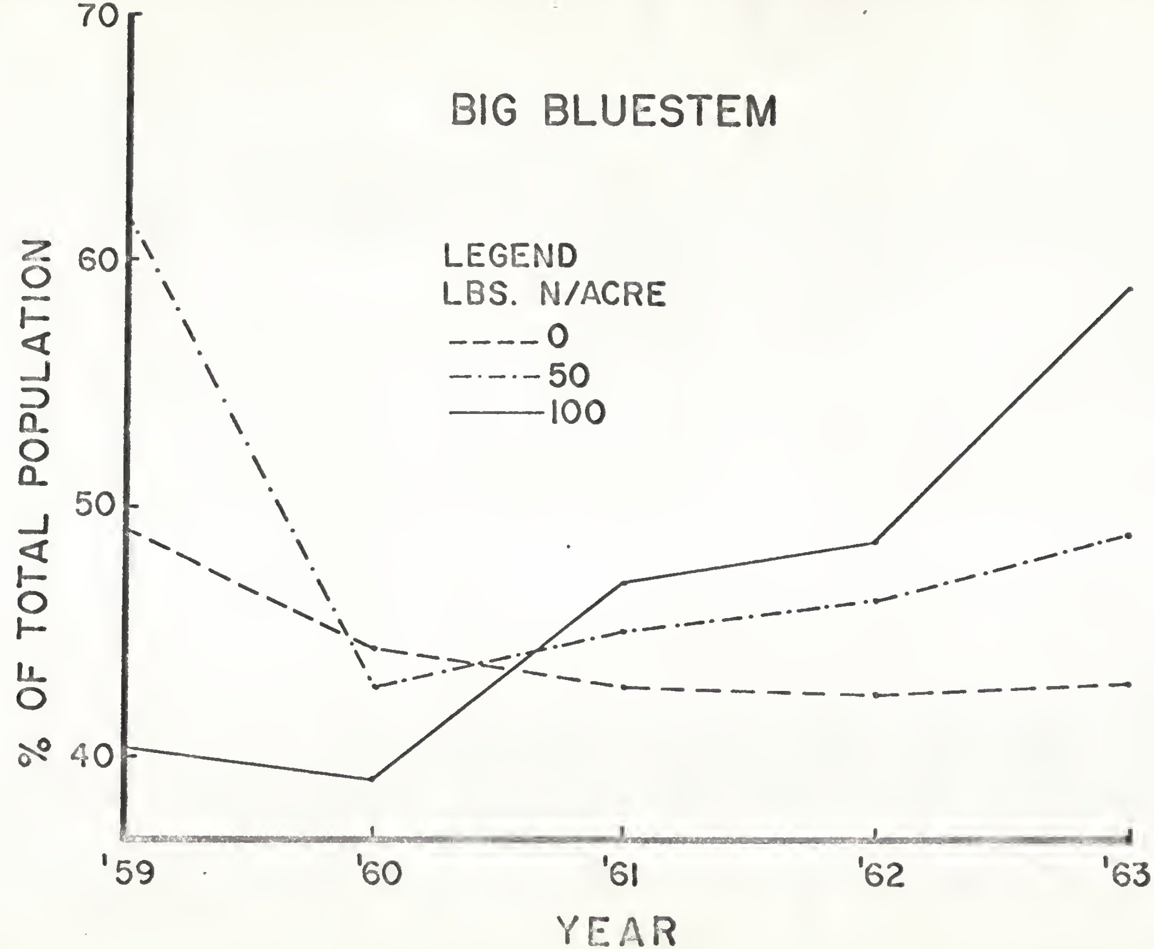
BIG BLUESTEM
LEGEND
LBS. N/ACRE
0
50
100
70
60
50
40
% OF TOTAL POPULATION
'59
'60
'61
'62
'63
YEAR

Figure 10

Soil Analysis

Soil tests indicated that there was a highly significant difference in amount of available phosphorus between plots that had received annual applications of 100 pounds of phosphoric anhydride (P_2O_5) per acre from 1951 to 1954 and those that had received no phosphorus. The plots receiving no phosphorus in the 1951 to 1954 experiment had from 9 to 15 pounds of available phosphorus per acre while those that had received 100 pounds of phosphoric anhydride (P_2O_5) annually for the 4 years had 75 to 105 pounds of available phosphorus per acre (Table 8). This residual phosphorus appeared to have no effect on the present vegetation.

There were no significant differences in the organic matter content of the soil in 1963 due to the fertilization treatments from 1951 to 1954 (Table 8). The values ranged from 3.7 to 4.0%.

The pH tended to be slightly lower in the plots that had received high rates of nitrogen from 1951 to 1954. However, this trend was not consistent because some exceptions can be noticed. The vegetation was not known to be affected by the slight differences in pH. This soil is naturally high in potassium. The potassium in all of the plots was in excess of the amount that could be detected by a standard soil test (550 pounds per acre).

SUMMARY AND CONCLUSIONS

This study was undertaken at Manhattan, Kansas, to determine the effect of fertilization on total yield of forage and crude protein content of a representative grass, big bluestem.

Table 8. Results of soil tests conducted on the experimental plots at Manhattan, Kansas, in April, 1963.

Treatment (1951-1954) lbs./acre of			Available Phosphorus	Organic Matter	pH
N	P_2O_5	K_2O	lbs./acre	%	
0	0	0	11	3.7	6.3
0	0	50	9	4.0	6.4
50	0	0	15	3.8	6.3
50	0	50	14	3.8	6.1
100	0	0	12	3.9	6.3
100	0	50	12	3.9	5.9
0	100	0	105	3.8	6.4
0	100	50	90	3.8	6.3
50	100	0	75	3.7	6.2
25	100	50	84	4.0	6.3
50	100	50	90	3.9	6.2
100	100	0	96	3.9	6.1
100	100	50	86	3.9	6.1
25	100	50+25N 1/	95	3.9	6.3
50	100	50+50N 2/	88	3.8	6.3
	LSD		17.0	NS	0.20

1/ Split application of 50 pounds of nitrogen.

2/ Split application of 100 pounds of nitrogen.

The application of nitrogen increased the forage production. The first 33-pound increment of nitrogen increased the yield 762 pounds and the second increased it 713 pounds per acre in the July harvest, which was definitely linear. In the September harvest there was a 596-pound and a 302-pound increase with the first 33 pounds of nitrogen and the second, respectively. There was no significant yield increase due either to applied or to residual phosphorus. The interaction between residual phosphorus and linear response to nitrogen indicated that the residual phosphorus may have increased the vegetation's response to nitrogen somewhat and made it more linear. There was no significant difference between the yields of the July and September harvests.

There was a small linear increase in crude protein in big bluestem due to the nitrogen that was applied. Crude protein for the July harvest ranged from 5.1% in the check plots to 5.8% in the plots that received 67 pounds of nitrogen per acre. In September the crude protein trend was similar, ranging from 3.3 to 4.0%, about 2% less than in July. The 45 pounds of applied phosphoric anhydride (P_2O_5) or the presence of residual phosphorus did not increase the crude protein content of big bluestem.

The only significant residual effect that remained in 1963 from the 1951 to 1954 fertilization program was the presence of more phosphorus in plots that had received 100 pounds of P_2O_5 annually in those 4 years than in plots that had received no phosphorus. Available phosphorus averaged 90 pounds per acre on plots that had received phosphorus from 1951 to 1954 and 12 pounds per acre on plots that had received no phosphorus. There was a trend toward slightly lower pH in plots that had received nitrogen in the prior treatment.

Large numbers of annual grasses were present in 1959 on plots that had received 100 pounds of nitrogen per acre annually from 1951 to 1954 but they disappeared in 2 years and by 1963 the vegetation was similar on all of the plots. The vegetation on the plots that had received 50 pounds of nitrogen in the prior fertilization program had essentially returned to normal by 1959.

Yields taken in 1961 indicated that the 1951 to 1954 treatment no longer had any effect on yield.

This experiment showed that the production of the native bluestem forage can be increased by nitrogen fertilization. However, the added return seldom exceeds the cost of the nitrogen. Crude protein in big bluestem was increased slightly but not enough to be of much practical importance. Possibly more response might be obtained in years of less climatic extremes. Botanical composition will need to be observed in the subsequent years to see if an undesirable shift in vegetation will again occur as it did from 1951 to 1954.

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APPENDIX

Table 1. Summary of the factorial analysis for yield of forage and crude protein content of big bluestem in 1963.

Source of Variation	D/F	Yield of Forage MS	Crude protein in Big Bluestem MS
Total	95		
Subtotal	47		
Replications	3	84,263.2**	0.037
Treatment	11		
P_a	1	11,440.7	0.175
P_r	1	14,065.0	0.618*
N_1	1	186,300.1**	7.910**
N_q	1	1,794.6	0.019
P_aP_r	1	135.4	0.008
P_aN_1	1	395.0	0.045
P_aN_q	1	7,044.6	0.359
P_rN_1	1	36,147.5*	0.098
P_rN_q	1	4,228.1	0.028
$P_aP_rN_1$	1	206.6	0.026
$P_aP_rN_q$	1	7,239.8	0.788*
Error A	33	8,600.7	0.132
Date	1	3,650.6	75.437**
DP_a	1	4,961.3	0.011
DP_r	1	24.1	0.285
DN_1	1	22,102.5*	0.138
DN_q	1	731.5	0.013
DP_aP_r	1	8,480.1	0.200
DP_aN_1	1	132.0	0.113
DP_aN_q	1	1,433.8	0.088
DP_rN_1	1	675.3	0.003
DP_rN_q	1	6.5	0.013
$DP_aP_rN_1$	1	18,192.8*	0.263
$DP_aP_rN_q$	1	4,200.3	0.005
Error B	36	4,122.7	0.128

P_a = 45 lbs. P_2O_5 applied in 1963
P_r = residual phosphorous
N_1 = linear response to nitrogen
N_q = quadratic response to nitrogen
D = date of harvest

* α = .05
** α = .01

Table 2. Summary of the analysis of variance for residual effects of the 1951 to 1954 fertilization program.

Source of Variation	D/F	pH MS	Organic Matter MS	Residual Phosphorus MS
Total	59			
Replications	3	0.07	0.17*	252
Treatment	14	0.07*	0.04	6400**
Error	42	0.02	0.05	142

* α = .05

** α = .01

NITROGEN AND PHOSPHORUS FERTILIZATION
OF ORDINARY UPLAND BLUESTEM RANGE

by

LOWELL EDWARD MOSER

B. S., Ohio State University, 1962

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These range fertilization trials were initiated to study the response of true prairie vegetation to nitrogen and phosphorus fertilizer. Total yield of forage, crude protein content of big bluestem, and the residual effects of a previous fertilization program were studied.

Zero, 33, and 67 pounds of nitrogen and 0 and 45 pounds of phosphoric anhydride (P_2O_5) per acre were used separately and in combination. The experiment was designed as a factorial and was conducted on ungrazed plots that had a previous fertilization program from 1951 to 1954.

The plots were split and a random half was cut in July. The other half was harvested in September. Forage was harvested by hand-clipping 2 one ten-thousandths acre quadrats in each half of the plot. The yields were expressed as pounds of oven-dry forage per acre. A sample of big bluestem was taken from each plot at both harvests and analyzed for nitrogen using the Kjeldahl method. Values were multiplied by 6.25 to approximate crude protein.

Botanical composition was studied from 1959 to 1963 to observe the recovery from the 1951 to 1954 fertilization program. Plants that touched a 3/16-inch metal rod one meter long were recorded. Soil tests were conducted to see if there remained any residual effects of the prior treatment.

There was a significant increase in yield in response to the increments of nitrogen applied. The first 33-pound increment of nitrogen per acre increased the oven-dry weight of forage 762 pounds per acre and the second one increased the yield 713 pounds in the July harvest. In the September harvest the yield was increased 596 and 302 pounds per acre by the first and second increments of nitrogen, respectively. The phosphorus that was applied and the residual phosphorus present had no direct effect on yield.

The application of nitrogen produced a small linear increase in the percentage of crude protein in big bluestem. Crude protein in the July harvest ranged from 5.1% in the check plots to 5.8% in plots that received 67 pounds of nitrogen per acre. Protein content of the big bluestem harvested in September averaged 3.3 to 4.0% for the 0 and 67-pound nitrogen plots, respectively, approximately 2% less than in July. The applied phosphorus or the residual phosphorus present did not increase the crude protein content of big bluestem.

Increased pounds of available phosphorus per acre was the only residual effect of the 1951 to 1954 fertilization program that could be detected in 1963. There was an average of 90 pounds of available phosphorus on plots that had received 100 pounds of phosphoric anhydride (P_2O_5) annually from 1951 to 1954 and an average of 12 pounds on those plots that had received no phosphorus. There was a trend toward a slightly lower pH on plots that had received nitrogen in the prior fertilization program.

There was a large amount of annual grasses in 1959 on the plots that had received 100 pounds of nitrogen per acre previously. In 2 years the annual grasses had nearly disappeared, and the vegetation was similar on all plots by 1963. Botanical composition will have to be studied in subsequent years to see if an undesirable shift in the vegetation will occur.

Production of native bluestem range can be increased by nitrogen fertilization, but value of the product seldom exceeds the cost of fertilization.