Nitrogen Fertilization on Native Rangeland with Ammonium Nitrate and Urea

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Numerous nitrogen fertilization of native rangeland plot studies were conducted in the Northern Plains during the 1950's through the 1970's. The source of the fertilizer nitrogen for these studies was usually ammonium nitrate. Reductions in its availability had occurred as a result of serious problems with the manufacture and storage of ammonium nitrate fertilizer. During the manufacture of ammonium nitrate, emissions of nitrous oxides were released into the atmosphere and the high costs for industrial controls of these pollutants were prohibitive (Power 1974). Moreover, ammonium nitrate had explosive characteristics that presented potentially dangerous problems for fertilizer suppliers to handle and store this type of fertilizer.

Urea rapidly overtook ammonium sulfate as the predominant replacement source of fertilizer nitrogen. In order to be able to predict the usefulness of urea for cultural practices on native rangeland, the effects of the replacement fertilizer needed to be compared to the effects determined for ammonium nitrate fertilizer during the previous three decades of research projects.

Presumably, each pound of mineral (inorganic) nitrogen in the soil should yield similar results regardless of source. However, when urea is hydrolyzed to ammonia and carbon dioxide, usually some of the ammonia is volatilized into the atmosphere (Power 1974). The quantity of lost ammonia increases when soil conditions have neutral or alkaline pH, limited water supply, warm temperatures, and/or the presence of organic mulches. In a review of the literature, Power (1974) found that urea at higher rates greater than 100 lbs N/ac was not as effective as ammonium nitrate and that production of aboveground herbage on grasslands was generally from 5% to 40% less on the high rates of urea treatments than on the same rates of ammonium nitrate. This lower effectiveness and the greater proportions of the applied urea nitrogen not accounted for in the ecosystem was attributed to greater volatilization of ammonia from surface broadcast application of high rates of urea than with ammonium nitrate. The relationships of effectiveness at lower rates of ammonium nitrate and urea were not evaluated but were considered to be similar (Power 1974).

Previous studies determined that nitrogen fertilization of native rangeland caused a shift in plant species composition with an increase in mid cool season grasses, primarily western wheatgrass, and a decrease in short warm season grasses, primarily blue grama. Early studies considered these changes to be beneficial (Rogler and Lorenz 1957; Lorenz and Rogler 1972; Whitman 1957, 1976). Later studies (Goetz et al. 1978) found these shifts in plant composition to be undesirable because the resulting reduction in ground cover increased the amount of soil exposed to erosion and increased the amount of open spaces available for invasion by undesirable perennial forbs, domesticated cool season grasses, and introduced annual and perennial grasses.

The objectives of the nitrogen fertilization of native rangeland plot study V were to evaluate the effectiveness of similar low rates of ammonium nitrate and urea and to evaluate the degree of differences in annual and biennial applications of ammonium nitrate and urea fertilizers (Manske and Goetz 1985b).

Procedure

Nitrogen fertilization of native rangeland plot study V (1982-1987) was conducted by Dr. Harold Goetz and Dr. Llewellyn L. Manske on 2.6 acres located on the SW¼, SW¼, NW¼, sec. 16, T. 143 N., R. 96 W., at the Dickinson Research Extension Center ranch near Manning, ND. The 30 X 60 foot plots were arranged in a randomized block design with three replications separated by 10 foot wide alleyways. The soil was Moreau silty clay, Typic Haploboroll, with a loam texture in the top 12 inches and a silty clay loam texture from the 12 inch to 48 inch depths. This clayey range site was enclosed with a barbed wire fence constructed to exclude cattle grazing on the plots until after all of the data for that season had been collected. The treatments included controls of 0 lbs N/ac and fertilization rates of 40 lbs N/ac and 60 lbs N/ac applied annually (EY) and biennially (EOY) and 100 lbs N/ac applied biennially (EOY). For each treatment rate, ammonium nitrate and urea fertilizers were surface broadcast applied in granular form in early spring on 4 May, 1982 to 1985 for the annual treatments and on 4 May, 1982 and 1984 for the biennial treatments (Goetz and Manske 1982, 1983, 1984; Manske and Goetz 1985a). The total four year weight of applied nitrogen was 80, 120, 160, 200, and 240 lbs N/ac for the 40 lbs N/ac EOY, 60 lbs N/ac EOY, 40 lbs N/ac EY, 100 lbs N/ac EOY, and 60 lbs N/ac EY treatments, respectively. The annual spring application of 60 lbs N/ac of ammonium nitrate and urea were continued in 1986 and mid summer treatments of 60 lbs N/ac of ammonium nitrate and urea were applied on 15 August, 1985 and 1986 (Manske 1986, 1987). Results from these additive treatments were not included in this report.

Traditionally, values from single herbage clips at peak aboveground herbage biomass were compared in fertilization studies. Peak herbage biomass normally occurs during the latter portion of July. Aboveground herbage biomass production was sampled by the clipping method four times during late May through August, 1982 to 1987. Vegetation in six quarter-meter frames were hand clipped to ground level for each treatment on each sample period. Herbage was separated into seven biotype categories: cool short, warm short, cool mid, western wheatgrass, warm mid, sedges, and forbs. The plant material was oven dried and weighed (Goetz and Manske 1982, 1983, 1984; Manske and Goetz 1985a).

Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method during the period of mid July to mid August, 1982 to 1987. A total of 1500 points were read annually for each treatment (Manske and Goetz 1985a). Forb and shrub densities were additionally sampled by the use of one-tenth meter square quadrats. Stems rooted within each frame were counted annually by species in 30 quadrats per treatment (Manske and Goetz 1985a).

Available soil water was determined by the gravimetric procedure from soil samples collected with the 1 inch Veihmeyer soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at monthly intervals during June through August, 1982 to 1987. Two replications of soil core samples were collected at three locations, north, central, and south, with one set from each of the two alleyways (Manske and Goetz 1985a).

Available soil mineral nitrogen was determined from soil core samples collected on each plot with the 1 inch Veihmeyer soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at monthly intervals during June through August, 1982 to 1985. Individual soil core samples from each depth were immediately frozen and kept frozen until analysis could be made by the soils laboratory at North Dakota State University (Manske and Goetz 1985a).

Results

The precipitation during the growing seasons of 1982 to 1985 was normal or greater than normal (table 1). During 1982, 1983, 1984, and 1985, 21.09 inches (150.97% of LTM), 13.59 inches (97.28% of LTM), 11.69 inches (83.68% of LTM), and 12.80 inches (91.62% of LTM) of precipitation were received, respectively. June, July, and October of 1982 were wet months and each received 133.96%, 142.17%, and 438.93% of LTM precipitation, respectively. April, May, August, and September received normal precipitation at 95.80%, 112.55%, 99.43%, and 122.46% of LTM. Perennial plants did not experience water stress conditions during 1982 (Manske 2008). August of 1983 was a wet month and received 252.84% of LTM precipitation. June and July received normal precipitation at 101.56% and 102.81% of LTM. May, September, and October were dry months and received 64.02%, 62.32%, and 54.96% of LTM precipitation, respectively. April was a very dry month and received 14.69% of LTM precipitation. Perennial plants were under water stress conditions during April and September, 1983 (Manske 2008). April and June of 1984 were wet months and each received 200.70% and 165.11% of LTM precipitation, respectively. August received normal precipitation at 109.09% of LTM. October was a dry month and received 73.28% of LTM precipitation. May, July, and September were very dry months and received 0.00%, 4.42%, and 38.41% of LTM precipitation, respectively. Perennial plants were under water stress conditions during May, July, and September, 1984 (Manske 2008). May and October of 1985 were wet months and each received 135.98% and 162.60% of LTM precipitation, respectively. April, August, and September received normal precipitation at 86.71%, 104.55%, and 122.46% of LTM. June and July were very dry months and received 49.22% and 42.97% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July, 1985 (Manske 2008).

Mean January to July precipitation averaged 108.22% of LTM for 1982 and 1984 when both the annual and biennial fertilization treatments were applied and mean January to July precipitation averaged 75.07% of LTM (near drought conditions) for 1983 and 1985 when only the annual fertilization treatments were applied. These disproportional climatic conditions favored the biennially applied treatments and disfavored the annually applied treatments.

The period in days between application of fertilization treatments (4 May) and the first measurable precipitation was 3, 2, 33, and 9 days for 1982, 1983, 1984, and 1985, respectively. Volatilization of the ammonia from ammonium nitrate and urea fertilizers would be expected to be minor in 1982 and 1983, and possibly a little greater in 1985. Volatilization would be expected to be fairly substantial for both ammonium nitrate and urea fertilizers during 1984. The divergent conditions of 1982 and 1984 when both annual and biennial fertilization treatments were applied presented ideal circumstances in which to evaluate differences in volatilization characteristics of ammonium nitrate and urea fertilizers.

The available soil water in the top 24 inches decreased progressively from 1982 to 1985 (table 2) similar to the progressive decrease in the April to August precipitation from 1982 to 1985 (table 1). The available soil water from the 24 inch to 48 inch depths changed little during the study.

The available soil mineral nitrogen during June, July, and August was low at 62 lbs/ac on the unfertilized treatment (table 3). The available mineral nitrogen on the ammonium nitrate and urea fertilization treatments diminished to low levels during June, July and August and was not significantly different ($P<0.05$) than that on the unfertilized treatment, except the 100 lbs N EOY urea treatment had significantly greater ($P<0.05$) mineral nitrogen at the 0-48 inch soil core depth and at the 6-12 inch depth than that on the unfertilized treatment. Goetz (1975) also found that the available mineral nitrogen from similar fertilization treatment rates diminished rapidly because of nitrogen immobilization by the soil-plant system and that during the growing season from early June the amounts of mineral nitrogen on the fertilization treatments were essentially the same as the amounts on the unfertilized treatment.

Soil pH ranged between 6.8 and 8.0 in the top 6 inches of soil and was not significantly different ($P<0.05$) among any of the ammonium nitrate and urea fertilization treatments and the unfertilized treatment. Low rates of nitrogen fertilizer did not change soil pH in four years.

Herbage weight of mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 4, 5, 6, and 7). Warm season grass herbage weight on the fertilization treatments were not significantly different ($P<0.05$) than that on the unfertilized treatment.

Percent composition for mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition on the fertilization treatments were significantly lower ($P<0.05$) for mid warm season grasses on the ammonium nitrate treatment of 60 lbs N EOY during July, and on the urea treatments of 60 lbs N EY and 100 lbs N EOY during May, and 40 lbs N EY and 60 lbs N EOY during August, and for short warm season grasses on the ammonium nitrate and urea treatments of 40 lbs N EY during June than on the unfertilized treatment.

Basal cover of mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Mid warm season grass basal cover was significantly lower ($P<0.05$) on the ammonium nitrate treatment of 60 lbs N EOY and on the urea treatment of 40 lbs N EOY than on the unfertilized treatment. Short warm season grass basal cover on the fertilization treatments were not significantly different ($P<0.05$) from that on the unfertilized treatment.

Herbage weight of western wheatgrass and mid and short cool season grasses were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of western wheatgrass was significantly greater ($P<0.05$) on the urea treatment of 40 lbs N EY during May and June than on the unfertilized treatment. Herbage weight of mid cool season grasses was significantly greater ($P<0.05$) on the ammonium nitrate treatments of 40 lbs N EY, 60 lbs N EOY, and 60 lbs N EY during May and June, and on the urea treatments of 60 lbs N EY during May, 60 lbs N EOY during June, and 100 lbs N EOY during May, June, and July than on the unfertilized treatment. Herbage weight of short cool season grasses on the fertilization treatments were not significantly different ($P<0.05$) from that on the unfertilized treatment.

Percent composition for western wheatgrass and mid cool season grasses were generally greater and percent composition for short cool season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for western wheatgrass was significantly greater ($P<0.05$) on the urea treatment of 40 lbs N EY during May and July than on the unfertilized treatment. Percent composition for mid cool season grasses was significantly greater ($P<0.05$) on the ammonium nitrate treatment of 40 lbs N EY during May, and on the urea treatments of 60 lbs N EOY and 60 lbs N EY during

May than on the unfertilized treatment. Percent composition for short cool season grasses on the fertilization treatments was not significantly different (P<0.05) from that on the unfertilized treatment.

Basal cover of western wheatgrass and mid cool season grasses were generally greater and basal cover of short cool season grasses was generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Basal cover of western wheatgrass, and mid and short cool season grasses on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight of upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, the sedge herbage weight was consistently lower than the weight on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of sedges were significantly greater (P<0.05) on the ammonium nitrate treatments of 60 lbs N EY during June and 100 lbs N EOY during May, and on the urea treatments of 60 lbs N EOY and 60 lbs N EY during May, and 100 lbs N EOY during May and June than on the unfertilized treatment. Herbage weight of sedges were significantly lower (P<0.05) on the ammonium nitrate treatments of 40 lbs N EY during June, and on the urea treatment of 40 lbs N EY during May and June than on the unfertilized treatment.

Percent composition for upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, percent composition was consistently lower than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for sedges was significantly greater (P<0.05) on the ammonium nitrate treatment of 60 lbs N EOY during August, and on the urea treatments of 60 lbs N EOY during August, and 100 lbs N EOY during May than on the unfertilized treatment. Percent composition for sedges was significantly lower (P<0.05) on the ammonium nitrate treatment of 40 lbs N EY during June and July, and on the urea treatment of 40 lbs N EY during May, June, July, and August than on the unfertilized treatment.

Basal cover of upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, basal cover was consistently lower than on the unfertilized treatment (table 12). Sedge basal cover on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight of forbs were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 60 lbs N EOY, the forb herbage weight was consistently lower, but not significantly (P<0.05), than the forb weight on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of forbs was significantly greater (P<0.05) on the ammonium nitrate and urea treatments of 40 lbs N EY during May than on the unfertilized treatment.

Percent composition for forbs were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for forbs was significantly lower (P<0.05) on the urea treatment of 60 lbs N EY during May than on the unfertilized treatment.

Basal cover of forbs were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Forb basal cover on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight, percent composition, and basal cover were generally lower for mid and short warm season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight, percent composition, and basal cover were generally greater for western wheatgrass and mid cool season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight was generally greater, and percent composition and basal cover were generally lower for short cool season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight, percent composition, and basal cover were generally greater for upland sedges on the annual and biennial fertilization treatments, except on the ammonium nitrate and urea treatments of 40 lbs N EY herbage weight, percent composition, and basal cover were lower, than on the unfertilized treatment. Herbage weight was generally greater; except on the ammonium nitrate and urea treatments of 60 lbs N EOY herbage weight was lower; and percent composition and basal cover were generally lower for forbs on the annual and biennial fertilization treatments than on the unfertilized treatment. General trends of the plant species shift on the annual and biennial fertilization treatments during the four years of this plot study V were the same as the shift in plant species composition found on previous nitrogen fertilization of native rangeland studies.

Peak aboveground herbage biomass usually occurs during the last two weeks in July. Most of the previous fertilization of native rangeland studies sampled herbage weight one time per year during late July or early August and compared these solitary herbage weights produced on the fertilization treatments. This study sampled aboveground herbage weight during May, June, July, and August to evaluate for differences in quantities and rates of herbage produced by plant categories on the fertilization treatments throughout the growing season.

Production of herbage weight by plant categories on the fertilization treatments did not occur in the same quantities during the growing season months as the quantity of herbage produced by plant categories on the unfertilized treatment (table 13 a, b, c). Peak herbage weights on the unfertilized treatment for cool season grasses, warm season grasses, total grasses, and total yield occurred during August, for sedges it occurred during May, and for forbs peak herbage occurred during July. During this four year study, peak herbage weight of total yield on the fertilized and unfertilized treatments occurred during July in 1982 and 1983 the same as peak herbage weight would occur during other typical growing seasons. During the growing seasons of 1984 and 1985, precipitation in July was well below normal (23.69% of long-term mean) followed by above average precipitation in August (106.82% of long-term mean) resulting in a shift in the occurrence of peak herbage biomass to August. The resulting four year mean herbage weight for total yield on the fertilization treatments were quite similar during July and August. Peak herbage weights on the fertilization treatments for cool season grasses, total grasses, and total yield occurred during July and August, for warm season grasses peak herbage occurred during August, for sedges it occurred during May, and for forbs peak herbage occurred during July or during August. The peak herbage weight of plant categories on fertilization treatments tended to occur earlier during the growing season than that on the unfertilized treatment (table 13 a, b, c).

Production of herbage weight by plant categories on the fertilization treatments did not occur at the same rates during the growing season months as the rate of herbage production by plant categories on the unfertilized treatment (table 14 a, b, c). Plant categories on the unfertilized treatment (0 lbs N) had greatest herbage weight for cool season grasses, warm season grasses, total grasses, and total yield during August, for sedges it occurred during May, and for forbs the greatest herbage weight occurred during July.

The urea treatment of 40 lbs N EOY (80 lbs N) had greater growth of warm season grasses, total grasses, and total yield during August. The ammonium nitrate treatment of 40 lbs N EOY (80 lbs N) and the ammonium nitrate and urea treatments of 60 lbs N EOY (120 lbs N) had greater growth of cool season grasses, total grasses, and total yield during July. The ammonium nitrate treatment of 40 lbs N EY (160 lbs N) had greater growth of warm season grasses, total grasses, and total yield during July. The urea treatment of 40 lbs N EY (160 lbs N) had greater growth of warm season grasses and total grasses during July and greater growth of cool season grasses and total yield during June. The ammonium nitrate and urea treatments of 100 lbs N EOY (200 lbs N) and 60 lbs N EY (240 lbs N) had greater growth of cool season grasses, total grasses, and total yield during June. Greater growth in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied (table 14 a, b, c).

Growth of herbage weight on the ammonium nitrate and urea fertilization treatments and on the unfertilized treatment occurred at different times and at different rates (table 15). The greatest herbage weight occurred during August on the unfertilized treatment. The greatest percent increase in herbage weight occurred during August on the urea treatment of 40 lbs N EOY. The greatest percent increase in herbage weight occurred during July on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 40 lbs N EY, and on the urea treatment of 60 lbs N EOY. The greatest percent increase in herbage weight occurred during June on the ammonium nitrate treatments of 100 lbs N EOY and 60 lbs N EY, and on the urea treatments of 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY. The greatest percent increase in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied (table 15).

The ammonium nitrate treatments of 40 lbs N EOY and 60 lbs N EY consistently out performed the respective urea treatments during each of the growing season months, except the August percent herbage increase on the urea treatment of 40 lbs N EOY was greater than that on the ammonium nitrate treatment. The urea treatment of 100 lbs N EOY consistently out performed the respective ammonium nitrate treatment during each of the growing season months (table 15).

The urea treatments of 60 lbs N EOY, 40 lbs N EY, and 100 lbs N EOY had greater percent increases in herbage weight during the early portions of the growing season than the respective ammonium nitrate treatments, and the ammonium nitrate treatments of 60 lbs N EOY and 40 lbs N EY had greater percent increases in herbage weight during the latter portions of the growing season than the respective urea treatments. The urea treatment of 40 lbs N EY had greater percent increases in herbage weight of 21.75% and 41.94% during May and June than the May and June percent increases in herbage weight of 18.91% and 37.28% on the ammonium nitrate treatment of 40 lb N EY. The ammonium nitrate treatment of 40 lbs N EY had greater percent increases in herbage weight of 43.78% and 27.80% during July and August than the July and August percent increases in herbage weight of 33.43% and 19.41% on the urea treatment of 40 lbs N EY (table 15).

Peak herbage weight of plant categories tended to occur earlier during the growing season on fertilization treatments than on the unfertilized treatment. Greater growth in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied. The greatest percent increase in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied. The greatest percent increase in herbage weight did not occur at the same time as the greatest aboveground herbage biomass. The greatest percent increase in herbage weight on the urea treatments tended to occur during the early portions of the growing season and the greatest percent increase in herbage weight on the ammonium nitrate treatments tended to occur later in the growing season than on the urea treatments.

The quantity and rate of growth in herbage weight was differentially affected by the quantity and type of nitrogen applied, making impartial comparisons of treatments with multiple nitrogen sources difficult to accomplish from single herbage sample dates per year. The mean herbage weight data from the June, July, and August growing season sample dates were used to remove the unintentional bias that results from single herbage sample date data (table 16). Mean cool season grass herbage weight was 1.6% and 15.7% greater on the urea treatments of 40 lbs N EY and 100 lbs N EOY than on the respective ammonium nitrate treatments, and was 17.8%, 23.5%, and 0.3% greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. Mean warm season grass herbage weight was 5.2% greater on the urea treatment of 40 lbs N EOY than on the respective ammonium nitrate treatment, and was 9.5%, 17.3%, 17.6%, and 38.0% greater on the ammonium nitrate treatments of 60 lbs N EOY, 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The annual urea treatments of 40 lbs N/ac and 60 lbs N/ac were detrimental to warm season grass herbage production. Mean total yield herbage weight was 11.5% greater on the urea treatment of 100 lbs N EOY than on the respective ammonium nitrate treatment, and was 7.6%, 10.4%, 5.4%, and 15.0% greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, 40 lbs N EY, and 60 lbs N EY than on the resepctive urea treatments. Generally, the herbage weight produced by the ammonium nitrate treatments was 5% to 38% greater than that produced by the respective urea treatments, except the urea treatment of 100 lbs N EOY out produced the respective ammonium nitrate treatment in cool season grasses, sedges, and total yield herbage weight consistently. The five ammonium nitrate treatments produced 4.9% greater mean cool season grass herbage weight, 15.5% greater mean warm season grass herbage weight, and 5.4% greater mean total yield herbage weight than the five urea treatments (table 16).

Differences in the pounds of herbage biomass produced per pound of nitrogen applied were used to evaluate production differences between ammonium nitrate and urea fertilization treatments (table 17). The pounds of cool season grass weight produced per pound of nitrogen ranged from 6 to 16 pounds of herbage for ammonium nitrate treatments and from 6 to 11 pounds of herbage for urea treatments. The pounds of warm season grass weight produced per pound of nitrogen ranged from less than 1 pound to 3 pounds of herbage for ammonium nitrate treatments and from a loss of 0.5 pound to a gain of 1.7 pounds of herbage for urea treatments. The pounds of total herbage yield weight produced per pound of nitrogen ranged from 9.5 to 17 pounds of herbage for ammonium nitrate treatments and from 6 to 14 pounds of herbage for urea treatments (table 17).

The pounds of cool season grass herbage produced per pound of nitrogen was 0.3 and 2.0 pounds greater on the urea treatments of 40 lbs N EY and 100 lbs N EOY than on the respective ammonium nitrate treatments, and was 5.8, 5.1, and 0.03 pounds greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The pounds of warm season grass herbage produced per pound of nitrogen was 0.9 pounds greater on the urea treatment of 40 lbs N EOY than on the respective ammonium nitrate treatment, and was 1.1, 1.4, 1.2, and 2.1 pounds greater on the ammonium nitrate treatments of 60 lbs N EOY, 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The pounds of total herbage yield produced per pound of nitrogen was 3.2 pounds greater on the urea treatment of 100 lbs N EOY than on the respective ammonium nitrate treatment, and was 5.2, 4.8, 1.9, and 3.4 pounds greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, 40 lbs N EY, and 60 lbs N EY than on the respective urea treatments. Generally, the pounds of herbage biomass produced per pound of nitrogen by the ammonium nitrate treatments were 0.03 to 5.8 pounds of herbage greater than that produced by the respective urea treatments, except the urea treatment of 100 lbs N EOY produced 2.0 pounds greater cool season grass herbage and 3.2 pounds greater total herbage yield than the respective ammonium nitrate treatment. The five ammonium nitrate treatments produced 1.7 pounds of cool season grass herbage, 1.0 pound of warm season grass herbage, and 2.4 pounds of total herbage yield per pound of nitrogen applied greater than the five urea treatments (table 17).

Both the annual and biennial fertilization treatments were applied in 1982 and 1984. The April to June precipitation was 8.36 inches and 8.17 inches during 1982 and 1984, respectively. The period in days between application of fertilizer (4 May) and the first measurable precipitation was 3 days in 1982 and 33 days in 1984. These divergent conditions of 1982 and 1984 were used to evaluate differences in volatilization characteristics of ammonium nitrate and urea fertilizer (table 18). The difference in the percent herbage weight gain between 1982 and 1984 was considered to be the percent lost herbage weight due to volatilization of the ammonia from the ammonium nitrate and urea fertilizers resulting from the differences between 3 and 33 days with no precipitation following fertilizer application in 1982 and 1984, respectively. The mean percent lost herbage weight for the ammonium nitrate treatments was 72.9%, 27.4%, and 53.3% for cool season grasses, warm season grasses, and total herbage yield, respectively. The mean percent lost herbage weight for the urea treatments was 79.1%, 22.9%, and 56.1% for cool season grasses, warm season grasses, and total herbage yield, respectively (table 18).

The percent lost cool season grass herbage weight was 8.7% and 30.0% greater on the ammonium nitrate treatments of 40 lbs N EOY and 60 lbs N EY than on the respective urea treatments, and was 45.3%, 17.7%, and 6.8% greater on the urea treatments of 60 lbs N EOY, 40 lbs N EY, and 100 lbs N EOY than on the respective ammonium nitrate treatments. The percent lost warm season grass herbage weight was 38.7% and 1.2% greater on the ammonium nitrate treatments of 40 lbs N EY and 100 lbs N EOY than on the respective urea treatments, and was 0.7%, 10.6%, and 5.9% greater on the urea treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective ammonium nitrate treatments. The percent lost total yield herbage weight was 7.4%, 1.3%, and 15.1% greater on the ammonium nitrate treatments of 40 lbs N EOY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments, and was 29.2% and 8.7% greater on the urea treatments of 60 lbs N EOY and 40 lbs N EY than on the respective ammonium nitrate treatments. The five ammonium nitrate treatments had 4.5% greater percent lost warm season grass herbage weight than the five urea treatments. The five urea treatments had 6.2% greater percent lost cool season grass herbage weight and 2.8% greater percent lost total herbage yield weight than the five ammonium nitrate treatments (table 18). The percent lost herbage weight was generally similar for ammonium nitrate and urea fertilizers between 1982 and 1984.

Herbage growth during the monthly periods of the growing season was affected by the quantity and the source of nitrogen applied. Plants on the ammonium nitrate treatments had greater percent growth during monthly periods than unfertilized plants 48% of the growing season. Plants on the urea treatments had greater percent growth during monthly periods than unfertilized plants 49% of the growing season. Plants on the unfertilized treatment had greater percent growth during monthly periods than plants on the ammonium nitrate treatments 52% of the growing season and greater percent growth than plants on the urea treatments 51% of the growing season (table 19 a, b, c).

Fertilized cool season grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during May and June, 100 lbs N EOY during June, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during June, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than cool season grasses on the unfertilized treatment. Unfertilized cool season grasses had greater percent growth than fertilized cool season grasses on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during July and August, 100 lbs N EOY during May, July, and August, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during May, July, and August, 100 lbs N EOY during July and August, and

60 lbs N EY during July and August (table 19 a, b, c). Figure 1 shows the greater percent growth of cool season grasses during May and June on the ammonium nitrate treatment of 60 lbs N EY and the greater percent growth during July and August on the unfertilized treatment.

Fertilized warm season grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June, July, and August, and 60 lbs N EY during June, July, and August, and on the urea treatments of 40 lbs N EOY during June, July, and August, 60 lbs N EOY during June and August, 40 lbs N EY during July, 100 lbs N EOY during June and July, and 60 lbs N EY during July and August than warm season grasses on the unfertilized treatment. Unfertilized warm season grasses had greater percent growth than fertilized warm season grasses on the ammonium nitrate treatments of 40 lbs N EOY during May, July, and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and August, 100 lbs N EOY during May, and 60 lbs N EY during May, and on the urea treatments of 40 lbs N EOY during May, 60 lbs N EOY during May and July, 40 lbs N EY during May, June, and August, 100 lbs N EOY during May and August, and 60 lbs N EY during May and June (table 19 a, b, c).

Fertilized total grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during June and July, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than total grasses on the unfertilized treatment. Unfertilized total grasses had greater percent growth than fertilized total grasses on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and August, 100 lbs N EOY during May, July, and August, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during May and August, 100 lbs N EOY during July and August, and 60 lbs N EY during July and August (table 19 a, b, c).

Fertilized total herbage yield had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June and August, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during May and June, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than total herbage yield on the unfertilized treatment. Unfertilized total herbage yield had greater percent growth than fertilized total herbage yield on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and August, 100 lbs N EOY during May and July, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during July and August, 100 lbs N EOY during July and August, and 60 lbs N EY during July and August (table 19 a, b, c). Cool season grasses, warm season grasses, and upland sedges had greater percent growth during May on the urea treatments than on the ammonium nitrate treatments. Cool season grasses, warm season grasses, and upland sedges had greater percent growth during June on the ammonium nitrate treatments than on the urea treatments.

Fertilized plants had a greater rate of growth in herbage weight during a short period in the early portion of the growing season, usually May and June. The rapid growth period occurred earlier for plants fertilized with urea than with ammonium nitrate and the rapid growth period occurred earlier with increased quantities of nitrogen applied. Unfertilized plants had a longer period of herbage weight growth; during the early portion, the rate of growth in herbage weight was lower than that of fertilized plants, and during the latter portion of the growing season, usually July and August, the rate of growth in herbage weight was greater than that of fertilized plants.

Percent growth of cool season grasses during May and June on the ammonium nitrate and urea treatments was 10.6% and 10.8% greater, respectively, than that on the unfertilized treatment. Percent growth of cool season grasses during July and August on the unfertilized treatment was 15.1% and 13.9% greater than those on the ammonium nitrate and urea treatments, respectively. Percent growth of total grasses during May and June on the ammonium nitrate and urea treatments was 7.7% and 7.5% greater, respectively, than that on the unfertilized treatment. Percent growth of total grasses during July and August on the unfertilized treatment was 7.7% and 7.5% greater than those on the ammonium nitrate and urea treatments, respectively. Percent growth of total herbage yield during May and June on the ammonium nitrate and urea treatments was 5.5% and 6.5% greater, respectively, than that on the unfertilized treatment. Percent growth of total herbage yield during July and August on the unfertilized treatment was 6.5% and 6.5% greater than those on the ammonium nitrate and urea treatments, respectively (tables 20 and 21). Percent growth of total grasses and total herbage yield on the urea treatment of 40 lbs N EOY was lower during May and June and greater during July and August than those on the unfertilized treatment (tables 20 and 21). During May and June, percent growth of cool season grasses, total grasses, and total herbage yield was greater on the fertilized treatments than those on the unfertilized treatment, and during July and August, percent growth was greater on the unfertilized treatment than those on the fertilized treatments.

Discussion

Nitrogen fertilization of native rangeland plot study V (1982-1987) was conducted to evaluate the effectiveness of low rates of urea fertilizer compared to the same rates of ammonium nitrate and to determine the degree of differences in annual and biennial applications of ammonium nitrate and urea fertilizers. The major findings from this study follow.

- Nitrogen fertilization of native rangeland resulted in greater production of herbage weight than the quantity of aboveground herbage produced on unfertilized rangeland. Annual applications of 40 lbs N/ac and 60 lbs N/ac increased herbage production 35.7% and 41.4% on the ammonium nitrate treatments and 30.3% and 26.4% on the urea treatments, respectively. Biennial applications of 40 lbs N/ac, 60 lbs N/ac, and 100 lbs N/ac increased herbage production 21.2%, 37.1%, and 40.9% on the ammonium nitrate treatments, and 13.6%, 26.7%, and 52.4% on the urea treatments, respectively. The biennial applications of ammonium nitrate and urea fertilizers produced 74.5% and 73.0% of the total herbage weight produced on the annual applications of the respective fertilizers. The years when both the annual and biennial treatments were applied received 33% more precipitation than the years when only the annual treatments were applied causing disproportionally favorable results on the biennial treatments. The biennial applications of ammonium nitrate treatments in plot study IV (1970-1978) realistically produced 54.3% of the total herbage weight produced on the annual application treatments.

- Nitrogen fertilization of native rangeland caused general trends of a shift in plant species composition the same as the shift in plant species composition found on previous nitrogen fertilization of native rangeland studies. Composition of warm season grasses was reduced and composition of mid cool season grasses was increased on annual and biennial applications of ammonium nitrate and urea fertilization treatments.

- Native rangeland soils increase in available soil water during early spring to July under normal precipitation conditions and then decrease in soil water during July to the end of the growing season as a result of greater evapotranspiration demand than precipitation infiltration. Range plants experienced water stress during 25% of the growing season months during the study period of 1982 to 1985 which was lower than the normal long-term conditions with plants under water stress during 33% of the growing season months. Soil water below the 24 inch depth changed little during the study period indicating few grass roots in the lower depths of the soil profile, probably a result of the heavy seasonlong grazing management during past decades. Previous nitrogen fertilization of native rangeland studies have found that soil water use was greater on the fertilized treatments than on the unfertilized treatment and that greater amounts of soil water were used from the treatments with heavier rates of nitrogen fertilizer.

- Nitrogen fertilization of native rangeland with low rates of annual and biennial applications of ammonium nitrate and urea fertilizers did not change soil pH in four years, 1982 to 1985. Smika et al. (1961) found that annual applications of ammonium nitrate fertilizer could reduce soil pH 6% to 9% after 9 years and that the increase in soil acidity increased the solubility and availability of phosphate.

- Nitrogen fertilization of native rangeland with low rates of annual and biennial applications of ammonium nitrate and urea fertilizers did not increase available mineral nitrogen in soil from mid June to the end of the growing season, except the urea treatment of 100 lbs N EOY had significantly greater total available mineral nitrogen of 114 lbs N/ac in the soil profile to the 48 inch depth and consistently produced greater quantities of aboveground herbage throughout the study. Goetz (1975) found that as soil warmed in early spring, the available mineral nitrogen increased. This first peak in available mineral nitrogen occurred around mid May on unfertilized treatments and on fertilized treatments with nitrogen applications in early to mid April. Nitrogen applications in early May may shift the first peak to later in May. The quantity of available mineral nitrogen during the first peak was greater on the treatments with higher nitrogen rates. Differences in the amount of available mineral nitrogen diminished rapidly early in the growing season because of nitrogen immobilization by the soil-plant system. During the remainder of the growing season from early or mid June, the amounts of mineral nitrogen on the fertilization treatments was essentially the same as the amount available on the unfertilized treatment.

- Nitrogen fertilization of native rangeland resulted in the peak herbage weight of plant categories on fertilization treatments to occur earlier in the growing season than peak herbage on the unfertilized treatment. Peak herbage weight on unfertilized native rangeland usually occurs during the last two weeks in July. An exception to these standard conditions occurred during the growing seasons with below normal precipitation in July followed by above average precipitation in August. Peak herbage weights for cool season grasses, warm season grasses, total grasses, and total herbage yield occurred during August on the unfertilized treatment. Peak herbage weights for cool season grasses, total grasses, and total herbage yield occurred earlier during the growing season on the fertilization treatments than on the unfertilized treatment even with the changes in precipitation pattern. The increases in herbage weight occurred earlier in the growing season on the urea treatments than on the ammonium nitrate treatments.

- Nitrogen fertilization of native rangeland resulted in the greater rates of growth in herbage weight and the greatest percent increase in herbage weight to occur earlier in the growing season with increases in total weight of nitrogen fertilizer applied during the four years of the study. The greatest herbage weight on the unfertilized treatment occurred during August. Urea nitrogen applied at 80 lbs/ac resulted in greater herbage growth in August. Ammonium nitrate nitrogen applied at 80 lbs/ac and ammonium nitrate and urea nitrogen applied at 120 lbs/ac and 160 lbs/ac resulted in greater herbage growth in July. Ammonium nitrate and urea nitrogen applied at 200 lbs/ac and 240 lbs/ac resulted in greater growth in June. The greater the total weight of nitrogen fertilizer applied, the earlier in the growing season the greatest increase in herbage weight occurred. The greater rate of growth and the greatest percent increase in herbage weight did not occur at the same time as the greatest aboveground herbage biomass.

- Nitrogen fertilization of native rangeland reduced the time period of active growth. Fertilized plants had a high rate of growth in herbage weight during a short period in the early portion of the growing season and had a low rate of growth or a loss of weight during the latter portion of the growing season. Unfertilized plants had a longer period of active herbage weight growth. The rate of growth for unfertilized plants was lower than the growth rate for fertilized plants during the early portion of the growing season and the rate of growth was greater than the growth rate for fertilized plants during the latter portion of the growing season.

- Nitrogen fertilization of native rangeland resulted in greater herbage weight produced on the ammonium nitrate treatments than on the urea treatments. The herbage weight produced on the ammonium nitrate treatments with low rates of 100 lbs N/ac or less ranged from 5% to 38% greater than the herbage produced on urea treatments with the respective low rates. These differences in herbage production between ammonium nitrate and urea fertilizers at low rates were similar to the differences in herbage production at high rates greater than 100 lbs N/ac that were reported (Power 1974) to range from 5% to 40% greater on ammonium nitrate treatments than on the same rates of urea treatments. The five ammonium nitrate treatments produced a mean 5.4% greater herbage weight than the five urea treatments. Pounds of herbage weight produced per pound of nitrogen ranged from 9.5 to 17 pounds of herbage on the ammonium nitrate treatments and from 6 to 14 pounds of herbage on the urea treatments. The five ammonium nitrate treatments produced a mean 2.4 pounds of herbage weight per pound of nitrogen greater than the pounds of herbage produced per pound of nitrogen on the five urea treatments.

- Nitrogen fertilization of native rangeland resulted in a high loss of herbage weight from nitrogen volatilization that occurred during 33 days with no precipitation following broadcast application of ammonium nitrate and urea fertilizers in 1984. Hydrolyzed nitrogen fertilizers are broken down to ammonia and carbon dioxide. Under some conditions, a portion of the ammonia is volatilized into the atmosphere. This lost quantity of nitrogen is not available to plants for herbage growth. The greater the rate of volatilization, the greater the loss in herbage weight production. The amount of lost herbage weight on the ammonium nitrate and urea treatments was 72.9% and 79.1% of the cool season grasses, 27.4% and 22.9% of the warm season grasses, and 53.3% and 56.1% of the total herbage weight, respectively. The urea treatments lost 1.5% greater herbage weight than the ammonium nitrate treatments as a result of volatilization of the ammonia.

- Nitrogen fertilization of native rangeland resulted in greater herbage growth rates during May and June on the fertilization treatments and greater herbage growth rates during July and August on the unfertilized treatment. Plants on the ammonium nitrate and urea treatments had greater percent herbage growth during 48% and 49% of the monthly periods than the plants on the unfertilized treatment, respectively, and plants on the unfertilized treatment had greater percent herbage growth during 52% and 51% of the monthly periods than the plants on the ammonium nitrate and urea treatments, respectively. Cool season grasses, warm season grasses, and upland sedges had greater percent herbage growth during May on the urea treatments than on the ammonium nitrate treatments, and had greater percent growth during June on the ammonium nitrate treatments than on the urea treatments. Percent growth of cool season grasses, total grasses, and total herbage weight was greater on the ammonium nitrate and urea fertilization treatments during May and June than on the unfertilized treatment, and percent herbage growth was greater on the unfertilized treatment during July and August than on the fertilization treatments.

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Table 1. Precipitation in inches for growing-season months and the annual total precipitation for 1982-1985, DREC Ranch, Manning, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1982-2007	1.43	2.39	3.21	2.49	1.76	1.38	1.31	13.97	16.77
1982	1.37	2.69	4.30	3.54	1.75	1.69	5.75	21.09	25.31
% of LTM	95.80	112.55	133.96	142.17	99.43	122.46	438.93	150.97	150.92
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.69	64.02	101.56	102.81	252.84	62.32	54.96	97.28	92.73
1984	2.87	T	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	200.70	0.00	165.11	4.42	109.09	38.41	73.28	83.68	76.80
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	14.78
% of LTM	86.71	135.98	49.22	42.97	104.55	122.46	162.60	91.62	88.13
1982-1985	1.42	1.87	3.61	1.82	2.49	1.19	2.39	14.79	17.13
% of LTM	99.30	78.24	112.46	73.09	141.48	86.23	182.44	105.87	102.15

Table 2. Mean soil water in inches per sample depth for fertilization treatments on the Moreau clayey range site, 1982-1985.

	Soil Depth in inches					
Years	0-6	6-12	12-24	24-36	36-48	0-48
1982	1.22a	1.10a	2.10a	1.71ab	1.54a	7.66a
1983	1.06b	0.87b	1.90b	1.94a	1.81a	7.59a
1984	0.89c	0.86b	1.32c	1.51b	1.70a	6.29b
1985	0.65d	0.61c	1.14c	1.29b	1.59a	5.28c

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 3. Mean soil mineral nitrogen content in pounds per acre for fertilization treatments on the Moreau clayey range site, 1982-1985.

	Soil Depth in inches					
Treatments	0-6	6-12	12-24	24-36	36-48	0-48
Unfertilized	8.34ab	7.05a	12.77ab	15.84ab	17.62a	61.61a
Ammonium nitrate						
40 lbs N EOY	9.29ab	6.41a	12.98a	14.53ab	17.14a	60.35a
40 lbs N EY	9.77ab	7.03a	13.64ab	15.36ab	15.62a	61.41a
60 lbs N EOY	8.86a	6.39a	11.62a	12.42a	14.99a	54.28a
60 lbs N EY	15.21b	9.09a	13.82a	13.78ab	13.47a	65.37a
100 lbs N EOY	10.50ab	14.27ab	17.33ab	15.40ab	19.69a	77.18ab
Urea						
40 lbs N EOY	8.61a	6.21a	12.37a	12.29a	15.88a	55.35a
40 lbs N EY	11.05ab	7.67a	13.75a	13.57ab	12.69a	58.73a
60 lbs N EOY	9.28ab	6.16a	11.74a	13.64a	12.61a	53.42a
60 lbs N EY	15.98b	9.23a	14.84ab	15.52ab	16.52a	72.07ab
100 lbs N EOY	29.28ab	22.44b	20.73b	24.17b	17.24a	113.85b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 4. Dry matter weight in pounds per acre for fertilization treatments 30 May on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	22.00a	179.10a	69.69a	149.21a	170.39a	140.35a	730.73a	150.75a	881.49a
Ammonium nitrate									
40 lbs N EOY	9.53a	145.49a	100.29ab	179.97a	177.22a	182.79abc	795.30a	146.71ab	942.01a
40 lbs N EY	4.36a	99.91a	170.27ab	256.31b	192.48a	105.46abc	828.79a	219.43bc	1048.22a
60 lbs N EOY	2.97a	124.31a	129.46ab	235.90b	189.91a	192.68ab	875.23a	130.65ab	1005.88a
60 lbs N EY	7.94a	172.26a	139.35ab	251.54b	263.44a	222.21ab	1056.74a	189.30abc	1246.04a
100 lbs N EOY	2.97a	123.50a	159.79ab	207.34ab	210.34a	246.19b	950.13a	147.27ab	1097.40a
Urea									
40 lbs N EOY	1.00a	178.59a	82.86a	173.04ab	180.55a	146.48a	762.53a	133.41ab	895.94a
40 lbs N EY	2.00a	130.84a	239.67b	193.88ab	183.35a	70.16c	819.89a	253.33c	1073.22a
60 lbs N EOY	6.53a	166.68a	166.94ab	261.87ab	138.95a	271.18b	1012.16a	124.46ab	1136.62a
60 lbs N EY	0.00a	155.42a	137.99ab	248.17b	207.36a	226.78b	975.72a	160.17abc	1135.89a
100 lbs N EOY	0.59a	121.11a	204.75ab	333.20b	200.22a	323.51b	1183.40a	189.72ab	1373.12a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 5. Dry matter weight in pounds per acre for fertilization treatments 23 June on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	6.04a	262.18a	85.43a	217.95a	246.96a	147.07a	928.86a	217.85a	1146.70a
Ammonium nitrate									
40 lbs N EOY	10.85a	275.96a	124.16a	336.59ab	290.06a	236.96a	1215.33b	181.20a	1396.53b
40 lbs N EY	20.20a	175.44a	190.78a	497.62b	345.77a	103.06b	1307.10b	267.13a	1574.23b
60 lbs N EOY	5.05a	279.71a	220.79a	483.78b	303.15a	136.77a	1395.05b	195.03a	1590.08b
60 lbs N EY	22.31a	314.74a	189.90a	477.71b	316.33a	252.74c	1510.54b	237.42a	1747.96b
100 lbs N EOY	13.23a	296.77a	245.13a	360.83ab	345.04a	216.65ac	1423.49b	234.15a	1657.64b
Urea									
40 lbs N EOY	57.98a	228.46a	107.61a	299.71ab	268.34a	112.23ab	1046.26a	249.89a	1296.15a
40 lbs N EY	3.73a	167.96a	320.25a	436.45ab	290.62a	74.94b	1275.21a	352.37a	1627.58b
60 lbs N EOY	4.75a	263.14a	198.23a	445.42b	218.08a	224.57ac	1298.04b	211.56a	1509.59ab
60 lbs N EY	5.07a	212.34a	171.02a	422.83ab	345.33a	232.94ac	1331.30b	173.09a	1504.39ab
100 lbs N EOY	10.12a	294.93a	203.06a	573.98b	349.20a	266.79c	1631.38b	218.29a	1849.67b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 6. Dry matter weight in pounds per acre for fertilization treatments 23 July on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	13.22a	277.57a	118.33a	289.98a	242.79a	171.28a	1070.35a	295.45a	1365.80a
Ammonium nitrate									
40 lbs N EOY	24.84a	280.58a	171.72ab	457.43ab	391.75a	178.00a	1459.81a	386.70a	1846.49a
40 lbs N EY	19.64a	382.98a	265.10ab	489.32ab	349.81a	91.42a	1575.41a	388.33a	1963.71a
60 lbs N EOY	0.60a	341.61a	301.22ab	557.20ab	334.61a	230.55a	1708.15a	235.49a	1943.66a
60 lbs N EY	98.73a	289.90a	136.03ab	580.23ab	388.72a	220.05a	1658.64a	319.03a	1977.67a
100 lbs N EOY	22.76a	357.84a	241.99ab	439.88ab	376.84a	252.94a	1629.01a	270.66a	1899.67a
Urea									
40 lbs N EOY	30.92a	292.74a	147.23a	335.42ab	296.69a	140.95a	1208.71a	309.66a	1518.37a
40 lbs N EY	25.44a	369.10a	341.66b	428.63ab	273.40a	69.98a	1490.71a	331.66a	1822.38a
60 lbs N EOY	13.69a	248.88a	238.60ab	588.12ab	259.43a	224.58a	1517.15a	284.57a	1801.74a
60 lbs N EY	1.34a	287.64a	265.47ab	512.29ab	299.54a	164.14a	1489.39a	244.70a	1734.09a
100 lbs N EOY	19.78a	406.91a	247.49ab	592.43b	328.90a	264.63a	1793.97a	314.74a	2108.70a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 7. Dry matter weight in pounds per acre for fertilization treatments 23 August on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	65.94a	363.79a	155.28a	303.08a	290.27a	184.94a	1317.06a	294.27a	1611.33a
Ammonium nitrate									
40 lbs N EOY	37.75a	408.54a	217.83a	397.39a	325.57a	192.26a	1531.27a	224.00a	1755.27a
40 lbs N EY	100.22a	393.67a	291.68a	482.73a	345.49a	118.94a	1703.00a	356.24a	2059.24a
60 lbs N EOY	38.20a	426.87a	271.79a	526.26a	389.78a	269.39a	1854.94a	266.45a	2121.39a
60 lbs N EY	38.95a	568.65a	154.49a	431.89a	360.52a	272.37a	1758.77a	346.54a	2105.32a
100 lbs N EOY	73.73a	506.01a	403.01a	456.70a	315.78a	233.11a	1930.06a	322.74a	2252.80a
Urea									
40 lbs N EOY	59.02a	421.08a	232.92a	307.88a	369.12a	222.01a	1556.52a	313.80a	1870.32a
40 lbs N EY	5.36a	349.65a	381.65a	518.70a	298.81a	87.59a	1619.86a	304.15a	1924.02a
60 lbs N EOY	0.00a	467.29a	308.49a	416.84a	258.09a	259.06a	1645.01a	269.11a	1914.12a
60 lbs N EY	38.35a	412.88a	252.04a	455.79a	306.11a	284.05a	1678.20a	295.67a	1973.87a
100 lbs N EOY	62.29a	445.37a	283.33a	561.69a	358.30a	246.00a	1895.47a	430.07a	2325.54a

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 8. Percent composition of weight yield for fertilization treatments 30 May on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	2.49a	20.05a	7.88a	16.84a	19.11a	16.19a	82.56a	17.44a	881.49
Ammonium nitrate									
40 lbs N EOY	1.05ab	15.69a	10.27a	19.12ab	17.97a	20.22abc	84.31a	15.69a	942.01
40 lbs N EY	0.46ab	10.41a	14.95ab	24.96b	16.39a	11.71abc	78.88a	21.12a	1048.22
60 lbs N EOY	0.35ab	13.34a	12.79a	24.49ab	16.95a	19.02a	86.94a	13.06a	1005.88
60 lbs N EY	0.73ab	15.22a	10.36a	21.29ab	18.52a	19.15ac	85.27a	14.73a	1246.04
100 lbs N EOY	0.35ab	12.60a	13.93ab	18.95ab	17.64a	23.66ac	87.12a	12.88a	1097.40
Urea									
40 lbs N EOY	0.12a	21.06a	8.67a	19.58ab	18.86a	16.98abc	85.28a	14.72a	895.94
40 lbs N EY	0.22a	12.79a	22.14b	17.40ab	15.31a	7.06b	74.92a	25.08a	1073.22
60 lbs N EOY	0.59ab	16.01a	14.23a	22.68b	11.15a	24.34ac	89.06a	10.94a	1136.62
60 lbs N EY	0.00b	15.17a	11.91a	21.87b	16.14a	21.17ac	86.25a	13.75a	1135.89
100 lbs N EOY	0.03b	9.13a	13.95ab	25.02ab	12.61a	24.06c	84.79a	15.21a	1373.12

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 9. Percent composition of weight yield for fertilization treatments 23 June on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	0.55a	22.89a	7.68a	18.86a	21.68a	12.36a	80.92a	19.08a	1146.70
Ammonium nitrate									
40 lbs N EOY	0.82a	19.74a	8.77a	24.32a	20.21a	17.88ab	87.27ab	12.73ab	1396.53
40 lbs N EY	1.37a	11.45b	11.61a	32.84a	21.11a	6.78b	83.46ab	16.54ab	1574.23
60 lbs N EOY	0.34a	17.78ab	13.92a	31.02a	18.30a	8.99ab	88.10ab	11.90ab	1590.08
60 lbs N EY	1.30a	18.86ab	10.87a	28.12a	16.75a	14.78a	86.98ab	13.02ab	1747.96
100 lbs N EOY	1.16a	17.90ab	14.43a	22.56a	19.13a	14.99ab	86.43ab	13.58ab	1657.64
Urea									
40 lbs N EOY	4.76a	17.74a	7.94a	24.00a	19.79a	9.39ab	81.27ab	18.74ab	1296.15
40 lbs N EY	0.31a	10.62b	18.21a	29.56a	16.30a	5.00b	78.76ab	21.25ab	1627.58
60 lbs N EOY	0.28a	17.86ab	12.58a	29.74a	13.32a	17.05a	86.57ab	13.43ab	1509.59
60 lbs N EY	0.45a	14.81ab	11.11a	27.95a	21.37a	17.31a	88.65b	11.35b	1504.39
100 lbs N EOY	0.77a	16.12ab	11.11a	31.17a	17.78a	15.77a	88.79ab	11.21ab	1849.67

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 10. Percent composition of weight yield for fertilization treatments 23 July on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	0.89a	21.04a	8.25a	21.10a	18.33a	12.49a	78.97a	21.04a	1365.80
Ammonium nitrate									
40 lbs N EOY	1.27ab	15.04a	9.37a	24.64a	21.66a	11.75a	80.79a	19.21a	1846.49
40 lbs N EY	1.24a	20.45a	13.12ab	26.22a	17.44a	5.61bc	82.67a	17.33a	1963.71
60 lbs N EOY	0.03b	18.02a	15.62ab	28.93a	16.16a	13.51a	88.88a	11.12a	1943.66
60 lbs N EY	5.66ab	15.15a	6.63a	30.31a	17.63a	13.06a	85.18a	14.82a	1977.67
100 lbs N EOY	1.56ab	19.98a	12.42a	23.85a	17.53a	15.45a	86.91a	13.09a	1899.67
Urea									
40 lbs N EOY	1.76ab	19.88a	9.48a	22.37a	18.85a	10.40ab	80.13a	19.87a	1518.37
40 lbs N EY	1.43ab	21.02a	18.32b	25.57a	13.88a	3.97c	83.18a	16.82a	1822.38
60 lbs N EOY	1.10ab	14.87a	13.14ab	32.96a	12.70a	16.04a	86.79a	13.21a	1801.74
60 lbs N EY	0.07ab	17.07a	14.24ab	31.29a	16.17a	10.26a	86.55a	13.45a	1734.09
100 lbs N EOY	0.84ab	19.02a	11.11ab	30.39a	13.80a	15.12a	86.51a	13.50a	2108.70

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 11. Percent composition of weight yield for fertilization treatments 23 August on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	3.63a	23.61a	8.78a	19.05a	19.93a	9.00a	81.86a	18.14a	1611.33
Ammonium nitrate									
40 lbs N EOY	2.19ab	21.39a	11.57a	22.74a	20.49a	9.77abc	87.54a	12.46a	1755.27
40 lbs N EY	4.41ab	20.59a	13.60a	24.69a	17.01a	5.01ac	84.05a	15.95a	2059.24
60 lbs N EOY	1.17ab	20.09a	12.57a	25.72a	18.74a	13.48b	88.39a	11.61a	2121.39
60 lbs N EY	1.12ab	28.38a	6.55a	20.78a	17.57a	13.07ab	84.20a	15.80a	2105.32
100 lbs N EOY	2.73ab	22.84a	16.92a	20.68a	13.80a	11.60abc	85.66a	14.34a	2252.80
Urea									
40 lbs N EOY	3.21ab	23.73a	11.96a	16.25a	20.74a	10.96ab	84.09a	15.91a	1870.32
40 lbs N EY	0.38b	18.06a	19.40a	29.32a	14.89a	3.98c	85.02a	14.98a	1924.02
60 lbs N EOY	0.00b	22.23a	16.98a	21.55a	13.62a	14.29b	88.09a	11.91a	1914.12
60 lbs N EY	1.22ab	21.11a	12.88a	23.19a	15.89a	14.76ab	85.35a	14.66a	1973.87
100 lbs N EOY	2.57ab	20.68a	11.29a	24.30a	13.70a	10.60ab	80.50a	19.50a	2325.54

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 12. Basal cover of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Basal Cover
Unfertilized	1.38a	15.80ab	1.39a	4.08a	3.97a	3.70a	30.31a	4.34a	34.65a
Ammonium nitrate									
40 lbs N EOY	1.18a	14.85ab	1.02a	4.47a	3.88a	4.37a	29.77a	3.37a	33.13a
40 lbs N EY	0.70a	14.00a	2.09a	5.39a	5.45a	3.45a	31.07a	4.40a	35.47a
60 lbs N EOY	0.25b	16.19ab	1.59a	5.37a	3.29a	3.97a	30.63a	3.70a	34.33a
60 lbs N EY	0.40ab	17.30ab	1.95a	4.28a	3.80a	5.65a	33.38a	3.79a	37.17a
100 lbs N EOY	0.82a	13.49a	2.49a	5.83a	4.00a	4.93a	31.55a	4.10a	35.65a
Urea									
40 lbs N EOY	0.45b	20.53b	1.98a	4.72a	3.93a	4.39a	36.01a	4.41a	40.41a
40 lbs N EY	0.39ab	15.02ab	3.08a	4.78a	4.82a	1.85a	29.93a	4.90a	34.84a
60 lbs N EOY	1.42a	13.23a	1.97a	5.42a	3.72a	6.15a	31.90a	4.36a	36.26a
60 lbs N EY	1.17a	15.47ab	1.97a	5.62a	5.39a	3.75a	33.35a	3.78a	37.13a
100 lbs N EOY	0.59ab	17.92b	2.20a	5.20a	2.97a	6.33a	35.20a	2.10a	37.30a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 13a. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	389.29	201.10	140.35	730.73	150.75	881.49
23 Jun	550.34	268.22	110.30	928.86	217.85	1146.70
23 Jul	651.10	290.79	128.46	1070.35	295.45	1365.80
23 Aug	748.63	429.73	138.70	1317.06	294.27	1611.33
Ammonium nitrate 40 lbs N EOY						
30 May	457.48	155.02	182.79	795.30	146.71	942.01
23 Jun	750.81	286.81	177.71	1215.33	181.20	1396.53
23 Jul	1020.90	305.42	133.50	1459.82	386.70	1846.52
23 Aug	940.79	446.29	144.19	1531.27	224.00	1755.27
40 lbs N EY						
30 May	619.06	104.27	105.46	828.79	219.43	1048.22
23 Jun	1034.17	195.64	77.29	1307.10	267.13	1574.23
23 Jul	1104.23	402.62	68.57	1575.41	388.33	1963.74
23 Aug	1119.90	493.89	89.21	1703.00	356.24	2059.24
60 lbs N EOY						
30 May	555.27	127.28	192.68	875.23	130.65	1005.88
23 Jun	1007.72	284.76	102.57	1395.05	195.03	1590.08
23 Jul	1193.03	342.21	172.91	1708.15	235.49	1943.66
23 Aug	1187.83	465.07	202.04	1854.94	266.45	2121.39

Table 13b. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	654.33	180.20	222.21	1056.74	189.30	1246.04
23 Jun	983.94	337.05	189.55	1510.54	237.42	1747.96
23 Jul	1104.98	388.63	165.03	1658.64	319.03	1977.67
23 Aug	946.90	607.60	204.28	1758.78	346.54	2105.32
100 lbs N EOY						
30 May	577.47	126.47	246.19	950.13	147.27	1097.40
23 Jun	951.00	310.00	162.49	1423.49	234.15	1657.64
23 Jul	1058.71	380.60	189.70	1629.01	270.66	1899.67
23 Aug	1175.49	579.74	174.83	1930.06	322.74	2252.80
Urea 40 lbs N EOY						
30 May	436.45	179.59	146.48	762.53	133.41	895.94
23 Jun	675.66	286.44	84.16	1046.26	249.89	1296.15
23 Jul	779.34	323.66	105.71	1208.71	309.66	1518.37
23 Aug	909.92	480.10	166.50	1556.52	313.80	1870.32
40 lbs N EY						
30 May	616.90	132.84	70.16	819.89	253.33	1073.22
23 Jun	1047.32	171.69	56.20	1275.21	352.37	1627.58
23 Jul	1043.69	394.54	52.49	1490.72	331.66	1822.38
23 Aug	1199.16	355.01	65.69	1619.86	304.15	1924.02

Table 13c. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	567.76	173.22	271.18	1012.16	124.46	1136.62
23 Jun	861.73	267.89	168.42	1298.04	211.56	1509.59
23 Jul	1086.15	262.57	168.43	1517.15	284.57	1801.74
23 Aug	983.42	467.29	194.30	1645.01	269.11	1914.12
60 lbs N EY						
30 May	593.52	155.42	226.78	975.72	160.17	1135.89
23 Jun	939.18	217.41	174.71	1331.30	173.09	1504.39
23 Jul	1077.30	288.98	123.11	1489.39	244.70	1734.09
23 Aug	1013.94	451.23	213.03	1678.20	295.67	1973.87
100 lbs N EOY						
30 May	738.18	121.71	323.51	1183.40	189.72	1373.12
23 Jun	1126.24	305.05	200.09	1631.38	218.29	1849.67
23 Jul	1168.82	426.69	198.46	1793.97	314.73	2108.70
23 Aug	1203.32	507.66	184.49	1895.47	430.07	2325.54

Table 14a. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	389.29	201.10	140.35	730.73	150.75	881.48
23 Jun	550.34	268.22	110.30	928.86	217.85	1146.70
23 Jul	651.10	290.79	128.46	1070.35	295.45	1365.80
23 Aug	748.63	429.73	138.70	1317.06	294.27	1611.33
Ammonium nitrate 40 lbs N EOY						
30 May	17.52	-22.91	30.24	8.84	-2.68	6.87
23 Jun	36.43	6.93	61.12	30.84	-16.82	21.79
23 Jul	56.80	5.03	3.92	36.39	30.89	35.20
23 Aug	25.67	3.85	3.96	16.26	-23.88	8.93
40 lbs N EY						
30 May	59.02	-48.15	-24.86	13.42	45.56	18.91
23 Jun	87.91	-27.06	-29.93	40.72	22.62	37.28
23 Jul	69.59	38.46	-46.62	47.19	31.44	43.78
23 Aug	49.59	14.93	-35.68	29.30	21.06	27.80
60 lbs N EOY						
30 May	42.64	-36.71	37.29	19.77	-13.33	14.11
23 Jun	83.11	6.17	-7.01	50.19	-10.47	38.67
23 Jul	83.23	17.68	34.60	59.59	-20.29	42.31
23 Aug	58.67	8.22	45.67	40.84	-9.45	31.65

Table 14b. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	68.08	-10.39	58.33	44.61	25.57	41.36
23 Jun	78.79	25.66	71.85	62.62	8.98	52.43
23 Jul	69.71	33.65	28.47	54.96	7.98	44.80
23 Aug	26.48	41.39	47.28	33.54	17.76	30.66
100 lbs N EOY						
30 May	48.34	-37.11	75.41	30.02	-2.31	24.49
23 Jun	72.80	15.58	47.32	53.25	7.48	44.56
23 Jul	62.60	30.88	47.67	52.19	-8.39	39.09
23 Aug	57.02	34.91	26.05	46.54	9.67	39.81
Urea 40 lbs N EOY						
30 May	12.11	-10.70	4.37	4.35	-11.50	1.64
23 Jun	22.77	6.79	-23.70	12.64	14.71	13.03
23 Jul	19.70	11.30	-17.71	12.93	4.81	11.17
23 Aug	21.54	11.72	20.04	18.18	6.64	16.07
40 lbs N EY						
30 May	58.47	-33.94	-50.01	12.20	68.05	21.75
23 Jun	90.30	-35.99	-49.05	37.29	61.75	41.94
23 Jul	60.30	35.68	-59.14	39.27	12.26	33.43
23 Aug	60.18	-17.39	-52.64	22.99	3.36	19.41

Table 14c. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	45.84	-13.86	93.22	38.51	-17.44	28.94
23 Jun	56.58	-0.12	52.69	39.75	-2.89	31.65
23 Jul	66.82	-9.70	31.11	41.74	-3.68	31.92
23 Aug	31.36	8.74	40.09	24.90	-8.55	18.79
60 lbs N EY						
30 May	52.46	-22.72	61.58	33.53	6.25	28.86
23 Jun	70.65	-18.94	58.40	43.33	-20.55	31.19
23 Jul	65.46	-0.62	-4.16	39.15	-17.18	26.97
23 Aug	35.44	5.00	53.59	27.42	0.48	22.50
100 lbs N EOY						
30 May	89.62	-39.48	130.50	61.95	25.85	55.77
23 Jun	104.64	13.73	81.41	75.63	0.20	61.30
23 Jul	79.51	46.73	54.49	67.61	6.53	54.39
23 Aug	60.74	18.13	33.01	43.92	46.15	44.32

Table 15. Herbage weight (lbs/ac) for total yield category and percent difference from unfertilized treatment during growing season months on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac		30 May	23 Jun	23 Jul	23 Aug
Unfertilized	0	lbs/ac	881.49	1146.70	1365.80	1611.33
Ammonium nitrate						
40 lbs N EOY	80	lbs/ac	942.01	1396.53	1846.49	1755.27
		%	6.87	21.79	35.19	8.93
60 lbs N EOY	120	lbs/ac	1005.88	1590.08	1943.66	2121.39
		%	14.11	38.67	42.31	31.65
40 lbs N EY	160	lbs/ac	1048.22	1574.23	1963.71	2059.24
		%	18.91	37.28	43.78	27.80
100 lbs N EOY	200	lbs/ac	1097.40	1657.64	1899.67	2252.80
		%	24.49	44.56	39.09	39.81
60 lbs N EY	240	lbs/ac	1246.04	1747.96	1977.67	2105.32
		%	41.36	52.43	44.80	30.66
Urea						
40 lbs N EOY	80	lbs/ac	895.91	1296.15	1518.37	1870.32
		%	1.64	13.03	11.17	16.07
60 lbs N EOY	120	lbs/ac	1136.62	1509.59	1801.74	1914.12
		%	28.94	31.65	31.92	18.79
40 lbs N EY	160	lbs/ac	1073.22	1627.58	1822.38	1924.02
		%	21.75	41.94	33.43	19.41
100 lbs N EOY	200	lbs/ac	1373.12	1849.67	2108.70	2325.54
		%	55.77	61.30	54.39	44.32
60 lbs N EY	240	lbs/ac	1135.89	1504.39	1734.09	1973.87
		%	28.86	31.19	26.97	22.50

Table 16. Four year mean June, July, and August herbage weight (lbs/ac) for fertilization treatments and percent difference from unfertilized treatment on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized	0						
lbs/ac		650.02		329.58		1374.61	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
lbs/ac		904.16	788.31	346.17	363.40	1666.11	1561.66
% difference		39.10	21.27	5.03	10.26	21.21	13.61
60 lbs N EOY	120						
lbs/ac		1129.53	977.10	364.01	332.58	1885.04	1741.81
% difference		73.77	50.32	10.45	0.91	37.13	26.71
40 lbs N EY	160						
lbs/ac		1086.10	1096.73	364.05	307.08	1865.74	1791.33
% difference		67.09	68.72	10.46	-6.83	35.73	30.32
100 lbs N EOY	200						
lbs/ac		1061.73	1163.62	471.26	413.13	1936.70	2094.64
% difference		63.33	79.01	42.99	25.35	40.89	52.38
60 lbs N EY	240						
lbs/ac		1011.94	1010.14	444.42	319.21	1943.65	1737.45
% difference		55.68	55.40	34.85	-3.15	41.40	26.40

Table 17. Herbage weight difference (lbs/ac) for fertilization treatments from unfertilized treatment and pounds of herbage per pound of nitrogen on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized	0						
lbs/ac		650.02		329.58		1374.61	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
lbs/ac difference		254.14	138.29	16.59	33.82	291.50	187.05
lbs/lb N		12.71	6.91	0.83	1.69	14.58	9.35
60 lbs N EOY	120						
lbs/ac difference		479.51	327.08	34.43	3.00	510.43	367.20
lbs/lb N		15.98	10.90	1.15	0.10	17.01	12.24
40 lbs N EY	160						
lbs/ac difference		436.08	446.71	34.47	-22.50	491.13	416.72
lbs/lb N		10.90	11.17	0.86	-0.56	12.28	10.42
100 lbs N EOY	200						
lbs/ac difference		411.71	513.60	141.68	83.55	562.09	720.03
lbs/lb N		8.23	10.27	2.83	1.67	11.24	14.40
60 lbs N EY	240						
lbs/ac difference		361.92	360.12	114.84	-10.37	569.04	362.84
lbs/lb N		6.03	6.00	1.91	-0.17	9.48	6.05

Table 18. Percent difference of mean June, July, and August herbage weight for fertilization treatments from unfertilized treatment produced in 1982 and 1984 and percent lost from 33 days with no precipitation in 1984 on the Moreau clayey range site.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized							
1982 lbs/ac		624.10		276.93		1184.23	
1984 lbs/ac		930.07		480.53		2054.43	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
1982 %		77.86	63.03	20.22	20.46	51.35	39.63
1984 %		15.69	9.55	10.72	10.23	10.43	6.06
% Lost		-62.17	-53.48	-9.50	-10.23	-40.92	-33.57
60 lbs N EOY	120						
1982 %		104.71	120.97	31.77	25.35	65.33	79.58
1984 %		45.27	16.28	15.20	-1.86	22.67	7.71
% Lost		-59.44	-104.69	-16.57	-27.21	-42.66	-71.87
40 lbs N EY	160						
1982 %		91.32	93.71	55.26	15.91	72.03	68.66
1984 %		40.05	24.76	0.33	-0.29	21.01	8.97
% Lost		-51.27	-68.95	-54.93	-16.20	-51.02	-59.69
100 lbs N EOY	200						
1982 %		147.14	160.73	63.28	63.46	100.27	110.57
1984 %		26.60	33.40	30.92	32.33	20.40	31.99
% Lost		-120.54	-127.33	-32.36	-31.13	-79.87	-78.58
60 lbs N EY	240						
1982 %		103.46	75.92	57.19	19.26	80.02	46.96
1984 %		32.21	34.70	33.58	-10.24	27.99	10.02
% Lost		-71.25	-41.22	-23.61	-29.50	-52.03	-36.94

Table 19a. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	52.00	46.80	83.17	55.48	51.02	54.71
23 Jun	21.51	15.62	-17.81	15.04	22.71	16.46
23 Jul	13.46	5.25	10.76	10.74	26.27	13.60
23 Aug	13.03	32.33	6.07	18.73	-0.40	15.24
Ammonium nitrate 40 lbs N EOY						
30 May	44.81	34.74	94.47	51.94	37.94	51.02
23 Jun	28.73	29.53	-2.63	27.43	8.92	24.62
23 Jul	26.46	4.17	-22.85	15.97	53.14	24.37
23 Aug	-7.85	31.56	5.53	4.67	-42.07	-4.94
40 lbs N EY						
30 May	55.28	21.11	83.63	48.67	56.51	50.90
23 Jun	37.07	18.50	-22.34	28.09	12.28	25.54
23 Jul	6.26	41.91	-6.92	15.76	31.21	18.91
23 Aug	1.40	18.48	16.37	7.49	-8.26	4.64
60 lbs N EOY						
30 May	46.54	27.37	65.95	47.18	49.03	47.42
23 Jun	37.92	33.86	-30.84	28.02	24.16	27.54
23 Jul	15.53	12.35	24.08	16.88	15.18	16.67
23 Aug	-0.44	26.42	9.97	7.91	11.62	8.38

Table 19b. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	59.22	29.66	84.99	60.08	54.63	59.19
23 Jun	29.83	25.81	-12.49	25.80	13.89	23.84
23 Jul	10.95	8.49	-9.38	8.42	23.55	10.91
23 Aug	-14.31	36.04	15.01	5.69	7.94	6.06
100 lbs N EOY						
30 May	49.13	21.81	90.05	49.23	45.63	48.71
23 Jun	31.78	31.66	-30.61	24.53	26.92	24.87
23 Jul	9.16	12.18	9.95	10.65	11.31	10.74
23 Aug	9.93	34.35	-5.44	15.60	16.14	15.68
Urea 40 lbs EOY						
30 May	47.97	37.41	64.02	48.99	42.51	47.90
23 Jun	26.29	22.26	-27.24	18.23	37.12	21.40
23 Jul	11.39	7.75	9.42	10.44	19.05	11.88
23 Aug	14.35	32.58	26.56	22.34	1.32	18.82
40 lbs N EY						
30 May	51.29	33.67	84.17	50.61	71.89	55.78
23 Jun	35.79	9.85	-16.75	28.11	28.11	28.81
23 Jul	-0.30	56.48	-4.45	13.30	-5.88	10.12
23 Aug	12.93	-10.02	15.83	7.97	-7.81	5.28

Table 19c. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	52.27	36.65	91.29	61.53	43.74	59.38
23 Jun	27.07	20.03	-34.59	17.38	30.61	19.49
23 Jul	20.66	-1.13	0.00	13.32	25.66	15.26
23 Aug	-9.46	43.32	8.71	7.77	-5.43	5.87
60 lbs N EY						
30 May	55.09	34.44	71.61	58.14	54.17	57.55
23 Jun	32.09	13.74	-16.44	21.19	4.37	18.67
23 Jul	12.82	15.86	-16.30	9.42	24.22	11.64
23 Aug	-5.88	35.96	28.39	11.25	17.24	12.15
100 lbs N EOY						
30 May	61.34	23.97	100.00	62.43	44.11	59.05
23 Jun	32.25	36.12	-38.15	23.63	6.64	20.49
23 Jul	3.54	23.96	-0.50	8.58	22.43	11.14
23 Aug	2.87	15.95	-4.32	5.35	26.82	9.32

Table 20. Percent herbage growth occurring during May and June for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Cool Season Grass		Total Native Grass		Total Yield	
Unfertilized	73.5		70.5		71.2	
Fertilized	Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	73.5	74.3	79.4	67.2	75.6	69.3
40 lbs N EY	92.4	87.1	76.8	78.7	76.4	84.6
60 lbs N EOY	84.5	79.3	75.2	78.9	75.0	78.9
60 lbs N EY	89.1	87.2	85.9	79.3	83.0	76.2
100 lbs N EOY	80.9	93.6	73.8	86.1	73.6	79.5

Table 21. Percent herbage growth occurring during July and August for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Cool Season Grass		Total Native Grass		Total Yield	
Unfertilized	26.5		29.5		28.8	
Fertilized	Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	18.6	25.7	20.6	32.8	19.4	30.7
40 lbs N EY	7.7	12.6	23.3	21.3	23.6	15.4
60 lbs N EOY	15.1	11.2	24.8	21.1	25.1	21.1
60 lbs N EY	-3.4	6.9	14.1	20.7	17.0	23.8
100 lbs N EOY	19.1	6.4	26.3	13.9	26.4	20.5

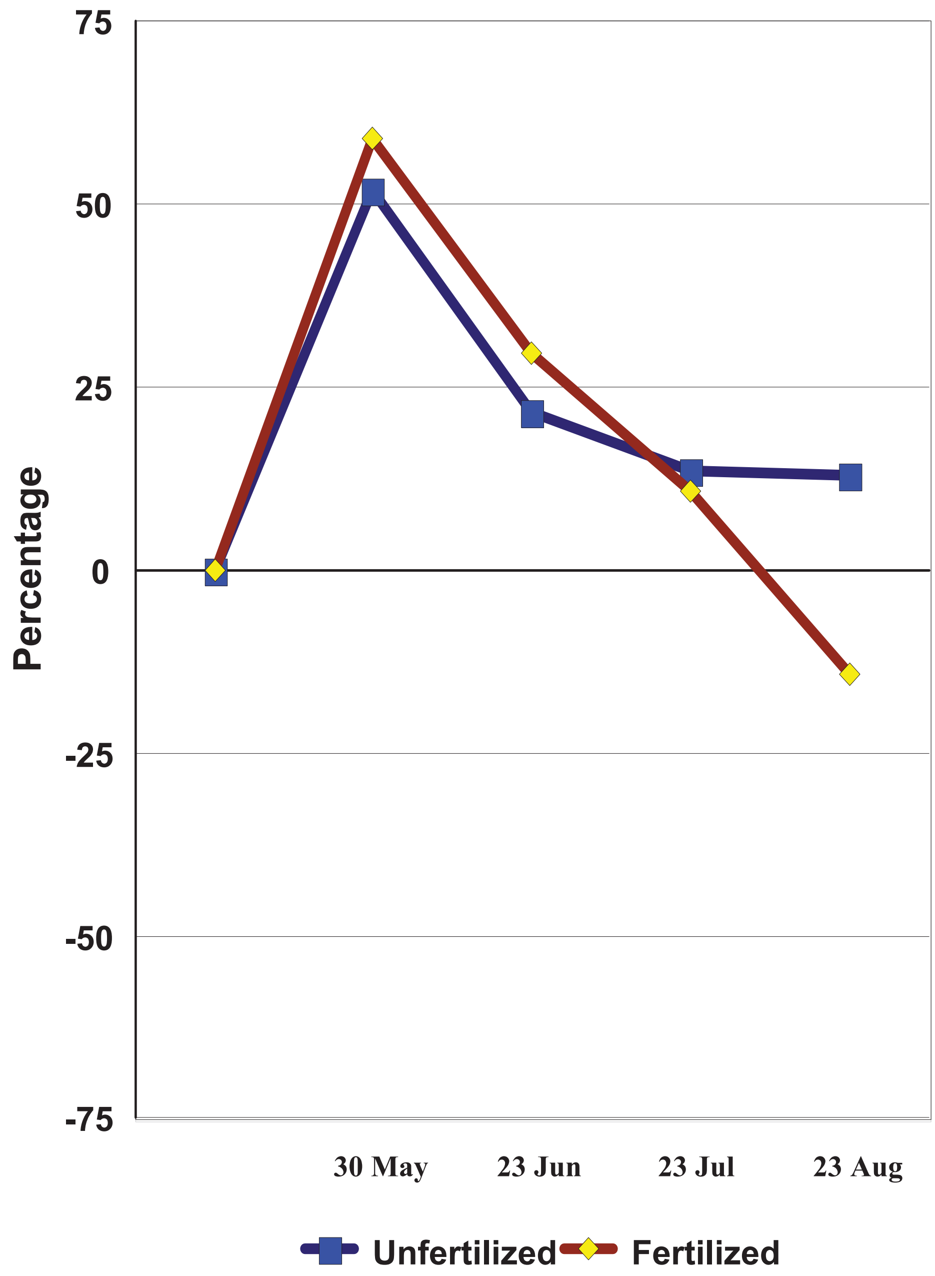

Figure 1. Percent herbage growth and senescence of cool season grasses for 60 lbs N EY and unfertilized treatments on the Moreau clayey range site, 1982-1985.

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