

Bromegrass Fertilization at Six Nitrogen Rates: Long and Short Term Effects

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Nitrogen (N) fertilization of pure grass stands is fundamental to economical forage production in North Dakota. Swallers and Stoa (8) reported in 1947 that N fertilization more effectively reduced the "sodbound" condition of northern bromegrass (*Bromus inermis* Leyss.) than cultivation. Carter (1,2) found N fertilizer levels up to 133 lbs N/acre significantly increased forage yields of several grasses at Fargo. Grass fertilization trial results from Carrington, Dickinson, Edgeley, Fargo, Langdon, Minot and Williston Agricultural Experiment Stations (4); The Northern Great Plains Research Center (7); and numerous demonstration sites throughout North Dakota (3) have shown conclusively the need for N fertilization in tamegrass production. However, most of these trials were of less than six years duration. Continued long-term N fertilization could alter forage production and quality through soil storage of nitrate-nitrogen, depletion of other essential plant nutrients, soil pH change from the acidifying effect of N fertilizer, or substantial stand loss.

Our objective was to determine the forage production, per cent crude protein and nitrate-nitrogen, and per cent of applied N recovered as crude protein (fertilization efficiency) in bromegrass hay as influenced by 22 years of N fertilization at six rates, and compare long-term forage and protein production data to short-term results reported previously by Carter (2) over six years of N fertilization.

Methods and Materials

An old northern bromegrass sod, established prior to 1929 at Fargo, ND, was used as the experimental site. Ammonium nitrate (33.5-0-0) at six rates (0, 33, 66, 133, 200, and 266 lbs N/acre) has been broadcast annually during late fall since 1954, or for 22 consecutive years, to the same 20 x 20-ft plots replicated twice in a randomized complete block design. Soil type is a Fargo clay which tested 29 and 450 lbs/acre actual phosphorus and potassium, respectively, in the 66 lbs N/acre treatment in 1970. Forty-six lbs/acre of actual phosphorus was applied broadcast to all treatments in 1970;

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potassium has not been applied. Spring-growth forage was harvested at the anthesis to milk growth stages of the grass (mid to late June) each year, and regrowth was harvested during the first week of September (vegetative to jointing stage) in 13 of 22 test years when seasonal rainfall permitted. Dry matter samples were analyzed for crude protein content by the micro-Kjeldahl method and nitrate-nitrogen by the Lowe and Hamilton (6) method. Per cent of applied N recovered as crude protein was calculated by subtracting the mineralized soil N (the N in the non-fertilized hay) from the forage's N content of each treatment and dividing by the fertilization rate.

Carter (2) reported the forage yield and crude protein percentage for the first six (1955-60) years of this experiment previously; these data will be used for the short-term N fertilization results reported herein. Larson, Carter, and Vasey (5) subsequently reported the average forage production and nitrate-nitrogen level accumulated in the soil profile after 15 years of N fertilization. Substantial nitrate-nitrogen accumulated in the soil profile with N rates 133 lbs/acre and above. However, the results suggested apparent lack of nitrate-nitrogen movement below the rooting depth of bromegrass in fine-textured soils under northern climatic conditions even under high rates of continuous N fertilization. The long-term fertilization results will refer to data collected during the 16th to 22nd year, a seven-year period from 1970-76.

Results and Discussion

Average annual forage yield from an old bromegrass sod as influenced by N fertilization level the past 22 years is presented in Figure 1. The average

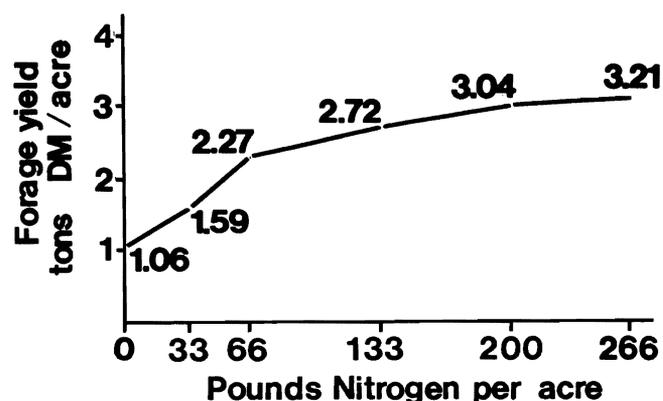


Figure 1. Average forage yield of an old bromegrass sod fertilized annually at six N rates for the past 22 years at Fargo, ND.

forage yield was increased by each additional N increment applied, but at a decreasing rate at the higher N levels. Annual forage yields were doubled by 66 lbs N/acre and tripled by 266 lbs N/acre fertilization treatments when compared to the non-fertilized bromegrass. If N retails for 20 cents/lb and good grass hay sells for \$40/ton (November, 1976 prices), every dollar invested in bromegrass fertilization at 66 lbs N/acre (probably most tame grass fertilization at modest rates) will return more than \$4.00 worth of harvestable hay, an excellent buy!

Nitrogen fertilization increased the annual variation in forage production within a treatment caused by seasonal variation in precipitation; i.e., the forage yield of non-fertilized bromegrass varied from 0.72 to 1.49 tons dry matter (DM)/acre excluding 1976, but the 66 lbs N/acre treatment varied from 1.56 to 3.30 tons DM/acre. Therefore, estimating the fertilized acreage necessary to produce the forage supply for a given size livestock operation would be more difficult and probably would necessitate greater hay reserves.

Forage yields were higher for the 33, 66 and 133 lbs N/acre treatments, but similar for the 0, 200 and 266 lbs N/acre treatments the last seven (1970-76) compared to the first six (1955-60) productive years of this 22-year experiment (Table 1). Apparently, the lower N treatments used applied N more efficiently in forage production in the long- than short-term. An earlier first harvest date (approximately June 20 the last seven years compared to July 1 the first six years) and early lodging has caused some stand deterioration in the 133, 200 and 266 lbs N/acre treatments.

First harvest forage yields of the 266 lbs N/acre treatment (and, to a lesser extent, the 200 lbs N/acre treatment) have tended to be lower in the long- than short-term. However, the differences noted between short- and long-term productivity cannot be explained entirely on stand since the non-fertilized treatment stands did not vary appreciably. An interaction between the 1970 phosphorus application and stand deterioration possibly could explain these results. If phosphorus was limiting the forage yield of N fertilized treatments but not the non-fertilized treatment, stand deterioration of the 200 and 266 lbs N/acre treatments may have limited forage yields to pre-phosphorus fertilization levels. However, soils testing 29 lbs phosphorus/acre are not likely to respond to phosphorus fertilization.

Per cent crude protein (PP) in bromegrass hay increased with increasing N rate in each harvest (Figures 2 and 3). The slightly higher PP in the first-harvest hays for the 0, 33, and 66 lbs N/acre treatments and the lower PP in the second-harvest hays the last five years compared to the first six years probably is a result of the earlier first-harvest date the last five years. The marked increase in PP in the first-harvest hay between 66 and 133 lbs

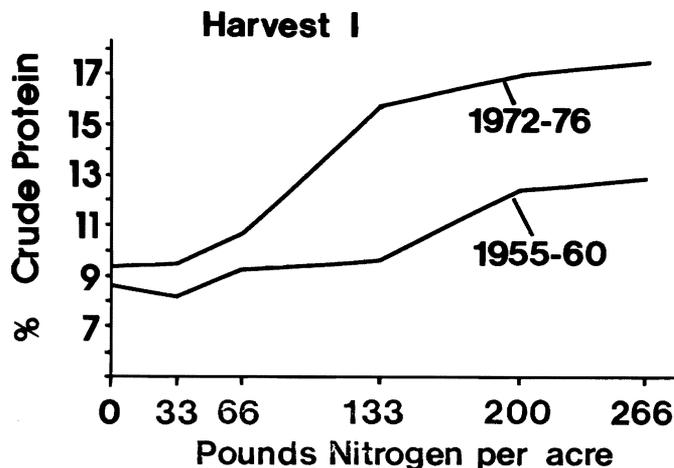


Figure 2. Per cent crude protein the first six and last five productive years in first-harvest forage from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

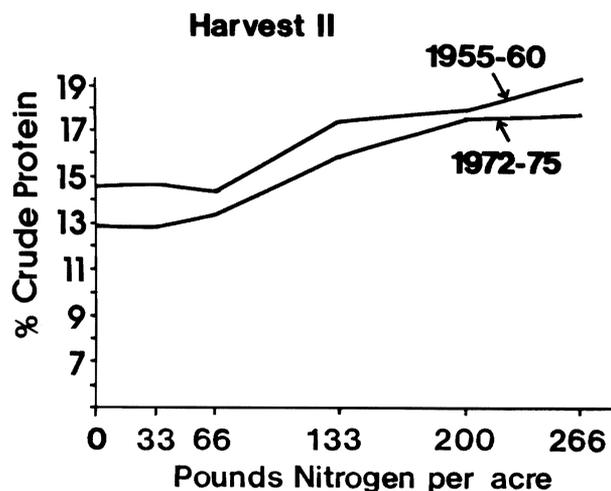


Figure 3. Per cent crude protein the first six and the last five productive years in second-harvest forage from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

N/acre treatments the last five years probably is due to substantial soil nitrate-nitrogen accumulation as determined by Larson et al. (5). However, the 1975 and 1976 PP values at higher fertility levels were lower than the previous three years, indicating a possible loss of the soil-stored nitrate-nitrogen.

Crude protein production/acre increased with increasing N rate for both sampling periods (Table 2). About 300 additional pounds crude protein/acre were produced at the three highest N levels the last five years compared to the first six years, primarily due to a higher PP. Assuming soybean oil meal retails for \$200/ton, N for 20 cents/lb, and 70 per cent protein digestibility, the additional protein produced the last five years by another 66-pound N increment (66 vs. 133 lbs N/acre treatments) would replace more than \$50 of soybean oil meal/acre in livestock rations.

Bromegrass is known to accumulate nitrate-nitrogen ($\text{NO}^3\text{-N}$) in the hay to potentially toxic levels (0.2 to 0.4% $\text{NO}^3\text{-N}$) under high N fertilization. Nitrate-nitrogen accumulation was detected in hay from the 133 lbs N/acre treatment (Table 3). Potentially toxic levels were detected only in 200 to 266 lbs N/acre treatment hays. The 1975 first-harvest forage of the 133 lbs N/acre treatment and the 200 and 266 lbs N/acre treatments in the second harvest contained less $\text{NO}^3\text{-N}$ than the same treatments in 1973 and 1974, probably reflecting the lower available N in the soil profile as a result of two consecutive years of abundant forage production.

Per cent of applied N recovered as crude protein in bromegrass hay, a measure of N fertilization efficiency, for 1955-60 and 1972-76 periods is shown in Figure 4. Nitrogen recovery was higher the last

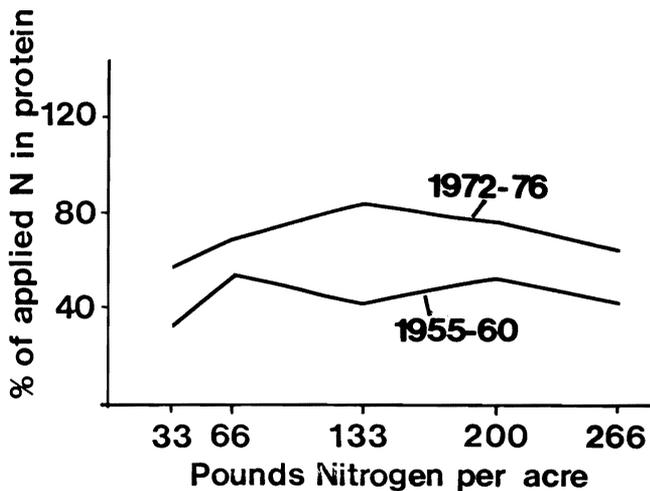


Figure 4. Average per cent of applied N recovered in 1955-60 and 1972-76 periods as crude protein in forage from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

five than the first six years at all N rates, primarily as a result of the higher PP in the first-harvest hay (Figure 2). The highest recovery rate (83 per cent) the last five years was observed with the 133 lbs N/acre treatment; the lowest recovery rate (57 per cent) was observed with the 33 lbs N/acre treatment. Nitrogen recovery at 33 lbs/acre is lower than the higher N treatments because a greater per cent of the applied N is tied up in the root biomass and its decomposition. The reason for the lower N recovery rate at 133 than at the 66 and 200 lbs N/acre treatments in the 1955-60 period is unclear. A higher recovery rate at N rates in excess of 133 lbs/acre would have been observed if the $\text{NO}^3\text{-N}$ content in the hay was included in the calculation. For example, the $\text{NO}^3\text{-N}$ of the 266 lbs N/acre treatment was in excess of 40 lbs N/acre in 1975.

Environmental conditions were important in determining the amount of N recovered as crude protein in a given year (Figure 5). Nitrogen recovery was very high, exceeding 100 per cent at 133 and 200 lbs N/acre, in wet years following a dry year;

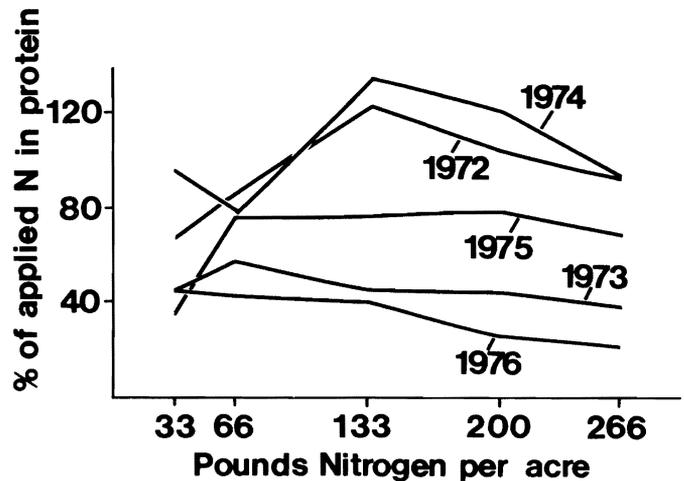


Figure 5. Environmental influence on per cent of applied N recovered as crude protein in forage from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

i.e., 1972 and 1974. Obviously, N applied during the dry year was utilized for forage and crude protein production in the wet year. These data indicate that the N fertilization level could be decreased slightly following a dry year since N stored in the soil from the previous year should be available for bromegrass growth.

Nitrogen recovered as crude protein was substantially lower the second year (1975) when two consecutive wet years occurred (Figure 5). Forage production was slightly lower and PP and $\text{NO}^3\text{-N}$ were lower significantly in 1975 than 1974, especially at higher N rates, indicating a possible N shortage for maximum forage and protein production. However, Larson et al. (5) found substantial $\text{NO}^3\text{-N}$ reserves in the soil in excess of 133 lbs N/acre. Nitrate leaching below the rooting depth of bromegrass on Fargo clay soils was not evident in their results. These data would suggest a possible loss of the $\text{NO}^3\text{-N}$ reserved through volatilization, and that it may be a wise management decision to increase the N rate applied following a wet season if rainfall prospects appear normal or above normal.

Conclusions and Recommendations

Nitrogen fertilization at 70 to 130 lbs N/acre is fundamental to economical tamegrass forage production in eastern North Dakota. Nitrogen applied at 66 and 133 lbs/acre produced 214 and 257%, respectively, of the non-fertilized bromegrass treatments the past 22 years at Fargo, ND. The higher N rate (133 lbs/acre) could be economical if the additional crude protein content in the hay replaces expensive protein supplements in livestock rations. Nitrate-nitrogen accumulation in the hay was not a problem at recommended bromegrass fertilization rates. However, N fertilization will increase the annual variation in forage production, necessitating larger hay reserves, if livestock numbers are increased based on the average productivity of fertilized grass. The last seven productive years were

higher yielding than the first six years of this 22-year experiment at recommended N rates, indicating that tamegrass productivity can be maintained over a long time by N fertilization. Crude protein production the last five years was higher than the first six years, especially at higher N rates, primarily due to a higher per cent protein and a slightly earlier harvest the last five years.

The fertilization rate should vary, depending on the previous year's productivity level and the avail-

able soil moisture. If the previous season was a low forage producing year, especially during the first harvest, and fall rainfall is minimal, the nitrogen rate should be reduced since some N carryover should occur. If the previous season was a high forage producing year and fall rainfall is normal to above normal, the N rate should be increased to prevent an N shortage and utilize available moisture efficiently. If abundant spring rains occur, an additional 20 to 40 lbs N applied prior to the spring flush of growth can be utilized also.

Table 1. Forage yield for the first six and last seven productive years of an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

Nitrogen rate (lbs/A)	Forage yield in tons dry matter per acre						Total Difference
	1955-60 ¹			1970-76 ¹			
	Cut I	Cut II	Total	Cut I	Cut II	Total	
0	0.78	0.28	1.06	0.72	0.33	1.05	-0.01
33	1.09	0.29	1.38	1.29	0.37	1.66	+0.28
66	1.69	0.36	2.05	1.88	0.46	2.34	+0.29
133	2.13	0.46	2.59	2.17	0.70	2.87	+0.28
200	2.50	0.72	3.22	2.36	0.82	3.18	-0.04
266	2.56	0.85	3.31	2.26	1.06	3.32	+0.01
LSD(.05)			0.28			0.41	
CV(%)			16.0			17.4	

¹Two harvests were taken in all years except 1955, 1970, and 1976 when a late season drought caused inadequate recovery growth for a second harvest.

Table 2. Pounds crude protein/acre for the first six and the last five years in forage harvested from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND.

Nitrogen rate (lbs/A)	Pounds crude protein (Kjeldahl N × 6.25) per acre						Total difference
	1955-60			1972-76			
	Cut I	Cut II	Total	Cut I	Cut II	Total	
0	133	77	210	107	104	211	+ 1
33	195	81	276	201	125	326	+ 50
66	335	99	434	338	149	487	+ 53
133	409	143	552	636	266	902	+350
200	622	243	865	786	350	1136	+271
266	610	300	910	804	453	1257	+347

Table 3. Per cent nitrate-nitrogen in forage harvested from an old bromegrass sod fertilized annually at six N rates since 1954 at Fargo, ND, 1973-75.

Nitrogen level (lbs/A)	Per cent nitrate-nitrogen ¹							
	June harvest				September harvest			
	1973	1974	1975	Avg.	1973	1974	1975	Avg.
0	0.007	0.007	0.005	0.006	0.006	0.003	0.004	0.004
33	0.010	0.005	0.004	0.006	0.005	0.004	0.005	0.005
66	0.008	0.005	0.004	0.006	0.010	0.004	0.008	0.007
133	0.150	0.115	0.035	0.100	0.065	0.013	0.012	0.030
200	0.325	0.320	0.225	0.290	0.315	0.180	0.043	0.179
266	0.490	0.525	0.710	0.575	0.740	0.595	0.170	0.502
LSD(.05)	0.299	0.271	0.083		0.110	0.164	0.044	
CV(%)	70.6	64.7	22.0		30.1	48.0	42.8	

¹The potentially toxic level for ruminant animals is 0.2 to 0.4% nitrate-nitrogen.

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In Memoriam



Brentzel

Former Plant Pathology Chairman Dies

W.E. Brentzel, Chairman of the Department of Plant Pathology, North Dakota Agricultural Experiment Station from 1925 until his retirement in 1959, died at his home in Fargo, June 14, 1977.

Professor Brentzel was born in Kelso, Missouri, March 27, 1889. He earned his B.S. (1915) and M.A. (1917) degrees at that state's university with a major in plant pathology. Later, he did additional graduate work at the University of Wisconsin. He joined the USDA in 1919 and was assigned to head the flax disease project as a cooperator with the North Dakota Agricultural Experiment Station at

Fargo. In 1925 he was appointed head of the Department of Plant Pathology in the Agricultural Experiment Station and served in that capacity until his retirement.

On the flax project, Brentzel worked with Prof. H.L. Bolley to develop flax varieties having greater wilt resistance by growing flax on heavily wilt-infested soil and selecting the surviving plants. His work on flax diseases contributed to the discovery that a stem canker of flax seedlings, which severely reduced stands in some seasons, was caused by high soil surface temperature instead of parasitic fungi. This disease has been designated "heat canker." Brentzel pioneered studies on the Pasmio disease of flax in the United States and published the results of his extensive investigations on this disease in the *Journal of Agricultural Research*.

As head of the Department of Plant Pathology, Brentzel transferred his research interests from flax to the diseases of cereals. He conducted extensive tests on the efficacy of numerous seed-treatment materials on improved stands and control of smuts and root rots. Also, he made extensive studies on the cause and development of black point in wheat.

With Brentzel's interest in fungicides as a means of controlling seed-borne diseases, it was natural that he would have a pioneer's interest in investigating the possibilities of controlling rust and leaf-spot diseases by chemical sprays and dusts. In cooperation with chemical companies and farmers he carried out a number of tests to determine their effectiveness and practicability.

Mr. Brentzel married Dr. Wanda Weniger, also a plant pathologist, July 30, 1925. She survives him as does their son, Edward R., who resides in Herndon, Virginia.