The Influence of Nitrogen and Phosphorus Ferilization on Nutrient Status and Profitability of Bromegrass on Ida Soils

I. Effect on Yields and Economics of Use

by W. C. Moldenhauer, G. V. Holmberg, J. T. Pesek and L. C. Dumenil

II. Effect on Chemical Composition of Bromegrass

by J. J. Hanway and W. C. Moldenhauer

Department of Agronomy
and
Agricultural Research Service
and Soil Conservation Service
United States Department of Agriculture
cooperating

AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology

Research Bulletin 532 . . . January 1965 . . . Ames, Iowa

CONTENTS

The Influence of Nitrogen and Phosphorus Fertilization on Nutrient Status and Profitability of Bromegrass on Ida Soils

This study was undertaken to determine the profitability and the feasibility of fertilizing bromegrass for grazing in the Monona-Ida-Hamburg soil association area. This area is well adapted to growing forage crops. Because of the high content of calcium and potassium, alfalfa grows well if phosphorus is applied. Bromegrass is able in some way to get nitrogen from alfalfa, and the two crops grow well together. The bloat danger in pasturing alfalfa or bromegrass-alfalfa mixtures, however, is well known to cattlemen in the area. Many believe the cost of nitrogen fertilizer to maintain productivity of bromegrass pastures is less than the cost of losses from bloat on bromegrass-alfalfa pastures.

The *profitability* of fertilizing bromegrass stands is examined in *Part I* of the study. The *feasibility* is examined in *Part II*. In Part I, returns at three levels of nitrogen cost and beef price and at three conversion ratios of forage to beef are calculated on the basis of experimental yields.

The effects of fertilizer application on the chemical composition of the bromegrass are presented in Part II. From the nutrient uptake studies, estimates are made of the lengths of time that nitrogen and phosphorus applications will remain effective. These studies also indicate the interrelationships among the three elements – nitrogen, phosphorus and potassium – and why addition of both nitrogen and phosphorus is more effective than either alone. The levels of nitrate nitrogen in the forage from the different cuttings are reported along with a discussion of levels considered harmful or dangerous to livestock.

This study doesn't give the final answer to bromegrass fertilization because the effects on livestock of nitrate nitrogen under a wide range of levels and conditions are not known, and N and P effects over a range of weather and soil conditions need more study. This study does, however, add some facts for consideration when decisions and recommendations are being made.

Part I. Effect on Yields and Economics of Use[1]

by W. C. Moldenhauer, G. V. Holmberg, J. T. Pesek and L. C. Dumenil

With the advent of watershed programs and especially of basin terraces in western Iowa, much land formerly cultivated has been retired. Basin terraces are built to keep runoff water from slopes of 20 percent or more from running over cultivated land with slopes of less than 20 percent. This presents a problem of what to do with the land above the basin terraces; cultivating this land would lead to excessive erosion, and the terraces would soon fill with silt.

Many areas above the basin terraces are in established stands of bromegrass or can easily be seeded to bromegrass. In general, the areas are extremely low in fertility, and the bromegrass forage yields are low and of poor quality. To assure a protective cover for control of soil and water losses, it is important to know if these areas can be fertilized profitably for forage production.

This study was designed to determine the response of bromegrass to applications of N and P in various combinations. The results were then used to calculate the most profitable rates and combinations of N and P with respect to land or fertilizer investment at varying prices of fertilizer and forage and at different forage-to-beef conversion ratios. Composition studies reported in Part II were made to determine nutrient balance in forage, to determine nitrate N content of forage resulting from various amounts of N applied and to determine the influence of uptake of N and P on each other and on uptake of K.

PROCEDURE

The fertilizer treatments in this experiment were selected to satisfy a modification of a general composite design described by Hader *et al.* (1). Two var-

[1]Project 1064 of the Iowa Agricultural and Home Economics Experiment Station in cooperation with the Agricultural Research Service and Soil Conservaton Service of the United States Department of Agriculture.

W. C. MOLDENHAUER is research soil scientist, Corn Belt Branch, Soil and Water Conservation Research Division, Agricultural Research Service, United States Department of Agriculture, and associate professor of soils, Iowa State University. G. V. HOLMBERG now is assistant state soil conservationist for Minnesota, Soil Conservation Service, United States Department of Agriculture. J. T. PESEK is professor and head, Department of Agronomy, Iowa State University. L. C. DUMENIL is associate professor of soils, Iowa State University.

iables, N and P, each were used at five levels. The coded spatial arrangement of the 13 treatment combinations is shown in fig. 1.

The applied treatments are listed in table 1. These were randomized within each site and applied on six different Ida silt loam sites in the Monona-Ida-Hamburg soil association area. Approximate location of the sites is shown in fig. 2.

Table 1. Pounds of N and P applied per acre.

Treatment	N	P	(P_2O_5)	Treatment	N	P	(P_2O_5)
1.	0	0		8.	200	176	(400)
2.	0	88	(200)	9.	300	44	(100)
3.	0	176	(400)	10.	300	132	(300)
4.	100	44	(100)	11.	400	0	
5.	100	132	(300)	12.	400	88	(200)
6.	200	0		13.	400	176	(400)
7.	200	88	(200)				

The design used was selected to reduce the plots to a practical number and still obtain the information necessary for obtaining a response surface based on five levels of each variable. Also, use of this design allowed the experiment to be carried out on several sites over a relatively large area with a limited number of plots. This permitted sampling of a range of conditions within the soil type.

The first fertilizer applications were made in April 1959. In April 1960, the plots were split, and all nitrogen treatments were reapplied to half of each plot. Yield measurements from the other half of each plot were taken to determine response to residual fertilizer from the 1959 treatments. Oven-dry yields and clipping dates are given in tables A-1 through A-6 of Appendix A. The first cutting was at the late-boot stage wherever possible, and subsequent cuttings were at 40-day intervals. An area of 100 sq. ft. was sampled for yield in 1959, and a 10-pound subsample was taken for a moisture determination. When less than 10 pounds was harvested, the entire sample was taken. In 1960, a 60-square-foot area was harvested, and a subsample was taken for moisture determination and chemical analysis. Yield results used in obtaining the response equations were the 1959 results plus 1960 yields from the refertilized plots (fig. 3 and last column in tables A-1 through A-6 of Appendix A). Multiple regressions of yield on quadratic functions of N and P, plus an interaction term, were calculated from data for each site.

After the forage-yield equations were determined, the fertilizer rates at which maximum net returns would be realized were calculated by setting the first partial derivative of each equation, with respect to each N and P, equal to the ratio of the cost of N (100 pounds) or P (44 pounds) to the value of a unit of forage necessary to produce 100 pounds of beef. The equations were solved simultaneously, and the results specified amounts of N and P to be applied for maximum net return at various beef prices and costs of N and at different conversion rates of forage to beef. Beef prices assigned were 20, 25 and 30 cents per pound; N was valued at 9, 12 and 15

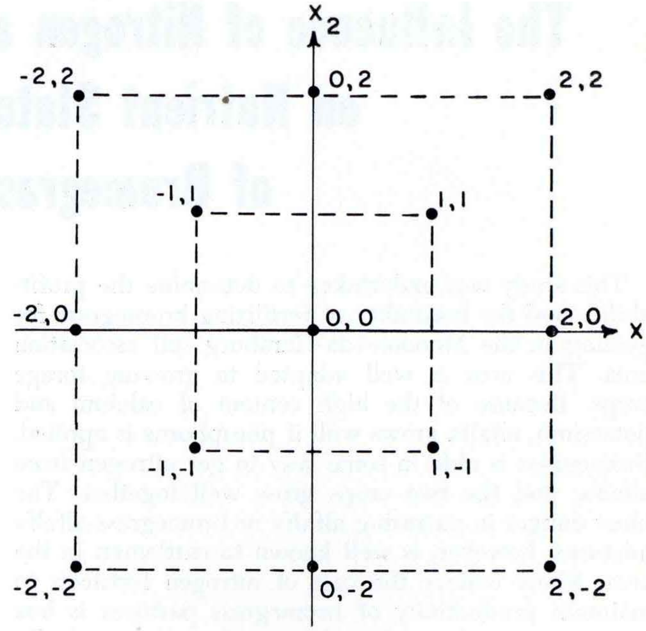

Fig. 1. Coded spatial arrangement of N and P treatment combinations where X_1 represents N and X_2 represents P.

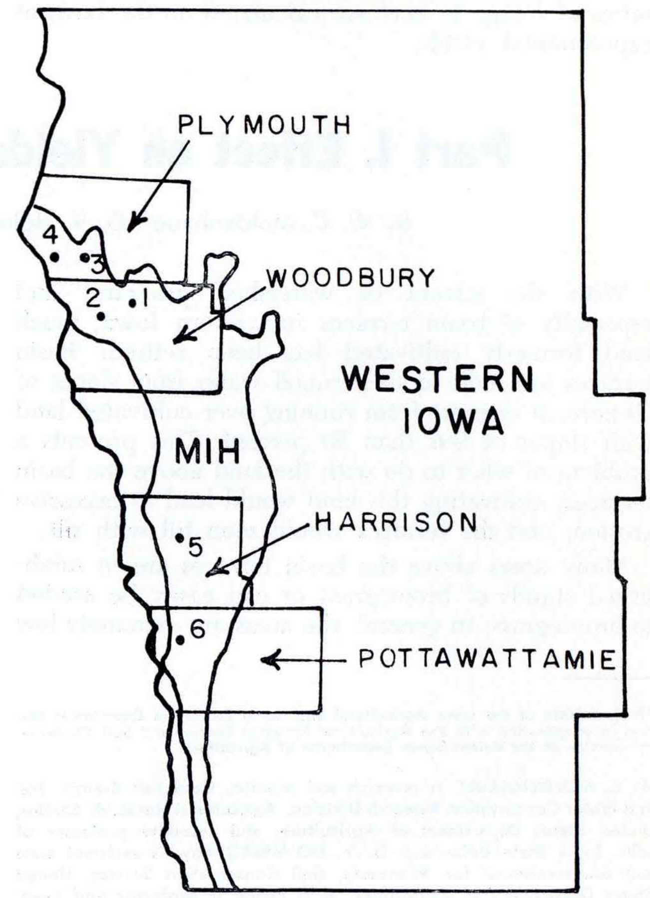

Fig. 2. Experimental sites in the Monona-Ida-Hamburg soil association area.

cents per pound. The value of P was set at 20.6 cents per pound, equivalent to P_2O_5 at 9 cents per pound; the conversion ratio of clippings to beef was varied, and assumed values of 15, 20 and 25 were used to represent a range of management skills in converting forage to beef. Applied P was assumed effective for an average of 5 years, and annual cost of P fertilizer is calculated as one-fifth of the total cost of applied P.

SOILS

Experimental work for this study was done on Ida soils in the Monona-Ida-Hamburg soil association area (6). This area is rolling to hilly, and most of the soils are formed from a thick mantle of medium-textured loess. The area is in western Iowa (fig. 2). The Monona silt loam soil occurs on the gentle ridges and moderately steep side slopes. The Ida silt or silt loam soil occurs on the steep side slopes and is grayish-brown, calcareous and commonly quite deficient in P and N. The Hamburg silt soil occurs on very steep cat-step bluffs near the Missouri River bottomlands and is not suited for row-crop cultivation.

Each of the six experimental sites selected for this study was on Ida soil. All sites had been planted to corn at times in the past and had been in a semi-permanent (5 years or longer) stand of bromegrass at the time of this study.

All sites were on slopes greater than 20 percent and had been severely eroded. The results of soil tests of the surface 6-inch layer of each site are given in table 2.

Nitrifiable N was determined by mixing 10 gms. of soil with vermiculite, leaching with 60 ml. of

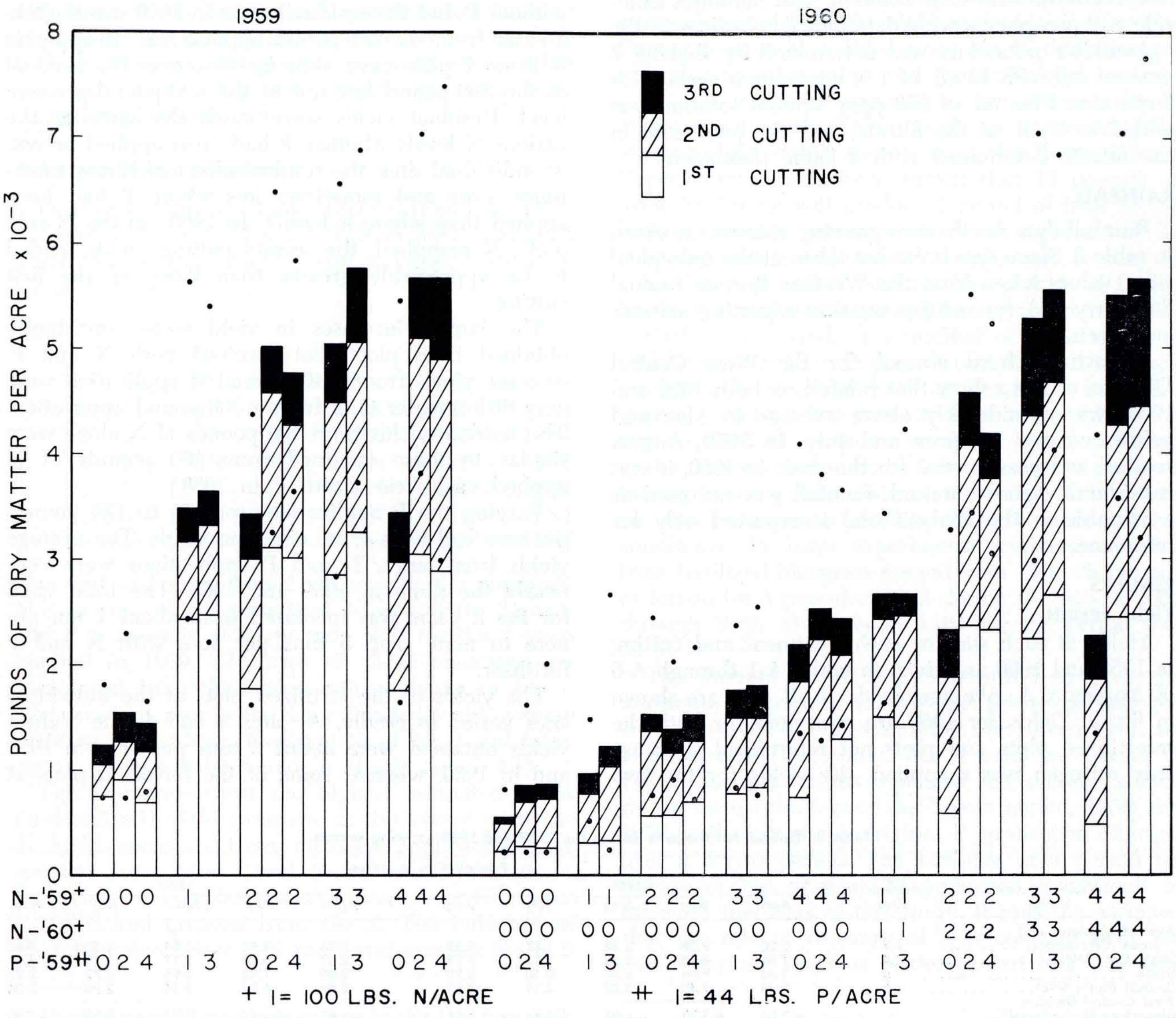

Fig. 3. Average dry-matter weights for various treatments and cuttings in 1959 and 1960 at all sites. (Dots show range of value for totals of all cuttings at all sites.)

Table 2. Soil test results on Ida soil from the six experimental bromegrass fertilization sites.

Site	Nitrifiable nitrogen[a] Parts per 2 million	Nitrifiable nitrogen[a] Fertility level	Available phosphorus[a] Parts per 2 million	Available phosphorus[a] Fertility level	Available potassium[a] Parts per 2 million	Available potassium[a] Fertility level
1	68	low[b]	0.75	very low[b]	400	high[b]
2	64	low	0.50	very low	252	high
3	62	low	1.00	very low	360	high
4	68	low	0.50	very low	344	high
5	46	very low	1.50	very low	223	high
6	68	low	0.50	very low	400	high

[a]N, P and K were all determined on air-dried samples.
[b]Level as defined by the Iowa State University Soil Testing Laboratory.

distilled water, incubating the mixture for 2 weeks at 35° C and releaching as before. An aliquot of the second leachate was evaporated to dryness and treated with phenoldisulfonic acid and ammonium hydroxide, and the nitrate N was determined colorimetrically.

The available P was determined by shaking 1.5 gms. of soil with 10.5 ml. of a solution 0.03 N in ammonium fluoride and 0.025 N in hydrochloric acid for 5 minutes. The filtrate was treated with an ammonium molybdate-sulfuric acid solution, and stannous chloride and phosphorus were determined colorimetrically.

Available potassium was determined by shaking 2 gms. of soil with 10 ml. of 1 N ammonium acetate for 5 minutes. Five ml. of 200 ppm. lithium solution was added to 5 ml. of the filtrate, and the potassium in the filtrate determined with a flame photometer.

RAINFALL

Rainfall data for the two growing seasons are given in table 3. Since data were not taken at the individual sites, values taken from the Weather Bureau Annual Summary (7) for nearby weather reporting stations are given.

Departures from normal for the West Central Division of Iowa show that rainfall, in both 1959 and 1960, was considerably above average in May and below average for June and July. In 1959, August rainfall was near normal for the area; in 1960, it was considerably above normal. Rainfall was not used as a variable in the analysis and is reported only for reference.

RESULTS

Yield results

Yields at each site for each treatment and cutting in 1959 and 1960 are given in tables A-1 through A-6 of Appendix A. Average yields of all sites are shown in fig. 3. Yields for 1960 are presented for both the refertilized plots and plots not refertilized. Because only nitrogen was reapplied, the yields for the two subplots of plots receiving no nitrogen (treatments 1, 2 and 3) are the same.

Yields from plots that received no fertilizer were lower in 1960 than in 1959. The total yield of three cuttings in 1959 varied from 740 to 1,760 and averaged 1,150 pounds per acre, whereas, in 1960, the total yield varied from 220 to 800 and averaged 530 pounds per acre. Lower yields in 1960 probably resulted from less favorable moisture conditions in 1960 than in 1959.

Applications of P alone gave small increases in yield at sites 1 and 2 in both years but had little effect at the other sites; thus, the average yield increases due to P alone were very small.

Applications of N alone gave yield increases at all sites in both years, but increases were never as great as where N and P were applied together. Two-hundred pounds of N per acre without P in 1959 gave essentially the same yield as did 400 pounds of N without P, but the residual effect in 1960 was slightly greater from the 400-pound applications. Reapplying N to no P plots gave some increase over the residual at the 200-pound but not at the 400-pound-per-acre level. Residual yields were much the same at the various N levels whether P had been applied or not. At individual sites, the residual effect of N was sometimes more and sometimes less where P had been applied than where it hadn't. In 1960, on the N-only plots, N reapplied, the second cutting yields tended to be appreciably greater than those of the first cutting.

The largest increases in yield were consistently obtained from plots that received both N and P. Average yields from a 400-pound N application were very little greater than from a 300-pound application. The residual yields from 400 pounds of N alone were similar to those obtained from 100 pounds of N applied each year (with P in 1959).

Varying the P application from 44 to 176 pounds per acre had little or no effect on yields. The average yields from larger N and P applications were very nearly the same in 1959 and 1960. The total yield for the 2 years was increased from about 1 ton per acre to more than 5 tons per acre with N and P fertilizer.

The yields of the fertilized plots at the individual sites varied markedly. At sites 3 and 4, the highest yields obtained were about 2 tons per acre in 1959 and in 1960, whereas some of the fertilized plots at

Table 3. Rainfall for the area during the 1959 and 1960 growing season.

Weather Bureau Station	Applicable to sites	1959 April	1959 May	1959 June	1959 July	1959 Aug.	1960 April	1960 May	1960 June	1960 July	1960 Aug.
		Precipitation in inches									
Ave. of Mapleton and Sioux City airport	1,2	2.20	9.08	3.98	1.87	2.95	2.33	4.91	3.04	2.50	5.65
Sioux City 8N[a]	3,4	1.68	8.95	1.52	1.63	3.94	2.67	6.18	2.17	1.70	7.84
Logan	5	3.42	9.06	6.57	0.50	3.30	2.00	7.35	3.96	2.72	8.08
Council Bluffs 6NE[a]	6	2.63	9.49	3.87	4.21	8.97	2.04	6.81	5.16	2.93	9.06
West Central Division (departure from normal)		+0.04	+5.30	−1.03	−2 56	−0.68	−0.55	+2.58	−1.37	−0.78	+2.02

[a]8N=8 miles north of the city; 6NE=6 miles northeast of the city.

site 2 yielded 3.5 tons or more in 1959. Yields from site 1 were similar to those from site 5 in 1960. Thus, the total yield of the heavily fertilized plots for both years varied from about 4 tons to about 7 tons per acre at the different sites.

Yields from the third cutting were low in both years despite above-average rainfall in August 1960. This shows that bromegrass, like all cool-season grasses, makes most of its growth in April, May and June and makes very little after early July, even though heavily fertilized.

The relative effectiveness of a given quantity of nitrogen applied at one time or split (half applied at each of two different times) can be evaluated by comparing yields when 400 pounds per acre of N were applied in 1959 and when this amount was applied in 200-pound-per-acre applications in both 1959 and 1960. When yields from the next to the last column in tables A-1 through A-6 of Appendix A are compared with those in the last column (summarized in table 4), it is evident that yields were greater at sites 1, 2, 4, 5 and 6 when 200 pounds per acre were added each year than when 400 pounds per acre were applied the first year only.

Yield prediction equations

Yield prediction equations obtained from total 1959-60 yields (plots refertilized with N in 1960) and from which the points on the response curve are calculated, are as follows:[2]

Site

1. $\hat{Y}=0.36+2.09N+0.99P-0.27N^2-0.22P^2+0.11NP$
2. $\hat{Y}=1.24+1.64N+1.52P-0.31N^2-0.37P^2+0.22NP$
3. $\hat{Y}=0.27+1.59N+1.00P-0.28N^2-0.23P^2+0.13NP$
4. $\hat{Y}=0.37+1.52N+0.68P-0.30N^2-0.18P^2+0.12NP$
5. $\hat{Y}=0.59+1.95N+0.74P-0.30N^2-0.19P^2+0.18NP$
6. $\hat{Y}=0.63+1.85N+0.79P-0.31N^2-0.18P^2+0.12NP$

Av. $\hat{Y}=0.58+1.77N+0.95P-0.29N^2-0.23P^2+0.15NP$

One unit of $\hat{Y}$ represents 1 ton of oven-dry clippings; N is in units of 200 pounds of N each of the 2 years, and P is in units of 44 pounds of P for the 2 years applied in 1959. The axes of these equations are transposed from the coded values shown in fig. 1. The constant represents the estimated yield without addition of fertilizer. Explanation of N, P and interaction terms can be found in Heady, et al. (3).

The equations show the highest estimated check (unfertilized) yield from site 2; the lowest from site 3. Yield increases from nitrogen application were greatest from sites 1 and 5 and least from site 4. Increases from application of P were least from sites 4 and 5 and greatest from site 2. The influence of the interaction between N and P was greatest at site 2.

[2]The b values for the NP terms in the equations for sites 4 and 6 are significant at the 5-percent level; all other b values are significant at the 1-percent level.

Table 4. Bromegrass yields in tons per acre when 400 pounds of N per acre were applied in 1959 and when 200 pounds per acre were applied in 1959 and again in 1960. (Averaged over 88 and 176 pounds of P applied in 1959 only.)

Site	200 lbs. N each year	400 lbs. N
1	4.92[a]	4.42
2	4.72	5.16
3	4.00	3.73
4	3.50	2.81
5	4.69	3.42
6	4.83	3.74
Av.	4.44	3.88

[a]Yields are total for 1959-60 in tons per acre.

The equation for average $\hat{Y}$ was obtained by using the average of the six site values for each treatment. This equation shows that the yield increase per unit of N was slightly less than twice the increase per unit of P. There was a slight yield increase due to the interaction of N and P.

Optimum fertilizer application for greatest returns

Optimum N and P rates and net returns per acre were calculated from the yield response equations for three prices of N, a fixed price for P, three forage-to-beef conversion ratios and three prices of beef.

All net return determinations are given at three management levels. These levels are represented by forage-to-beef ratios. Results from the Western Iowa Experimental Farm have shown that 15 pounds of oven-dry forage will produce 1 pound of beef at the highest possible management level represented by chopping forage with a field chopper and feeding in a feedlot. A pound of beef for 16.3 pounds of forage has been found under grazing in one experiment (5).

Harlan (2) found, in a number of experiments in Oklahoma, that 10 to 12 pounds of native range forage produced 1 pound of beef on yearlings. In actual grazing practice, however, at least twice this much was required to produce a pound of beef in addition to the reserves that must be left ungrazed to preserve the vigor and productivity of the range. This means an actual conversion of 20 or 25 to 1 under grazing conditions. In Iowa experiments, conversion ratios from fertilized bluegrass ranged from 16 to 35 pounds of forage for 1 pound of beef during the period 1956 through 1963. The average ratio for the period was 22 to 1.[3]

The amount of N and P required to give the maximum net profit at various beef prices and nitrogen costs are given in tables 5 and 6. The price of P is set at 20.62 cents per pound (or 9 cents per pound of P_2O_5). The net returns represent the average annual return from results over the 2-year period, 1959 and 1960, with cost of the original P application charged over a 5-year period. The estimate of a period for release of the original P application is difficult to make on the basis of this study. It must be assumed that the rate of recovery of P is constant over the entire period. There is evidence that this was true

[3]Annual Progress Report, Shelby-Grundy Experimental Farm. Iowa Agr. and Home Econ. Exp. Sta. and Coop Ext. Serv., OEF 63-2. 1963. (Mimeo.)

Table 5. Optimum nitrogen and phosphorus requirements, fertilizer cost, yields and maximum net annual returns at three conversion ratios of forage to beef.

Site	Beef price per pound	Annual application of nitrogen required (lbs./acre) at per lb. cost of:			Application of phosphorus (P) required (lbs./acre) at N cost of:			Biennial yield above check (tons/acre) at N cost of:			Total fertilizer cost ($) for 2 years at N cost of:			Net annual return ($) at N cost of:		
	(c)	9c	12c	15c	9c	12c	15c	9c	12c	15c	9c	12c	15c	9c	12c	15c
15:1 ratio																
Av.	20	239	197	156	93[a]	87	81	4.30	3.92	3.45	50.60	54.50	53.40	b	22.10	16.80
all	25	268	235	201	103	99	94	4.54	4.31	4.01	56.70	64.40	68.10	b	b	b
sites	30	287	259	232	110	107	102	4.68	4.52	4.31	60.80	71.10	77.90	b	b	b
20:1 ratio																
Av.	20	191	136	80	75	67	59	3.76	3.10	2.27	40.60	38.00	29.10	15.80	12.00	8.20
all	25	230	186	141	89	83	77	4.20	3.78	3.25	48.60	51.30	48.60	b	21.60	16.40
sites	30	256	218	182	99	93	88	4.44	4.15	3.78	54.10	60.10	61.70	b	b	25.90
25:1 ratio																
Av.	20	143	74	5	58	48	38	3.07	2.03	0.74	30.50	21.60	4.50	9.30	5.40	3.60
all	25	191	136	80	75	67	59	3.76	3.10	2.27	40.60	38.20	29.00	17.30	11.90	8.20
sites	30	223	177	131	87	80	74	4.14	3.68	3.10	47.40	49.20	45.40	b	19.50	14.50

[a]Multiply pounds of P by 2.3 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.
[b]Because the nitrogen application called for is more than 200 pounds per acre annually, net returns are not shown. Net returns with a 200-pound annual nitrogen application are given in table 6.

during the 2 years of this study. It is assumed that the very favorable early spring weather conditions encountered during this study would not hold over more than a 2-or-3-year period. This would lengthen the period of recovery of applied P. The assumption is made that the land would be grazed whether fertilizer was applied or not, so the only additional cost was for fertilizer application ($1 per acre annually should be a reasonable charge to subtract to cover cost of spreading fertilizer).

N applications greater than 200 pounds per acre were required in many cases for maximum net returns or the rate at which the maximum return per pound of fertilizer was realized. Because of danger to livestock from excessive nitrate accumulations in the forage (discussed in Part II of this report), results from applications of more than 200 pounds per acre of N were not used. Adding N in two increments in succeeding years rather than in one 400-pound application had two advantages. Yield was increased by splitting the application (table 4), and nitrate accumulation was held down. Where higher applications were calculated in table 5, net-return data are given for applications of 200 pounds per acre of nitrogen in table 6. Values in tables 5 and 6 were calculated using the yield prediction equation for the average of all sites. Variability among sites is shown by the frequency distribution of net returns in tables 7, 8 and 9.

Net returns in tables 6 through 9 represent returns after all expenditures for fertilizer had been subtracted. Thus, a net return of 0 is the break-even point. Net returns as high as $65 to $75 per acre were calculated for sites 1 and 2 (table 7). The average net return for all sites was $55 to $60 per acre when beef price was 30 cents per pound and N cost 9 cents per pound. At the 30-cent beef price, the average net return for all sites was $45 to $50 per acre even with an N cost of 15 cents per pound. With an N cost of 9 cents per pound, average net return for all sites was $40 to $45 per acre with a beef price of 25 cents and $30 to $35 per acre with a beef price of 20 cents per pound. With a beef price of 20 cents per pound, average net returns for all sites were $20 to $25 and $15 to $20 per acre at N costs of 12 cents and 15 cents, respectively. In general, net returns from sites 1, 2 and 5 were above average, and net returns from sites 3, 4 and 6 were below average. Site 1 gave higher returns than the others in most cases; returns at site 4 were much lower than the others.

For the highest annual net return calculated ($73.10 per acre), an investment in fertilizer of $22.10 would be required annually. This amounts to a $3.31 return over and above each dollar invested in fertilizer. Of course, to get a 15:1 forage-to-beef conversion ratio, it would be necessary to harvest the forage with a chopper, resulting in considerable expense for machinery and labor. An intermediate return was $36.40 per acre for site 6, calculated with 12-cent

Table 6. **Optimum phosphorus requirement, fertilizer cost, yields and maximum net annual returns at three conversion ratios of forage to beef when nitrogen is limited to 200 pounds per acre.**

Site	Beef price per pound (c)	Biennial application of P required (lbs./acre)	Biennial yield above check (tons/acre)	Total fertilizer cost ($) for 2 years at N cost of: 9c	12c	15c	Net annual return ($) at N cost of: 9c	12c	15c
15:1 ratio									
Av.	20	87	2.76	43 20	55.20	67.20	31.00	[a]	[a]
all	25	93	2.79	43.70	55.70	67.70	44.70	38.70	32.70
sites	30	98	2.80	44.10	56.10	68.10	57.80	52.30	46.30
20:1 ratio									
Av.	20	76	3.85	42.30	54.30	66.30	[a]	[a]	[a]
all	25	85	3.93	43.00	55.00	67.00	27.60	[a]	[a]
sites	30	91	3.98	43.50	55.50	67.50	37.90	31.90	[a]
25:1 ratio									
Av.	20	50	3.50	40.10	52.10	64.10	[a]	[a]	[a]
all	25	57	3.60	40.70	52.70	64.70	[a]	[a]	[a]
sites	30	61	3.66	41.00	53.00	65.00	23.40	[a]	[a]

[a]Since the maximum net return is realized at a nitrogen rate below 200 pounds per acre annually, table 5 should be used to obtain optimum nitrogen and phosphorus application rates and maximum net returns.

Table 7. **Maximum annual net returns by sites at a 15:1 conversion ratio of forage to beef.**

Net annual return ($) per acre	Nitrogen price per pound (c): 9			12			15		
	Beef price per pound (c): 30	25	20	30	25	20	30	25	20
	Sites								
70-75	1								
65-70	2			1					
60-65	5			2			1		
55-60	6,av.	1		5	1		2		
50-55	3	2		av.					
45-50		5		3,6	2		5,av.	1	
40-45		6,av.	1		5		3,6	2	
35-40	4		2		6,av.			5	
30-35		3	5,av.	4	3	1,2		6,av.	
25-30		4	3,6			5	4	3	1,2
20-25					4	3,6,av.			5
15-20			4					4	3,6,av.
10-15						4			
5-10									4

Table 8. **Maximum annual net returns by sites at a 20:1 conversion ratio of forage to beef.**

Net annual return ($) per acre	Nitrogen price per pound (c): 9			12			15		
	Beef price per pound (c): 30	25	20	30	25	20	30	25	20
	Sites								
45-50	1,2								
40-45				1.2					
35.40	5,6,av.	1					1		
30-35	3	2		av.	1		2		
25-30	4	5,6,av.		3,5,6	2		av.		
20-25		3	1,2		5,av.		3,5,6	1,2	
15-20			5,6,av.	4	3,6	1,2		5,av.	
10-15		4	3		4	3.5,6,av.	4	3,6	1,2
5-10			4					4	3,5,6,av.
0- 5						4			4

Table 9. **Maximum annual net returns by sites at a 25:1 conversion ratio of forage to beef.**

Net annual return ($) per acre	Nitrogen price per pound (c): 9			12			15		
	Beef price per pound (c): 30	25	20	30	25	20	30	25	20
	Sites								
30-35	1,2								
25-30	5			1,2					
20-25	3,6,av.	1,2		5			1,2		
15-20		5,6,av.	1	3,6,av.	1,2		5		
10-15	4	3	2,5		3,5,6,av.	2	3,6,av.	1,2	
5-10		4	3,6,av.	4	4	1,3,5,av.	4	5,6,av.	1,2
0- 5			4			4,6		3,4	3,4,5,6,av.

N and 25-cent beef. Here, the annual per-acre investment in fertilizer was calculated to be $27.80. The return was $1.31 over and above each dollar invested in fertilizer. A low return was $17.50 per acre for site 6, calculated with 15-cent N and 20-cent beef. The annual per-acre investment in fertilizer was $25.95. The return was 67 cents over and above each dollar invested in fertilizer.

Returns decreased rapidly as the conversion ratio of forage to beef became less favorable (tables 8 and 9). Whereas, with the 15:1 ratio, a good return was shown at all except the most unfavorable beef price and N cost levels; good returns were calculated at the 20:1 and 25:1 ratios only with the most favorable beef price and N cost levels.

It is desirable to know the maximum returns per dollar invested as well as the maximum returns per pound of fertilizer applied which are shown in tables 5 through 9. For this purpose, a procedure developed by Pesek and Heady (4) was used. Results are shown in table 10. This table shows the net returns per acre for the N rates that give the maximum return per dollar invested in N. Because the method was developed for only one variable, the P rate was held constant at 88 pounds per acre (200 pounds P_2O_5), and N was varied.

The results of this procedure seem reasonable at higher net returns, but, in some cases (especially at lower levels of net annual return), the maximum returns per dollar invested calculated from table 10[4] are lower than the returns per dollar invested calculated from tables 5 through 9. This is the result of using a constant P level. The accuracy of the value chosen, even though it is an average value, becomes less as the true maximum return per dollar invested requires a P application higher or lower than the value chosen. Accurate values of maximum return per dollar invested will require a method whereby N and P levels can be varied simultaneously.

OTHER CONSIDERATIONS

While economic returns from fertilizing bromegrass are calculated in precise terms in this study, several factors must be considered, the effects of which are not fully known.

The first consideration is nitrate accumulation in the forage during the early and most productive period of growth 3 to 4 weeks before the first cutting was made in these experiments. The effects of various nitrate levels are not known precisely, and they vary from situation to situation as pointed out in Part II of this bulletin.

The second consideration is possible reduction in feed conversion rates at high N rates. Woelfel and Poulten (8) found a significant decrease in apparent

[4]Net return per dollar invested $= \frac{2(\text{net annual return})}{\text{total fertilizer cost}}$.

Table 10. Nitrogen application required to give the maximum return per dollar invested at all ratios of forage to beef with an 88-pound-per-acre biennial application of phosphorus (200 lbs./acre P_2O_5).

Site	Beef price per pound (c)	Annual N application at N cost of:			Biennial yield above check at N cost of:			Total fertilizer cost ($) for 2 years at N cost of:			Net annual return ($) at ratio of: 15:1 at N cost of:			20:1 at N cost of:			25:1 at N cost of:		
		9c	12c	15c	9c	12c	15c	9c	12c	15c	9c	12c	15c	9c	12c	15c	9c	12c	15c
1	20	147	109	76	3.94	3.33	2.72	33.60	33.40	29.90	35.70	27.70	20.80	22.60	16.60	12.20	14.70	10.00	6.80
	25	147	109	76	3.94	3.33	2.72	33.60	33.40	29.90	48.80	38.80	29.30	32.40	24.90	19.00	22.60	16.60	12.20
	30	147	109	76	3.94	3.33	2.72	33.60	33.40	29.90	62.00	49.90	39.40	42.20	33.20	25.80	30.40	23.20	17.60
2	20	79	28	0	3.02	2.12	1.56	21.50	13.90	7.20	29.40	21.40	17.20	19.40	14.20	11.90	13.30	10.00	7.40
	25	79	28	0	3.02	2.12	1.56	21.50	13.90	7.20	39.50	28.40	22.40	27.00	19.60	16.00	19.40	14.20	11.90
	30	79	28	0	3.02	2.12	1.56	21.50	13.90	7.20	49.50	35.40	27.60	34.50	24.80	19.80	25.40	18.50	15.10
3	20	105	69	32	2.72	2.23	1.66	26.20	23.80	17.00	23.20	17.80	13.60	14.10	10.40	8.00	8.70	5.90	4.80
	25	105	69	32	2.72	2.23	1.66	26.20	23.80	17.00	32.20	25.20	19.10	20.90	16.00	12.20	14.10	10.40	8.00
	30	105	69	32	2.72	2.23	1.66	26.20	23.80	17.00	41.40	32.70	24.60	27.80	21.50	16.30	19.60	14.80	11.40
4	20	127	104	84	2.40	2.15	1.91	30.10	32.20	32.50	16.90	12.50	9.20	8.90	5.40	2.80	4.10	1.00	0
	25	127	104	84	2.40	2.15	1.91	30.10	32.20	32.50	24.80	19.60	15.50	14.90	10.70	7.60	8.90	5.40	1.60
	30	127	104	84	2.40	2.15	1.91	30.10	32.20	32.50	32.80	26.80	21.90	20.90	16.10	12.30	13.80	9.60	6.60
5	20	162	135	113	3.65	3.27	2.93	36.30	39.60	41.20	30.50	23.80	18.40	18.30	12.80	8.70	11.00	6.30	2.80
	25	162	135	113	3.65	3.27	2.93	36.30	39.60	41.20	42.60	34.60	28.20	27.40	21.00	16.00	18.30	12.80	8.70
	30	162	135	113	3.65	3.27	2.93	36.30	39.60	41.20	54.80	45.50	38.00	36.50	29.20	23.30	25.60	19.40	14.60
6	20	133	104	79	3.10	2.71	2.33	31.10	32.20	31.10	25.80	20.00	15.50	15.40	11.00	7.80	9.20	5.60	3.10
	25	133	104	79	3.10	2.71	2.33	31.10	32.20	31.10	36.00	29.10	23.30	23.20	17.80	13.60	15.40	11.00	7.80
	30	133	104	79	3.10	2.71	2.33	31.10	32.20	31.10	45.90	38.20	31.00	30.90	24.60	19.40	21.60	16.40	12.40
Av.	20	123	95	66	3.14	2.69	2.22	30.00	29.90	26.80	26.80	20.80	16.20	16.40	12.00	8.80	10.10	6.50	4.40
	25	123	95	66	3.14	2.69	2.22	30.00	29.90	26.80	37.30	30.20	23.60	24.20	18.60	14.40	16.40	12.00	8.80
	30	123	95	66	3.14	2.69	2.22	30.00	29.90	26.80	47.80	38.70	31.00	32.10	25.40	20.00	22.60	17.20	13.20

digestibility of N-free extract and in digestible energy as N fertilization rates increased to 200 pounds per acre on timothy. In most cases reported, the decreases are slight if N rates are 200 pounds per acre or less.

The third consideration is that the results in this study were obtained in years when May rainfall was above normal (more than twice normal in 1959). Since this is the period of greatest growth of bromegrass, yields undoubtedly benefited from the above-normal rainfall. Response to high N application very likely would not be so great under conditions of less rainfall.

A fourth consideration is difficulty in utilizing bromegrass during its most productive period. To do this effectively requires an excellent management program using several forages with different periods of peak productiveness. Only with this type of program can stocking rates high enough to make most efficient use of one species be maintained during its peak productive period.

A fifth consideration, on the other hand, is that the crude protein and P content of fertilized grass is much higher than that from unfertilized. This undoubtedly increases the value of hay by some amount. The P content of the unfertilized grass at the experimental sites was below the level required by beef animals. Fertilization with P brought the level above that required.

DISCUSSION

The two most pertinent considerations in determining fertilizer use on Ida soils are the possibility of nitrate accumulations in forage during early growth and the relatively low returns per dollar invested in fertilizer (when compared with other crops). Application of 200 pounds of N per acre is the absolute maximum and data from this experiment show that, in some cases, even 200 pounds per acre caused a dangerously high accumulation of nitrates—especially early in the season. Nitrates began to increase rapidly somewhere between 100 and 200 pounds of N application. It appears, from the results discussed in Part II of this bulletin, that applications as great as 150-175 pounds per acre of N would not lead to excessive nitrate accumulations except in cases of drouth or perhaps early in the spring.

Optimum N levels are calculated as less than 200 pounds per acre. Where calculated levels of N were higher than 200 pounds they have been reduced to a 200-pound-per-acre rate because of the danger from nitrate accumulation. Reducing the N application below the optimum reduces the net return, but, without further study, it is not considered safe to apply N rates higher than 200 pounds per acre. It is possible that a 100- to 150-pound-per-acre N application in mid-March and another in mid-May might give the same yields with less danger from nitrate accumulation.

The highest annual net return calculated from table 10 is $3.69 over and above each dollar invested annually in fertilizer (site 1, 15:1 conversion ratio, 9-cent nitrogen, 30-cent beef). The annual calculated nitrogen application is 147 pounds per acre, which is presumed to be a safe rate of application. The calculated maximum net return for the average of six sites under these same conditions is $3.19 per dollar invested in fertilizer. The lowest average net return at the 15:1 conversion ratio is $1.21 with 15-cent N and 20-cent beef.

With a forage-to-beef conversion ratio of 20 to 1, average maximum net returns are $1.60 and $2.10 for every dollar invested with 9-cent N and with 25-cent and 30-cent beef, respectively, or $1.70 with 12-cent N and 30-cent beef. With less favorable N costs and beef prices, net returns from fertilizer drop rapidly. Average N applications are well below 150 pounds in all cases in table 10.

Variability among sites was the result of several factors, such as rainfall, P level and amount of erosion. This last factor depended on steepness of slope and previous cropping. Further studies could be made to determine the type of site on which response to N and P is likely to be most profitable.

Results of this study should not be taken as recommendations in pasture fertilization. Considerable research is being done concerning nitrate accumulation and pasture management. Recommendations will be made after consideration of all the available results.

SUMMARY OF PART I

The purpose of this study was to determine net returns from fertilizing established bromegrass stands on areas of Ida soil too steep to farm economically to row crops. The experimental work was done in 1959 and 1960.

The experiment used a composite design repeated at six locations in the Monona-Ida-Hamburg soil association area. The northernmost and southernmost sites were approximately 100 miles apart. The sites had all grown corn at one time, and all slopes were greater than 20 percent. Nitrogen was applied in increments of 100 pounds from 0 to 400 pounds per acre in 1959 and reapplied at the same rates in 1960. Phosphorus was applied in increments of 44 pounds from 0 to 176 pounds per acre in 1959 only.

Multiple regressions of yield on quadratic functions of N and P, plus an interaction term, were calculated from data for each site. Net returns were estimated by using costs of 9, 12 and 15 cents per pound for N; returns of 20, 25 and 30 cents per pound for beef; and 15:1, 20:1 and 25:1 conversion ratios of forage to beef. Price of P was held constant at 20.62 cents per pound (9 cents per pound of P_2O_5).

Yields from unfertilized plots were very low, averaging 0.58 ton per acre in 1959 and 0.26 ton in 1960.

Addition of P fertilizer alone doubled yields over the unfertilized treatment at some sites, gave small increases on others and even decreased yields in several cases. Nitrogen applied without phosphorus increased yields over the unfertilized treatment, but yields fell far short of those where both N and P were applied. The 400-pound-per-acre N application did not increase yields greatly over the 300-pound-per-acre application in most cases. A 400-pound N application was more effective when applied at a rate of 200 pounds per acre per year than at 400 pounds per acre once every 2 years.

Highest net annual returns, calculated on the basis of this experiment, of course, were at the lowest N cost (9 cents), highest beef price (30 cents) and highest conversion ratio of forage to beef (15:1). In most cases, however, optimum N requirements for maximum net annual returns were greater than the 200-pound-per-acre level, considered dangerously high from the standpoint of nitrate accumulations in bromegrass. Therefore, calculations of net returns were made at the 200-pound-per-acre level rather than at the optimum level. Highest calculated average net annual return per acre at the best possible combination of N cost, beef price and conversion ratio was $57.80, with an annual fertilizer cost of $22.05. The range in net annual return from using the best combination was from $73.10 – with an annual fertilizer cost of $22.10 – to $37.60 – with a fertilizer cost of $21.50. Calculated average net annual returns at the poorest combination of N cost, beef price and conversion ratio was $3.60, with an annual fertilizer cost of $2.25. The range in net annual return at this combination was from $8.50 – with an annual fertilizer cost of $3.80 – to $0.40 – with an annual fertilizer cost of $0.20. The annual fertilizer applications in each case (except where the 200-pound-per-acre rate of N was exceeded) are those that would result in the highest net annual return for the combination of costs and returns specified.

Calculated maximum returns per dollar invested in fertilizer were obtained at N applications well below 200 pounds per acre. Using the average of six sites, the maximum return for each dollar invested in fertilizer was $3.19 at the most favorable combination of N cost, beef price and conversion ratio. At one site, where a large response was obtained from an 88-pound-per-acre application of P, the calculated maximum return for each dollar invested at the most favorable combination was $4.60.

While economic returns from fertilizing bromegrass are calculated in precise terms in this study, the effects of several factors are not known precisely. Most important of these is the effect of nitrate N on cattle gains. The change of nitrate N content of fertilized grass with time during the season and under various soil moisture situations needs more study as does the effect of various levels of nitrate N on cattle gains and survival. Feed conversion ratios of fertilized bromegrass also need more study. The effect of nitrogen application on yield and nutrient uptake in seasons of little rainfall was not determined but needs to be investigated.

LITERATURE CITED IN PART I

1. Hader, R. J., M. E. Harward, D. D. Mason and D. P. Moore. An investigation of some of the relationships between copper, iron, and molybdenum in the growth and nutrition of lettuce: I. Experimental design and statistical methods for characterizing the response surface. Soil Sci. Soc. Amer. Proc. 21:59-64. 1957.
2. Harlan, Jack. Beef yields from grass. Okla. Agr. Exp. Sta. Bul. B-547. 1960.
3. Heady, Earl O., John T. Pesek and William G. Brown. Crop response surfaces and economic optima in fertilizer use. Iowa Agr. Exp. Sta. Res. Bul. 424. 1955.
4. Pesek, John and Earl O. Heady. Derivation and application of a method for determining minimum recommended rates of fertilization. Soil Sci. Soc. Amer. Proc. 22:419-423. 1958.
5. Schultz, E. F., W. R. Lanford, Jr., E. M. Evans, R. M. Patterson and W. B. Anthony. Relationship of beef gains to forage yields. Agron. Jour. 51:207-211. 1959.
6. Simonson, R. W., F. F. Riecken and G. D. Smith. Understanding Iowa soils. Wm. C. Brown, Dubuque, Iowa. 1952.
7. U. S. Department of Commerce, Weather Bureau. 1959 and 1960 Annual Summaries for Iowa.
8. Woelfel, C. G., and B. R. Poulton. The nutritive value of timothy hay as affected by nitrogen fertilization. Jour. Anim. Sci. 19:696-699. 1960.

Part II. Effect on Chemical Composition of Bromegrass[5]

by J. J. Hanway and W. C. Moldenhauer

Since the feeding value of a forage depends on its chemical composition, it is important to consider the effects of fertilizer applications on the composition as well as on the dry-matter yields of the bromegrass forage produced. Furthermore, the uptake of N and P from fertilizer applications on these calcareous soils very deficient in N and P is of considerable interest to research workers in other areas where similar conditions exist and to workers interested in nutrient uptake problems generally.

REVIEW OF LITERATURE

The percentage of total N in bromegrass generally shows a progressive decline from early in the growing season to maturity (4, 11, 12, 16, 17). Frequent clipping of the grass to represent grazing maintains a young, immature grass growth with a high percentage of total N (11). The percentage of N in the plants at any stage of growth may be increased markedly by applications of N fertilizers (1, 2, 4, 5, 7, 9, 12, 17, 19). However, applications of relatively small amounts of N may increase the dry-matter yield but have relatively little effect on the total N percentage in the grass (1). Applications of P and K may result in slight decreases in the percentage of total N (12). In a greenhouse study, however, Washko (18) found that increasing the level of K available to bromegrass plants resulted in increases in the percentage of N in the plants.

The percentage of total N in the grass also varies with environmental conditions. Shading increases the percentage of N in both the roots and the above-ground parts of bromegrass (16, 19). The percentage of total N in the above-ground parts of the plant showed a decline with an increase in the length of day, but differences in day length had no effect on the percentage of N in the roots, and increasing day length resulted in a slight increase in the percent N in the rhizomes (19). Different strains of bromegrass may vary markedly in the percentage of total N in the hay (11).

Bromegrass shows less tendency to accumulate nitrate N than some of the annual cereal crops (6), but nitrates will accumulate in bromegrass under many conditions (4, 5, 6). Carey et al. (4) found that the percentage of nitrate N in bromegrass was low in mid-April, increased rapidly during the next month and then decreased rapidly as the plants matured. The nitrate content of the grass often increases as the level of N fertilization increases (4, 5, 6). The form of N applied may influence the amount of nitrate in the plants. Carey et al. (4) found that applications of ammonium nitrate markedly increased the nitrate content of bromegrass, whereas applications of urea or cyanamide caused only slight increases. Crawford[6] has found very high nitrate contents in bromegrass grown in the greenhouse as compared with bromegrass grown under field conditions. This was probably associated with the influence of light intensity, since shading has been shown to increase the nitrate content of many plants (6).

The effects of other factors on nitrate contents of various plants has been reviewed by Crawford et al. (6) and by Hanway et al. (10), and much of this information undoubtedly is applicable to bromegrass. Nitrate contents vary among different parts of the plants and usually are highest in the stems. High concentrations of nitrates are often found in drouth-stricken plants. Applications of herbicides, such as 2,4-D, have been shown to increase the nitrate content of plants. High levels of K and low levels of P, S and Mo have increased the concentration of nitrates in plants.

The percentage of P in bromegrass also generally decreases as the plants mature (7). Applications of P fertilizer have been shown to increase the P content of bromegrass (14, 15). Applications of N fertilizer have resulted in increases, decreases and no change in the P content of bromegrass forage (2, 3, 17). In Nebraska studies, the increases in P concentrations in the plants resulting from N fertilization occurred primarily in the early stages of growth. From a greenhouse experiment where soil temperature was increased from 41 to 80° F., Nielsen et al. (14) reported increased P contents in bromegrass with increasing temperature even though no P was applied. When P was applied, however, they found decreased percent P in the plants from increases in soil temperature.

The K content of bromegrass has been shown to be directly related to the levels of available K in the soil or to the amount of K applied (14, 15). Nielsen et al. (14) found that, where K was added, the K percentage in the bromegrass was greater at soil temperatures of 67° F. than at higher or lower soil tem-

---

[5]Project 1516 of the Iowa Agricultural and Home Economics Experiment Station in cooperation with the Agricultural Research Service and Soil Conservation Service of the United States Department of Agriculture.

J. J. HANWAY is professor of soils, and W. C. MOLDENHAUER is associate professor of soils and research soil scientist, ARS, USDA.

[6]R. F. Crawford. New York Agr. Exp. Sta. (Cornell). Ithaca, New York. Personal communication. 1956.

peratures. Russell et al. (17) and App et al. (2) showed that application of N for N-deficient bromegrass markedly increased percent K in the plants.

PROCEDURE

The subsample of bromegrass forage taken from each plot for moisture determination in the study reported in Part I of this bulletin was ground and stored for chemical analysis.

A 0.5-gram sample of the dried, ground plant material was digested for 24 hours in 8 ml. of concentrated H_2SO_4 with copper as a catalyst. The digest was then diluted to 90 ml. with ammonia-free distilled water. The nitrogen content was determined by Nesslerization of an aliquot of the diluted digest and determination of the intensity of resultant color by use of an Evelyn photo-electric colorimeter. The phosphorus content was determined by adding vanadomolybdate solution to an aliquot of the digest and determining the intensity of the resultant color with the Evelyn colorimeter. The potassium content of the digest was determined by using a flame photometer with lithium as an internal standard.

Nitrate N was determined by placing duplicate 0.5-gram samples of the dried, ground plant material in micro-Kjeldahl flasks, by adding ammonia-free water and 0.1 gram of MgO to each flask and 2 ml. of a $Ti_2(SO_4)_3$ [7] solution to one flask and steam distilling. The ammonia released was trapped in a saturated boric acid solution and titrated with standard acid. Nitrate N was calculated from the difference in ammonia released from the two flasks due to the $Ti_2(SO_4)_3$ addition. When the nitrate content was too high to be determined by this procedure, a 0.5-gram sample of the plant material was extracted with 50 ml. of boiling water, and a suitable aliquot of the extract was used in the steam distillation in place of the original plant material.

RESULTS

N content of bromegrass

Percent total N. The percentages of N in the bromegrass from the different cuttings of the different sites are reported in table B-1 of Appendix B. The percentages of N for the different treatments of the different cuttings, averaged over all sites, are reported in tables 11 and 12 for 1959 and 1960, respectively.

Applications of N increased percent N in the bromegrass markedly in all cuttings in both years. The average percent N in the bromegrass from plots that received no N ranged from 1.4 to 1.8 in 1959 but was higher in 1960, ranging from 1.8 to 2.6 percent. At individual sites, the range was from 1.0 to 2.0 percent in 1959 and from 1.4 to 3.2 percent in 1960. These generally higher percentages of N in 1960 were associated with lower yields than were obtained in 1959. An application of 400 pounds of N per acre resulted in average N contents in the bromegrass of about 3 percent in all except the first cutting in 1960 when the N content was increased to more than 4 percent and as high as 5.2 percent in the grass from one plot at site 6. The relatively low yield at sites 3 and 4 in 1959 from the plots with high rates of N were associated with higher N percentages (3.6 to 4.0) than occurred at the other sites. Intermediate rates of N application resulted in N percentages intermediate between the extremes for the 0- and 400-pound rates. In both years, an application of 100 pounds of N per acre markedly increased the percentage of N in the grass of the first cutting but had little effect in subsequent cuttings. The residual effect of applications of 200 pounds or more of N per acre in 1959 was appreciable in the first cutting of 1960 and was observable in the second but not in the third cutting of 1960.

Applications of P had relatively little effect on the percentage of N in the bromegrass from plots where no N was applied. Where 400 pounds of N per acre were applied, applications of P generally resulted in higher N percentages. Where 200 pounds of N per acre were applied, applications of P resulted in increased percentages of N in the first cutting and slightly decreased percentages of N in subsequent cuttings.

Table 11. Effect of N and P fertilizer applications on the percentage of N in bromegrass, 1959. (Average of six experiments.)

Pounds of P applied per acre[a]	Percent N when pounds of N applied per acre were: 0	100	200	300	400
First cutting					
0	1.4	..	2.3	..	2.4
44	..	2.1	..	2.8	..
88	1.4	..	2.6	..	3.0
132	..	2.0	..	2.9	..
176	1.5	..	2.6	..	3.2
Second cutting					
0	1.4	..	2.4	..	2.6
44	..	1.5	..	2.5	..
88	1.5	..	2.0	..	2.8
132	..	1.5	..	2.6	..
176	1.4	..	2.1	..	2.9
Third cutting					
0	1.7	..	2.4	..	2.8
44	..	2.0	..	2.6	..
88	1.8	..	2.0	..	3.0
132	..	1.9	..	2.6	..
176	1.6	..	2.2	..	2.9

[a]0, 44, 88, 132 and 176 lbs. per acre are equivalent to 0, 100, 200, 300 and 400 lbs. of P_2O_5 per acre, respectively.

Table. 12. Effect of N and P fertilizer applications on the percentage of N in bromegrass, 1960. (Average of six experiments.)

Pounds of P applied per acre 1959	Percent N when pounds of N applied per acre were: (1959) 0 (1960) 0	100 / 0	200 / 0	300 / 0	400 / 0	100 / 100	200 / 200	300 / 300	400 / 400
First cutting									
0	2.0	..	2.4	..	3.0	..	3.7	..	3.8
44	..	2.1	..	2.5	..	3.3	..	4.1	..
88	2.1	..	2.3	..	2.8	..	3.9	..	4.0
132	..	2.1	..	2.6	..	3.2	..	4.1	..
176	1.9	..	2.3	..	2.9	..	4.1	..	4.3
Second cutting									
0	1.8	..	2.2	..	2.3	..	2.4	..	2.6
44	..	1.9	..	2.0	..	2.0	..	2.9	..
88	1.8	..	2.0	..	2.1	..	2.3	..	3.0
132	..	1.9	..	2.0	..	2.1	..	2.6	..
176	1.8	..	2.0	..	2.1	..	2.2	..	3.2
Third cutting									
0	2.3	..	2.3	..	2.6	..	2.7	..	2.7
44	..	2.5	..	2.2	..	2.2	..	2.7	..
88	2.5	..	2.0	..	2.3	..	2.1	..	3.2
132	..	2.5	..	2.3	..	2.4	..	2.7	..
176	2.6	..	2.2	..	2.3	..	2.2	..	3.0

[7] $Ti_2(SO_4)_3$ was obtained from the British Drug House, Ltd., Poole, England. Similar reagent from other sources was not satisfactory for this procedure.

Pounds N removed by bromegrass. The average effects of N and P fertilizer applications on the pounds of N removed in the bromegrass are shown in table 13 and illustrated in part B of fig. 4. The pounds of N removed in the bromegrass from the individual sites is reported in table B-3 of Appendix B.

Table 13. Effect of N and P fertilizer applications on the pounds of N removed per acre in the bromegrass hay. (Average of six experiments.)

Pounds of P applied per acre 1959		Pounds of N per acre in the bromegrass when pounds of N applied per acre were:								
	(1959)	0	100	200	300	400	100	200	300	400
	(1960)	0	0	0	0	0	100	200	300	400
1959										
0		13	..	76	..	84				
44		..	63	..	124	..				
88		22	..	110	..	160				
132		..	62	..	148	..				
176		19	..	106	..	165				
1960										
0		10	..	35	..	55	..	61	..	64
44		..	19	..	38	..	72	..	174	..
88		17	..	28	..	63	..	140	..	189
132		..	26	..	43	..	73	..	184	..
176		17	..	32	..	62	..	134	..	203
Total (1959+1960)										
0		23	..	111	..	139	..	137	..	148
44		..	82	..	162	..	135	..	301	..
88		39	..	138	..	223	..	250	..	349
132		..	88	..	191	..	135	..	332	..
176		36	..	138	..	227	..	240	..	368

The average amount of N removed in the hay in 1959 was increased from 13 pounds per acre to a maximum of 165 pounds per acre and, in 1960, was increased from 10 to a maximum of 203 pounds of N per acre. Applications of N alone resulted in much smaller removals of N than where P was also applied. This was largely because of smaller increases in dry-matter yields where N only was applied (fig. 3) but also was partly due to lower percentages of N in the bromegrass from these plots.

Where P was applied in addition to the N, about 35 to 45 percent of the N applied in 1959 was removed in the bromegrass harvested that year. In 1960, another 5 to 10 percent of the N applied in 1959 was removed in the bromegrass hay where no additional N was applied in 1960. Thus, during the 2-year period, an average of 45 to 50 percent of the N applied in 1959 was removed in the hay, with very little difference in percentage recovery of applied N at different rates of application. The percentage recovery of applied N did vary among the different sites, depending primarily on the yields of bromegrass. At no site, however, was more than about two-thirds of the applied N recovered in the bromegrass hay.

Where N was applied in 1960 on plots that had received N and P in 1959, the effects in 1960 of the N and P applications were similar to those in 1959, but total N removal was slightly greater than in 1959. Recovery of applied N in the bromegrass hay in 1960 was similar to that obtained in 1959 – except where 400 pounds of N was applied each year; at this rate, recovery was slightly less in 1960 than in 1959.

As shown in part B of fig. 4, the average amount of N removed in the bromegrass was proportional to the amount applied, and where P was applied, the amount removed increased (more or less) linearly to a total of 600 pounds of N applied over the 2-year period, whereas dry matter increased curvilinearly. The rate of N recovery decreased where 800 pounds of N had been applied in the 2 years.

Percent nitrate N. The percentages of nitrate N in the bromegrass from the different cuttings of the different sites are reported in table B-1 of Appendix B. The effects of N and P applications on nitrate N contents of the different cuttings averaged over all sites are shown in tables 14 and 15 for 1959 and 1960, respectively.

In both 1959 and 1960, applications of 200 pounds or more of N per acre markedly increased the percentages of nitrate N in the bromegrass of the first cutting after the N was applied. This agrees with the results of Carter (5). Applications of 400 pounds of N per acre resulted in average nitrate contents of more than 0.4 percent nitrate N (approximately 3 percent nitrate expressed as KNO_3) in this first cutting hay, and applications of 200 pounds of N per acre resulted in nitrate contents of slightly less than half this amount. At individual sites, the nitrate N content in the bromegrass from plots that received 400 pounds of N per acre was as high as 0.6 percent nitrate N,

Table 14. Effect of N and P fertilizer applications on percentages of nitrate-nitrogen in bromegrass, 1959. (Average of six experiments.)

Pounds of P applied per acre	Percent of NO_3-N[a] when pounds of N applied per acre were: 0	100	200	300	400
First cutting					
0	0.03	...	0.07	...	0.20
44	...	0.03	...	0.20	...
88	0.01	...	0.16	...	0.42
132	...	0.02	...	0.26	...
176	0.02	...	0.15	...	0.44
Second cutting					
0	0.03	...	0.17	...	0.14
44	...	0.02	...	0.14	...
88	0.02	...	0.05	...	0.29
132	...	0.02	...	0.16	...
176	0.01	...	0.08	...	0.30
Third cutting					
0	0.02	...	0.04	...	0.09
44	...	0.02	...	0.05	...
88	0.02	...	0.03	...	0.12
132	...	0.02	...	0.04	...
176	0.01	...	0.03	...	0.22

[a]To convert % NO_3-N to % KNO_3, which is often used as the basis for expressing nitrate contents of plant material, multiply by 7.2.
0.21% NO_3-N = 1.5% KNO_3.

Table 15. Effect of N and P fertilizer applications on percentages of nitrate-nitrogen in bromegrass, 1960. (Average of six experiments.)

Pounds of P applied per acre 1959		Percent NO_3-N[a] when pounds of N applied per acre were:								
	(1959)	0	100	200	300	400	100	200	300	400
	(1960)	0	0	0	0	0	100	200	300	400
First cutting										
0		0.01	...	0.01	...	0.01	...	0.08	...	0.10
44		...	0.01	...	0.01	...	0.03	...	0.23	...
88		0.01	...	0.01	...	0.03	...	0.18	...	0.39
132		...	0.01	...	0.02	...	0.02	...	0.25	...
176		0.01	...	0.01	...	0.04	...	0.18	...	0.42
Second cutting										
0		0.01	...	0.02	...	0.03	...	0.10	...	0.18
44		...	0.01	...	0.01	...	0.02	...	0.17	...
88		0.01	...	0.01	...	0.02	...	0.05	...	0.37
132		...	0.01	...	0.01	...	0.02	...	0.15	...
176		0.01	...	0.01	...	0.03	...	0.04	...	0.37
Third cutting										
0		...	...	...	...	0.01	...	0.01	...	0.05
44		...	...	...	...	...	0.01	...	0.03	...
88		...	...	...	...	0.02	...	0.01	...	0.16
132		...	...	...	...	...	0.01	...	0.04	...
176		...	...	...	...	0.01	...	0.01	...	0.12

[a]See footnote on table 14.

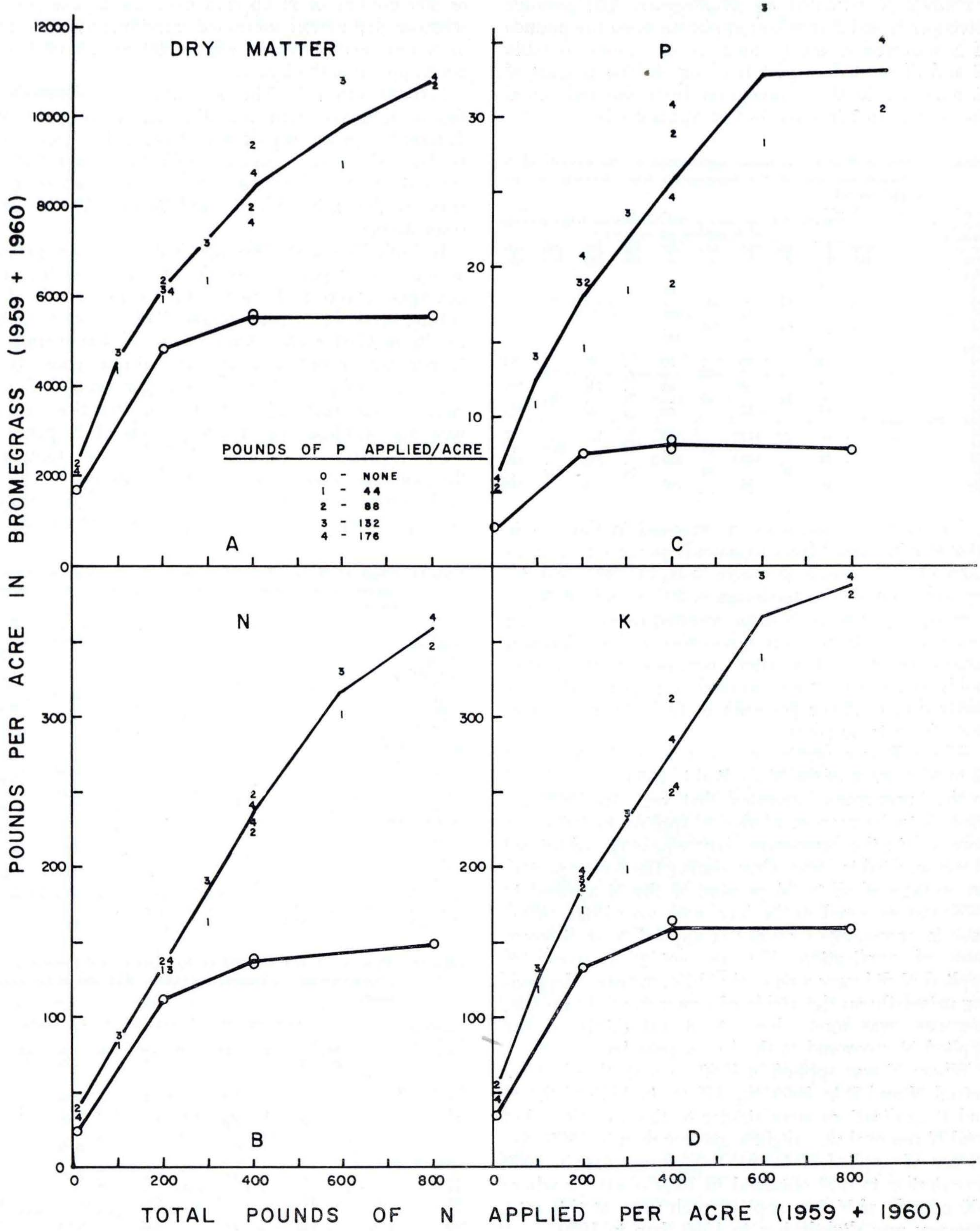

Fig. 4. Effect of N and P fertilizer application on the pounds of bromegrass dry matter produced per acre and the pounds of N, P and K removed per acre in the bromegrass hay during 1959 and 1960 (average of six experiments).

and, at site 4 in 1959, an application of 200 pounds of N resulted in nitrate N content of more than 0.4 percent.

Where 100 pounds of N per acre or less was applied, the nitrate N content of the bromegrass was always low. In the hay from only one such plot was the nitrate N content as high as 0.08 percent, and the average for all sites never exceeded 0.03 percent. Where higher rates of N were applied, the nitrate contents were large in the first cutting after the N was applied and generally decreased in succeeding cuttings. Applications of 200 pounds of N per acre increased nitrate N of the first cutting, but, only in the second cutting on plots that received no P fertilizer, did it result in large nitrate contents in following cuttings. Applications of 300 pounds of N per acre increased nitrate contents in the first and second cuttings but had little effect on the third cutting. Applications of 400 pounds of N per acre increased nitrate contents in all three cuttings of the year in which the N was applied but had very little residual effect on cuttings the following year.

Applications of P fertilizer increased nitrate contents in the first cutting of bromegrass of both years where 200 pounds or more of N per acre were applied and had a similar effect in the second and third cuttings where 400 pounds of N per acre were applied. In the second cuttings from plots that received 200 pounds of N per acre, however, the P fertilizer applications consistently decreased nitrate contents in the bromegrass.

P content of bromegrass

Percent total P. Percentages of P in the different cuttings from the different sites are reported in table B-2 of Appendix B. The effects of the different fertilizer treatments on the percent P in the bromegrass of the different cuttings averaged over all sites are reported in tables 16 and 17 for 1959 and 1960, respectively.

The average P content of the bromegrass from plots that received no N or P fertilizer was consistently low in both years, varying from 0.12 to 0.19 percent in the different cuttings. Among individual sites, the range was from 0.08 to 0.28 percent P. Percent P in the bromegrass from the unfertilized plots was especially low in the second and third cuttings in 1959.

Applications of P alone in 1959 consistently increased the percent P in the plants. In all cuttings of both years, except the second cutting of 1959, the applications of P alone resulted in average P contents of 0.25 $\pm$ 0.02 percent, with 88 pounds per acre of P being as effective as 176 pounds. Yield increases associated with these increases in percent P generally were small; in many instances, there was no increase in yield because yields were limited primarily by the extreme N deficiency in these soils.

Applications of N alone had relatively little effect

Table 16. Effect of N and P fertilizer applications on the percentages of P in bromegrass, 1959. (Averages of six experiments.)

Pounds of P applied per acre	Percent P when pounds of N applied per acre were: 0	100	200	300	400
First cutting					
0	0.17	...	0.16	...	0.16
44	...	0.30	...	0.37	...
88	0.22	...	0.40	...	0.38
132	...	0.37	...	0.44	...
176	0.24	...	0.45	...	0.42
Second cutting					
0	0.12	...	0.13	...	0.12
44	...	0.18	...	0.22	...
88	0.18	...	0.22	...	0.21
132	...	0.21	...	0.25	...
176	0.18	...	0.26	...	0.25
Third cutting					
0	0.14	...	0.13	...	0.12
44	...	0.22	...	0.24	...
88	0.27	...	0.24	...	0.22
132	...	0.26	...	0.26	...
176	0.23	...	0.27	...	0.24

Table 17. Effect of N and P fertilizer applications on the percentages of P in bromegrass, 1960. (Average of six experiments.)

Pounds of P applied per acre 1959	Percent P when pounds of N applied per acre were: (1959) 0 (1960) 0	100 0	200 0	300 0	400 0	100 100	200 200	300 300	400 400
First cutting									
0	0.18	...	0.16	...	0.14	...	0.14	...	0.14
44	...	0.23	...	0.24	...	0.28	...	0.31	...
88	0.24	...	0.24	...	0.25	...	0.35	...	0.33
132	...	0.24	...	0.27	...	0.34	...	0.41	...
176	0.24	...	0.27	...	0.30	...	0.40	...	0.40
Second cutting									
0	0.19	...	0.16	...	0.14	...	0.17	...	0.14
44	...	0.21	...	0.22	...	0.18	...	0.24	...
88	0.24	...	0.24	...	0.22	...	0.25	...	0.24
132	...	0.24	...	0.25	...	0.26	...	0.27	...
176	0.26	...	0.24	...	0.24	...	0.26	...	0.25
Third cutting									
0	0.19	...	0.14	...	0.13	...	0.14	...	0.13
44	...	0.21	...	0.20	...	0.21	...	0.20	...
88	0.25	...	0.20	...	0.20	...	0.20	...	0.20
132	...	0.26	...	0.22	...	0.24	...	0.23	...
176	0.24	...	0.23	...	0.21	...	0.22	...	0.22

on the percent P in the grass in 1959 but consistently decreased percentages in 1960. Only at site 1 did the percent P in the bromegrass in 1960 from plots that received 400 pounds of N per acre and no P in 1959 exceed 0.16 percent. These very low P contents in the grass from plots where no P was applied, but where the N deficiency had been corrected by an application of N, reflect the extreme P deficiency in all these soils.

Applications of both N and P consistently increased the percent P in the bromegrass. In the first cutting of both years, the grass from plots that had received both N and P consistently contained larger percentages of P than did the grass from plots that had received either N or P alone. In the second and third cuttings, the percentages of P resulting from applications of both N and P were always larger than where N only had been applied but were not always larger than where only P had been applied. Although P fertilizer was applied only in 1959, the residual effect in 1960 appeared similar to the effect in the year it was applied. Where both N and P had been applied, the average P content of the first cutting in both years reached a maximum of 0.40 to 0.45 percent. At individual sites, levels as high as 0.65 percent P were obtained. The average P content of second and third cuttings where both N and P had been applied varied relatively little from 0.25 percent P, and the content did not exceed 0.34 percent P at any individual site.

Pounds of P removed by bromegrass. The effect of the different fertilizer treatments on the pounds of P removed in the bromegrass hay at the different sites is reported in table B-3 of Appendix B, and the average of all sites is reported in table 18. The effect of the fertilizer treatments on the total P removed in the 2 years is illustrated in part C of fig. 4.

Table 18. Effect of N and P fertilizer applications on the pounds of P removed per acre in bromegrass. (Average of six experiments all cuttings.)

Pounds of P applied per acre		Pounds of P per acre in the bromegrass when pounds of N applied per acre were:								
	(1959)	0	100	200	300	400	100	200	300	400
	(1960)	0	0	0	0	0	100	200	300	400
1959										
0		1.6	..	5.0	..	4.8				
44		..	8.8	..	14.7	..				
88		3.2	..	15.9	..	16.2				
132		..	10.9	..	19.6	..				
176		2.9	..	17.2	..	18.3				
1960										
0		1.0	..	2.4	..	3.1	..	3.5	..	3.1
44		..	2.1	..	3.8	..	5.9	..	13.8	..
88		2.0	..	3.2	..	2.9	..	13.2	..	14.7
132		..	3.1	..	4.3	..	8.2	..	18.1	..
176		2.6	..	3.8	..	6.6	..	13.9	..	17.4
1959 and 1960										
0		2.6	..	7.4	..	7.9	..	8.5	..	7.9
44		..	10.9	..	18.5	..	14.7	..	28.5	..
88		5.2	..	19.1	..	19.1	..	29.1	..	30.9
132		..	14.0	..	23.9	..	19.1	..	37.7	..
176		5.5	..	21.0	..	24.9	..	31.1	..	35.7

The low yields and low P content of the bromegrass where no fertilizer was applied resulted in very small removals of P from these plots. The total removed in 2 years averaged 2.6 pounds of P per acre, and the maximum at any one site was 3.8 pounds of P per acre.

Applications of either N or P alone increased slightly the amount of P removed in the bromegrass hay. Since applications of P alone increased the percent P in the grass but had relatively little effect on yields, the average amount of P removed from these plots was only slightly more than 5 pounds of P per acre. Applications of N fertilizer alone resulted in some increase in yield but often lowered the percent P in the plants so that the total P removed from these plots averaged only about 8 pounds of P per acre.

Applications of both N and P increased P removal greatly due to both increased yields and P contents of the bromegrass. The amount of P removed in the grass from these treatments appeared to depend more on the amount of N applied, which had the dominant effect on yield, than on the amount of P applied. However, the total P removed was slightly greater where the higher rates of P had been applied.

Where N was applied in 1960, P removal was comparable to that removed in 1959 even though P was applied only in 1959. This indicates that the availability of the P from the P fertilizer application was essentially the same in 1960 as it had been in 1959, the year it was applied.

Since increasing the P application had a relatively small effect on the amount of P removed over that removed where the low rate (44 pounds of P per acre) was applied, the percent recovery of applied P from this low rate is of interest. Average removal of P from the plots that received 44 pounds of P per acre in 1959 and 300 pounds of N per acre each year amounted to 28.5 pounds of P per acre. This can be compared with the removal of about 8 pounds of P per acre where no P was applied. This indicates that about 20 pounds more P (equivalent to 45 percent of the amount applied) was removed in the grass from these plots in the 2 years. At site 2, where the yield was highest of any site, total P removed for this treatment amounted to about 49 pounds of P per acre as compared with about 10 pounds per acre where no P was applied, or an increased removal in the 2 years equivalent to 90 percent of the applied P.

K content of bromegrass

Percent total K. The percentages of K in the different cuttings of the different sites are shown in table B-2 of Appendix B, and the averages for all sites are reported in tables 19 and 20 for 1959 and 1960, respectively.

Table 19. Effect of N and P fertilizer applications on the percentage of K in bromegrass, 1959. (Averages of six experiments.)

Pounds of P applied per acre	Percent K when pounds of N applied per acre were: 0	100	200	300	400
First cutting					
0	2.0	..	2.7	..	2.6
44	..	3.2	..	3.6	..
88	2.1	..	3.7	..	3.7
132	..	3.3	..	3.8	..
176	2.2	..	3.8	..	3.9
Second cutting					
0	1.5	..	2.6	..	2.5
44	..	2.0	..	2.6	..
88	1.7	..	2.5	..	2.7
132	..	2.2	..	2.8	..
176	1.6	..	2.6	..	2.9
Third cutting					
0	1.9	..	2.8	..	2.7
44	..	2.5	..	3.0	..
88	2.4	..	2.7	..	3.2
132	..	2.2	..	3.2	..
176	2.0	..	3.0	..	3.1

Table 20. Effect of N and P fertilizer applications on the percentage of K in bromegrass, 1960. (Average of 6 experiments.)

Pounds of P applied per acre (1959)		Percent of K when pounds of N applied per acre were:								
	(1959)	0	100	200	300	400	100	200	300	400
	(1960)	0	0	0	0	0	100	200	300	400
First cutting										
0		2.2	..	2.5	..	2.6	..	2.7	..	2.6
44		..	2.4	..	2.7	..	3.5	..	4.0	..
88		2.4	..	2.5	..	3.0	..	3.9	..	4.1
132		..	2.4	..	2.9	..	3.4	..	4.4	..
176		2.2	..	2.7	..	3.0	..	4.0	..	4.4
Second cutting										
0		2.2	..	2.7	..	3.1	..	3.3	..	3.1
44		..	2.3	..	2.7	..	3.1	..	3.4	..
88		2.4	..	2.4	..	3.1	..	3.4	..	3.7
132		..	2.5	..	2.7	..	3.1	..	3.5	..
176		2.4	..	2.4	..	3.0	..	3.6	..	3.6
Third cutting										
0		2.4	..	2.6	..	2.9	..	2.9	..	2.8
44		..	2.4	..	2.5	..	2.5	..	3.4	..
88		2.6	..	2.3	..	2.7	..	2.8	..	3.4
132		..	2.7	..	2.5	..	2.6	..	3.3	..
176		2.6	..	2.4	..	2.7	..	2.9	..	3.6

The average K content of the bromegrass from the unfertilized plots at all sites varied from 1.5 to 2.4 percent K in the different cuttings. Values as low as 1.0 percent were obtained at one site. Percentages of K in the grass from these plots were generally greater in 1960 than in 1959.

Applications of P alone had little effect on the percent K in the bromegrass. Applications of N fertilizer alone generally increased the percent K in the plants resulting in average K contents of from 2.5 to 3.3 percent K.

Bromegrass from plots that received both N and P fertilizer applications contained even higher percentages of K. The average percent K in the first cutting of each year from plots that received high rates of N and P fertilizer was approximately 4 percent and, in the second and third cuttings, was about 3 percent or more. At individual sites, percentages of K in the first cutting from these plots were as high as 5.0 to 5.9 percent.

Pounds K removed by bromegrass. The pounds of K removed in the bromegrass hay from the different sites is shown in table B-3 of Appendix B, and the averages of all sites are summarized in table 21. The average effect of the fertilizer treatments on the total amount of K removed in the bromegrass during the 2-year period is illustrated in part D, fig. 4.

Table 21. Effect of N and P fertilizer applications on the pounds of K removed per acre in the bromegrass. (Average of six experiments.)

Pounds of P applied per acre (1959)	Pounds of K per acre in the bromegrass when pounds of N applied per acre were:								
(1959)	0	100	200	300	400	100	200	300	400
(1960)	0	0	0	0	0	100	200	300	400
1959									
0	22	...	94	...	90				
44	...	96	...	153	...				
88	32	...	154	...	178				
132	...	101	...	186	...				
176	26	...	154	...	181				
1960									
0	12	...	40	...	64	...	70	...	68
44	...	22	...	46	...	77	...	187	...
88	24	...	33	...	74	...	160	...	205
132	...	33	...	49	...	87	...	210	...
176	21	...	39	...	72	...	131	...	213
Total (1959 + 1960)									
0	34	...	134	...	154	...	164	...	158
44	...	118	...	199	...	173	...	340	...
88	56	...	187	...	252	...	314	...	383
132	...	134	...	235	...	188	...	396	...
176	47	...	193	...	253	...	285	...	394

K removal from the unfertilized plots was small because of low yields and low K contents of the bromegrass. Total removal for the 2 years averaged only 34 pounds of K per acre. The maximum removal of 56 pounds per acre occurred at site 2.

Applications of P alone increased K removal very little since P alone had little influence on yield or percent K in the plants. Applications of N, and especially of N and P together, increased yields and the percentage K in the bromegrass. These applications, therefore, resulted in very large increases in K removal. The average K removal from plots that received high rates of N and P amounted to about 200 pounds of K per acre each year. At sites 1 and 2 as much as 500 pounds of K per acre was removed in the bromegrass in 2 years.

Figure 4 shows that pounds of N and K removed in the bromegrass hay are approximately equal. The pounds of P removed from plots that received P fertilizer applications are about one-tenth of the amount of N or K removed. Where N fertilizers were applied without P, the amount of P removed is more nearly one-twentieth of the amount of N or K removed.

DISCUSSION

In addition to large increases in dry-matter yields, applications of N and P fertilizer resulted in much higher percentages of crude protein[8] and P in the bromegrass hay. Crude protein contents generally were increased from about 10 percent to almost 20 percent. P contents were increased from very low values, often 0.15 percent or less, to 0.25 percent and higher. These increases undoubtedly improve the feeding value of the hay produced.

However, the fertilizer treatments also often increased the nitrate content of the forage, and this tends to reduce the feeding value of the hay. Applications of 200 pounds of N or more per acre resulted in nitrate contents in the forage that are often considered toxic to livestock (10). Therefore, heavy applications of N for bromegrass should only be used with caution.

The relatively low recovery of applied N by the bromegrass on the calcareous soils is of considerable interest and needs further study. On the average, about half the applied N was recovered in the bromegrass forage, and in no case was more than about two-thirds of the total N applied recovered in the hay. The percentage recovery was essentially the same for all except the very heavy rate of application. This tends to indicate that a certain proportion of the applied N was lost. This could occur by different processes, such as volatilization of ammonia, denitrification or biological immobilization. If some means could be devised to prevent this apparent loss of applied N, the cost of N fertilization could be reduced appreciably.

The following observations are of special interest: (a) the low rate of P application was almost as effective as higher rates, (b) there was an apparent high recovery of the P from the low rate of P fertilizer application (44 lbs. of P per acre or 100 lbs. P_2O_5 per acre) and (c) the applied P appeared to be as available the following year as in the year applied. The apparent average recovery of applied P over the 2-year period from the 44-pound-per-acre rate of P application was 45 percent and, at one site, was 90 percent. This indicates that, where adequate N is applied on these soils, this rate of P fertilization should be effective for a period of from 2 to 4 years. Heavier rates of application would be expected to be effective much longer.

The fact that N and P fertilizer applications increased the percent K in the bromegrass is another observation that requires further study. The reason for this increase in percent K is not obvious. Similar results were obtained in Nebraska (17). The Nebraska study indicated that this increase in percent K was associated with a decrease in the relative proportion that calcium and magnesium made up of the total cations, but that the increase in percent K had relatively little effect on the percent calcium and

[8] Percent crude protein is calculated by multiplying percent total N by 6.25.

magnesium in the bromegrass hay. The removal of approximately 400 pounds of K per acre in the bromegrass over the 2-year period reflects the relatively high availability of K in these soils.

SUMMARY OF PART II

The percent total N in the bromegrass depended upon:

1. The amount of N applied—the higher the rate of N application, the higher was the percent N in the grass, and the longer the effect lasted; and
2. Whether P was applied or not—application of 44 pounds or more of P per acre increased the percent N in the grass where N was adequate but often tended to decrease percent N where N was not adequate.

Recovery of applied N during the 2-year period was essentially constant for all rates of application, with an average of 45 percent for all sites, and did not exceed two-thirds at any site.

The nitrate content of the forage was increased by N applications. In some cases, the nitrate content was further increased when P was applied in addition to N, and, in other cases (especially later cuttings), the nitrate content was decreased where P was applied. Applications of 200 pounds or more of N per acre resulted in potentially toxic levels of nitrate in the forage.

Percent P in the bromegrass forage was increased by P applications, especially where N was applied also. Recovery of applied P was small except where N also was applied. The amount of P recovered in the bromegrass was not much higher from high rates of P than from the lower rates. An average of 45 percent of the low (44-pound-per-acre) P application was recovered in the forage during the 2 years, although as much as 90 percent was recovered at one site. Applications of N and P markedly increased the percent K in the bromegrass.

LITERATURE CITED IN PART II

1. Anderson, K. L., R. E. Krenzin and J. C. Hide. The effect of nitrogen fertilizer on bromegrass in Kansas. Jour. Amer. Soc. Agron. 38:1058-1067. 1946.
2. App, Frank, Vernon Ichesaka and Tejpal S. Gill. The value of green manure crops in farm practice. Better Crops With Plant Food 40, No. 3:16-22, 41-43. 1956.
3. Beeson, K. C. The effect of mineral supply on the mineral concentration and nutritional quality of plants. Bot. Rev. 12:424-455. 1946.
4. Carey, V., H. L. Mitchell and K. Anderson. Effect of nitrogen fertilizer on the chemical composition of bromegrass. Agron. Jour. 44:467-469. 1952.
5. Carter, L. P. Effectiveness of inorganic nitrogen as a replacement for legumes grown in association with forage grasses. Unpublished Ph. D. thesis, Iowa State University Library. Ames, Iowa. 1960.
6. Crawford, R. F., W. K. Kennedy and W. C. Johnson. Some factors that affect nitrate accumulation in forages. Agron. Jour. 53:159-162. 1961.
7. Dotzenko, A. D. Effect of different nitrogen levels on the yield, total nitrogen content and nitrogen recovery of six grasses grown under irrigation. Agron. Jour. 53:131-133. 1961.
8. Fortman, H. C. Responses of varieties of bromegrass (*Bromus inermis*, Leyss.) to nitrogen fertilization and cutting treatments. N. Y. (Cornell) Agr. Exp. Sta. Mem. 322. 1953.
9. Grant, E. A. and C. S. Brown. Yield and nitrogen uptake of forage seedings as affected by nitrogen fertilization. Canad. Jour. Plant Sci. 41:176-187. 1961.
10. Hanway, J. J., J. B. Herrick, T. L. Willrich, P. C. Bennett and J. T. McCall. The nitrate problem. Iowa Coop. Ext. Serv. Spec. Report No. 34. 1963.
11. Hopper, T. H. and L. L. Nesbitt. The chemical composition of some North Dakota pasture and hay grasses. N. Dak. Agr. Exp. Sta. Bul. 236. 1930.
12. Laughlin, W. M. Influence of fertilizers on the crude protein yields of bromegrass pasture in the Matanuska Valley. Soil Sci. Soc. Amer. Proc. 17:372-374. 1953.
13. Lorenz, R. J., C. W. Carlson, G. A. Rogler and H. Holmen. Bromegrass and bromegrass - alfalfa yields as influenced by moisture level, fertilizer rates, and harvest frequency. Agron. Jour. 53:49-52. 1961.
14. Nielsen, K. F., R. L. Halstead, A. J. MacLean, S. J. Bourget and R. M. Holmes. The influence of soil temperature on the growth and mineral composition of corn, bromegrass and potatoes. Soil Sci. Soc. Amer. Proc. 25:369-372. 1961.
15. Parsons, J. L., M. Drake and W. G. Colby. Yield and vegetative and chemical composition of forage crops as affected by soil treatments. Soil Sci. Soc. Amer. Proc. 17:42-46. 1953.
16. Roberts, E. N. Wyoming forage plants and their chemical composition, No. 7. Wyo. Agri. Exp. Sta. Bul. 146. 1926.
17. Russell, J. S., C. W. Bourg and H. F. Rhoades. Effect of nitrogen fertilizers on the nitrogen, phosphorus and cation contents of bromegrass. Soil Sci. Soc. Amer. Proc. 18:292-296. 1954.
18. Washko, W. W. Effect of potassium upon the nitrogen and mineral content of bromegrass. Agron. Jour. 41:101-103. 1949.
19. Watkins, J. M. The growth habits and chemical composition of bromegrass, *Bromus inermis*, Leyss, as affected by different environmental conditions. Jour. Amer. Soc. Agron. 32:527-538. 1940.

APPENDIX A

Table A-1. Yields of bromegrass hay in tons per acre from site 1, the William Hughes farm near Moville.

No.	Treatment Lbs./acre N	Treatment Lbs./acre P[a]	1959 cutting and dates 1st May 27	1959 2nd July 23	1959 3rd Sept. 10	1959 Total	1960 cuttings and dates, N treatment reapplied 1st May 24	2nd July 11	3rd Oct. 17	Total	1960 Residual 1st May 24	2nd July 11	3rd Oct. 17	Total	Totals 1959 and 1960 residual	Totals 1959 and 1960 re-fertilized
1	0	0	0.16	0.14	0.07	0.37	0.15	0.07	0.11	0.33	0.15	0.07	0.11	0.33	0.70	0.70
2	0	88	0.20	0.18	0.13	0.51	0.22	0.18	0.07	0.47	0.22	0.18	0.07	0.47	0.99	0.99
3	0	176	0.26	0.37	0.18	0 81	0.22	0.29	0.18	0.69	0.22	0.29	0.18	0.69	1.51	1.51
4	100	44	0.91	0.32	0.05	1.28	0.95	0.40	0.11	1.46	0.22	0.22	0.11	0.55	1.83	2.74
5	100	132	0.89	0.49	0.15	1.53	0.69	0.58	0.15	1.42	0.26	0.18	0.18	0.62	2.15	2.95
6	200	0	0.84	0.85	0.16	1.85	0.44	0.77	0 40	1.61	0.19	0.21	0.04	0.44	2.29	3.46
7	200	88	1.37	1.10	0.19	2.66	1.31	0.91	0.37	2.59	0.36	0.19	0.15	0.70	3.36	5.25
8	200	176	1.22	0.64	0.18	2.04	1.39	0.87	0 29	2.55	0.59	0.29	0.18	1.06	3.10	4.59
9	300	44	1.24	1.19	0.23	2.66	1.47	1.31	0.69	3.47	0.37	0.26	0.07	0.70	3.36	6.13
10	300	132	1.68	1.23	0.25	3.16	1.54	1.20	0.62	3.36	0.29	0.33	0.18	0.80	3.96	6.52
11	400	0	0.69	1.06	0.13	1.88	0.50	1.01	0.50	2.01	0.80	0.76	0.44	2.00	3.88	3.89
12	400	88	1.28	1.61	0.29	3.18	1.13	1.24	1.10	3.47	0.76	0.33	0.11	1.20	4.38	6.65
13	400	176	1.20	1.65	0.33	3.18	1.42	1.17	0.80	3.39	0.69	0.40	0.19	1.28	4.46	6.57
..	Av.	...	0.92	0.83	0.18	1.93	0.88	0.77	0.41	2.06	0.39	0.29	0.15	0.83	2.77	3.99

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.

Table A-2. Yields of bromegrass hay in tons per acre from site 2, the Lewis Foster farm near Climbing Hill.

No.	Treatment Lbs./acre N	Treatment Lbs./acre P[a]	1959 cutting and dates 1st June 11	1959 2nd July 23	1959 3rd Sept. 10	1959 Total	1960 cuttings and dates, N treatment reapplied 1st May 24	2nd July 11	3rd Oct. 17	Total	1960 Residual 1st May 24	2nd July 11	3rd Oct. 17	Total	Totals 1959 and 1960 residual	Totals 1959 and 1960 re-fertilized
1	0	0	0.48	0.14	0.10	0.72	0.14	0.26	0	0.40	0.14	0.26	0	0.40	1.12	1.12
2	0	88	0 87	0.25	0.23	1.35	0 22	0.36	0.22	0 80	0.22	0.36	0.22	0.80	2.16	2.16
3	0	176	0.66	0.21	0.11	0.98	0.26	0.73	0	0.99	0.26	0.73	0	0.99	1.97	1.97
4	100	44	2.12	0.39	0.31	2.82	0.62	0.76	0.30	1.68	0.18	0.37	0.18	0.73	3.55	4.50
5	100	132	2.13	0.39	0.18	2.70	0.59	1.27	0.22	2.08	0.18	0.51	0	0.69	3.39	4.78
6	200	0	1.38	0.43	0.24	2.05	0.33	0.70	0.25	1.28	0.62	0.44	0.15	1.21	3.26	3.33
7	200	88	2.15	0.41	0.28	2.84	0.70	1.13	0.36	2.19	0.28	0.46	0.26	1.00	3.84	5.03
8	200	176	2.08	0 46	0.38	2.92	0.84	0.30	0.36	1.50	0.19	0.35	0	0.54	3.46	4.42
9	300	44	2.54	0.39	0.35	3.28	0.87	1.39	0.73	2.99	0.18	0.73	0.22	1.13	4.41	6.27
10	300	132	2.47	0.55	0.42	3.44	1.10	1.30	0.59	2.99	0.40	0.44	0.33	1.17	4.61	6.43
11	400	0	0.90	0.41	0.26	1.57	0 04	0.54	0.11	0.69	0.21	0.43	0.19	0.83	2.40	2.26
12	400	88	2.36	0.69	0.46	3.51	0.87	0.99	0.66	2.52	0.47	0.59	0.22	1.28	4.79	6.03
13	400	176	2.41	0.74	0.60	3.75	0.84	1.24	1.02	3.10	0 62	0.76	0.40	1.78	5.53	6.85
..	Av.	...	1.73	0.42	0.30	2.46	0.57	0 84	0.37	1.79	0.30	0.49	0.17	0.97	3.42	4.25

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.

Table A-3. Yields of bromegrass in tons per acre from site 3, the Lester Williams farm near Sioux City.

No.	Treatment Lbs./acre N	Treatment Lbs./acre P[a]	1959 cutting and dates 1st May 27	1959 2nd July 23	1959 3rd Sept. 10	1959 Total	1960 cuttings and dates, N treatment reapplied 1st May 24	2nd July 11	3rd Oct. 17	Total	1960 Residual 1st May 24	2nd July 11	3rd Oct. 17	Total	Totals 1959 and 1960 residual	Totals 1959 and 1960 re-fertilized
1	0	0	0.18	0.18	0 06	0.42	0.10	0.17	0 02	0.29	0.10	0.17	0.02	0.29	0.71	0.71
2	0	88	0.18	0.18	0.04	0.40	0.11	0.26	0.03	0.40	0.11	0.26	0.03	0.40	0.81	0.81
3	0	176	0.18	0.32	0.06	0.56	0.14	0.19	0 07	0.40	0.14	0.19	0.07	0.40	0.96	0.96
4	100	44	0.63	0.51	0 06	1.20	0.74	0.47	0.07	1.28	0.18	0.29	0.07	0.54	1.74	2.48
5	100	132	0.64	0.46	0.02	1.12	0.84	0 36	0.04	1.24	0.15	0.25	0.06	0.46	1.58	2.36
6	200	0	0.32	0.60	0.07	0.99	0.26	0.73	0.11	1.10	0.19	0.51	0.07	0.77	1.76	2.09
7	200	88	0.73	0.80	0.07	1.60	1.28	0.76	0.19	2.23	0.31	0.39	0.07	0.77	2.33	3.83
8	200	176	0.98	0.87	0.15	2 00	1.13	0 84	0.19	2.16	0.40	0.44	0.15	0.99	2.99	4.16
9	300	44	0.87	0.81	0.13	1.81	1.13	0.80	0.37	2.30	0.65	0.33	0.19	1.17	2.98	4.01
10	300	132	0.85	1.06	0.24	2.15	1.10	0.95	0 36	2.41	0.51	0.37	0.11	0.99	3.14	4.56
11	400	0	0.26	0.49	0.07	0.82	0.11	0.62	0 11	0 84	0.18	0.59	0.07	0.84	1.66	1.66
12	400	88	0.99	1.03	0 26	2.28	1.32	0.88	0 54	2.74	1.06	0.62	0.18	1.86	4.14	5.02
13	400	176	0.89	0.81	0.13	1.83	1.21	0.61	0 36	2.18	0.91	0 43	0.15	1.49	3.32	4.01
..	Av.	...	0.59	0.62	0.10	1.32	0.74	0 59	0.19	1.51	0.38	0.37	0.10	0.84	2.18	2.83

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.

Table A-4. Yields of bromegrass in tons per acre from site 4, the Amos Ross farm near Sioux City.

No.	Treatment Lbs./acre N	Treatment Lbs./acre P[a]	1959 cutting and dates 1st May 27	1959 2nd July 23	1959 3rd Sept. 10	1959 Total	1960 cuttings and dates, N treatment reapplied 1st May 24	2nd July 11	3rd Oct. 17	Total	1960 Residual 1st May 24	2nd July 11	3rd Oct. 17	Total	Totals 1959 and 1960 residual	Totals 1959 and 1960 re-fertilized
1	0	0	0.30	0.18	..[b]	0.48	0.11	0.15	0	0.26	0.11	0.15	0	0 26	0.74	0.74
2	0	88	0 23	0.14	..	0.37	0.04	0 07	0	0 11	0 04	0 07	0	0 11	0.48	0.48
3	0	176	0.27	0.11	..	0.38	0.04	0.07	0	0.11	0.04	0 07	0	0.11	0.50	0.50
4	100	44	0 89	0.54	..	1.43	0.73	0 40	0.11	1.24	0.12	0.15	0.03	0 30	1.73	2.67
5	100	132	0.50	0.58	..	1.08	0.28	0.19	0	0.47	0.04	0.07	0	0.11	1.19	1.56
6	200	0	0.16	0.64	..	0.80	0 04	0 55	0 18	0.77	0.04	0.33	0	0.37	1.17	1.57
7	200	88	1.08	0.75	..	1.83	0.95	0.51	0.22	1.68	0.34	0.22	0 04	0.60	2.43	3.51
8	200	176	1.02	0.78	..	1.80	1.17	0.44	0.07	1.68	0.51	0 33	0.02	0.86	2.66	3.48
9	300	44	0.62	0.78	..	1.40	1.21	0.62	0.18	2.01	0.55	0.33	0.11	0.99	2.39	3.41
10	300	132	1.00	0 82	..	1.82	1.25	0.53	0.19	1.97	0.81	0.37	0.07	1.25	3.07	3.79
11	400	0	0 28	0.52	..	0.80	0.07	0.59	0.07	0 73	0.07	0.59	0 07	0.73	1.53	1.53
12	400	88	0.97	0.89	..	1.86	1.17	0.40	0.18	1.75	0.87	0.33	0.15	1.35	3.21	3.61
13	400	176	0.67	0.80	..	1.47	1.13	0 33	0.11	1.57	0 69	0.22	0.04	0.95	2 42	3.04
..	Av.	...	0 61	0.60	..	1.21	0.63	0.37	0.10	1.10	0.33	0.25	0.04	0.61	1.82	2.31

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.
[b]Bromegrass was so short clipping was not attempted.

Table A-5. Yields of bromegrass in tons per acre from site 5, the Martin Johnson farm near Logan.

	Treatment		1959 cutting and dates				1960 cuttings and dates								Totals	
	Lbs./acre						N treatment reapplied				Residual					
No.	N	P[a]	1st May 27	2nd July 23	3rd Sept. 10	Total	1st May 24	2nd July 11	3rd Oct. 17	Total	1st May 24	2nd July 11	3rd Oct. 17	Total	1959 and 1960 residual	1959 and 1960 re-fertilized
1	0	0	0.40	0.18	..[b]	0.58	0.07	0.11	0.02	0.20	0.07	0.11	0.02	0.20	0.79	0.79
2	0	88	0.39	0.19	..	0.58	0.15	0.18	0.04	0.37	0.15	0.18	0.04	0.37	0.95	0.95
3	0	176	0.31	0.16	..	0.47	0.07	0.04	0.04	0.15	0.07	0.04	0.04	0.15	0.62	0.62
4	100	44	1.33	0.23	..	1.56	0.84	0.40	0.04	1.28	0.18	0.18	0.04	0.40	1.96	2.84
5	100	132	1.45	0.37	..	1.82	1.10	0.40	0.07	1.57	0.22	0.88	0.22	1.32	3.14	3.39
6	200	0	1.09	0.73	..	1.82	0.58	0.51	0.19	1.28	0.37	0.51	0.15	1.03	2.85	3.10
7	200	88	1.33	0.93	..	2.26	1.68	0.87	0.15	2.70	0.22	0.25	0.04	0.51	2.77	4.96
8	200	176	1.39	0.69	..	2.08	1.24	0.91	0.19	2.34	0.22	0.11	0.02	0.35	2.43	4.42
9	300	44	1.27	1.08	..	2.35	1.24	1.27	0.34	2.85	0.40	0.22	0.04	0.66	3.01	5.20
10	300	132	1.37	1.23	..	2.60	1.46	1.16	0.37	2.99	0.26	0.26	0.07	0.59	3.19	5.59
11	400	0	1.18	0.79	..	1.97	0.51	0.80	0.19	1.50	0.65	0.44	0.11	1.20	3.17	3.47
12	400	88	1.25	1.29	..	2.54	1.56	1.10	0.51	3.17	0.54	0.33	0.07	0.94	3.48	5.71
13	400	176	1.26	1.36	..	2.62	1.50	1.64	0.66	3.80	0.51	0.18	0.04	0.73	3.35	6.42
..	Av.	...	1.08	0.71	..	1.79	0.92	0.72	0.22	1.86	0.30	0.28	0.07	0.65	2.44	3.65

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.
[b]Bromegrass was so short clipping was not attempted.

Table A-6. Yields of bromegrass in tons per acre from site 6, the Donald Anderson farm near Honey Creek.

	Treatment		1959 cutting and dates				1960 cuttings and dates								Totals	
	Lbs./acre						N treatment reapplied				Residual					
No.	N	P[a]	1st June 15	2nd July 23	3rd Sept. 10	Total	1st May 24	2nd July 11	3rd Oct. 17	Total	1st May 24	2nd July 11	3rd Oct. 17	Total	1959 and 1960 residual	1959 and 1960 re-fertilized
1	0	0	0.68	0.05	0.15	0.88	0.04	0.07	..[b]	0.11	0.04	0.07	..[b]	0.11	0.99	0.99
2	0	88	0.80	0.14	0.19	1.13	0.11	0.15	..	0.26	0.11	0.15	..	0.26	1.39	1.39
3	0	176	0.50	0.14	0.17	0.81	0.04	0.07	..	0.11	0.04	0.07	..	0.11	0.92	0.92
4	100	44	1.29	0.25	0.19	1.73	0.55	0.25	..	0.80	0.04	0.22	..	0.26	1.99	2.53
5	100	132	1.71	0.18	0.28	2.17	0.62	0.33	..	0.95	0.11	0.18	..	0.29	2.46	3.12
6	200	0	1.46	0.32	0.36	2.14	0.11	0.51	..	0.62	0.22	0.40	..	0.62	2.76	2.76
7	200	88	2.51	0.37	0.30	3.18	1.06	0.80	..	1.86	0.18	0.25	..	0.43	3.61	5.04
8	200	176	2.20	0.28	0.26	2.72	1.06	0.84	..	1.90	0.15	0.22	..	0.37	3.09	4.62
9	300	44	1.88	0.58	0.34	2.80	0.76	0.70	..	1.46	0.15	0.25	..	0.40	3.20	4.26
10	300	132	2.25	0.44	0.45	3.14	1.35	0.80	..	2.15	0.11	0.26	..	0.37	3.51	5.29
11	400	0	1.85	0.37	0.44	2.66	0.15	0.51	..	0.66	0.22	0.44	..	0.66	3.32	2.69
12	400	88	2.11	0.55	0.36	3.02	1.13	0.80	..	1.93	0.40	0.22	..	0.62	3.64	5.33
13	400	176	2.13	0.53	0.47	3.13	1.21	0.76	..	1.97	0.36	0.34	..	0.70	3.83	5.33
..	Av.	...	1.64	0.32	0.30	2.27	0.63	0.51	..	1.14	0.16	0.24	..	0.40	2.67	3.41

[a]Multiply pounds of P by 2.30 to obtain pounds of P_2O_5 or multiply pounds of P_2O_5 by 0.44 to obtain pounds of P.
[b]Plots were grazed before third cutting could be taken.

APPENDIX B

Table B-1. Percentages of total nitrogen and of nitrate nitrogen in bromegrass as influenced by N and P fertilizer applications.

Fertilizer treatment (lbs./A.)			% total N per cutting						% nitrate N per cutting					
1959		1960	1959			1960			1959			1960		
N	P	N	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Site 1 (William Hughes)														
0	0	0	1.5	1.3	1.8	2.3	1.7	2.1	0.03	0.01	0.02	0.01	0.01	..
0	88	0	1.5	1.6	1.8	2.4	1.9	2.0	0.01	0.02	0.04	0.01	0.01	..
0	176	0	1.8	1.5	..	2.5	1.7	2.3	0.02	0.00	..	0.01	0.01	..
100	44	0	2.1	1.6	1.9	2.0	1.7	2.3	0.02	0.01	0.04	0.01	0.01	..
100	132	0	2.1	1.7	2.1	2.0	2.0	2.3	0.02	0.04	0.04	0.01	0.01	..
200	0	0	2.6	2.2	2.0	2.1	2.2	1.9	0.09	0 05	0.02	0.01	0.01	..
200	88	0	2.8	1.9	2.0	2.2	1.7	1.8	0.14	0.02	0.04	0.01	0.01	..
200	176	0	2.9	1.8	2.2	2.5	1.8	2.1	0.16	0.03	0.05	0.02	0.01	..
300	44	0	2.7	2.0	2.3	2.5	1.8	2.1	0.21	0.07	0.03	0.01	0.01	..
300	132	0	2.8	2.3	2.3	2.6	1.9	2.2	0.32	0.08	0.07	0.01	0.01	..
400	0	0	2.7	2.4	2.5	3.1	2.3	2.7	0.23	0.08	0.21	0.03	0.03	0.01
400	88	0	2.9	2.4	3.0	2.8	1.9	2.0	0.52	0.15	0.21	0.02	0.01	0.01
400	176	0	3.1	2.8	2.6	2.6	1.9	2.3	0.52	0.25	0.35	0.01	0.01	0.01
100	44	100				3.2	1.9	1.9				0.02	0.01	0.01
100	132	100				3.3	1.8	2.2				0.01	0.01	0.01
200	0	200				4.3	2.7	2.6				0.09	0.04	0.01
200	88	200				4.2	2.1	2.0				0.09	0.01	0.01
200	176	200				4.0	2.2	2.1				0.11	0.02	0.01
300	44	300				4.4	2.8	2.3				0.28	0.13	0.02
300	132	300				4.3	3.1	2.1				0.37	0.16	0.01
400	0	400				4.2	2.7	3.3				0.11	0.13	0.05
400	88	400				3.4	2.9	3.1				0.40	0.39	0.17
400	176	400				4.6	3.2	2.7				0.42	0.30	0.05
Site 2 (Lewis Foster)														
0	0	0	1.4	1.2	1.5	2.0	1.9	..	0.01	0.01	0.02	0.01	0.01	..
0	88	0	1.5	1.4	1.6	2.3	1.6	2.4	0.02	0.02	0.01	0.01	0.01	..
0	176	0	1.5	1.2	1.5	1.5	2.1	..	0.00	0.01	0.01	0.01	0.01	..
100	44	0	1.7	1.2	2.0	2.2	1.8	2.4	0.00	0.03	0.02	0.01	0.01	..
100	132	0	1.7	1.3	1.8	2.2	1.8	..	0.04	0.02	0.01	0.01	0.01	..
200	0	0	2.2	1.8	2.3	2.3	1.9	2.3	0.01	0.05	0.02	0.01	0.01	..
200	88	0	2.1	1.5	2.0	2.4	1.9	2.4	0.02	0.02	0.02	0.01	0.01	..
200	176	0	2 0	1.7	2.0	2.6	2.0	2.8	0.02	0.04	0.03	0.01	0.01	..
300	44	0	2.5	2.3	2.6	2.5	2.0	2.2	0.05	0.05	0.04	0.01	0.01	..
300	132	0	2.5	2.6	2.8	2.8	1.8	2.3	0.11	0.11	0.05	0.01	0.01	..
400	0	0	2.6	2.3	3.1	2.8	2.1	2.6	0.16	0.11	0.17	0.01	0.02	0.01
400	88	0	2.9	2.5	3.0	2.5	1.7	2.5	0.20	0.19	0.28	0.01	0.01	0.01
400	176	0	3.2	3.0	3.4	3.2	1.9	2.5	0.25	0.24	0.27	0.04	0.02	0.02
100	44	100				3.5	2.2	2.2				0.02	0.05	0.01
100	132	100				3.5	2.9	2.5				0.01	0.08	0.02
200	0	200				3.4	1.9	2.7				0.09	0.06	0.01
200	88	200				4.1	2.3	2.1				0.12	0.05	0.01
200	176	200				3.9	2.3	2.3				0.11	0.01	0.01

Table B-1 (continued)

Fertilizer treatment (lbs./A.)			% total N per cutting						% nitrate N per cutting					
1959		1960	1959			1960			1959			1960		
N	P	N	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
300	44	300				4.6	3.1	2.5				0.23	0.22	0.02
300	132	300				4.7	2.2	2.7				0.23	0.03	0.02
400	0	400				4.5	2.2	2.6				0.11	0.18	0.07
400	88	400				4.2	2.9	3.1				0.38	0.32	0.12
400	176	400				3.6	3.6	3.0				0.37	0.48	0.13
Site 3 (Lester Williams)														
0	0	0	1.6	1.6	1.7	1.9	1.5	2.6	0.03	0.03	0.02	0.01	0.01	..
0	88	0	1.8	1.7	1.7	2.1	1.5	2.7	0.01	0.00	0.02	..	0.01	..
0	176	0	1.9	1.6	1.6	2.1	1.6	3.2	0.01	0.02	0.01	0.01	0.01	..
100	44	0	2.8	1.6	1.8	2.0	1.6	2.5	0.00	0.00	0.01	0.01	0.01	..
100	132	0	2.7	1.6	1.7	2.1	1.3	2.6	0.00	0.01	0.01	0.01	0.01	..
200	0	0	2.9	2.0	2.4	2.6	1.9	2.4	0.07	0.05	0.05	0.01	0.01	..
200	88	0	3.5	2.0	2.1	2.1	1.5	1.9	0.14	0.04	0.02	0.01	0.01	..
200	176	0	3.4	2.1	2.3	2.1	1.8	2.2	0.18	0.06	0.01	0.01	0.01	..
300	44	0	3.3	2.5	2.9	2.4	1.7	2.2	0.32	0.23	0.10	0.01	0.02	..
300	132	0	3.4	2.2	2.9	2.4	2.1	2.5	0.40	0.21	0.07	0.02	0.01	..
400	0	0	2.8	2.4	2.5	2.9	2.0	2.8	0.22	0.13	0.04	0.02	0.03	0.01
400	88	0	3.8	2.8	3.0	3.3	2.2	2.7	0.58	0.44	0.17	0.07	0.03	0.04
400	176	0	4.0	2.7	2.7	3.4	2.3	2.8	0.60	0.32	0.15	0.09	0.06	0.02
100	44	100				..	1.8	2.2				..	0.01	0.01
100	132	100				3.2	1.8	1.8				0.02	0.01	0.01
200	0	200				3.3	2.1	3.0				0.06	0.06	0.01
200	88	200				3.5	2.3	2.2				0.17	0.07	0.01
200	176	200				..	2.2	2.6				..	0.06	0.01
300	44	300				3.7	2.6	3.2				0.26	0.23	0.06
300	132	300				3.5	2.7	3.1				0.33	0.24	0.07
400	0	400				3.6	2.2	2.4				0.06	0.18	0.04
400	88	400				4.1	3.2	4.0				0.44	0.63	0.35
400	176	400				4.2	3.0	3.7				0.40	0.41	0.26
Site 4 (Amos Ross)														
0	0	0	1.3	1.4	..	1.8	1.5	..	0.02	0.05	...	0.01	0.01	...
0	88	0	1.2	1.4	..	1.7	1.4	..	0.01	0.00	...	0.01	0.01	...
0	176	0	1.3	1.3	..	1.7	1.5	..	0.02	0.00	...	0.01	0.01	...
100	44	0	2.2	1.5	..	2.0	1.4	1.7	0.07	0.01	...	0.01	0.01	...
100	132	0	2.5	1.4	..	1.9	1.5	..	0.06	0.00	...	0.01	0.01	...
200	0	0	1.6	2.3	..	2.7	1.9	..	0.07	0.40	...	0.01	0.01	...
200	88	0	3.1	2.2	..	2.3	1.5	1.6	0.48	0.19	...	0.01	0.01	...
200	176	0	2.9	2.3	..	2.2	1.5	1.5	0.40	0.28	...	0.01	0.01	...
300	44	0	3.1	2.4	..	2.9	2.0	2.3	0.23	0.32	...	0.04	0.04	...
300	132	0	3.4	2.6	..	3.0	1.9	2.1	0.43	0.37	...	0.04	0.02	...
400	0	0	1.6	2.5	..	3.0	2.2	2.2	0.15	0.32	...	0.01	0.09	0.01
400	88	0	3.0	2.5	..	3.1	2.4	2.2	0.49	0.38	...	0.06	0.06	0.02
400	176	0	3.6	2.7	..	3.3	2.1	2.1	0.48	0.47	...	0.06	0.06	0.01
100	44	100				3.4	2.0	1.8				0.06	0.01	0.01
100	132	100				3.3	1.8	..				0.04	0.01	...
200	0	200				3.8	2.7	2.4				0.08	0.31	0.02
200	88	200				3.6	2.1	2.5				0.22	0.09	0.01
200	176	200				3.9	2.2	1.9				0.32	0.12	0.01
300	44	300				3.5	2.1	3.2				0.22	0.20	0.04
300	132	300				3.6	1.8	3.3				0.43	0.20	0.07
400	0	400				3.0	2.3	2.3				0.07	0.34	0.06
400	88	400				4.0	2.6	2.9				0.26	0.33	0.12
400	176	400				4.0	2.8	3.3				0.35	0.34	...
Site 5 (Martin Johnson)														
0	0	0	1.5	1.6	..	1.9	1.9	2.3	0.06	0.05	...	0.01	0.01	...
0	88	0	1.4	1.6	..	2.0	2.6	2.9	0.03	0.04	...	0.01	0.01	...
0	176	0	1.4	1.4	..	1.8	2.2	2.9	0.04	0.02	...	0.01	0.01	...
100	44	0	2.0	1.7	..	2.0	2.8	3.4	0.05	0.05	...	0.02	0.01	...
100	132	0	1.9	1.6	..	2.2	3.0	3.2	0.02	0.02	...	0.01	0.02	...
200	0	0	2.3	3.0	..	2.4	2.9	2.7	0.10	0.06	...	0.02	0.01	...
200	88	0	2.5	2.2	..	2.0	2.7	2.2	0.09	0.03	...	0.01	0.01	...
200	176	0	2.4	2.2	..	1.9	2.2	2.5	0.08	0.04	...	0.02	0.01	...
300	44	0	2.5	3.1	..	2.3	2.0	2.0	0.32	0.12	...	0.01	0.01	...
300	132	0	2.7	2.8	..	2.3	2.3	2.6	0.20	0.11	...	0.02	0.01	...
400	0	0	2.7	3.4	..	2.8	2.6	2.7	0.38	0.11	...	0.01	0.01	0.01
400	88	0	2.9	3.2	..	2.4	2.5	2.1	0.50	0.31	...	0.01	0.01	0.01
400	176	0	2.7	3.2	..	2.4	2.1	1.9	0.48	0.31	...	0.01	0.01	0.01
100	44	100				3.0	2.1	2.7				0.02	0.01	0.01
100	132	100				2.7	2.2	2.9				0.02	0.01	0.02
200	0	200				3.3	2.7	2.8				0.07	0.03	0.01
200	88	200				3.5	2.6	1.9				0.24	0.04	0.01
200	176	200				4.0	2.3	1.9				0.14	0.01	0.01
300	44	300				4.1	3.2	2.4				0.21	0.13	0.03
300	132	300				4.0	3.1	2.2				0.30	0.13	0.01
400	0	400				3.7	2.9	2.8				0.14	0.11	0.04
400	88	400				4.2	3.5	3.0				0.46	0.31	0.03
400	176	400				4.5	3.2	2.4				0.47	0.29	0.04
Site 6 (Donald Anderson)														
0	0	0	1.1	1.4	1.7	2.0	2.1	..	0.01	0.04	0.02	0.01	0.01	...
0	88	0	1.1	1.4	2.0	2.3	2.0	..	0.00	0.02	0.02	0.01	0.01	...
0	176	0	1.0	1.2	1.7	1.9	2.0	..	0.00	0.02	0.02	0.01	0.01	...
100	44	0	1.6	1.6	2.2	2.0	2.0	..	0.02	0.02	0.03	0.01	0.01	...
100	132	0	1.3	1.3	2.0	2.0	1.9	..	0.01	0.02	0.01	0.01	0.01	...
200	0	0	2.0	3.0	2.8	2.7	2.4	..	0.08	0.19	0.08	0.01	0.01	...
200	88	0	1.8	2.2	2.1	2.6	2.2	..	0.09	0.02	0.03	0.01	0.01	...
200	176	0	2.2	2.4	2.3	2.4	2.0	..	0.07	0.02	0.03	0.01	0.01	...
300	44	0	2.4	2.5	2.4	2.2	2.2	..	0.06	0.04	0.03	0.01	0.01	...
300	132	0	2.6	2.8	2.4	2.6	2.0	..	0.11	0.08	0.03	0.01	0.01	...
400	0	0	2.1	2.9	2.3	3.3	2.7	..	0.07	0.11	0.12	0.01	0.02	...
400	88	0	2.5	3.2	2.9	2.4	2.1	..	0.23	0.29	0.08	0.01	0.02	...
400	176	0	2.9	3.0	3.0	2.5	2.1	..	0.30	0.19	0.12	0.02	0.01	...
100	44	100				3.2	2.0	..				0.01	0.01	...
100	132	100				3.5	2.1	..				0.01	0.01	...
200	0	200				3.9	2.1	..				0.06	0.08	...
200	88	200				4.6	2.3	..				0.24	0.02	...
200	176	200				4.7	2.2	..				0.24	0.02	...
300	44	300				4.5	3.4	..				0.20	0.13	...
300	132	300				4.8	2.9	..				0.46	0.15	...
400	0	400				4.1	3.1	..				0.10	0.15	...
400	88	400				4.4	3.1	..				0.39	0.25	...
400	176	400				5.2	3.6	..				0.48	0.41	...

Table B-2. Percentages of phosphorus and potassium in bromegrass as influenced by N and P fertilizer applications.

Fertilizer treatment (lbs./A.)			% P per cutting						% K per cutting					
1959		1960	1959			1960			1959			1960		
N	P	N	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Site 1 (William Hughes)														
0	0	0	0.22	0.15	0.17	0.23	0.24	0.20	2.3	1.6	1.9	2.5	2.2	2.4
0	88	0	0.28	0.23	0.33	0.27	0.26	0.22	2.6	1.9	2.8	2.5	2.3	2.2
0	176	0	0.34	0.25	...	0.30	0.30	0.25	2.9	2.0	..	2.8	2.6	2.8
100	44	0	0.38	0.20	0.19	0.22	0.22	0.22	4.0	2.4	2.4	2.3	2.2	2.8
100	132	0	0.48	0.28	0.30	0.24	0.24	0.25	4.2	2.4	2.5	2.4	2.2	2.6
200	0	0	0.23	0.13	0.11	0.16	0.12	0.14	3.4	2.7	3.1	2.4	2.2	2.5
200	88	0	0.46	0.24	0.24	0.24	0.22	0.20	4.4	2.5	2.8	2.5	2.2	2.3
200	176	0	0.56	0.28	0.24	0.30	0.26	0.24	5.0	2.6	3.2	3.0	2.7	2.6
300	44	0	0.50	0.23	0.26	0.28	0.24	0.22	4.5	2.5	3.0	2.8	2.6	2.8
300	132	0	0.50	0.25	0.21	0.30	0.26	0.24	4.4	2.8	3.0	3.1	2.9	2.6
400	0	0	0.29	0.12	0.13	0.21	0.17	0.16	3.9	2.6	3.1	3.0	3.4	3.4
400	88	0	0.47	0.20	0.21	0.26	0.23	0.21	4.6	2.7	3.4	3.1	3.1	2.1
400	176	0	0.50	0.25	0.21	0.29	0.24	0.24	4.5	2.7	3.1	2.9	2.8	2.6
100	44	100				0.26	0.21	0.19				3.4	3.4	2.3
100	132	100				0.34	0.24	0.23				3.6	3.1	2.4
200	0	200				0.14	0.14	0.13				3.0	3.4	3.1
200	88	200				0.34	0.26	0.22				4.1	3.8	2.6
200	176	200				0.39	0.30	0.24				4.0	3.8	2.7
300	44	300				0.32	0.25	0.22				3.9	3.8	3.4
300	132	300				0.36	0.28	0.23				4.3	4.3	3.3
400	0	400				0.16	0.14	0.13				3.3	3.7	3.5
400	88	400				0.31	0.24	0.22				4.6	4.3	4.4
400	176	400				0.36	0.26	0.25				4.4	3.7	3.8
Site 2 (Lewis Foster)														
0	0	0	0.18	0.11	0.13	0.18	0.18	...	2.2	1.2	1.5	1.9	2.3	..
0	88	0	0.25	0.18	0.23	0.25	0.24	0.29	2.5	1.6	2.7	2.3	2.3	3.1
0	176	0	0.24	0.15	0.20	0.23	0.29	...	2.4	1.3	2.4	2.0	2.8	..
100	44	0	0.28	0.19	0.24	0.26	0.13	0.27	2.7	1.4	2.8	2.4	2.1	2.7
100	132	0	0.30	0.21	0.23	0.26	0.27	...	2.7	1.8	2.3	2.5	2.5	..
200	0	0	0.14	0.11	0.11	0.16	0.23	0.16	2.7	2.0	2.9	2.5	1.9	2.3
200	88	0	0.35	0.21	0.24	0.29	0.28	0.28	2.9	1.9	2.9	2.6	2.3	2.8
200	176	0	0.36	0.25	0.28	0.30	0.20	0.31	2.8	1.8	2.9	2.7	2.1	3.1
300	44	0	0.38	0.28	0.28	0.30	0.29	0.29	3.1	2.1	3.8	2.7	2.9	2.8
300	132	0	0.40	0.30	0.29	0.32	0.26	0.27	3.0	2.6	3.8	3.0	2.5	2.5
400	0	0	0.13	0.10	0.12	0.14	0.12	0.13	2.5	2.0	3.2	2.5	2.7	2.8
400	88	0	0.33	0.21	0.23	0.26	0.22	0.26	2.9	2.3	3.1	2.6	2.5	3.1
400	176	0	0.43	0.31	0.29	0.40	0.30	0.30	3.0	2.8	3.2	3.3	2.9	3.1
100	44	100				0.43	0.11	0.26				4.2	2.4	2.6
100	132	100				0.40	0.34	0.26				3.3	3.4	2.6
200	0	200				0.14	0.24	0.14				2.4	2.4	3.0
200	88	200				0.53	0.32	0.24				5.0	3.1	2.8
200	176	200				0.46	0.25	0.28				4.2	2.6	2.9
300	44	300				0.65	0.34	0.30				5.6	3.3	3.2
300	132	300				0.64	0.32	0.28				5.5	2.9	3.1
400	0	400				0.12	0.12	0.17				2.6	2.5	2.2
400	88	400				0.44	0.29	0.26				4.6	3.3	3.8
400	176	400				0.65	0.34	0.28				5.9	3.7	3.7
Site 3 (Lester Williams)														
0	0	0	0.15	0.12	0.13	0.18	0.16	0.14	1.8	1.8	2.2	2.3	2.0	2.7
0	88	0	0.23	0.17	0.23	0.24	0.20	0.19	1.9	2.0	1.8	2.5	2.1	2.2
0	176	0	0.24	0.17	0.23	0.24	0.22	0.22	1.9	2.0	1.8	2.3	2.3	2.6
100	44	0	0.39	0.18	0.21	0.23	0.20	0.18	3.7	2.6	2.2	2.7	2.3	2.2
100	132	0	0.47	0.20	0.22	0.24	0.20	0.22	3.8	2.6	2.0	2.5	2.2	1.8
200	0	0	0.16	0.11	0.12	0.12	0.10	0.10	2.6	2.5	2.4	2.5	2.6	2.3
200	88	0	0.46	0.21	0.20	0.23	0.20	0.17	4.0	3.1	2.9	2.6	2.3	2.3
200	176	0	0.52	0.26	0.32	0.26	0.25	0.21	4.2	3.1	3.3	2.7	2.7	2.2
300	44	0	0.35	0.18	0.21	0.20	0.18	0.16	3.6	2.9	3.0	2.8	2.8	2.6
300	132	0	0.51	0.20	0.24	0.26	0.24	0.22	4.7	2.9	3.2	2.9	3.0	3.1
400	0	0	0.15	0.10	0.09	0.12	0.11	0.11	2.2	2.4	1.6	2.7	3.1	2.9
400	88	0	0.45	0.20	0.20	0.27	0.22	0.26	4.4	3.1	3.1	2.3	4.0	3.5
400	176	0	0.50	0.20	0.19	0.31	0.22	0.16	4.5	3.0	2.9	3.4	3.7	3.2
100	44	100				...	0.21	0.24				..	3.6	2.6
100	132	100				0.31	0.20	0.17				3.4	3.4	2.5
200	0	200				0.11	0.10	0.12				2.6	2.9	2.9
200	88	200				0.29	0.22	0.20				3.3	3.8	3.3
200	176	200				...	0.26	0.24				..	4.1	3.9
300	44	300				0.22	0.18	0.18				3.4	3.8	4.1
300	132	300				0.39	0.24	0.24				5.0	4.1	3.9
400	0	400				0.14	0.10	0.10				2.5	2.9	2.0
400	88	400				0.34	0.26	0.19				3.9	4.4	2.3
400	176	400				0.31	0.18	0.20				3.6	3.7	3.8
Site 4 (Amos Ross)														
0	0	0	0.08	0.08	...	0.13	0.14	...	1.0	1.6	..	2.0	2.3	..
0	88	0	0.12	0.16	...	0.20	0.20	...	1.0	1.7	..	2.2	2.4	..
0	176	0	0.14	0.16	...	0.20	0.22	...	1.1	1.6	..	1.7	2.1	..
100	44	0	0.26	0.13	...	0.23	0.19	0.16	3.0	2.1	..	2.5	2.0	1.7
100	132	0	0.36	0.16	...	0.22	0.22	...	3.2	2.3	..	2.2	2.1	..
200	0	0	0.08	0.10	...	0.14	0.12	...	1.1	2.8	..	2.2	3.2	..
200	88	0	0.37	0.16	...	0.21	0.19	0.15	3.8	2.4	..	2.3	2.3	1.5
200	176	0	0.38	0.20	...	0.25	0.21	0.16	3.4	2.6	..	2.6	2.2	1.4
300	44	0	0.27	0.15	...	0.17	0.16	0.13	3.2	2.6	..	2.7	2.9	2.1
300	132	0	0.42	0.20	...	0.19	0.22	0.16	3.7	2.6	..	3.1	2.9	1.6
400	0	0	0.09	0.10	...	0.14	0.14	0.10	1.0	2.4	..	2.1	3.2	2.6
400	88	0	0.32	0.16	...	0.22	0.20	0.14	3.3	2.5	..	2.8	3.4	2.4
400	176	0	0.38	0.18	...	0.24	0.17	0.15	3.6	2.8	..	2.9	2.7	2.4
100	44	100				0.23	0.17	0.14				3.6	3.2	2.5
100	132	100				0.31	0.20	...				3.4	2.6	..
200	0	200				0.14	0.14	0.12				2.5	4.6	2.5
200	88	200				0.27	0.16	0.14				3.6	2.9	3.2
200	176	200				0.40	0.20	0.16				4.6	3.5	2.6
300	44	300				0.18	0.22	0.14				3.4	2.5	3.1
300	132	300				0.31	0.20	0.18				3.9	2.5	3.4
400	0	400				0.12	0.12	0.10				1.5	3.4	2.8
400	88	400				0.24	0.19	0.14				3.4	3.4	2.9
400	176	400				0.31	0.18	0.16				4.2	3.2	3.4

Table B-2 (continued)

Fertilizer treatment (lbs./A.)			% P per cutting						% K per cutting					
1959		1960	1959			1960			1959			1960		
N	P	N	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Site 5 (Martin Johnson)														
0	0	0	0.28	0.17	...	0.21	0.23	0.22	3.1	1.5	..	2.5	2.0	2.0
0	88	0	0.27	0.18	...	0.24	0.26	0.31	2.9	1.6	..	2.6	2.8	3.2
0	176	0	0.28	0.19	...	0.22	0.25	0.25	2.8	1.5	..	2.3	2.2	2.3
100	44	0	0.33	0.20	...	0.22	0.24	0.23	3.6	2.0	..	2.5	2.9	2.8
100	132	0	0.39	0.22	...	0.25	0.30	0.32	3.6	1.9	..	2.8	3.4	3.7
200	0	0	0.24	0.16	...	0.17	0.18	0.15	3.8	3.0	..	2.6	3.2	3.2
200	88	0	0.51	0.26	...	0.22	0.24	0.22	4.2	2.6	..	2.4	2.7	2.6
200	176	0	0.54	0.28	...	0.24	0.23	0.25	4.4	2.9	..	2.6	2.5	2.5
300	44	0	0.54	0.28	...	0.24	0.23	0.25	4.2	2.9	..	2.5	2.4	2.3
300	132	0	0.52	0.30	...	0.24	0.26	0.20	4.0	3.1	..	2.6	2.8	2.5
400	0	0	0.20	0.18	...	0.13	0.16	0.14	3.6	3.0	..	2.6	3.4	3.0
400	88	0	0.50	0.27	...	0.25	0.21	0.17	4.3	2.6	..	2.7	2.8	2.5
400	176	0	0.44	0.31	...	0.27	0.26	0.19	4.4	2.8	..	2.7	2.8	2.3
100	44	100				0.26	0.21	0.23				3.1	3.3	2.7
100	132	100				0.32	0.30	0.28				3.3	3.4	3.0
200	0	200				0.16	0.16	0.13				3.2	3.5	3.1
200	88	200				0.33	0.29	0.19				3.4	3.3	2.3
200	176	200				0.37	0.28	0.19				3.4	3.6	2.2
300	44	300				0.29	0.24	0.16				3.8	3.4	3.1
300	132	300				0.38	0.30	0.20				3.5	3.2	2.9
400	0	400				0.16	0.15	0.15				3.0	3.1	3.4
400	88	400				0.34	0.27	0.20				3.7	3.0	3.4
400	176	400				0.44	0.29	0.22				3.9	3.1	3.2
Site 6 (Don Anderson)														
0	0	0	0.12	0.12	0.13	0.16	0.19	...	1.8	1.2	1.9	2.3	2.3	..
0	88	0	0.17	0.17	0.28	0.25	0.27	...	1.8	1.5	2.2	2.5	2.3	..
0	176	0	0.19	0.16	0.26	0.26	0.28	...	1.8	1.1	1.9	2.3	2.2	..
100	44	0	0.18	0.16	0.26	0.22	0.26	...	2.4	1.4	2.5	2.1	2.2	..
100	132	0	0.24	0.20	0.29	0.22	0.24	...	2.4	1.9	1.9	2.1	2.5	..
200	0	0	0.12	0.17	0.19	0.20	0.20	...	2.7	2.7	3.0	2.9	3.0	..
200	88	0	0.28	0.27	0.29	0.27	0.29	...	2.9	2.7	2.1	2.7	2.3	..
200	176	0	0.34	0.31	0.34	0.28	0.30	...	3.1	2.8	2.5	2.7	2.4	..
300	44	0	0.19	0.19	0.22	0.24	0.22	...	2.9	2.9	2.4	2.6	2.4	..
300	132	0	0.30	0.26	0.31	0.29	0.27	...	3.2	3.0	2.7	2.8	2.3	..
400	0	0	0.11	0.13	0.16	0.13	0.13	...	2.5	2.5	2.9	2.8	3.0	..
400	88	0	0.20	0.23	0.26	0.26	0.24	...	2.8	3.1	3.1	2.9	2.6	..
400	176	0	0.29	0.26	0.28	0.28	0.28	...	3.2	3.1	3.2	3.0	2.9	..
100	44	100				0.24	0.19	...				3.2	2.8	..
100	132	100				0.33	0.29	...				3.5	2.9	..
200	0	200				0.12	0.22	...				2.6	2.8	..
200	88	200				0.32	0.25	...				3.9	3.6	..
200	176	200				0.38	0.30	...				4.0	3.7	..
300	44	300				0.21	0.19	...				3.6	3.9	..
300	132	300				0.39	0.27	...				4.2	3.8	..
400	0	400				0.13	0.19	...				2.6	3.0	..
400	88	400				0.29	0.22	...				4.5	3.7	..
400	176	400				0.32	0.27	...				4.4	4.1	..

Table B-3. Pounds of nitrogen, phosphorus, and potassium removed in bromegrass hay as influenced by applications of N and P fertilizers.

Fertilizer treatment (lbs./A.) 1959 N	1959 P	1960 N	Site number (1959) 1	2	3	4	5	6	Site number (1960) 1	2	3	4	5	6
Pounds of nitrogen per acre (all cuttings)														
0	0	0	12	22	14	13	18	22	14	16	11	8	8	5
0	88	0	17	42	14	10	17	30	21	33	14	3	18	11
0	176	0	21	28	19	10	14	19	30	39	17	4	7	4
100	44	0	51	94	55	56	62	59	22	31	21	10	19	10
100	132	0	62	89	51	42	68	62	26	27	15	4	74	12
200	0	0	90	87	47	36	96	100	19	53	33	15	56	32
200	88	0	123	114	88	102	110	122	28	44	26	23	25	21
200	176	0	87	114	113	97	99	124	48	38	40	34	14	16
300	44	0	125	163	108	78	134	139	31	49	52	51	29	18
300	132	0	165	176	121	113	146	167	36	54	56	66	28	16
400	0	0	96	81	42	36	120	131	111	41	39	34	67	39
400	88	0	172	196	152	105	158	175	61	56	109	78	47	29
400	176	0	187	240	124	93	158	188	61	91	92	58	34	33
100	44	100							82	92	21	71	71	46
100	132	100							75	129	...[a]	26	83	58
200	0	200							102	64	55	36	78	31
200	88	200							167	127	136	103	172	137
200	176	200							165	98	...[a]	116	151	139
300	44	300							239	207	152	125	204	119
300	132	300							238	196	154	124	210	180
400	0	400							135	34	41	35	97	45
400	88	400							221	175	212	128	244	152
400	176	400							254	216	169	119	277	184
Pounds of phosphorus per acre (all cuttings)														
0	0	0	1.4	2.2	1.1	0.8	2.9	1.2	1.5	1.4	1.1	0.7	0.9	0.2
0	88	0	2.9	6.3	1.7	1.1	2.9	4.4	2.5	4.2	1.6	0.5	1.9	1.4
0	176	0	3.7	4.2	2.3	1.2	2.4	3.4	4.0	5.5	1.8	0.5	1.7	2.4
100	44	0	8.5	14.8	7.1	6.1	9.9	6.6	2.5	3.0	2.4	1.2	1.9	1.4
100	132	0	12.4	15.1	7.8	5.6	13.3	10.8	3.1	3.8	1.9	0.5	7.9	1.4
200	0	0	6.8	5.4	2.6	1.6	7.7	6.1	1.2	4.6	1.5	0.9	3.6	2.5
200	88	0	19.1	18.0	10.5	10.6	18.8	18.2	3.2	5.8	3.2	2.3	2.5	2.5
200	176	0	18.7	19.4	15.7	11.1	19.3	18.7	6.0	4.0	4.9	4.1	1.7	2.1
300	44	0	19.4	23.4	9.6	5.8	19.2	11.1	3.7	6.7	4.5	3.3	3.0	1.8
300	132	0	24.4	25.5	14.4	12.0	22.1	19.0	4.4	6.7	5.0	4.9	3.0	2.0
400	0	0	7.0	3.7	1.9	1.6	7.7	6.6	7.5	2.2	1.9	2.0	3.4	1.8
400	88	0	20.1	20.5	14.3	9.2	19.9	13.1	6.1	6.3	9.3	5.6	4.5	3.2
400	176	0	22.0	28.7	12.9	8.2	19.9	18.1	7.0	12.3	8.3	4.3	3.9	4.0
100	44	100							7.1	7.1	...[a]	5.1	6.4	3.7
100	132	100							8.4	14.9	6.9	2.5	10.1	6.1
200	0	200							4.6	5.1	2.4	2.1	4.1	2.0
200	88	200							15.5	16.7	11.7	7.5	17.1	11.0
200	176	200							17.8	11.5	...[a]	11.5	15.3	13.3
300	44	300							19.3	25.7	9.4	7.7	14.8	6.0
300	132	300							21.1	26.2	15.2	10.8	20.0	15.2
400	0	400							6.0	1.8	1.8	1.7	4.8	2.4
400	88	400							18.2	17.2	15.9	7.8	19.0	10.3
400	176	400							20.8	25.5	11.4	8.8	26.1	12.1
Pounds of potassium per acre (all cuttings)														
0	0	0	16	28	16	12	31	32	16	18	14	11	9	5
0	88	0	35	64	16	10	30	41	43	41	18	5	21	12
0	176	0	31	43	22	10	23	28	38	52	19	4	7	5
100	44	0	93	143	77	76	107	80	26	35	27	13	22	11
100	132	0	108	137	75	60	121	102	30	35	21	5	90	14
200	0	0	116	106	51	40	130	120	21	56	40	23	62	38
200	88	0	191	156	114	121	164	182	34	51	36	27	27	22
200	176	0	170	155	150	112	166	168	62	40	53	45	18	19
300	44	0	182	200	120	82	173	162	39	66	66	54	33	20
300	132	0	236	209	160	119	190	199	48	64	60	75	32	18
400	0	0	119	78	38	32	135	140	133	46	51	45	72	39
400	88	0	231	197	171	111	178	178	74	69	135	80	53	35
400	176	0	223	233	139	95	191	204	74	113	106	55	40	42
100	44	100							99	106	...[a]	86	82	50
100	132	100							95	140	86	30	106	64
200	0	200							106	66	63	63	96	35
200	88	200							200	163	158	114	182	143
200	176	200							134	109	...[a]	145	162	150
300	44	300							266	241	172	127	206	112
300	132	300							282	238	220	140	202	176
400	0	400							148	35	47	47	95	39
400	88	400							314	200	209	120	221	165
400	176	400							279	272	164	126	266	172

[a]Data from first cutting missing.