Fate of Applied Fertilizer Nitrogen on Native Rangeland

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Residual effects from nitrogen fertilizer in grasslands appear to be much more prolonged than for cultivated soils (Power and Alessi 1971).

The fate of applied fertilizer nitrogen on native rangeland ecosystems is dependent on the immobilization and mineralization of nitrogen by various biotic and abiotic factors called nitrogen sinks. Power (1977) determined the nitrogen content in the various sinks of a grazed semiarid native mixed grass prairie ecosystem near Mandan, ND that had been annually fertilized with 80 lbs N/ac for 11 years by G.A. Rogler and R.J. Lorenz. Power (1977) subtracted the nitrogen content of the various nitrogen sinks of the unfertilized pasture from the nitrogen content of the respective sinks of the fertilized pasture to determine the content and percentage of the applied fertilizer nitrogen in each nitrogen sink. The fate of nitrogen as a percent of applied fertilizer determined by Power (1977) is shown in the left column of table 1. The fate of applied fertilizer nitrogen during one year (50 lbs N/ac per year) and during eleven years (550 lbs N/ac per 11 years) of the fertilization of native rangeland grazing study conducted at the Dickinson Research Extension Center (1972-1982) are shown in the center and right columns of table 1, respectively.

The largest nitrogen sinks after eleven years of fertilization treatments were the soil mineral nitrogen (41%), grass root material (19%), and organic surface litter (16%). Fertilizer nitrogen remaining in the aboveground herbage and grass crowns was only 3% (Power 1977) (table 1). None of the fertilizer nitrogen was lost by leaching through the soil profile (Power 1970). The nitrogen not accounted for was 18%, of which other research suggests 5% was gaseous nitrogen lost to the atmosphere and 13% was immobilized in soil organic matter (Power 1975).

Black and Wight (1972) concluded that the plant-soil nutrient cycling systems of rangeland have a large portion of the soil nitrogen required for plant growth tied up in the organic phase in relatively unavailable forms. A large amount of fertilizer nitrogen was immobilized into grass roots, soil organic matter, and microbial tissue. About half of the immobilized nitrogen was found in the grass roots. The nitrogen immobilization capacity in grassland soils was somewhat variable and was influenced by soil texture, vegetation type, root growth, lignin content of organic matter, amount and mineralogy of clay material, and environmental parameters of soil temperature, soil oxygen, and soil water (Power 1972). The immobilized nitrogen in organic forms could be mineralized later by soil microorganisms and recirculated through the ecosystem. Mineralization breaks down organic materials into ammonia and carbon dioxide, or other low molecular weight carbon compounds. Most of the ammonia released is readily hydrolyzed to the ammonium form. Some of the ammonium is nitrified by oxidation to the nitrite form, then oxidized again to the nitrate form. The ammonium and nitrate produced by the mineralization and nitrification processes are added to the plant available inorganic (mineral) nitrogen pool in the soil (Power 1972).

Soil mineral nitrogen (ammonium NH_4 and nitrate NO_3) was available above the 3 foot soil depth in early spring the first year on high fertilization treatment rates greater than 160 lbs N/ac. Lower fertilization rates, greater than 40 lbs N/ac, required two to six years before increased inorganic nitrogen was available during early spring (Power 1972). Power (1977) determined after 11 years of annual applications of ammonium nitrate that 41% of the applied fertilizer nitrogen was available as soil mineral nitrogen with a small amount in the ammonium form (2%) and most in the nitrate form (39%) (table 1).

Only a small amount of fertilizer nitrogen was assimilated into the aboveground herbage per year. Smika et al. (1961) determined the fertilizer nitrogen fate after 9 years of annual applications of ammonium nitrate that 11.1% of the 30 lbs N/ac rate and that 18.8% of the 90 lbs N/ac rate had been incorporated into the aboveground herbage. Smika et al. (1965) determined the fertilizer nitrogen fate after 4 years of annual applications of ammonium nitrate that under natural moisture conditions 17% to 25% of the applied nitrogen was incorporated into the aboveground herbage. Power (1977) determined the aboveground fertilizer nitrogen fate at the end of the eleventh growing season of a grazed semiarid rangeland pasture with annual applications of ammonium nitrate to be at least a total of 18% and that 2% remained in the live aboveground herbage and 16% remained in the organic surface litter (table 1).

Livestock grazing removes only a small portion of the nitrogen from the aboveground herbage, leaving a significant part of the nitrogen in the remaining live aboveground herbage, the standing dead vegetation, and the litter. Most of the nitrogen consumed by grazing livestock is returned to the soil surface in urine and feces waste. Grazing livestock retain only a small amount of the nitrogen consumed, about 15% in a nonlactating animal and about 30% in a lactating animal (Russelle 1992). Power (1977) determined that about 3% of the applied nitrogen was removed from the grassland pasture as livestock product (table 1).

Some soil mineral nitrogen is immobilized when fixed by adsorption onto clay particles. The type of clay mineral affects the retention of ammonium. Clay materials with expanding lattices, such as montmorillonite, have greater surface area and adsorptive capacity for ammonium than clay minerals with nonexpanding lattices, such as kaolinite (Legg 1975).

Soil nitrogen is lost to the atmosphere through denitrification and ammonia volatilization. Denitrification is the reduction of the nitrite or nitrate mineral nitrogen to form nitrous oxide or dinitrogen gas. Denitrification probably accounts for only a small part of total nitrogen losses from pastures and rangeland because grass plants readily take up mineral nitrogen. Gaseous ammonia forms during mineralization of soil organic nitrogen to ammonium. Under some conditions the ammonia escapes into the atmosphere by volatilization. Ammonia volatilization losses generally increase with increasing aridity. Power (1977) estimated that about 5% of the applied nitrogen was lost to the atmosphere in gaseous form (table 1).

Fertilizer nitrogen applied to native rangeland soils is retained at greater quantities for considerably longer time periods than the same amount of fertilizer nitrogen applied to cropland soils because of the relatively rapid immobilization of mineral nitrogen into organic forms by perennial grass roots and soil microbial activity. These living components of grassland ecosystems can immobilize about 178 lbs N/ac in one growing season and around 285 lbs N/ac to 339 lbs N/ac within three or four years and the amount of nitrogen immobilized in live tissue can remain near that high range thereafter (Power 1972). The turnover rate of immobilized organic root material operates on a 3- to 4-year cycle (Power 1972). Mineralization of some of the organic nitrogen immobilized in perennial grass roots increases the supply of available mineral nitrogen (Power 1977). Rates of immobilization of mineral nitrogen to organic nitrogen and rates of mineralization of organic nitrogen to mineral nitrogen effect the quantity of available mineral nitrogen in grassland soils.

Cropland soils lack perennial grass roots and the ability to preserve a large portion of the mineral nitrogen as immobilized organic nitrogen. Mineral nitrogen in cropland soils is vulnerable to great losses through denitrification and ammonia volatilization.

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Table 1. Fate of applied fertilizer nitrogen on native rangeland pasture, 1972-1982, following first approximation percentages of fertilizer nitrogen fate in grazed semiarid rangeland developed by Power (1977).

Biotic and Abiotic Nitrogen Sinks	Fate of N as Percent of Applied Data from Power 1977 %	Fate of N from 50 lbs N/ac per year lbs N/yr	Fate of N from 550 lbs N/ac per 11 years lbs N/11 yrs
Retained in Ecosystem	92%	46.0	506.0
Plants	22%	11.0	121.0
aboveground herbage	2%	1.0	11.0
crown	1%	0.5	5.5
roots	19%	9.5	104.5
Litter	16%	8.0	88.0
Soil Mineral Nitrogen	41%	20.5	225.5
ammonium NH_4	2%	1.0	11.0
nitrate NO_3	39%	19.5	214.5
Soil Organic Nitrogen unmeasured estimate	13%	6.5	71.5
Lost to Ecosystem	8%	4.0	44.0
Beef Tissue	3%	1.5	16.5
Gaseous Losses unmeasured estimate	5%	2.5	27.5
Leaching	0%	0.0	0.0

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