Influence of Soil Mineral Nitrogen on Native Rangeland Plant Water Use Efficiency and Herbage Production

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Native rangelands managed by traditional grazing practices are deficient in available soil mineral nitrogen and produce less than potential quantities of herbage biomass (Wight and Black 1972). The biogeochemical processes of these rangeland ecosystems typically function at levels that cycle nitrogen at rates of about 59 pounds or less of mineral nitrogen per acre per year and produce only one half to one third of the potential quantities of herbage biomass (Wight and Black 1972). The remedy for the problem of low herbage production on native rangeland is not repetitive applications of nitrogen fertilizer because the additional herbage produced from nitrogen fertilization has unprofitably high costs (Manske 2009b) and the long-term effects from nitrogen fertilization cause shifts in plant species composition with reductions of the native grass species and increases of the domesticated and introduced grass species (Manske 2009a). However, the results from more than three decades of nitrogen fertilization research on native rangelands provides insight into the underlying causes of the problem of herbage production at below potential quantities on native rangelands managed by traditional grazing practices.

Nitrogen fertilization of native rangeland increases the quantity of available soil mineral nitrogen. Total herbage biomass production on native rangeland increases with the increases in quantity of soil mineral nitrogen (Rogler and Lorenz 1957, Whitman 1957, Whitman 1963, Smika et al. 1965, Goetz 1969, Power and Alessi 1971, Lorenz and Rogler 1972, Goetz 1975, Taylor 1976, Whitman 1976, Goetz et al. 1978, Wight and Black 1979). The greater quantities of available soil mineral nitrogen cause the soil water use efficiency to improve in grassland plants (Smika et al. 1965, Wight and Black 1972, Whitman 1976, 1978). Water use efficiency (pounds of herbage produced per inch of water use) is difficult to measure quantitatively because soil water can be lost through evaporation or transpiration. Precipitation use efficiency (pounds of herbage produced per inch of precipitation received) is less complicated to measure than water use efficiency. Wight and Black (1972) found that precipitation use efficiency of grasslands improved with increased quantities of soil mineral nitrogen and that the pounds of herbage produced per inch of precipitation were greater on the nitrogen fertilized treatments than on the unfertilized treatments. Wight and Black (1979) compared herbage production on traditionally managed rangeland with the typical ambient deficiency of available mineral nitrogen to herbage production on nitrogen fertilized rangeland without a deficiency of available mineral nitrogen. During ten years of study with normal growing season precipitation, the deficiency of mineral nitrogen on the traditionally managed rangeland caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the herbage produced per inch of precipitation on the rangeland without a mineral nitrogen deficiency.

Nitrogen cycling in Northern Plains rangeland ecosystems managed by traditional grazing practices is inadequate to supply the quantity of mineral nitrogen necessary for minimum potential herbage production. A deficiency in available mineral nitrogen causes reductions in grassland plant water use efficiency and reductions in herbage biomass production to below potential levels during growing seasons with normal precipitation and no deficiency in available water. During growing seasons with below normal precipitation, both the deficiency in available water and the deficiency in available mineral nitrogen contribute to the resulting reductions in herbage production. During drought growing seasons, the percent reduction in herbage production is greater than the percent reduction in precipitation because of the additional reductions in water use efficiency and herbage production caused by the deficiency of mineral nitrogen. Semiarid rangelands would produce herbage biomass at the maximum level for whatever soil water was available if the ecosystems were not deficient in mineral nitrogen (Power and Alessi 1971). Herbage production on native rangeland ecosystems at minimum potential herbage yields would require nitrogen cycling at a rate of about 100 pounds of available mineral nitrogen per acre per year and that maximum potential herbage yields would be produced at rates of about 165 pounds of mineral nitrogen per acre per year (Wight and Black 1972).

Native rangeland plants need hydrogen, carbon, and nitrogen to produce herbage biomass. The hydrogen comes from soil water absorbed through the roots. The carbon comes from atmospheric carbon dioxide fixed through photosynthesis in the leaves. The nitrogen comes from the mineral nitrogen mineralized from soil organic nitrogen by rhizosphere microorganisms (Manske 2007). The total amount of energy fixed by chlorophyllous plants on rangeland ecosystems is not limited by the availability of radiant energy from the sun or by the availability of atmospheric carbon dioxide. The availability of water, which is an essential requirement for plant growth and has a dominant role in physiological processes, does not limit herbage production on rangeland ecosystems to the extent that mineral nitrogen availability does (Wight and Black 1972). Available soil mineral nitrogen is the major herbage growth limiting factor in Northern Plains rangelands (Wight and Black 1979). Grassland soils are not deficient of nitrogen and do not require application of additional fertilizer nitrogen. Most of the grassland nitrogen is immobilized in the soil as organic nitrogen in living tissue and nonliving detritus. Grassland soils in the Northern Plains contain about 3 to 8 tons of organic nitrogen per acre. Soil organic nitrogen must be converted into mineral nitrogen through mineralization by soil microorganisms in order to be available to grassland plants. The greater the biomass of soil microorganisms, the greater the quantity of available mineral nitrogen.

Rangelands managed by the twice-over rotation grazing strategy are not deficient in available mineral nitrogen. The biologically effective twice-over rotation grazing management strategy is designed to use partial defoliation of grass tillers at beneficial phenological growth stages to meet the biological requirements of grassland plants and to stimulate rhizosphere organism activity that enhances the biogeochemical processes in grassland ecosystems and increases the quantity of organic nitrogen mineralized into inorganic (mineral) nitrogen at amounts sufficient for herbage production at maximum potential yield levels (Manske 2007).

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