Effect of Nitrogen Fertilization on Certain Factors of a Western Nebraska Range Ecosystem[1]

D. F. BURZLAFF, G. W. FICK, AND L. R. RITTENHOUSE

Professor of Agronomy, former NSF Undergraduate Research Participant, and Graduate Student; University of Nebraska, respectively.

Highlight

Applications of nitrogen fertilizer increased yields and protein content of Western Nebraska range forage. Amounts of acid extractable phosphorus in the soil decreased following nitrogen fertilization. Forages from fertilized plots showed no appreciable increase in phosphorus content. Increased yields were not accompanied by major changes in available soil moisture or development of underground plant parts. This data was collected over a 1-year period under a National Science Foundation, Undergraduate Research Participation grant.

Commercial fertilizers have been applied to the more arid grasslands of the United States in attempts to increase forage production.

Carter (1955) reported native ranges in North Dakota responded to nitrogen fertilization in proportion to the amount of moisture that was available. Applications of 15 to 25 lb N/A resulted in yield increases sufficient to pay for fertilizer. Nitrogen fertilization added days to the period of active growth because growth started earlier and continued longer than on nonfertilized range. Rogler and Lorenz (1957) found supporting evidence at Mandan, North Dakota. Application of 30 and 90 lb N/A gave highly significant yield increases over control plots. On a basis of forage production nitrogen fertilization approached economic feasibility. Most of the yield increase resulted from the response of western wheatgrass (*Agropyron smithii*) to nitrogen fertilizer.

Smika et al. (1961) investigated soil changes and variations in moisture extraction brought about by nitrogen fertilization. They reported that a 30 lb N/A application of ammonium nitrate reduced soil pH from 6.5 to 6.1. A 90 lb N/A application further reduced it to a pH of 5.9. It was also reported by these investigators that a decreasing pH apparently increased the availability of phosphorus. The effects of nitrogen fertilizer on certain soil and vegetation characteristics when applied at varying rates to a range site in western Nebraska are reported in this paper.

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Procedure and Study Site

Nitrogen fertilizer was applied at three rates to four replicates of a sands range site in a randomized complete block design on April 17, 1964. The treatments were 0, 15, 30, and 60 lb N/A applied as ammonium nitrate.

Samples to be used for soil tests were taken with a hydraulic soil probe to a depth of five ft. Four cores were taken in each plot, sectioned and composited to provide soil samples. Each core was divided into 1-ft increments. The surface foot was further divided into two 6-inch increments.

The modified Bray and Kurtz No. 1 method (1945) was used to determine acid extractable phosphorus. Soil moisture percentages were obtained from each plot by gravimetric determinations at 2-week intervals. Inches of available water were calculated for the surface five ft of the soil profile of each plot. The calculations of soil moisture availability were based on field capacity (0.1 atm) and wilting point (15 atm) determinations with pressure plate and pressure membrane equipment.

Cores for determining underground plant material were removed in late summer. A hydraulic coring machine was used to remove root cores in 6-inch increments to a depth of five ft. Cores were dried for 24 hours at 70 C.

Separation of roots from soil was accomplished by a modification of the technique described by McKell et al. (1961). The technique was modified by allowing the sample to soak in a dispersing solution of Calgon (sodium hexametaphosphate) prior to washing.

Composition percentages of the vegetation were determined by the focal-point technique (Burzlaff, 1966). Forage yields were obtained by clipping and drying vegetation from two quadrats, each 1-meter square, at each plot in mid-August. Samples of dried forage were analyzed for nitrogen and phosphorus content.

This study was conducted at the Scotts Bluff Experimental Range in southern Sioux County. The long-term precipitation average is 12.83 inches annually. Approximately 7.00 inches of this falls from May 15 to September 30 (U.S.D.C. Weather Bureau, 1963). In the study year 7.55 inches of precipitation were measured during this interval at the study site.

The soils are medium to fine textured sands. The soil texture becomes increasingly fine with depth of profile because of the influence of underlying Brule siltstone.

Composition percentages of the vegetation in the study year were: blue grama (*Bouteloua gracilis*) 35%; prairie sandreed (*Calamovilfa longifolia*) 27%; needleandthread (*Stipa comata*) 17%; sand bluestem (*Andropogn halii*) 8%; sand dropseed (*Sprobolus cryptandrus*) 5%; and accumulated species of minor importance, 8%.

Results and Discussion

Forage Yield.—Yields of forage from native range were increased significantly (5% level) as a result of applications of 30 and 60 lb N/A (Table 1). The 60 lb N/A treatment did not significantly increase forage yields over those of the 30 lb N/A treatment.

The 30 lb N/A treatment was considered to be the most economical rate, although under current price structures even this rate could not be considered a profitable practice. These yield responses

Table 1. Forage yields of native range of a sand range site as influenced by mid-April application of nitrogen fertilizer at varying rates.

Treatment-lb/A	Lb/A dry matter[1]
0 + 0 + 0	962_a
15 + 0 + 0	1055_a
30 + 0 + 0	1436_b
60 + 0 + 0	1500_b

[1] Yields associated with the same letter are not significantly different at the 5% level. Those associated with different letters are significantly different at the 5% level.

Table 2. Crude protein percentages of range forage as influenced by varying applications of nitrogen fertilizer and sampling dates.

	Lb N/Acre				Mean for
Sampling date	0	15	30	60	dates[1]
5-28	9.75	15.06	13.28	15.51	13.40_a
6-25	6.94	7.92	8.50	10.51	8.47_b
7-25	4.44	5.03	6.05	7.04	5.64_c
8-29	4.69	4.78	5.03	5.59	5.02_c
9-25	4.38	4.81	5.09	5.67	4.99_c
Treatment means[1]	6.04_a	7.52_b	7.59_b	8.86_b	

[1] Means associated with a specific letter are not significantly different at the 5% level. Means associated with different letters are significantly different at the 5% level.

Table 3. Percentage of acid-extractable phosphorus of forage harvested from a sands range site at various dates after nitrogen fertilization.

	Lb N/Acre				Mean for
Sampling date	0	15	30	60	dates[1]
May 25	.18	.18	.16	.18	$.18^1{}_a$
June 25	.16	.14	.16	.16	$.16_a$
July 25	.12	.11	.11	.11	$.11_b$
Aug 25	.10	.09	.08	.08	$.09_b$
Sept 25	.09	.09	.08	.08	$.09_b$
Treatment means[1]	$.13_a$	$.12_a$	$.12_a$	$.12_a$	

[1] Means associated with the same letter are not significantly different at the 5% level. Means associated with different letters are significantly different at the 5% level.

Table 4. Acid-extractable phosphorus in ppm at various depths in the profile of a sand range site after nitrogen fertilization.

Sample depth	Lb N/Acre				Mean for sample
inches	0	15	30	60	depth[1]
0–6	5.6	4.0	4.2	2.6	4.1_a
6–12	2.9	2.4	2.3	1.8	2.3_b
12–24	2.8	2.2	2.2	1.7	2.2_b
24–36	2.7	2.0	1.7	1.5	2.0_b
36–48	2.6	2.2	1.7	1.6	2.0_b
48–60	2.9	2.7	2.2	1.9	2.4_b
Treatment means[1]	3.3_a	2.6_b	2.4_{bc}	1.9_c	

[1] Means associated with the same letter are not significantly different at the 5% level. Means associated with different letters are significantly different at the 5% level.

were consistent with results obtained at Ft. Hays, Kansas (Launchbaugh, 1962).

Crude Protein Content.—The crude protein content of the forage from nitrogen fertilized plots wash higher than from the nonfertilized plots at all sampling dates. Significantly greater amounts of protein (Table 2) were found in forages from plots fertilized with varying rates of nitrogen as compared to that from nonfertilized range. Protein content of forage decreased significantly (5% level) after initial sampling date. The rate of decline in protein percentage decreased after the 3rd sampling date. There were no significant differences between the means for protein content on the last three sampling dates. These trends follow those reported by Streeter et al. (1966).

Phosphorus Content—forage and soil.—The phosphorus content of range forage varied significantly with advance in maturity under all treatments (Table 3). There were no differences among fertilizer treatments. When yield increases are considered, the removal of available phosphorus from the soil would be greater on the nitrogen fertilized ranges. Acid-extractable phosphorus in the soil decreased throughout the five-ft profile under increased nitrogen fertilization (Table 4). This is consistent with results reported by Smika et al. (1961). The acid extractable phosphorus decreased with depth to 48 inches and increased in the fifth ft under all treatments.

Soil Moisture Content.—Smika et al. (1961) reported stimulation of root growth at certain soil depths resulted from nitrogen fertilization of native rangeland. This resulted in greater moisture extraction and nutrient use in early years of their study. After four years there was little change in available soil moisture except in the upper two ft.

Although differences in available soil moisture among fertilizer treatments were not significant at any sampling date, the fertilized treatments showed less available soil moisture at most sampling dates. The depletion of previous year's moisture and supplies from spring precipitation occurred abruptly between June 18 and July 2 (Table 5). This can be considered a result of the lack of precipitation together with increased demands on available soil moisture by rapid growth of warm-season grasses and greater evaporation losses because of high temperatures. Soils from nonfertilized plots contained more available moisture until mid-August when the amount of available moisture fluctuated in the

Table 5. **Surface inches of available soil moisture (1/10–15 atm) on various sampling dates in a 5-ft profile following *application* of nitrogen fertilizers to a sands range site.**

Date of sampling	Lb N/Acre				Means for dates[1]
	0	15	30	60	
5- 7-63	2.06	1.60	2.21	2.32	2.04_a
5-21-63	2.36	2.27	2.61	2.05	2.32_a
6- 4-63	2.13	2.41	1.82	2.76	2.28_a
6-18-63	3.40	2.39	2.87	2.27	2.73_a
7- 2-63	.81	.51	.61	.64	$.64_b$
7-16-63	.61	.61	.32	.40	$.49_b$
7-30-63	.55	.17	.26	.17	$.29_b$
8-13-63	.22	.23	.26	.22	$.24_b$
8-27-63	.46	.46	.32	.29	$.38_b$
9-10-63	.32	.30	.27	.18	$.27_b$
9-24-63	1.22	1.28	1.16	1.39	1.26_c
10- 8-63	.54	.49	.38	.48	$.47_b$
Treatment means[1]	1.22_a	1.06_a	1.09_a	1.09_a	

[1]Means associated with the same letter are not significantly different at the 5% level. Means associated with different letters are significantly different at the 5% level.

Table 6. **Grams of underground plant material in successive 6 × 1⅝-in. soil cores. 135 days after applying nitrogen fertilizer to a sands range site.**

Depth of sample inches	Lb N/Acre				Means for sample depth
	0	15	30	60	
0– 6	1.75	2.02	1.69	1.67	1.78_a
6–12	.74	.67	.74	.83	$.74_b$
12–18	.42	.44	.36	.37	$.40_c$
18–24	.40	.25	.25	.34	$.31_{cd}$
24–30	.29	.18	.25	.28	$.25_d$
30–36	.25	.21	.19	.23	$.22_d$
36–42	.22	.24	.26	.24	$.24_d$
42–48	.22	.20	.16	.19	$.19_d$
48–54	.21	.16	.17	.23	$.19_d$
54–60	.23	.15	.18	.19	$.19_d$
Treatment means[1]	$.473_a$	$.452_a$	$.425_a$	$.457_a$	

[1]Means associated with the same letter are not significantly different at the 5% level. Means not associated with different letters are significantly different at the 5% level.

surface six inches with occasional showers. Late summer precipitation added substantial amounts of available moisture to soil supplies. By the terminal sampling date, fall growth of nitrogen-fertilized, cool-season grasses had again depleted soil moisture reserves.

Production of Underground Plant Material.—Investigations of root production and distribution as influenced by fertilization, indicated varied and conflicting results. Holt and Fisher (1960) found that nitrogen caused deeper rooting of coastal bermudagrass but did not affect total weight of root material.

Data from the Scotts Bluff Experimental Range indicate that there were no significant changes in either distribution within a profile or total production of underground plant material per profile (Table 6) as a result of nitrogen fertilization. There was a slight but insignificant decline in total production of underground plant material as a result of N fertilization. This disagrees with McKell et al. (1962) and Kmoch et al. (1957) who reported an increase in quantity of roots, but no change in distribution of roots throughout the profile as a result of nitrogen fertilization of annual grasses. Lorenz and Rogler (1966) showed significant increases of root weight under nitrogen treatments.

The distribution of underground plant material throughout the profile at this site was considerably different from that presented by Lorenz and Rogler (1966). They found 77% of the roots were in the first ft and 91% in the surface two ft of the soil profile. The data from Scotts Bluff on a sand range site indicated 55% for the surface ft and 70% of the total underground plant material in the surface 2 ft, with no significant difference among treatments to a depth of 5 ft in the profile. This was very much like the distribution of roots shown by Burton (1966) for the most drouth-tolerant species growing on deep sand at Tifton, Georgia.

Conclusions

Forage yields of prairie vegetation of a sand range site in western Nebraska can be significantly increased by application of 30 lb or more of nitrogen fertilizer. In this area of limited precipitation there were no significant differences in available soil moisture as a result of the fertilizer treatment, even though consistently lower amounts of available soil moisture were found under nitrogen fertilization after June 4. Increased forage production was not accompanied by an increase in underground plant material.

Application of nitrogen fertilizer was associated with significant decreases in the acid extractable phosphorus of the soil. There was no consequent increase in the phosphorus content of the forage. Nitrogen fertilization increased the protein content of early spring forage growth. The influence diminished with advance in season, to the point of no significant differences after late July.

LITERATURE CITED

Bray, Roger H., and L. T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59:39–45.

Burton, G. W. 1966. Significance of the underground parts of several southern grasses. Proc. Amer. Forage and Grassland Council, 30–39.

Burzlaff, D. F. 1966. The focal-point technique of vegetation inventory. J. Range Manage. 19:222–223.

CARTER, J. F. 1955. Nitrogen fertilization. N. Dak. Agr. Exp. Sta. Bimon Bull. 17:188–197.

HOLT, E. C., AND F. L. FISHER. 1960. Root development of coastal bermudagrass with high nitrogen fertilization. Agron. J. 52:593–596.

KMOCH, H. G., R. E. RAMIG, R. L. FOX, AND F. E. KOEHLER. 1957. Root development of winter wheat as influenced by soil moisture and nitrogen fertilization. Agron. J. 49:20–25.

LAUNCHBAUGH, J. L. 1962. Soil fertility investigations and effects of commercial fertilizers on reseeded vegetation in West-central Kansas. J. Range Manage. 15:27–34.

LORENZ, R. J., AND G. A. ROGLER. 1966. Root growth of northern plains grasses under various fertilizer and management treatments. Proc. Amer. Forage and Grassland Council. 1–11.

MCKELL, C. M., A. M. WILSON, AND M. B. JONES. 1961. A flotation method for easy separation of roots from soil samples. Agron. J. 53:56.

MCKELL, C. M., M. B. JONES, AND E. R. PERRIER. 1962. Root production and accumulation of root material on fertilized annual range. Agron. J. 59:459–461.

ROGLER, G. A., AND R. J. LORENZ. 1957. Nitrogen fertilization on northern Great Plains rangelands. J. Range Manage. 10:156–160.

SMIKA, D. E., H. J. HAAS, G. A. ROGLER, AND R. J. LORENZ. 1961. Chemical properties and moisture extraction in rangeland soils as influenced by nitrogen fertilizer. J. Range Manage. 14:213–216.

STREETER, C. L. 1966. Effect of state of maturity, method of storage and storage time on nutritive value of sandhill's upland hay. J. Range Manage. 19:55–59.

U.S.D.C. WEATHER BUREAU. 1963. Climatological Data, Nebraska: Yearly summary, Vol. 60. U.S. Gov. Printing Office, Washington, D. C.