Chemical Properties and Moisture Extraction in Rangeland Soils as Influenced by Nitrogen Fertilization[1]

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Fertilization of native rangeland has been studied in the Great Plains area for only the past 13 years. During this period several investigators (Klipple and Retzer 1959, Lodge 1959, McIlvain and Savage 1950, Rogler and Lorenz 1957, and Westin, Buntley, and Brage 1955) reported increased herbage production as a result of nitrogen fertilization. Changes in botanical composition with nitrogen fertilization have been observed in some studies. These investigators made no mention, however, of the effect of nitrogen fertilizer on chemical properties of the soil and the moisture withdrawal pattern.

It has been found that fertilizer materials leave a residue in the soil which may be acidic, basic, or neutral. Pierre (1933) stated that nitrogen fertilizer compounds containing the ammonium form of nitrogen will ultimately increase soil acidity. He reported that ammonium sulfate, ammonium phosphate, ammonium nitrate, and urea all increased soil acidity while sodium nitrate, calcium nitrate and calcium cyanamide decreased soil acidity (Pierre 1928). Wander (1954) reported that after 12 years of fertilization with equivalent amounts of nitrogen as ammonium sulfate and sodium or potassium nitrate, the soil was considerably more acid under the ammonium treatment than under the nitrate treatment to a depth of 6 feet. He also found that on plots limed for pH control in the surface soil, the subsoil was considerably more acid where the ammonium form was used than where the nitrate form had been applied.

The effect of pH on the availability of soil phosphorus has been illustrated by Burd (1948) and Gardner and Kelley (1940). In these investigations minimum phosphate solubility occurred near pH 7.0 but increased at higher or lower pH values.

An investigation to evaluate the effects of fertilization of native rangeland was initiated at the Northern Great Plains Field Station, Mandan, North Dakota in 1951. A report on the vegetative aspects of this investigation was made by Rogler and Lorenz (1957). The objectives of the studies reported here were to evaluate the influence of 9 applications of nitrogen fertilizer on (1) the chemical properties of the soil and (2) the moisture extraction pattern of native range.

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Methods and Materials

Five by 20-foot plots of mixed native grass on soil classified as Eakin silt loam were fertilized annually for 9 years with 0, 30, and 90 pounds of nitrogen per acre as ammonium nitrate. The dominant species of the area at the beginning of the study were blue grama *(Bouteloua gracilis)*, western wheatgrass *(Apropyron smithii)*, and needle-and-thread *(Stipa comata)* grasses and thread-leaf-sedge *(Carex filifolia)*.

Each treatment was replicated 3 times. Soil Samples for chemical analysis were collected in October 1959 in 6-inch increments to a depth of 2 feet and in 1-foot increments from 2 to 6 feet. Samples were not taken when the experiment was initiated, but it is assumed that all plots were equal in nitrogen, phosphorus, and pH at the beginning of the study. Three soil cores from different locations within each plot were composited to make a sample. Samples were air dried and rolled to pass a 2 mm sieve. Laboratory analyses included total nitrogen, available phosphorus, and pH as determined by Kjeldahl (Association of Official Agricultural Chemists 1955), sodium bicarbonate extraction (Olsen, Cole, Watanabe, and Dean 1954), and saturated paste (United States Salinity Laboratory Staff, 1954) procedures, respectively.

Soil samples for moisture determinations were started in 1954, 3 years after the experiment was initiated. Samplings were made by 1-foot increments to a depth of 6 feet in May or early June and October. Two cores in each plot were composited for one sample. The amount of moisture present in each sample was determined gravimetrically.

Results and Discussion

Nitrogen

Total soil nitrogen determinations (Table 1) indicate that for the overall 6-foot depth there was a general increase in soil nitrogen with increasing nitrogen fertilizer rates. Significant increases over the no-fertilizer treatment occurred in the first and second depths with 30 pounds of nitrogen and highly significant increases occurred in the same depths with 90 pounds of nitrogen. Within the 6-foot depth, however, some increments showed a decrease with fertilizer. There was a significant decrease in the 24- to 36-inch increment under the 30-pound nitrogen treatment and a highly significant decrease in the same increment under the 90-pound nitrogen treatment. These decreases are attributed to increased root activity in the lower depths.

Nitrogen applied during the 9-year period totaled 270 and 810 pounds for the 30- and 90-pound treatments, respectively. The overall soil nitrogen increases of 240 and 560 pounds per acre account for only 88.9 and 69.1 percent of the total nitrogen applied in the 30- and 90-pound treatments, respectively. When the nitrogen content of the herbage attributed to the fertilizer was totaled for the 9-year period and added to the increase in nitrogen in the soil, all of the nitrogen applied in the 30-pound treatment and 87.9 percent of the applied in the 90-pound treatment was accounted for.

Soil pH

Nine annual applications of 30 pounds of nitrogen per acre, changed surface soil (0 to 6 inches) pH from 6.5 to 6.1 (Table 2). This was an increase in acidity of 6.2 percent (significant at 0.05 level) over that of the non-fertilized plot. With 9 applications of 90 pounds of nitrogen, soil acidity in the same soil increment was increased by 9.2 percent (significant at 0.01 level). Tables 1 and 2 reveal that statistically significant soil acidity increases and total nitrogen increase occurred in the same depth increments. Inasmuch as ammonium nitrate is an acid-forming material small changes in pH would logically be expected. Throughout the profile where total nitrogen increases were small or non-existent, pH remained constant irrespective of fertility treatment.

Available Phosphorus

When surface soil acidity increased, corresponding increases in available phosphorus were found (Table 3). The increase, however, was significant (0.05 level) only under the 90-pound application rate. Below 12 inches, available phosphorus fluctuated within depths and in general decreased where fertilizer had been applied. These decreases were significant in only the 18- to 24- and 60- to 72-inch increments. Some of the decrease within these lower depths may have been due to natural soil variability but can probably be attributed to increased root activity.

Moisture

During the last 6 years of the study the effect of nitrogen fertilizer on soil moisture was determined (Figure 1). Since fertilization was started 3 years prior to the initiation of moisture sampling, soil moisture differentials due to fertilizers undoubtedly had already been established, especially in the lower 4 depths. Throughout the sampling period yearly soil moisture fluctuations in the first and second foot depths were due to the relation of sampling time to precipitation. It would be expected that spring moisture in the first foot of soil would be similar under all treatments. However, since spring samples were taken in late May or early June, growth had already started and fertilized grasses made a greater early spring growth.

Haas (1958) found that weight of grass roots throughout a 6-foot depth was increased by nitrogen fertilizer applications of 90 pounds per acre. Hunter and Kelley (1946) found that roots can absorb moisture and nutrients from moist soil and depths of 4 feet and transport them through soil at or below the permanent wilting point to the plant top. During the sampling period soil moisture in all depths under the 30- and 90-pound nitrogen treatments was lower than where the grass had not been fertilized. This indicated root activity. Through the 1957 sampling period there was a general decrease in soil moisture within sampling depths of all treatments. After that time very

Table 1. Total soil nitrogen in native grass plots fertilized annually for a 9-year period.

Depth	Nitrogen Applied		
	0	30	90
Inches	— — — — — (Pounds per acre) — — — — —		
0-6	5400	5820*	6020**
6-12	2940	3040*	3200**
12-18	2140	2140	2220
18-24	1580	1580	1580
24-36	2200	1920*	1880**
36-48	1320	1320	1240
48-60	1080	1080	1080
60-72	1040	1040	1040
Sum	17700	17940	18260
Increase		240	560

* Significant at 0.05 level.
** Significant at 0.01 level.

Table 2. Soil pH as influenced by nitrogen fertilization.

Depth	Nitrogen Applied		
	0	30	90
Inches	— — — — (Pounds per acre) — — — —		
0-6	6.5	6.1*	5.9**
6-12	6.6	6.6	6.4
12-18	6.7	6.7	6.7
18-24	7.2	7.2	7.2
24-36	7.6	7.6	7.6
36-48	7.9	7.8	7.9
48-60	7.9	7.9	7.9
60-72	8.0	7.9	8.0

* Significant at 0.05 level.
** Significant at 0.01 level.

Table 3. Available phosphorus in native grass plots fertilized annually for 9-year period.

Depth	Nitrogen Applied		
	0	30	90
Inches	— — — — (Pounds per acre) — — — —		
0-6	27.99	29.33	31.32*
6-12	13.16	13.21	13.29
12-18	12.80	10.99	10.89
18-24	11.06	8.95**	9.80**
24-36	9.38	7.21	7.01
36-48	6.66	6.31	6.55
48-60	6.27	6.58	5.44
60-72	10.44	8.94*	7.80**
Sum	97.76	91.52	92.10

* Significant at 0.05 level.
** Significant at 0.01 level.

little change occurred under any treatment except in the first 2 feet of soil. It is believed that as the fertilized plants needed moisture not supplied by precipitation, root growth was stimulated into the moist soil of the deeper depths and resulted in greater moisture withdrawal. As previously pointed out, the decrease in total nitrogen and available phosphorus content in some of the deeper increments further indicated increased root activity in those depths.

Summary

Ammonium nitrate was applied annually during 9 years at rates of 0, 30 and 90 pounds of nitrogen per acre to native range plots. At the end of this period total soil nitrogen, available phosphorus, and pH determinations were made. During the last 6 years, spring and fall soil moisture determinations were made to evaluate the effect of fertilization on soil moisture withdrawal.

For the overall 6-foot depth there was an increase in total soil nitrogen. Increases occurred in the first 2 depths under both the 30- and 90-pound treatments. Some decrease occurred, however, in the 24- to 36-inch increment under both treatments. These decreases were possibly the result of increased root activity within these depths.

The increases in total soil nitrogen accounted for 88.9 percent and 69.1 percent of all the nitrogen applied in the 30- and 90-pound treatments, respectively, during the 9-year period. With the addition of the fertilizer nitrogen recovered in harvested herbage, a complete account of the 30-pound applications and 87.9 percent of the 90-pound applications was made.

In the 0- to 6-inch surface increment soil acidity was increased 6.2 and 9.2 percent by the application of 30 and 90 pounds of ammonium nitrate nitrogen, respectively.

Phosphorus availability in the surface soil increased with in-

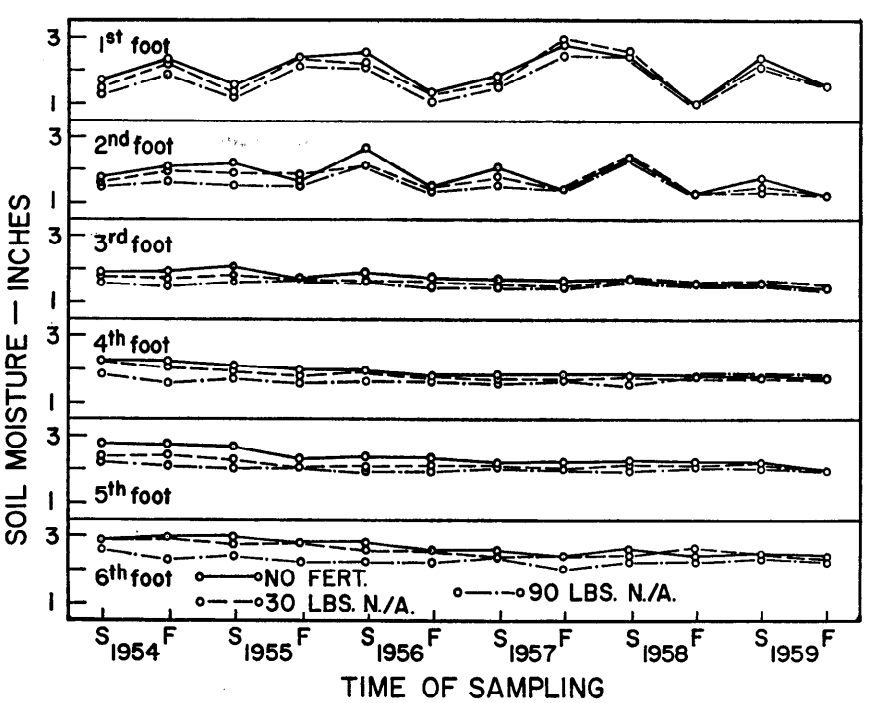

FIGURE 1. Effect of nitrogen fertilizer on spring and fall soil moisture extraction by native grass.

creasing nitrogen rates. Increase in soil acidity was the determinant of the increased phosphorus availability. Less available phosphorus was present in the lower portion of the profile where nitrogen fertilizer had been applied. This was attributed to increased root activity in the lower depths.

Moisture withdrawal increased in all soil depths with the addition of nitrogen fertilizer. Greater moisture extraction accompanied greater fertilization rates. However, after 1957, there was little change in moisture withdrawal under any treatment. In the early years of the study there were indications that fertilization stimulated root growth and moisture use in the subsoil.

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