Nitrate-Nitrogen Accumulation in Range Plants after Massive N Fertilization on Shortgrass Plains

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Highlight: *Following massive nitrogen (N) fertilization, at rates of 224, 448, and 672 kg N/ha applied in April 1969, nitrate accumulation by species and plant groups on mixed-grass prairie was measured for 3 years. All species and plant groups accumulated Nitrate-N in direct relation to rates of applied N. Two annual forbs accumulated nitrate-N above the 2000 ppm level, which is considered toxic to livestock. In 1970, the first year of residual effect, slimleaf goosefoot contained nitrate-N levels two to three times higher than the potentially toxic level, and in 1971 greenflower pepperweed contained nitrate-N levels slightly above the potentially toxic level. The use of massive rates of N as a range improvement practice should be used with caution unless potentially toxic species are controlled.*

The availability of soil moisture and nitrogen limits forage production on rangelands. Only the N supply is readily susceptible to manipulation by man. In recent years, the economic feasibility of fertilizing rangelands has increased.

On most ranges, N fertilizers have been applied in annual increments rarely exceeding 112 kg N/ha (Rauzi et al., 1968; Rogler and Lorenz, 1957). Even at low rates of less than 30 to 40 kg N/ha per year, carryover or residual responses of herbage are not uncommon (Black, 1968; Houston, 1971).

There has been increased interest in the application of massive rates of N on rangelands as a means of eliminating the cost of annual applications. The fertilizer N applied in excess of the N-immobilizing capacity of the range plant-soil ecosystem appears to remain in the soil in mineral form until utilized by the range vegetation (Power, 1967). Consequently, it appears that saturation of the range plant-soil ecosystem with a massive rate of N fertilizer may eliminate N as a limiting factor for range forage production for many years, resulting in maximum production from the available moisture (Power and Alessi, 1971).

There is also evidence that high rates of N fertilizers have other effects on range vegetation. The vegetational responses may include long term changes in botanical composition and increased levels of N in the herbage. In the central Great Plains, Hyder and Bement (1972) found that N fertilization of abandoned cropland greatly reduced the proportion of pioneer perennial grasses, sand dropseed (*Sporobolus cryptandrus* [Torr.] A. Gray) and red threeawn (*Aristida longiseta* Steud.), and increased the proportion of annual forbs, slimleaf goosefoot (*Chenopodium leptophyllum* Nutt.), prairie sunflower (*Helianthus petiolaris* Nutt.), and Russian thistle (*Salsola kali* L.). Smith et al. (1968) also found substantial invasion by annual forbs with high rates of N fertilization.

Massive applications of N may increase nitrate-N content of herbage to a point toxic to grazing animals. If this occurs, the increased herbage yields obtained from massive rates of N are of no value. There is an optimum level of nitrate-N in plants which provides maximum yield with probably little or no toxicity (Hylton et al., 1970). However, this optimum level may easily be exceeded by massive-N

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applications through saturation of the nitrate reducing systems of the plant (Reid, 1966). There is some evidence that at least one species found on many rangelands, lambsquarter goosefoot *(Chenopodium album* L.), may have little or no natural capacity to reduce nitrate-N to plant proteins (Marthaler, 1937). This species may then accumulate nitrate-N to very high levels. For this reason, any study of plant responses to massive rates of N fertilization should include analyses of the nitrate-N content of herbage.

A study of range plant and soil-N responses to massive rates of N was conducted from 1969 to 1971. This paper reports the nitrate-N concentrations of range vegetation found in this study. The responses of herbage yields, protein content, botanical composition, and soil mineral N status are more long-term in nature and will be published later.

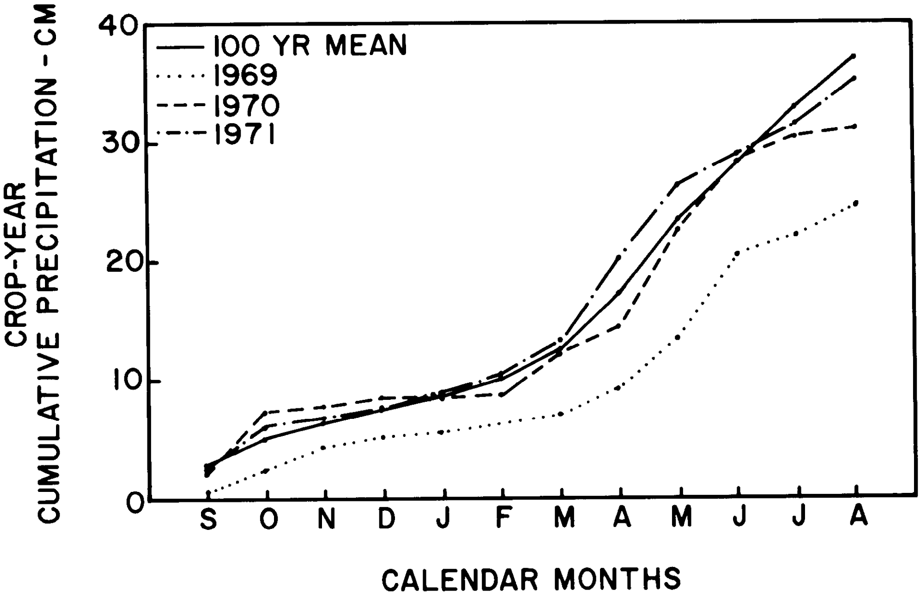

Fig. 1. *Accumulative precipitation amounts (cm) by months for the crop-years (September 1-August 31) of 1969, 1970, 1971, and 100-year mean at Cheyenne, Wyoming.*

Methods and Materials

Study plots 4.5 x 15 m were established on mixed-grass prairie located about 8 kilometers south of Cheyenne, Wyo. The dominant vegetative association is blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) and western wheatgrass (*Agropyron smithii* Rydb.). The soil has been classified as either Pachic Argiustoll or Aridic Pachic Argiustoll (Sligo clay loam with gravel in lower layers) depending on the moisture regime. The plot layout was a randomized block in three replications. Three rates of N (224, 448, and 672 kg/ha or 200, 400, and 600 lb./acre) were broadcast on the surface as single applications in April 1969. The nitrogen applied was ammonium-nitrate (33% N).

Individual species and groups of species were harvested by hand in mid-July of 1969, 1970, and 1971. Western wheatgrass was harvested individually all 3 years. Blue grama, needleandthread *(Stipa comata* Trin. and Rupr.), and slimleaf goosefoot were harvested individually in 1970. Greenflower pepperweed *(Lepidium densiflorum* Schrad.) was harvested individually in 1970. Other species harvested in 1970 or in 1971 were grouped into wheatgrasses, including both western wheatgrass and thickspike wheatgrass (*Agropyron dasystachum* [Hook.] Scribn.), perennial grasses other than wheatgrasses, perennial forbs, and annual species other than greenflower pepperweed. Samples of total herbage were harspecies other than greenflower pepperweed. Samples of total herbage were harvested biweekly in 1970 with a mechanical plot harvester, beginning May 22 and ending July 17, and in Mid-July, 1971.

All herbage samples were dried in a forced-air oven at 70 C and ground through a 1 mm screen in a Wiley mill. The 2,6-xylenol method described by Sabatka et al. (1972) was used for determining nitrate-N concentrations.

Precipitation was below average during the crop-year of 1969 (Fig. 1), particularly during the critical fall and spring periods. Precipitation was above average in the fall and early spring of both the 1970 and 1971 crop-years, while late spring and summer precipitation was below average.

Results

Nitrate Concentration in Different Species

Massive N fertilization significantly ($P > .95$) increased nitrate-N concentration in western wheatgrass in mid-July all three years of sampling (Fig. 2). The nitrate-N concentration increased with each increment of N applied in the year of fertilization and in the 2 years of residual effects. The nitrate-N concentration reached a peak in 1970 and then decreased for the control and the 672 kg N/ha treatments. However, for the 224 and 448 kg N/ha treatments, the nitrate-N concentration increased both from 1969 to 1970 and from 1970 to 1971.

The nitrate-N concentrations in the individual species and groups of species harvested in mid-July of 1970 and 1971 also increased significantly ($P > .99$) with each increment of N applied (Table 1). Blue grama had the lowest concentrations of nitrate-N of any of the species sampled in 1970; slimleaf goosefoot, an annual forb, had the highest concentrations.

In 1971 the lowest concentrations of nitrate-N occurred in either perennial grasses (including blue grama) other than western wheatgrass, or in perennial forbs, depending on the rate of N applied. The perennial forbs had the lowest concentrations of nitrate-N at the higher rates of applied N. Greenflower pepperweed, an annual forb, had the highest concentrations of nitrate-N in 1971.

Seasonal Trends in Nitrate Concentration

Massive N fertilization significantly ($P > .99$) increased the nitrate-N concentration in total herbage during the late spring and early summer of 1970, regardless of time of harvest (Fig. 3). As with western wheatgrass, the nitrate-N concentration of total herbage increased with

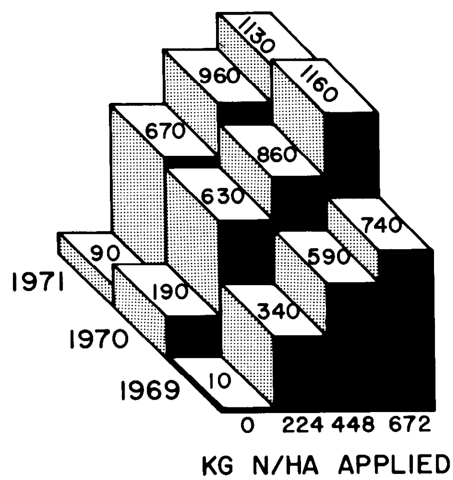

Fig. 2. *Nitrate-nitrogen concentrations (ppm) in western wheatgrass herbage harvested in mid-July 1969-70-71, after applying massive amounts of nitrogen fertilizer in April 1969.*

Table 1. Nitrate-N concentrations (ppm) of herbage harvested in mid-July 1970 and 1971, by major species, plant groups, and total herbage.

Year of harvest and species	Rate of N applied in 1969 (kg N/ha)			
	0	224	448	672
1970				
Wheatgrasses	160	550	790	1160
Blue grama	170	180	260	310
Needleandthread	240	620	1110	1310
Slimleaf goosefoot	1130	4870	4650	5510
Total herbage	160	1220	1990	2210
1971				
Wheatgrasses	90	680	960	1130
Other perennial grasses	60	240	740	1220
Perennial forbs	100	580	610	860
Greenflower pepperweed	50	1240	1760	2070
Other annuals	100	340	820	1230
Total herbage	90	580	1070	1370

each increment of N applied. The nitrate-N concentration reached a peak for all rates of applied N in early July and then decreased through mid-July.

The rapid increase in nitrate-N concentration in late June corresponded well with rapid growth of slimleaf goosefoot during this period.

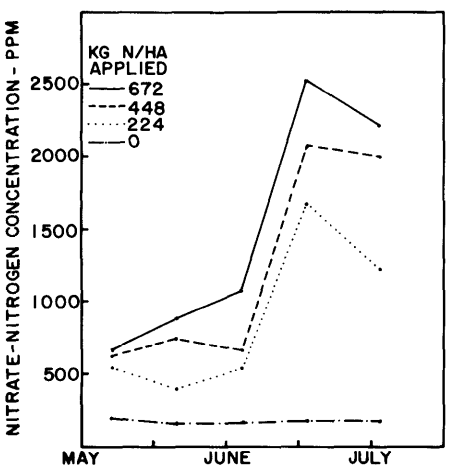

Fig. 3. *Nitrate-nitrogen concentrations (ppm) in total herbage harvested from late May to mid-July 1970, after applying massive amounts of nitrogen fertilizer in April 1969.*

Botanical Composition

In mid-July of both 1970 and 1971 the proportion by weight (oven-dry) of total herbage contributed by perennial grasses decreased and the proportion contributed by annual species increased in response to the applied N (Fig. 4). The proportion of perennial forbs was not changed by the applied N in 1970 but was reduced in 1971.

In 1970, slimleaf goosefoot greatly increased in abundance and yield in response to the increasing rates of applied N. In 1971, slimleaf goosefoot decreased and a second annual forb, greenflower pepperweed, increased.

Discussion and Conclusion

Minimum toxic levels of nitrate in forage for cattle vary from less than 0.20% (2000 ppm) to 0.35% nitrate-N (dry weight) (Lawrence et al., 1968). Bradley et al. (1940) placed the lower limit of toxicity in hay at 0.21% nitrate-N and stated that ingestion of 2.5 kg (5.5 lb.) of hay containing 0.69% nitrate-N would cause fatal poisoning of a 227 kg (500 lb.) animal.

Western wheatgrass, the wheatgrasses as a group, blue grama, needleandthread, other perennial grasses, and perennial forb components never exhibited potentially toxic levels of nitrate-N (2000 ppm) during the course of the study. The nitrate-N concentrations in slimleaf goosefoot in 1970 were two to three times the potentially toxic level. Nitrate-N concentrations in total herbage also reached potentially toxic levels in 1970. There seems little doubt that the high levels of nitrate-N in total herbage in 1970 were due almost entirely to the very high concentration in slimleaf goosefoot.

Nitrate concentration in greenflower pepperweed reached the potentially toxic level in 1971, but only at the highest rate of applied N (672 kg/ha).

The year to year variations in nitrate-N concentration may be influenced by moisture level as well as by the rates of applied N. The first year, 1969, was below average in precipitation, while 1970 and 1971 were essentially average. Nitrate-N concentrations in western wheatgrass were lower in 1969 than in 1970 or in 1971. This may be due to the low late winter and early spring precipitation in 1969, which could have limited availability of the applied N. The above average moisture in late winter-early spring of both 1970 and 1971 probably increased availability of soil-N for uptake by the vegetation. Power's (1967) findings in North Dakota tend to support this conclusion. The high fall and spring moisture of 1970 also could have influenced the drastic increase in abundance of slimleaf goosefoot in 1970, in addition to the stimulating effect of the applied N.

It is clear from the results of this study that massive rates of nitrogen of 225 kg/ha or more on rangelands can cause potentially toxic levels of nitrate-N in some species for 2 to 3 years. The potentially toxic concentrations were found only in annual forbs, which are not grazed readily by cattle but may be by sheep. The abundance of the toxic species present varies

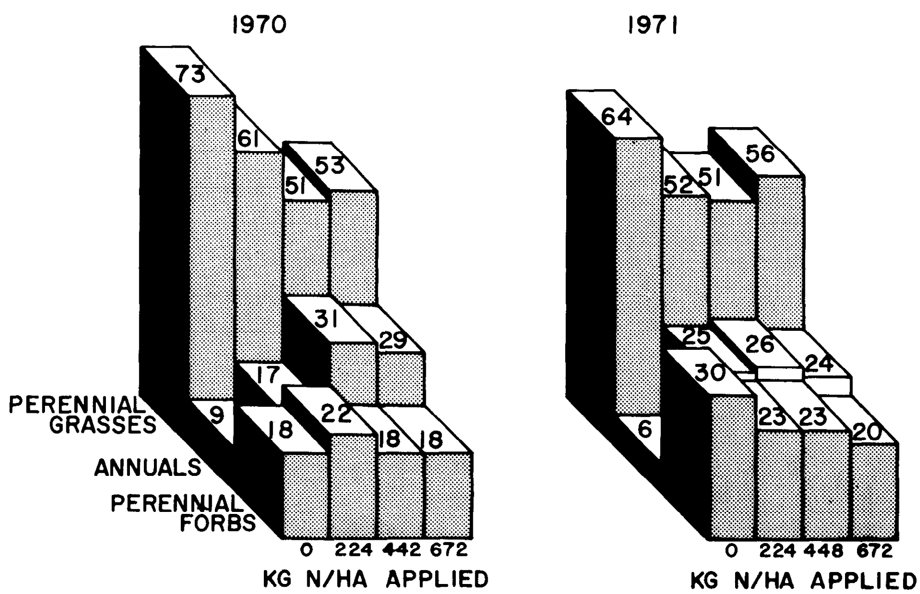

Fig. 4. *Composition by weight (%, oven-dry) of herbage harvested in mid-July 1970 and 1971, after applying massive amounts of nitrogen fertilizer in April 1969.*

from year to year. It may be necessary to control these species with herbicides to prevent livestock losses.

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