Evaluation of nitrogen fertilization and grazing effects on a porcupine grass (Stipa spartea var. curtiseta) community

by Leonard Roy Roath

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Science Management
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Abstract:
Evaluation of nitrogen fertilization and grazing treatments on a porcupine grass community was initiated on the Rohde-Langen Ranch, north of Glasgow, Montana, in 1970, to determine if increased utilization of porcupine grass could be achieved.

Nitrogen fertilizer (ammonium nitrate) was applied at five rates, in 50 pound increments, 0-200 pounds of actual nitrogen per acre. The 200 pounds of nitrogen per acre treatment was applied as 600 pounds of nitrogen per acre in one foot bands on three foot centers. An exclosure was established and moved each spring to create varying lengths of grazing deferment following initial fertilizer applications.

Porcupine grass yield did not respond significantly to nitrogen application. Wheatgrasses increased in yield and density with added nitrogen. The remaining vegetation demonstrated no uniform yield response to fertilization. Palatability of all species was greatly increased in the first season following fertilization but decreased substantially the following year. Extreme utilization adversely affected yield and cover of porcupine grass but other species showed no uniform response.

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ABSTRACT

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INTRODUCTION

The Northern Great Plains provides a range resource which is worth millions of dollars to the agricultural economy in production of livestock products. Throughout the years livestock producers have depended upon the forage produced by these natural grasslands.

Livestock producers face serious problems in obtaining economical utilization of this vast resource. The climate is severe with summer temperatures exceeding 100 degrees Fahrenheit and winter minimums sometimes falling to -50 degrees Fahrenheit. Drought is an ever present problem facing producers. To complicate these problems, one or more dominant forage species may not be palatable to grazing animals.

A prominant non-palatable species on portions of the northern glaciated plains is porcupine grass (*Stipa spartea* var. *curtiseta* Trin.). This species may occupy up to 50 percent of the range surface area. Because of its low palatability, porcupine grass is often used very little by livestock.

Fertilization and grazing treatments were used in an attempt to increase palatability and thus utilization of porcupine grass. This thesis is an evaluation of the effects of fertilization and grazing on the plant community and an estimate of relative changes in livestock utilization.

REVIEW OF LITERATURE

Early Range Fertilization Research

Range fertilization studies were initiated on the Northern Great Plains as early as 1925. A part of this work was done on the Northern Montana Agricultural Research Center at Havre (Heady, 1952). This study involved sequential applications of barnyard manure coupled with several mechanical treatments and reseeding of crested wheatgrass (Agropyron desertorum (Fisch.) C. Richt.) and sweetclover (Melilotus spp.). The various treatments were applied to a native range site characterized as a Stipa-Bouteloua type with a dense clubmoss (Selaginella densa Rydb.) understory (Heady, 1952).

The seeding success was not enhanced by manure, but manure created a definite increase of native grass and a decrease in dense clubmoss. Application of manure stimulated the vegetation to produce larger yields than those from mechanically treated plots. Western wheatgrass (Agropyron smithii Rydb.) demonstrated a small positive response to fertilization. Height measurements taken in 1947 revealed a residual effect from four successive years application of barnyard manure (Heady, 1952).

The Havre study was somewhat superficial in evaluating vegetational responses and changes in vegetation composition trends. It did, however, show the basic effects of application of additional nitrogen to a mixed prairie range system.

Later work took a more comprehensive approach in evaluation of nitrogen effects on the ecosystem. The scope was expanded to many types of vegetation and environments. A great many methods were also employed. In spite of the wide variety of locations, vegetation, and environments, many research reports concur on several conclusions. The discussion following will attempt to summarize these conclusions.

Sources of Nitrogen

Some of the early work done on range fertilization employed manure as a nitrogen source. Manure was used because it was readily available, inexpensive and contained a relatively high nitrogen content. One such study was described by Heady (1952). Later, some workers compared the effects of manure with those of commercial fertilizers (Klipple and Retzer, 1959; Lodge, 1959; Smoliak, 1965; McKell, 1970). All of these authors reported positive yield responses to both sources of nitrogen. McKell (1970) found that organic fertilizers released nitrogen more slowly than commercial fertilizers but the length of residual effects were similar.

Ammonium nitrate has been the most common source of nitrogen when commercial fertilizers were used. Several workers compared commercial sources of nitrogen, such as urea, ammonium sulphate, ammonium phosphate, and ammonium nitrate (Holt, 1961; Houston, 1973; McKell, 1970; Power, 1970; Smoliak, 1965; Sneva, 1973; Thomas, 1964). Most authors concluded that the amount of nitrogen applied was more important than the source. Houston and van der Sluijs (1973), however, reported response differences between urea and ammonium nitrate when applied in the fall of the year.

The use of solid form fertilizers has dominated range fertilization work because of the relative ease of application. Recently, however, there has been some experimentation with application of liquid fertilizers to rangeland (Houston and van der Sluijs, 1973). Liquid fertilizers usually have a higher nitrogen content and a lower cost per pound of nitrogen making the cost per acre lower. Houston and van der Sluijs (1973) demonstrated that when applied in the fall, foliar applications of liquid fertilizers can be subject to high volatilization losses.

Time of Application

The fall period has been the most common time for application of nitrogen in the Northern Great Plains area. The fall period has been used primarily because it usually precedes a period of relatively high precipitation. The addition of nitrogen in this period, accompanied by later winter spring moisture, allows greater stimulation of plants which normally produce the majority of their growth in the spring period.

Houston and van der Sluijs (1973) disclosed that fall application of liquid urea fertilizer stimulated less yield response than liquid urea applied in June and July. Sneva (1973), on the other hand, showed no differences in yield response of created wheatgrass, associated with season of fertilizer application.

Vegetation Responses to Nitrogen Application

Initiation of Spring Growth.

One of the first nitrogen fertilizer effects to become evident is earlier than usual green-up of grasses. Apparently the metabolic stimulation of the plant by nitrogen causes this reaction (Holt et al., 1961). In addition to earlier spring green-up of grasses on fertilized plots, added nitrogen extends the green forage period (Duncan, 1970; Lorenz and Rogler, 1973; Retzer, 1954). This extension of the green forage season is especially prevalent in cool season grasses. Holt and Wilson (1961) reported that the green forage period of warm season, desert grasses in southern Arizona was significantly lengthened by application of nitrogen. This extended green forage period may be partially due to increased water-use efficiency of fertilized plants (Holt and Wilson, 1961).

Water-Use Efficiency.

Most authors agree that addition of nitrogen increases water-use efficiency of vegetation. Again, this seems to be particularly true for cool season grasses. Some of the authors supporting this conclusion are: Black (1968) working on native and seeded vegetation in Montana; Cosper and Thomas (1961) in North Dakota; Johnston et al.

(1969) in Alberta; and Smika et al. (1965) in North Dakota. Cline and Richard (1973) disclosed that the water-use efficiency of an annual grass, cheatgrass brome (Bromus tectorum L.) was also greatly increased by addition of nitrogen.

Holt and Wilson (1961), Reed and Dwyer (1970), and Owensby et al. (1971) reported water-use efficiency increases in warm season grasses. Lehman et al. (1968) recorded very low water-use efficiency in irrigated blue grama (Bouteloua gracilis (HBK) Lag.).

Yield.

Perhaps the most commonly observed vegetation response to nitrogen application is an increase in herbage production. Fertilization studies have been done in extremely wide and varied range types and environments. Nearly all reports disclose significant yield increases due to nitrogen effects.

In recent years a considerable amount of research has been done on nitrogen yield responses of native vegetation in the Northern Great Plains. Black (1968) reported consistently increased yields of native grasses in the mixed prairie of northeastern Montana. Other authors who have received similar results from mixed prairie vegetation are Burzlaff et al. (1968); Heady (1952); Johnston et al. (1968); Klages and Ryerson (1965); Lorenz and Rogler (1973); Nichols et al. (1969); Smika et al. (1965); Smoliak (1965); Thomas et al. (1968); and Van Dyne (1961). Rogler and Lorenz (1957) reported that in the mixed prairie, increases in yield of cool season grasses contributed more to the total yield than other vegetational components. The work of Choriki et al. (1969), Goetz (1969), Johnston et al. (1967) and Lodge (1959) supported this conclusion. Two authors, Goetz (1969) and Johnston et al. (1967), reported a negative yield response of fertilized needle-and-thread (Stipa comata Trin. and Rupr.). Johnston et al. (1967) and Taylor (1967) disclosed a trend of fertilized warm season grasses particularly blue grama to decrease in yield.

The yield increase of cool season grasses due to added nitrogen is not confined to the mixed prairie. Cosper et al. (1967), Houston and van der Sluijs (1973), and Klipple and Retzer (1959) showed increases in cool season grasses on the shortgrass plains. Owensby (1970) also reported yield increases in cool season grass on upland bluestem range. In contrast, Rauzi et al. (1968) found that fertilization created no significant yield increases of cool season grass yields on the shortgrass prairie.

Many other vegetation types show increases in yield in response to nitrogen. Kelsey et al. (1973), Lehman et al. (1968), Owensby et al. (1970), Owensby (1971), and Reed and Dwyer (1970) reported yield increases of vegetation in the tall grass prairie. Holt and Wilson (1961) concluded that nitrogen fertilizer increased the production of native and seeded grass in the southern desert of Arizona.

Grasses in mesic environments also responded favorably to nitrogen.

Browns (1972) and Hooper et al. (1969) found herbage yield increases in mountain vegetation in response to nitrogen. Freyman and van Ryswyk (1969), and Mason and Miltmore (1969) reported yield increases in Canadian pinegrass types as the result of nitrogen application.

Several authors have reported positive nitrogen yield responses of seeded range vegetation. Hull (1963) and Sneva (1973) recorded significant yield increases in crested wheatgrass on the northern plains. Bromegrass (Bromus inermis Lag. ss.), a rhizomatous cool season grass, demonstrated large responses to the addition of nitrogen (Colville et al., 1963; Johnston et al., 1968).

A principal problem on deteriorated perennial grass range has been invasion of winter annual grasses such as cheatgrass brome. Burgess and Evans (1965), and Cline and Richard (1972) concluded that cheatgrass brome demonstrated very large yield increases in response to addition of nitrogen. In one case, the cheatgrass yield response was so large that a stand of intermediate wheatgrass (Agropyron intermedium (Haste.) Beaur.) could no longer compete for moisture. This resulted in the death of the wheatgrass (Burgess and Evans, 1965). In California, where much rangeland vegetation is a complex of annual grasses, the results of fertilization experiments were highly variable. McKell et al. (1970) showed significant increases in annual grass yield with several rate applications of chicken manure. Martin et al. (1964), and Woolfolk and Duncan (1962), however, show plantings of perennial grasses responding more to the nitrogen application than did annual grasses.

Composition Change.

From early range fertilization studies until the present, it has been apparent that application of nitrogen fertilizer to a native grassland ecosystem can cause changes in vegetational composition. An evaluation of an early study at Havre, Montana, revealed an apparent shift in composition structure with decreases in dense clubmoss and warm season grass accompanied by increases in cool season grasses (Dolan, 1966; Heady, 1954; Taylor, 1967). Rogler and Lorenz (1957) also noted a similar shift in composition in a study in North Dakota, but added that cool season rhizomatous grasses were the most favored of any species group. Of the warm season grasses, blue grama usually demonstrated the greatest decrease in yield. Apparently this is because the Northern Great Plains is approaching the edge of the range of blue grama in which it is not an effective competitor for nutrients. Cosper and Thomas (1961) and Cosper et al. (1967) pointed out that western wheatgrass seemed particularly benefitted by fertilization. Authors observing the same trend were Choriki et al. (1969); Goetz (1969); Rauzi et al. (1968); and Taylor (1967). Johnston et al. (1964) noted increases in western wheatgrass, thickspike wheatgrass (Agropyron dasystachym (Hook.) Scribn.), and fringed sagewort (Artemisia frigida Willd.). At the same time, decreases in the cool season grasses, prairie junegrass (Koeleria cristata (L.) Pers.) and needle-and-thread and a warm season grass, blue grama, also were noted. Goetz (1969; 1970) reported that needle-and-thread demonstrated a definite tolerance limit for nitrogen. Exceeding this tolerance limit caused the death of that species. The detrimental change in range composition also was forecast by Owensby et al. (1971) when they noted an undesirable shift from warm season grass to cool season grass on the bluestem prairie following nitrogen application. The research reports of Gay and Dwyer (1965) and Owensby (1970) also concur on the shift from a warm season composition to that of cool season grasses. Duncan and Hylton (1970) reported that like warm season grasses, legumes show a tendency to decrease on fertilized areas.

Several authors have discovered an invasion of weeds on fertilized plots. Houston (1954) was among the first to note an apparent increase of weed production on nitrogen fertilized plots. Cosper and Thomas (1961) clearly noted the problem, in their research by noting that application of fertilizer to rangeland may create a serious problem in control of non-grass species, especially if range condition is poor. Nichols et al. (1964) found that 2,4 dichlorophenoxy acetic acid applications accompanying nitrogen treatments resulted in more vigorous and taller grass plants. Johnston et al. (1964) found foxtail barley (Hordeum jubatum L.) and weeds invaded fertilized plots. Houston et al. (1973) and Houston and van der Sluijs (1973) reported increases of annual weeds, particularly slimleaf goosefoot (Chenopodium leptophyllum Nutt.), Russian thistle (Salsola kali L.), and green flower pepperweed (Lepidium densiflorum Shrad.). In addition to an increase in density of weeds, the weeds seem to have an affinity to accumulate nitrates, often to a toxic level on high nitrogen application treatments.

Few studies have followed composition changes after the initial response because of the expense and the long period of time required to follow such changes. However, Ryerson[1/] noted a great influx in annual and perennial weeds, on nitrogen plots near Moccasin, Montana, six growing seasons following fertilization.

Competition.

Acting hand in hand with composition change is intraspecific competition for limiting factors. In most range environments this is water. Heinrich et al. (1960) on seedings reported increases in intraspecific competition with application of nitrogen fertilizer. This competition created a trend toward a monoculture of the most competitive species. In a comparison of five seeded species (Agropyron desortorum, Agropyron inerme, Agropyron riparium, Elymus junceus and Stipa viridula), they found that Agropyron desertorum was the most competitive.

[1/]Ryerson, unpublished data.

Protein.

Nitrogen fertilization seems to stimulate plants to produce additional plant protein. Increases in plant protein have been reported in nearly all types of vegetation which have been fertilized with nitrogen. The production of additional protein is particularly important in rangeland because protein is often limited in range forage, creating a nutrient stress situation for range animals.

Cosper and Thomas (1961), working on mixed prairie vegetation in North Dakota, reported significant increases in nitrogen content in range vegetation as the result of fertilization. Colville et al. (1963) reported a six percent crude protein increase in smooth bromegrass with annual application of nitrogen.

Hull (1963) and Sneva (1973), in work done in the Great Basin, showed significant increases in the crude protein content of crested wheatgrass. Owensby et al. (1971) also showed protein increases in big bluestem (Andropogon gerardi Vitro.). Other authors showing similar increases in protein content in vegetation with the addition of nitrogen are Black (1968), in Montana native grasslands; Browns (1972), on high elevation mountain range; Cosper et al. (1967), on North Dakota mixed prairie; and Martin et al. (1964), on California annual grass range.

Choriki et al. (1969) noted considerable accumulations of nitrate - nitrogen in grass forage on fertilized plots. Houston et al. (1973)

reported that nitrate - nitrogen accumulated in forage in direct proportion to the amount of nitrate applied. Dee and Fox (1967) found increases in forage protein in the summer period but reported that weathering of vegetation caused substantial drops in the forage protein content. The high protein plants lost protein at the same rate as the plants with lower protein content, thus the high protein plants carried more protein into the winter period. In contrast, Burzlaff et al. (1968) reported no differences in protein content of cured forage. Freyman and van Ryswyk (1969), working in British Columbia, reported increased crude protein in pinegrass (Calamogrostis rubescens Buckl.) with the addition of nitrogen. In addition, they reported that palatability was significantly increased, which implies a direct link between palatability and crude protein content of forage.

Palatability.

Heady (1964) defined palatability as an inherent plant attribute, making the plant acceptable to a grazing animal. Dubbs (1966) also pointed out that palatability and crude protein in forage were closely associated. Apparently the increase of crude protein content makes fertilized plants increasingly acceptable to the animal. Duncan et al. (1970) found that while protein content of forage increased, lignin, regarded as a negative palatability attribute, remained the same. Johnston et al. (1967), in southern Alberta, disclosed substantial increases in the palatability of range grasses that had been fertilized.

Smith and Lang (1957) and Hooper et al. (1969) noted large increases in livestock use on fertilized areas. This probably was indicative of improved palatability. Holt and Wilson (1961) recorded far greater utilization on vegetation on the Santa Rita Experimental Range after nitrogen fertilization. There was a 29 percent increase in blue grama consumption by wether lambs, when fed forage from fertilized plots (Kelsey et al., 1973). Einarsen (1946) found that deer harvested in an area of high protein forages were substantially heavier than deer harvested from areas having low protein forages. Nitrogen applications improve forage quality for all types of ruminants by increasing crude fiber and protein in forage (Duvall, 1970). Hanson and Smith (1970) found that domestic livestock were selective only to an area of higher palatability. Wildlife tend to be very selective to specific forage plants, taking only the most palatable and nutritious plants. Thomas et al. (1964), working in the Black Hills, found that spring utilization of grass by deer was confined nearly exclusively to the fertilized plots.

Soil Responses

In a grassland system nitrate movement is considerably different than in a cropland cultivated system. Movement is more limited in depth and diffusion because of transformations of nitrate - nitrogen into other forms of nitrogenous products which are less mobile. A high percent of nitrogen is tied up in living matter, humus, associated with soil aggregates (Power, 1968).

Levin (1964) stated that rapid leaching of nitrates is prevented by a granular soil structure because nitrates are retained within aggregates. Stewart et al. (1967) stated that nitrate accumulates in soil beds, and even substantial rainfall does not affect nitrate levels by leaching away nitrogen unless a saturated flow develops.

The organisms beneath a grassland cover seem to be particularly adept at the immobilization of nitrate. This is done by altering nitrates into other nitrogen forms. Stewart et al. (1967) showed that in most sod sites there was less than 0.5 ppm nitrates in core samples. Stewart also reported that 12 of 17 samples taken from a sod site, to a depth of ten feet, were nitrate free. Samples taken from cultivated sites showed only five of 22 samples were nitrate free. Power (1972) reported that a grassland has a tremendous capacity to immobilize nitrogen and that only very high rates of nitrogen application result in a saturation at that capacity. In addition, Tyler et al. (1958) showed that after adding nitrate fertilizer to a ryegrass cover the nitrate level was steadily reduced after the initiation of the rapid spring growth period. By mid-July, concentrations of nitrates in the topsoil were less than two parts per million.

Richardson (1938) showed that grassland soils rarely contain appreciable quantities of nitrate. Some volatilization of nitrate may occur when soil moisture is high and soil temperatures warm (Tyler et al., 1958).

Economics

The economic return of range fertilization has long been, and continues to be, a point of considerable controversy. Several factors influence the economic feasibility of nitrogen fertilization of rangeland. Among the most important of these are (1) the vegetation species to be fertilized, (2) the availability of water, precipitation or irrigation, (3) the application rate and cost of fertilizer, (4) the length of time residual responses continue, (5) vegetation composition changes and value of forage, and (6) control of livestock utilization and distribution.

The vegetation species is important because of the unique attributes of each species to show different potentials for yield response to a particular fertilizer treatment. Different species respond differently to the same level of nitrogen (Johnston et al., 1969).

Nitrogen response depends on availability of water (Cosper and Thomas, 1961). Therefore, nitrogen applied in a dry year is unlikely to produce expected responses.

Nitrogen application rate and cost per unit may be the most decisive factor in application of fertilizer on some ranges. High application rates and high cost per unit of nitrogen could create a situation making fertilization economically unfeasible on any range.

Residual effects become important because of the cost of repeated applications necessary to maintain the desired level of production.