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
Montana State University
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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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EVALUATION OF NITROGEN FERTILIZATION AND GRAZING EFFECTS ON A PORCUPINE GRASS (*Stipa spartea* var. *curtiseta*) COMMUNITY

by

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

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in

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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.

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.

The length of residual nitrogen effect is not well established. Most studies using low rates of nitrogen application found the effect was generally not evident after two growing seasons (Black, 1968; Browns, 1972). McKell et al. (1970) found effects extending into the third growing season. High rates of nitrogen application may have residual effects lasting three or more years. The residual effect of high nitrogen application rates is confounded with precipitation and composition changes. This may cause vegetational responses many years after the original treatment (Ryerson and Taylor[1/]).

Composition changes should probably be the one most important factor in determining feasibility of fertilization of native range. A detrimental composition change may outweigh any increases in yield received from nitrogen. The value of forage and livestock utilization of forage produced are also important considerations in the economics of fertilization.

Most studies have shown that fertilization on native range was not feasible or was very marginal (Burgess et al., 1965; Duvall, 1970; Owensby et al., 1970; Rogler and Lorenz, 1957). Mason and Miltmore (1969) reported that fertilization with 60 lb. of N/acre was economically feasible on pinegrass in Southern British Columbia. In several cases, nitrogen fertilization of annual ranges or seeded pastures was

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[1/] Unpublished data

reported feasible (Lehman et al., 1968; Martin et al., 1964; Woolfolk et al., 1962).



FIGURE 1 General topography of the northern glaciated plains.

STUDY AREA DESCRIPTION

Topography, Geology and Soils

The study area is located on the Rohde-Langen Ranch, in Valley County, approximately 40 miles northwest of Glasgow, Montana. The entire area is located on the northern glaciated plains (Figure 1).

The area is dominated by sedimentary rocks of Mesozoic origin which have been altered by two glacial periods. The present surface configuration of undulating terrain was created primarily by the Keewatin ice sheet during the Wisconsin glaciation period (Giesseker, 1933). The second glaciation period did little to change the overall topography but did develop good north to south drainage ways. At present the glaciated plains of Montana typically slope west to east at an average drop of eight feet per mile with common twenty-five to fifty foot undulations and up to one hundred fifty feet of relief in drainages (Giesseker, 1933).

Sedimentary derived soils form moderately light-textured soils of the Phillips - Scobey - Theony Association.

The study plots are located on the Phillips soil series developed from clay loam glacial till, classified as Borillic Paleargid of the fine Montmerillionite family.[1/] Phillips soil series is characterized

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[1/] Soil classification of the United States.

by a light colored loam over brown prismatic clay subsoil. The calcium carbonate layer is usually about fourteen inches, but may range deeper.

The solum overlays extremely mixed, variable glacial drift (Southard, 1969). Soils are alkaline to moderately alkaline.

Vegetation

The study area is a mixed prairie type with porcupine grass and western wheatgrass present as dominant species. Coupland et al. (1960) described the northern plains as a Stipa-Agropyron association, with needle-and-thread and wheatgrass co-dominants in upland sites while porcupine grass and wheatgrass dominate vegetation in swales and more mesic sites. Green needlegrass (Stipa viridula Trin.) is a widely dispersed co-dominant in some areas. Understory vegetation is composed primarily of a dense mat of clubmoss with an interspersion of sun sedge (Carex heliophila Mack.) and blue grama. Other vegetation indigenous to the study area is Sandberg bluegrass (Poa secunda Presl.), thickspike wheatgrass, Montana wheatgrass (Agropyron albicans Scribn. & Smith), prairie junegrass, plains reedgrass (Calamogrostis montanensis Scribn.), needleleaf sedge (Carex eleocharis Bailey), death camas (Zygadenus spp.), silver scurfpea (Psoralea argophylla Pursh.), American vetch (Vicia americanna Muhl.), Hood's phlox (Phlox hoodii Rich.), and fringed sagewort. For a more complete list see Appendix A.

Climate

The prevailing climate is classified as a continental climate. Wide temperature extremes between seasons is the rule rather than the exception. Winter minimums drop below -50 degrees Fahrenheit and summer maximums often exceed 100 degrees Fahrenheit. The November to March period is characterized by nearly constant north winds and average temperatures below freezing (Table 1). Chinook winds are less common in the study area than in plains area closer to mountains (Giesseker, 1933).

Precipitation.

Rainfall is at best erratic with about two-thirds of the annual precipitation occurring in the April to August period (Table 2). Drought is very common and may persist three or more years. Summer rain showers are common and often come as violent cloudbursts occasionally accompanied by hail, especially in July and August (Giesseker, 1933).

The pattern of distribution of precipitation during the year on the Northern Great Plains is probably more important to the vegetative production than the total amount of precipitation received (Coupland, 1960).

The precipitation received in the September through March period is generally low and probably creates only enough stored soil moisture for shallow rooted grasses and ephemeral forbs (Table 2). This early

TABLE 1 Average monthly temperature for the September-August period on porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County. (Means from three stations: Hinsdale, Opheim 12 SSE, and Glasgow WBAP.) 1/

TEMPERATURE, DEGREES FAHRENHEIT

	1970			1971								
	S	O	N	D	J	F	M	A	M	J	J	A
ACTUAL	53.1	40.8	24.2	8.4	2.5	13.1	22.8	42.8	53.4	62.7	65.6	73.8
NORMAL	56.7	45.4	28.1	17.7	9.8	13.6	26.7	43.4	55.1	62.3	70.7	67.8
DEPARTURE FROM NORMAL	-4.6	-4.6	-3.9	-9.3	-7.2	- .5	-3.9	- .6	-1.7	+ .4	+5.1	+6.0

	1971			1972								
	S	O	N	D	J	F	M	A	M	J	J	A
ACTUAL	53.9	43.2	31.4	7.9	2.4	7.9	28.4	42.1	53.9	63.0	61.8	68.5
NORMAL	56.7	45.4	28.1	17.7	9.8	13.6	26.7	43.4	55.1	62.3	70.7	67.8
DEPARTURE FROM NORMAL	-2.8	-3.2	+3.3	-9.8	-7.4	-5.7	+1.7	-1.3	-1.2	+ .7	-8.9	+ .7

	1972			1973								
	S	O	N	D	J	F	M	A	M	J	J	A
ACTUAL	51.3	39.6	30.8	5.8	18.1	23.6	39.0	41.6	56.1	65.6	69.8	72.9
NORMAL	56.7	45.4	28.1	1.7	9.8	13.6	26.7	43.4	55.1	62.3	70.7	67.8
DEPARTURE FROM NORMAL	-5.4	-5.8	+2.7	+4.1	+8.3	+10.0	+12.3	-1.8	+1.1	+3.3	-0.9	+5.1

1/ National Oceanic and Atmospheric Administration.

TABLE 2 Average monthly precipitation for the September-August period on porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County. (Means from three stations: Hinsdale, Opheim 12 SSE, and Glasgow WBAP.) 1/

PRECIPITATION IN INCHES

	1970				1971								
	S	O	N	D	J	F	M	A	M	J	J	A	TOTAL
ACTUAL	1.48	.45	.53	.19	.74	.08	.13	.35	1.11	2.07	.76	.82	8.71
NORMAL	.94	.84	.47	.45	.48	.41	.56	1.01	1.49	2.98	1.33	1.49	12.45
DEPARTURE FROM NORMAL	+.54	-.39	+.06	-.26	+.28	-.33	-.43	-.66	-.38	-.92	-.57	-.65	-3.74

	1971				1972								
	S	O	N	D	J	F	M	A	M	J	J	A	TOTAL
ACTUAL	.97	.69	.01	.28	.50	.61	.58	1.03	2.98	4.44	2.31	.95	15.35
NORMAL	.94	.84	.47	.45	.48	.41	.56	1.01	1.49	2.98	1.33	1.49	12.45
DEPARTURE FROM NORMAL	+.04	-.15	-.46	-.17	+.02	+.20	+.02	+.02	+1.49	+1.42	+.98	+.73	+2.90

	1972				1973								
	S	O	N	D	J	F	M	A	M	J	J	A	TOTAL
ACTUAL	.95	.23	.02	.53	.02	.13	.26	1.58	.78	3.05	.89	1.04	9.48
NORMAL	.94	.84	.47	.45	.48	.41	.56	1.01	1.49	2.98	1.33	1.49	12.45
DEPARTURE FROM NORMAL	+.01	-.61	-.45	+.08	-.46	-.28	-.30	+.57	-.71	+.07	-.44	-.45	-2.97

1/ National Oceanic and Atmospheric Administration.

spring soil moisture probably produces little advantage for the deeper rooted and warm season perennial grasses. Compounding the effect of low September through March soil moisture levels are the warm early spring temperatures (Table 1). Both of these factors draw moisture from the soil surface. This creates a severe stress on plants even though the winter and early spring periods are not generally regarded as drought periods.

The April through August period accounts for most of the yearly precipitation. Using the 50 year normal from the National Oceanic and Atmospheric Administration, the average precipitation received in this period is 8.3 inches or 67 percent of the total annual precipitation. The rainfall received in this period is far more available for plant use than precipitation received in other periods because the vegetation forms a dense ground cover that minimizes runoff except during torrential rains. These plants are in an active growing state and use most available soil moisture before substantial evaporation takes place.

During the study period, October 1970 through August 1973, the precipitation was abnormally distributed with no year approaching normal (Figure 2). The years 1970 - 1971 and 1972 - 1973 had very low total precipitation, while 1971 - 1972 had abnormally high precipitation.

Even though two of the three years had abnormally low precipitation, all years showed the same relative pattern of precipitation as

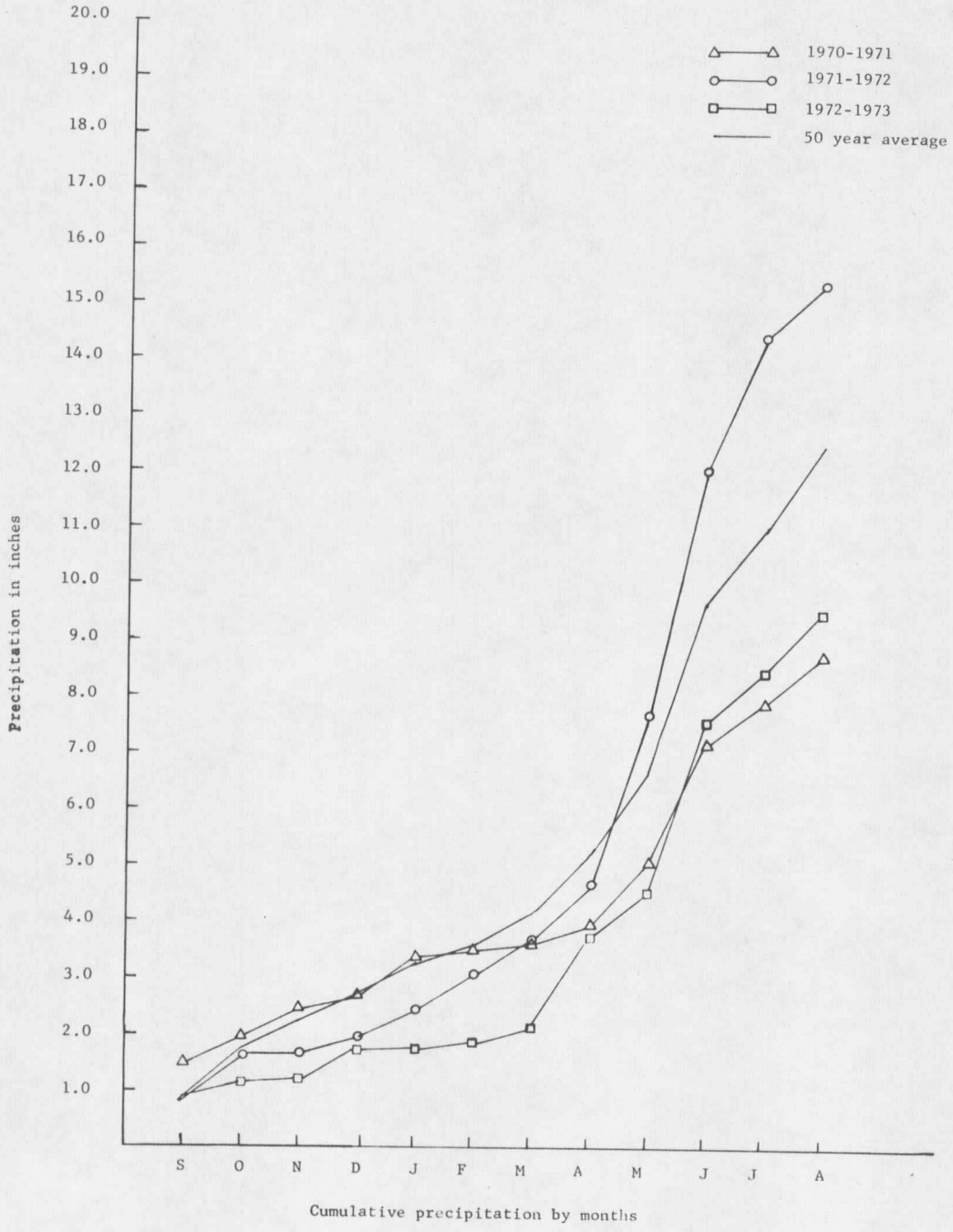


FIGURE 2 Cumulative precipitation for the September-August period, 1970 - 1973.

the 50 year normal with the greater percent of the yearly moisture coming during the April through August period. The years 1970 - 1971 had 58.7 percent and 1972 - 1973 had 77.4 percent of the total yearly precipitation coming during the spring and summer period. This amounts to 61 percent and 88 percent of the normal rainfall of the period, respectively.

The interaction between precipitation and temperature is shown in Figure 3. Physiologic drought periods are assumed to occur when one-half mean monthly temperature in ^{o}C. exceeds monthly precipitation in millimeters (Emberger et al., 1962). This figure shows a characteristic drought pattern occurring late in the summer period. In years with below average rainfall the drought period is evident earlier in the season and an additional drought period appears in the early spring period.

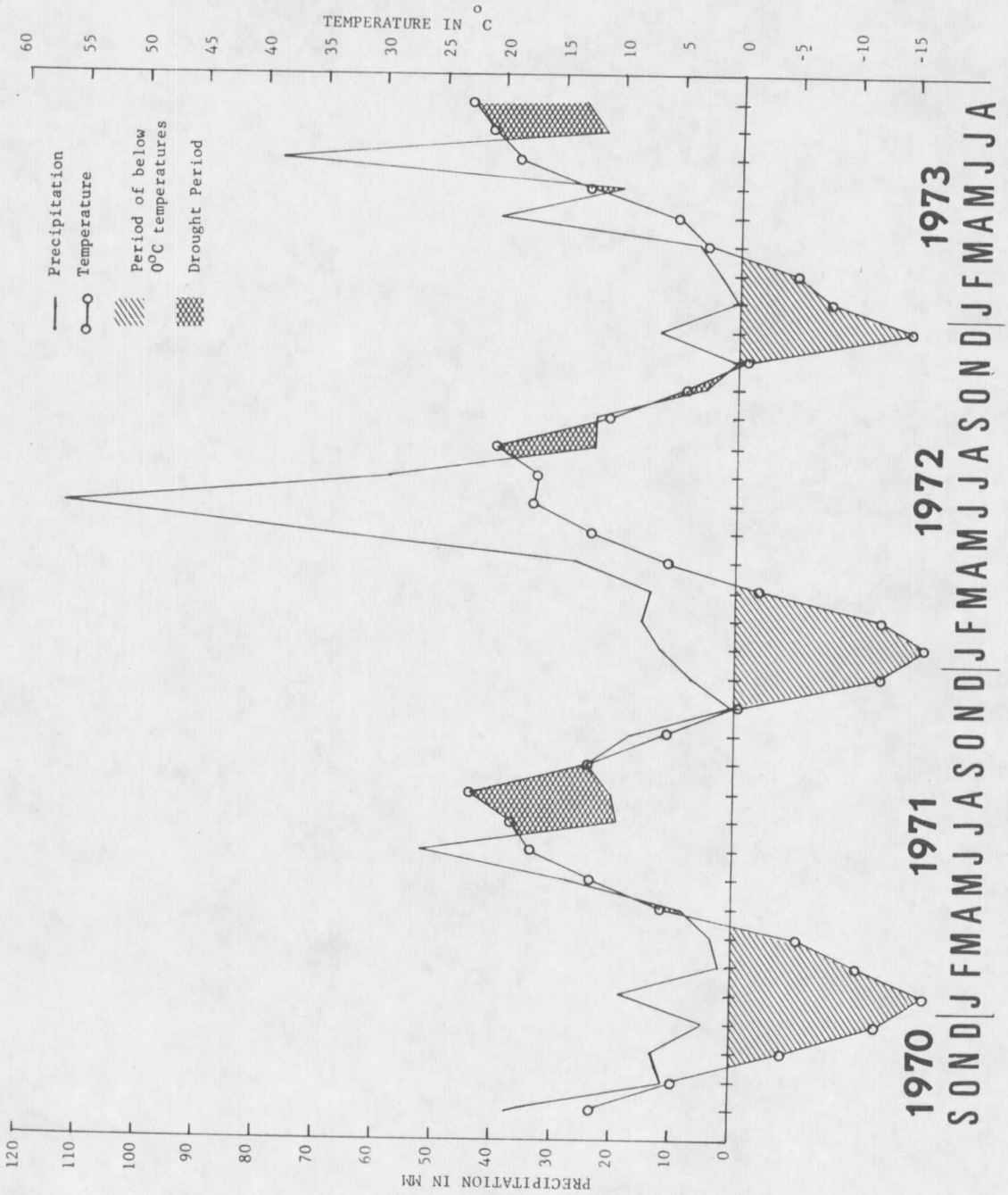


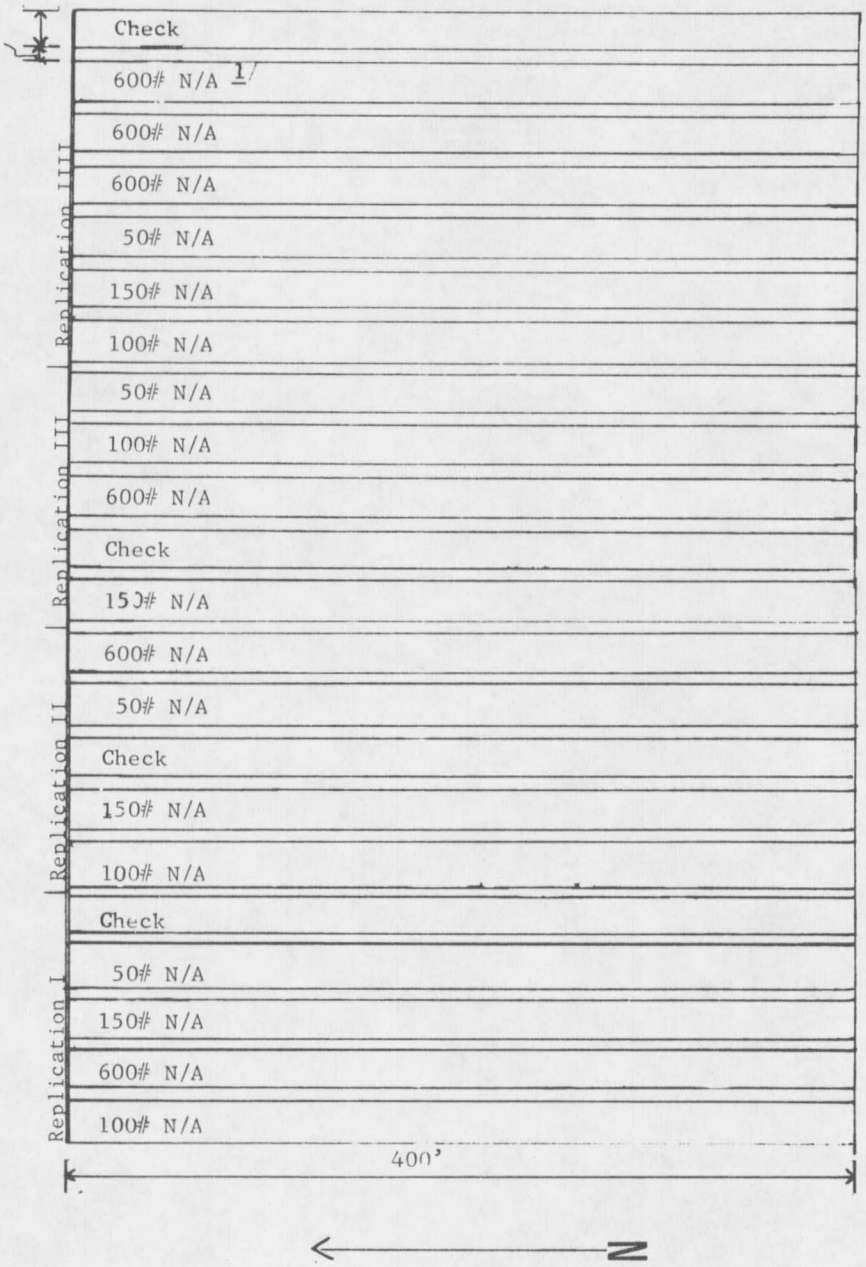
FIGURE 3 Precipitation and temperature interaction on the porcupine grass community on the Rohde-Langen Ranch.

METHODS AND PROCEDURES

The porcupine grass fertilizer - grazing study was established on the Rohde-Langen Ranch in an approximately 12,000 acre pasture in October of 1970. The site is on a rolling glacial till upland positioned on a gentle to moderate east southeast exposure slope.

The individual fertilizer plots were 12 feet wide and 400 feet long. The fertilizer strips were oriented north northeast and south southwest, perpendicular to any expected moisture gradient. The fertilizer treatments were arranged in a randomized complete block design, with four replicates. A 150 feet x 360 feet sheep-tight exclosure was placed near the center of the treatment plots (Figure 4). The treatment strips extended beyond the exclosure fence on two sides. Such a positioning arrangement allowed the exclosure to be extended in the spring of each successive year, creating a split block design with varying lengths of deferment (Figure 4).

Ammonium nitrate was applied at rates of 0, 50, 100, 150, and 200 pounds of actual nitrogen per acre. Application was implemented through the use of a 12 foot pull type gravity flow fertilizer spreader. The spreader was calibrated to deliver 50 lb. of N/acre. Therefore the variable rates were made by one or more passes on each strip. The 200 lb. of N/acre rate was applied by calibrating the spreader for delivery of 200 lb. of N/acre but the fertilizer was applied in three passes, on one foot wide bands spaced three feet apart. A five foot



1/ 600# N/A applied in one foot bands on three foot centers.

FIGURE 4 Field map of porcupine grass (Stipa spartea, variety curtiseta) study on Rohde-Langen Ranch, North Valley County.

buffer strip was left between each 12 foot wide treatment strip to prevent fringe overlap.

The sampling for vegetative production was done on or around August 1 each year for three successive years. Production samples were taken using 5.4 square foot circular plots randomly placed. All current year vegetative matter was clipped to ground level. The clipping procedure entailed the separation of vegetation into seven categories (group separates) wheatgrasses, porcupine grass, green needlegrass, miscellaneous grasses and grass-like plants, miscellaneous forbs, fringed sagewort, and shrubs.

Ten clip samples per plot were taken in 1970. The following two seasons the sample size was reduced to five because of space limitation and the confounding effect of previously clipped areas.

Samples were dried at 110°C. for a 24 hour period, then stored with a desiccant until weighed. All group separate samples were weighed to the nearest one-tenth gram on a Metler balance. The sample weights were punched on computer cards to be analyzed at the Computer Center at Montana State University.

Coefficients of variation were calculated on 1972 yield data to determine which group separates showed the most variation. Those group separates which were not present in at least one-half of the samples, or which showed very high coefficients of variation were eliminated from further analysis.

Bartlett's test for homogeneity of variance was performed on wheatgrass, porcupine grass and miscellaneous grass. This was used to indicate validity of parametric statistical comparisons. Data analyzed in an analysis of variance must be homogeneous to satisfy the criterion that vegetation is randomly distributed.

The 1971 herbage yield data were analyzed as a randomized complete block design using standard analysis of variance and an F-ratio to test significance. The 1972 and 1973 yield data were analyzed using an analysis for split-block design.

Ordination procedures (Swan et al., 1969) were done on total production values of 15 stands. This included all possible combinations of five fertilizer and three grazing treatments in the year 1973.

Utilization estimates on porcupine grass were taken in October 1971 and April 1972. Utilization estimates were taken in 1971 by measuring 100 grazed and 100 non-grazed porcupine grass plants to train the technician's eye. Thereafter the estimates were made by ocular estimation of utilization. Utilization in 1972 was calculated by measuring 100 grazed and 100 ungrazed plants per treatment. A t-test was used for comparison of means from utilization measurements.

Soil samples were obtained in April 1972. Three, five foot deep samples per plot were taken with a power auger soil sampler. These samples were separated into one foot increments which were individually mixed. A representative sample from each increment was then placed in

a small plastic bag. The 200 lb. of N/acre plot was more intensively sampled with a hydraulic sampler. A one inch core sample was taken to the depth of the calcium carbonate layer. Nine cores were taken, beginning at the center of the one foot 600 lb. of N/acre band and progressively sampling across the non-fertilized area to the center of an adjacent fertilized band. The core samples were divided into four inch increments and each increment was placed in a separate soil can. The samples were held at a low temperature while in transport from the field to laboratory facilities. The samples were weighed on a Metler balance, dried in ovens at 60°C., then weighed again. Percent moisture content by weight was calculated. Montana State Soils Testing Laboratory analyzed samples for soil nitrates.

Percent basal area cover determinations were made in the summer of 1973. Ocular estimates were performed employing 2x5 decimeter frames as a reference tool. Ten estimates were made per plot. These estimates were used to determine relative changes in vegetative composition caused by fertilization and grazing treatments.

RESULTS AND DISCUSSION

Assumptions

The grasslands of the northern glaciated plains seem to show a great stability of herbage yield, demonstrating no extreme variation in yield response among very wet and very dry year (Coupland, 1961). Therefore it is assumed the variability of herbage yields in study is more likely to be due to treatment effects than due to any moisture gradient. It will be assumed that there is not a moisture gradient within the study area, even though there is a slight slope perpendicular to the treatment strips.

Fertilization studies on the Northern Great Plains have established that cool season grasses, particularly rhizomatous cool season grasses, demonstrate the largest responses to nitrogen fertilization (Goetz, 1969; Rauzi et al., 1968; Taylor, 1967). Western wheatgrass, the primary cool season rhizomatous grass on the study area, and porcupine grass, the most abundant cool season bunchgrass on the area, were chosen as the primary response indicator species. Most results presented in the discussion will be in reference to these two species. Other group separates sampled were relatively constant in proportion to total yield. The variation present seemed to be related more to the influence of the major species than to treatment response.

Smith (1967) established that nearly all grass reproduction on

clubmoss range was the result of vegetative reproduction (rhizomes) rather than sexual reproduction (seeds). Therefore, it is assumed, because dense clubmoss is the primary understory species in the porcupine grass community, that vegetation responses to fertilization would be the results of increases in plant size and/or vegetation reproduction of grasses, rather than the establishment of new plants from seeds.

Vegetational Response in 1971

Production.

Herbage yields obtained in the summer of 1971, the first growing season following fertilization, are shown in Table 3. The vegetational yield response to fertilization was more apparent in component group yield means than in total yield means.

Wheatgrasses. Research done on the Northern Great Plains revealed that rhizomatous wheatgrasses often demonstrate greater yield responses to nitrogen application than other vegetation components (Choriki et al., 1969; Goetz, 1969; Rogler and Lorenz, 1957; Taylor, 1967). Wheatgrasses in the porcupine grass community displayed a similar response, producing the greatest proportionate response of any other group. A two-fold response appears to be associated with increases in nitrogen application rate. Nitrogen may have increased the water use efficiency of wheatgrass. The production increases were substantial even though the study area was under drought conditions (Table 1).

TABLE 3 Vegetational response to fertilization of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1971.

VEGETATION SEPARATES	FERTILIZER TREATMENTS (LBS N/ACRE) 0	50	100	150	200[1]	MEAN
	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a
WHEATGRASSES	58	107	150	167	166	130
PORCUPINE GRASS	1047	1055	1136	1146	1257	1128
GREEN NEEDLEGRASS	3	22	T	4	5	7
MISCELLANEOUS GRASSES	259	360	298	249	305	294
TOTAL PERENNIAL GRASSES	1367	1544	1584	1566	1733	1559
MISCELLANEOUS FORBS	22	25	18	21	55	28
FRINGED SAGEWORT	7	27	10	13	9	13
TOTAL	1396	1596	1612	1600	1797	1600

[1] Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

Porcupine Grass. Porcupine grass remained the cool season dominant grass following fertilization, producing far greater yields than any other species, regardless of fertilizer treatment.

There was no apparent trend in porcupine grass yields with increasing nitrogen rates. This phenomenon might be a preliminary indication that, on this site, the production of porcupine grass is not seriously limited by natural soil fertility.

Miscellaneous Grasses. Miscellaneous grass yields were relatively consistent across all fertilizer levels, showing small but erratic variations in yield means. The miscellaneous grass production was greatest for the 50 pounds of nitrogen per acre fertilizer treatment.

Minor Components. Green needlegrass, miscellaneous forbs and fringed sagewort were minor yield components of the total yield. The herbage production of all three categories was erratic with increases of applied nitrogen. The variation of yield means was probably partially due to inadequate sampling. The minor components were present in very small quantities and quite often displayed clustered distribution.

Green needlegrass and fringed sagewort displayed yield increases at the 50 pounds of nitrogen per acre level.

Total Perennial Grasses and Total Production. The summation of erratic herbage yields of some vegetational components caused both total perennial grass means and total yield means to show a uniform

trend across fertilizer treatments.

Statistical Analysis.

Several types of statistical procedures were used to analyze the data. These statistical methods were coefficient of variation, Bartlett's test for homogeneity of variance, and analysis of variance.

Coefficient of Variation. Coefficients of variation (Appendix B), from 1972 data, indicated that high variation was prevalent in most vegetation yield data. The group separates fringed sagewort, green needlegrass, and miscellaneous forbs consistently exhibited very high coefficients of variance. Therefore, they were not considered in any further statistical analysis.

Bartlett's Test for Homogeneity of Variance. Replicate treatment data were subjected to Bartlett's test for homogeneity of variance to establish the applicability of the analysis of variance. This test revealed that the two hundred pounds of nitrogen per acre treatment on wheatgrass had heterogeneous variance (Table 4). This heterogeneity among data is one observation from a total of fifteen ovservations. At the five percent level of significance one observation in twenty is expected, by chance, to display lack of homogeneity. Because of this small deviation from the expected value, the assumption was made that the segment of vegetation being considered was relatively homogeneous. Therefore, the standard analysis of variance was applicable. However, this assumption casts some doubt on the results of an analysis of

TABLE 4 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1971.

	DEFERRED 1971		
Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	2.487	1.62	0.26
50	4.320	3.82	1.74
100	2.180	1.20	1.20
150	0.490	0.94	1.97
200[1/]	12.001**	1.25	1.92

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

** Different at the 0.01 level of probability.

variance. Tests of other groups were homogeneous.

Analysis of Variance. The results of the analyses of variance are presented in Tables 5 and 6. The analyses of all four categories, wheatgrass, porcupine grass, miscellaneous grasses and total perennial grasses, revealed a significant block effect. This effect was probably due to inherent variation in soil fertility.

Wheatgrasses: The yield means of fertilizer treatments on wheatgrasses were significantly different, reflecting response to the main effect of fertilizer treatment. The variation among means disclosed by the analysis of variance was probably from the increase in plant size and number, especially on the high nitrogen application rates.

Porcupine Grass: Porcupine grass showed no significant yield difference with the application of nitrogen fertilizer.

Total Perennial Grasses: The components of total perennial grasses were relatively homogeneous except for green needlegrass. An analysis of variance was assumed to be valid for total perennial grasses because green needlegrass comprised a very minute part of the total yield, injecting a relatively small amount of error. Total perennial grass yield means were significantly different across fertilizer rates. This difference must be attributed to the variation occurring within the wheatgrass and miscellaneous grass yields over-riding the low variability of porcupine grass.

Total Vegetational Yield: The total herbage yield contained the

TABLE 5 Complete block analysis of variance on vegetational components, wheatgrasses and porcupine grass, of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1971.

	WHEATGRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	2,954,670	199		
Block	466,952	3	155,651	14.00**
Fert.	353,095	4	88,274	7.94**
Error	2,134,624	192	11,118	

** Different at the 0.01 level of probability.

	PORCUPINE GRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	47,824,000	199		
Block	5,707,800	3	1,902,600	8.91**
Fert.	1,153,940	4	288,484	1.35
Error	40,962,260	192	213,345	

** Different at the 0.01 level of probability.

TABLE 6 Complete block analysis of variance on vegetational components, miscellaneous grasses and total perennial grasses, or porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1971.

	MISCELLANEOUS GRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	6,745,030	199		
Block	634,388	3	211,463	7.00**
Fert.	308,369	4	77,092	2.55 *
Error	5,802,273	192	30,220	

	TOTAL PERENNIAL GRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	37,725,800	199		
Block	3,163,810	3	1,054,600	6.36**
Fert.	2,716,080	4	679,020	4.09 *
Error	31,845,910	192	165,864	

* Different at the 0.05 level of probability.

** Different at the 0.01 level of probability.

components green needlegrass, miscellaneous forbs and fringed sagewort. All showed extreme variation in yields. The variation of each component summed into the total yield compounded the variation of that total. Because of the high variation included from these components, an analysis of variance was not performed.

Utilization of Porcupine Grass.

Utilization estimates determined from stubble height differences between grazed and ungrazed porcupine grass plants were taken in October of 1971. The results of these estimates are presented in Table 7.

Utilization of porcupine grass was significantly greater for each increment increase in fertilizer rate, with the exception of the increase from 100 pounds of nitrogen per acre to 150 pounds of nitrogen per acre. The zero pounds of nitrogen per acre fertilizer treatment plot may have received a disproportionate amount of use (46.3%) because of overlap of grazing use by cattle concentrated on other treatments. There was no way to evaluate this overlap of grazing use.

Apparently the palatability of porcupine grass was directly affected by the level of application of nitrogen (Figure 5). The palatability changes may have been caused by increased crude protein (Johnston et al., 1967), decreased lignin (Duncan et al., 1970), or nitrate accumulation (Lorenz and Rogler, 1973), or a combination of all these factors. The exact effect nitrogen fertilization has on palatability of vegetation is not known.

TABLE 7 Utilization estimates of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in October, 1971.

Lbs. N/A	STUBBLE HEIGHT IN CMS. GRAZED	UNGRAZED	PER CENT UTILIZATION
0	13.4	25.0 a 2/	46.3 3/
50	5.8	26.2 b	78.0
100	2.7	23.2 c	88.7
150	2.1	24.4 cd	91.2
200 1/	1.5	24.7 d	94.0

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 Lbs. N/A on the strips which is equivalent to 200 Lbs. N/A on an over-all application.

2/ Means without letters in common are significantly different (P = 0.05).

3/ t-test done on differences between means of stubble heights.

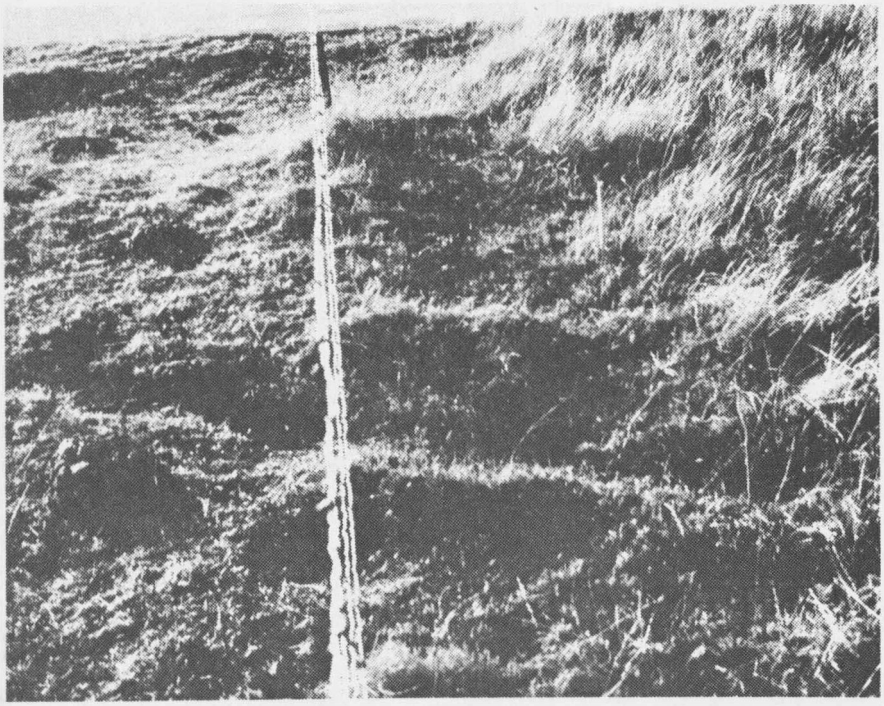


FIGURE 5 Forage utilization by livestock in 1971.

Vegetational Responses in 1972

Production.

The second season vegatational response to fertilization and the results of grazing and deferment treatments are shown in Tables 8 and 9. In the second season after fertilization, wheatgrasses and porcupine grass remained the dominant species.

Wheatgrasses. The wheatgrass yields from the continuous deferment (deferred 1971, 1972) treatment showed a steady trend toward increased yield with increasing fertilizer levels. There was nearly a six-fold herbage yield increase across fertilizer rates. The wheatgrass response from the grazing treatment, grazed 1971, deferred 1972, also exhibited a uniform trend toward increased production with increasing increments of nitrogen applied. Above normal precipitation in the 1972 growing season (Table 2) may be one factor influencing high wheatgrass yields. The nine degree below normal July temperatures (Table 1) also may have had a hand in creating favorable conditions for wheatgrass growth, by extending the active growth period. The interaction of high moisture and relatively cool temperatures with readily available nitrogen apparently created very favorable conditions for increased herbage production of wheatgrasses.

Porcupine Grass. The herbage production of porcupine grass for any given nitrogen level from the deferred 1971, 1972 grazing treatment was consistently greater than yields from the grazed 1971, deferred 1972

TABLE 8 Vegetation response to fertilization (applied Fall, 1970) of porcupine grass communities, deferred 1971 and 1972 on Rohde-Langen Ranch.[1/]

	FERTILIZER TREATMENTS (LBS A/ACRE)				
VEGETATION SEPARATES	0	50	100	150	600
	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a
WHEATGRASSES	110	242	310	303	624
PORCUPINE GRASS	517	648	896	1071	1055
GREEN NEEDLEGRASS	6	65	0	3	37
MISCELLANEOUS GRASSES	277	521	574	498	599
TOTAL PERENNIAL GRASSES	910	1476	1780	1875	2315
MISCELLANEOUS FORBS	48	78	64	49	68
FRINGED SAGEWORT	40	18	6	27	79
TOTAL	998	1572	1850	1951	2462

[1/] Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

TABLE 9 Vegetation response to fertilization (applied Fall, 1970) of porcupine grass communities, grazed 1971 - deferred 1972, on Rohde-Langen Ranch.[1/]

	FERTILIZER TREATMENTS (LBS N/ACRE)				
VEGETATION SEPARATES	0	50	100	150	600
	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a
WHEATGRASSES	233	228	298	404	897
PORCUPINE GRASS	428	397	485	541	370
GREEN NEEDLEGRASS	9	4	6	11	3
MISCELLANEOUS GRASSES	423	259	315	384	505
TOTAL PERENNIAL GRASSES	1093	888	1104	1340	1775
MISCELLANEOUS FORBS	88	75	69	102	136
FRINGED SAGEWORT	22	10	8	11	23
TOTAL	1203	973	1181	1453	1934

[1/] Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

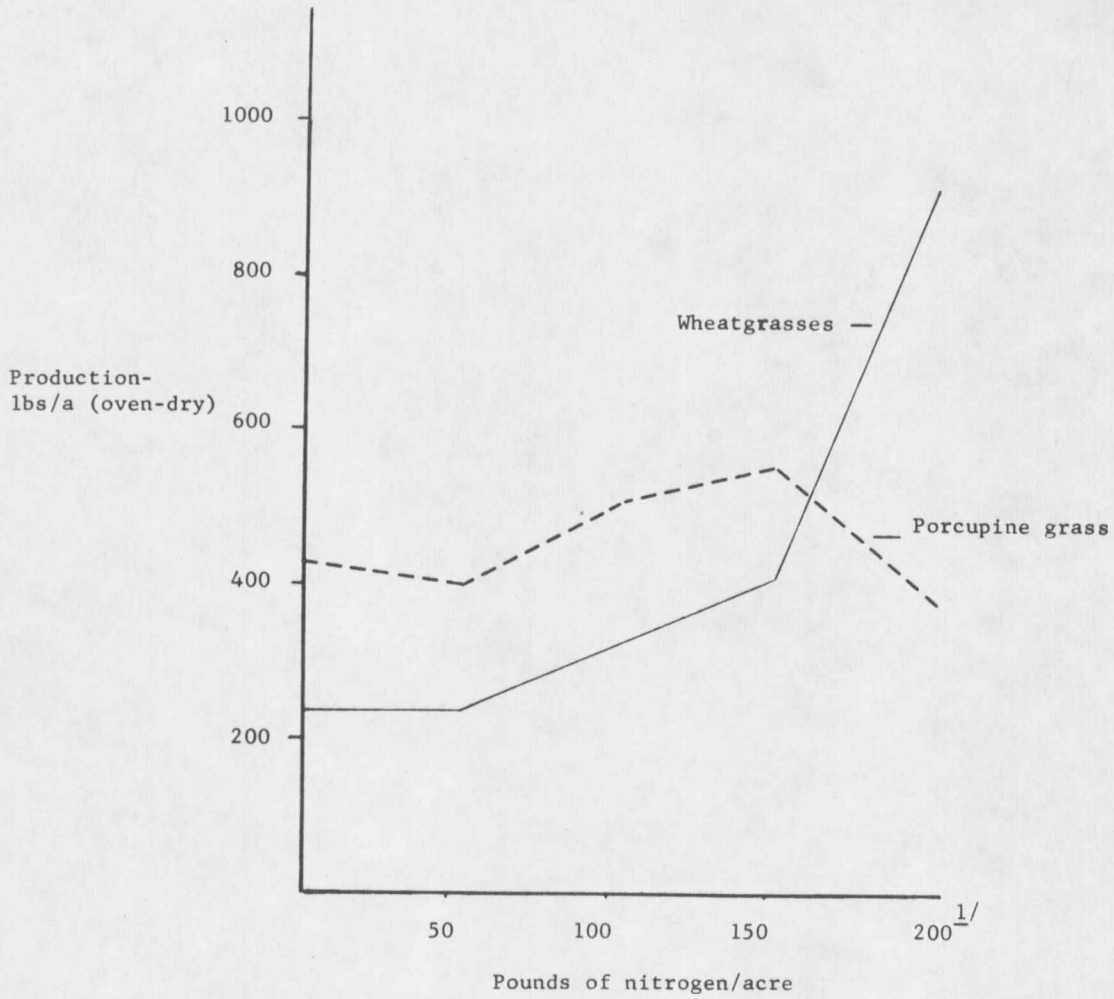
grazing treatment. The difference in yield was apparently directly related with the grazing effect from the previous year (comparing Tables 8 and 9).

Porcupine grass remained as the major contributor to the total yield for the area, on all fertilizer treatments excepting the 200 pounds of nitrogen per acre treatment from the grazed 1971, deferred 1972 grazing treatment. On that treatment, the herbage had been subject to extreme utilization the previous season.

Comparative Responses of Vegetation.

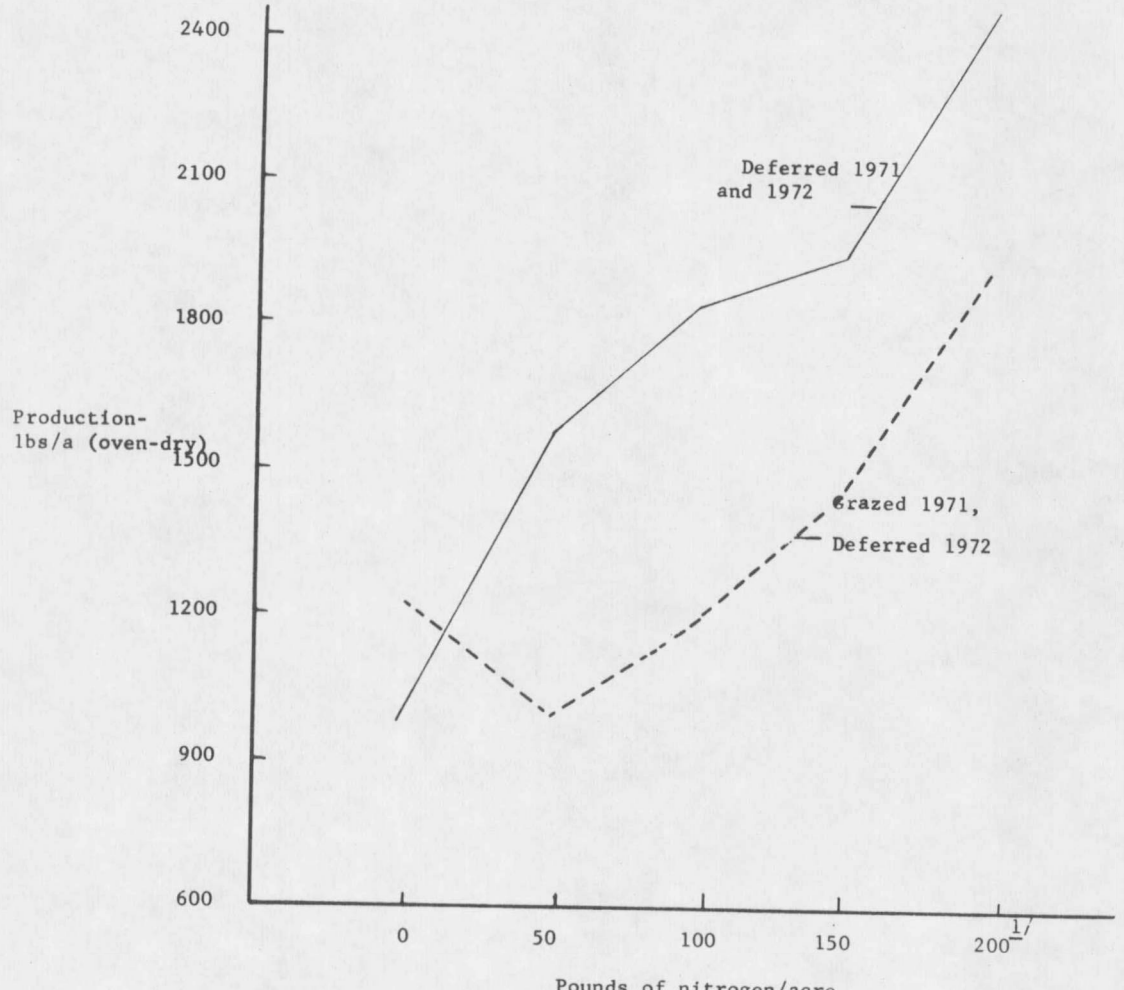
The comparative responses of wheatgrasses and porcupine grass to the grazing-deferrment treatment are shown in Figure 6. The increase of wheatgrass yields and the decrease of porcupine grass yields gave the appearance of a replacement of porcupine grass by wheatgrasses at fertilizer levels greater than 150 pounds of nitrogen per acre. This change could partially be due to a competitive advantage of wheatgrasses in competition for nutrients and water. It is hypothesized that the two grass species responded to two semi-independent stimuli. The wheatgrasses probably responded to above normal precipitation in 1972. Porcupine grass was seemingly responding to the detrimental effect of over-utilization which created a physiological stress on the plant.

The graphs of total vegetation response to fertilization, relative to the two grazing treatments, revealed the two lines may be similar (Figure 7). The major portion of the difference in the total



1/ Nitrogen at 600# level applied in a one foot band on three foot centers giving an overall rate of 200# N/A.

FIGURE 6 Responses of two grass species to fertilization, grazing and deferment, area fertilized fall, 1970; grazed summer 1971, deferred during grazing season 1972 (Rohde-Langen Ranch).



1/ Nitrogen at 600# level applied in a one foot band on three foot centers giving an overall rate of 200# N/A.

FIGURE 7 Total vegetational response to fertilization with deferment, grazing and deferment in 1972, fertilizer applied fall, 1970 (Rohde-Langen Ranch).

yield between the two grazing treatments was the reduction in porcupine grass yield in response to grazing the previous year.

Statistical Analysis.

Bartlett's Test for Homogeneity. Bartlett's test for homogeneity of variance (Tables 10 and 11) showed one significant group out of ten for wheatgrass. One significant mean in ten is nearing the outer limits of confidence for applicability of an analysis of variance. Since wheatgrasses were a dominant species, the analysis of variance was performed, although the assumption of homogeneity might be invalid. Thus the results of the analysis of variance on wheatgrasses will be subject to error.

Miscellaneous grasses showed two significant groups. Since miscellaneous grasses were not major influence species, the data was not subjected to an analysis of variance.

Porcupine grass showed no non-homogeneous observations.

Analysis of Variance. A split-block analysis of variance was employed to determine the treatment effect and to partition error.

Wheatgrasses: The analysis performed on wheatgrasses revealed a significant block effect (Table 12). This block effect could have been related to vegetational differences, environmental gradients and substrate differences.

The main effect of fertilizer levels significantly affected wheatgrass yields. The grazing treatments produced no differences in yield

TABLE 10 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety curtiseta) communities deferred 1971, 1972 on the Rohde-Langen Ranch, North Valley County in 1972.

Lbs. N/A	DEFERRED 1971, 1972		
	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	7.959*	15.913**	3.852
50	1.768	0.242	2.220
100	1.205	1.144	2.847
150	5.489	3.329	2.650
200 1/	6.929	4.493	4.696

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

* Different at the 0.05 level of probability.

** Different at the 0.01 level of probability.

TABLE 11 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety ourtiseta) communities grazed 1971, deferred 1972, on the Rohde-Langen Ranch, North Valley County in 1972.

	GRAZED 1971, DEFERRED 1972		
Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	5.916	4.850	1.511
50	1.660	1.425	1.482
100	5.390	7.037	3.278
150	0.196	9.214*	3.372
200 1/	0.392	0.998	0.599

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

* Different at the 0.05 level of probability.

TABLE 12 Split block analysis of variance on vegetational components, wheatgrasses, of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1972.

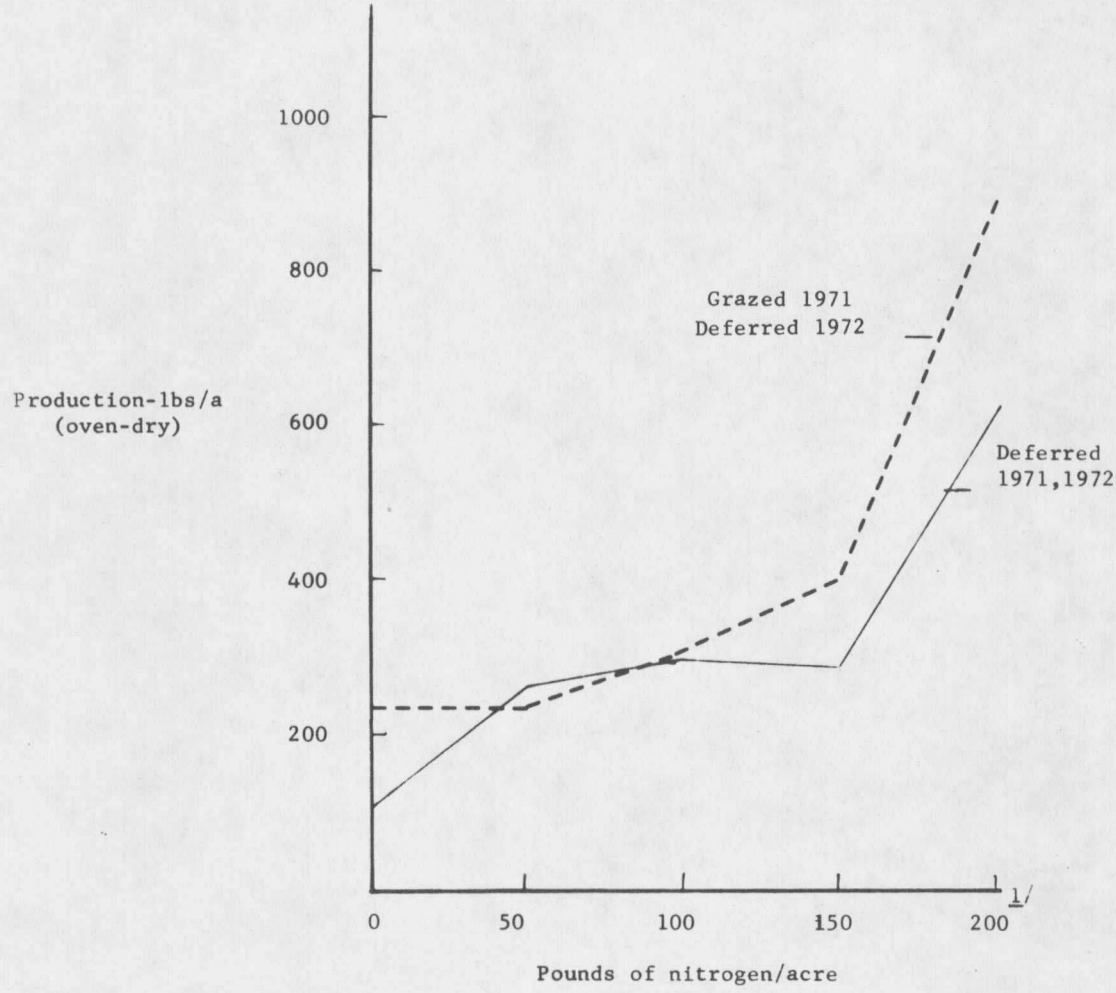
	WHEATGRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total (F)	10166.0	39		
Blocks	1681.7	3	560.6	11.4*
Fert.	4296.3	4	1074.1	21.8*
Error A	3013.5	12		
Grazing	149.7	1	149.7	3.04
Error B	533.5	3		
G*Fert.	147.2	9	16.4	.33
Error C	344.1	7	49.2	

* Different at the 0.05 level of probability.

means. In addition, the grazing fertilizer interaction was non-significant. The small differences between the line slopes of the graph of yields from the two grazing treatments versus fertilizer increment, seemed to support the conclusion that there was no significant interaction effect (Figure 8).

Porcupine Grass: The block effect for porcupine grasses was non-significant. A standard F-test on porcupine grass yields across fertilizer treatments revealed no difference (Table 13). The lack of significance difference may have been created by extreme variation injected by a wide split in yield mean values, with two high means and three low means. To reduce the influence of this variation, a single degree of freedom F-test was performed comparing only the high mean and low mean. The test reduced the variation sufficiently to disclose a significant difference between the 0 and 150 pounds of nitrogen per acre treatments.

The main effect of grazing treatment caused significantly different porcupine grass yields. The low yields from the grazed 1971, deferred 1972 treatment probably were not an indication of composition change, but rather was a probable indication of plant vigor reduction resulting from extreme utilization. A graphic expression of this vigor reduction is presented in a comparison of grazed 1971, deferred 1972, and deferred 1971, 1972 grazing treatments (Figure 9).



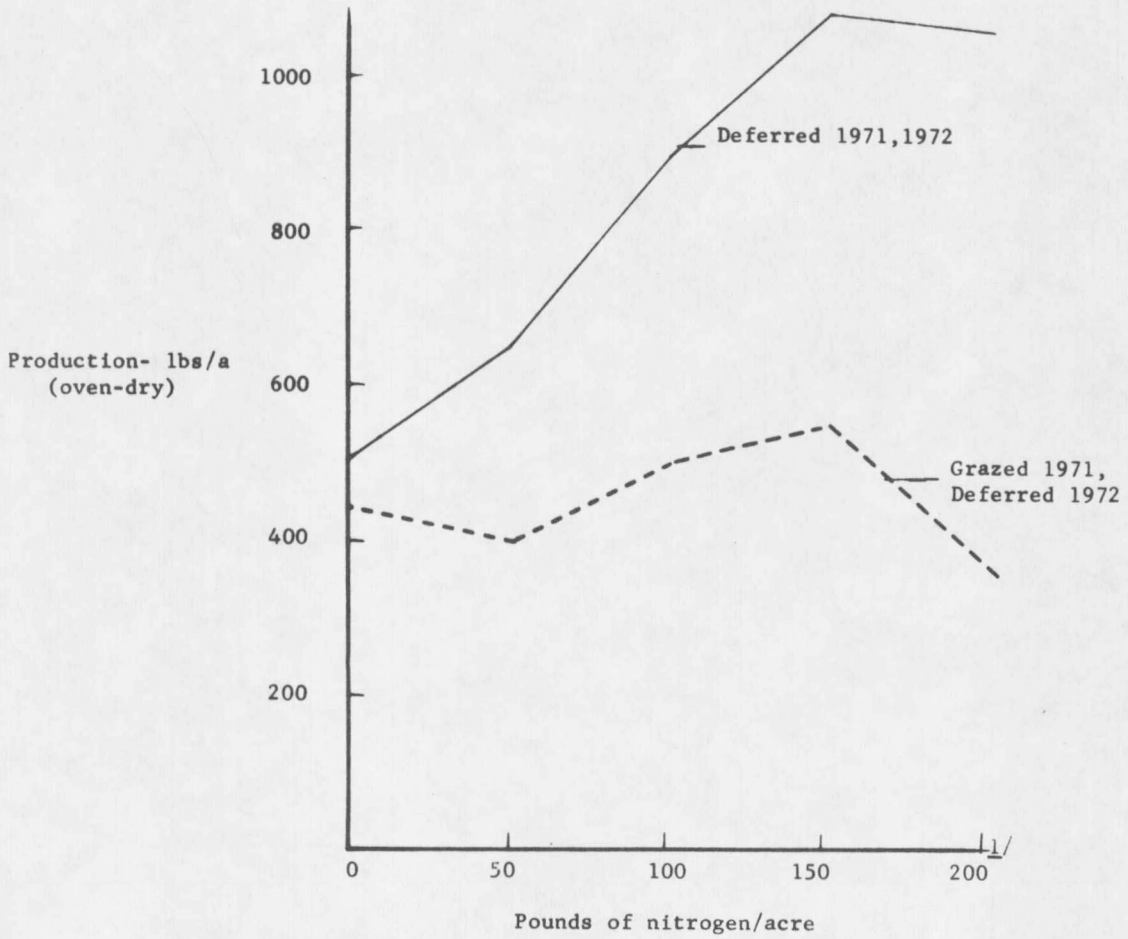
1/ Nitrogen at 600# level applied in one foot bands on three foot centers giving an overall rate of 200# N/A.

FIGURE 8 Wheatgrass changes in a fertilized porcupine grass community in response to deferment and grazing in 1972. Fertilizers applied fall, 1970 (Rohde-Lsngen Ranch).

TABLE 13 Split block analysis of variance on vegetational components, porcupine grass, of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1972.

	PORCUPINE GRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	12928.6	39		
Blocks	731.7	3	243.9	1.57
Fert.	1751.3	4	437.8	2.82
Error A	1663.0	12		
Grazing	5146.1	1	5146.1	33.1**
Error B	1044.8	3		
G*Fert.	1503.6	9	167.1	1.08
Error C	1088.1	7	155.4	

** Different at the 0.01 level of probability.



1/ Nitrogen at 600# level applied in one foot bands on three foot centers giving an overall rate of 200# N/A.

FIGURE 9 Porcupine grass response to fertilization, deferment and grazing in 1972. Fertilizers applied fall, 1970 (Rohde-Langen Ranch).

Comparisons Between Years.

The pattern of vegetational response of the deferred 1971, 1972 grazing treatment was nearly the same as the response of the deferred one-year treatment in 1971 (Figure 10). The interaction of environmental factors with nitrogen in 1972 was likely the primary cause of the increased production in wheatgrasses and miscellaneous grasses on high nitrogen application rates. The porcupine grass and forbs demonstrated little response to increased moisture supply or addition of fertilizer.

The total yield of deferred 1971 versus grazed 1971, deferred 1972 is graphically presented in Figure 11. In all but one case, the 200 pounds of nitrogen per acre treatment, the total yield in 1972 was below the 1971 total yield. Part of this difference might be caused by lower amounts of available residual nitrogen in the second season. Another cause for lower yields in 1972 was probably the depression of porcupine grass yields by high utilization in the previous season. Yields in 1971 were not seriously depressed by previous use (1970) because non-fertilized porcupine grass is relatively unpalatable, and thus normally receives minimal utilization.

The production of the 200 pounds of nitrogen per acre fertilizer treatment in 1972 probably exceeded the 1971 yield because of increased wheatgrass yields. These increases in yield may have been caused by a precipitation nitrogen interaction. A small part of the difference may

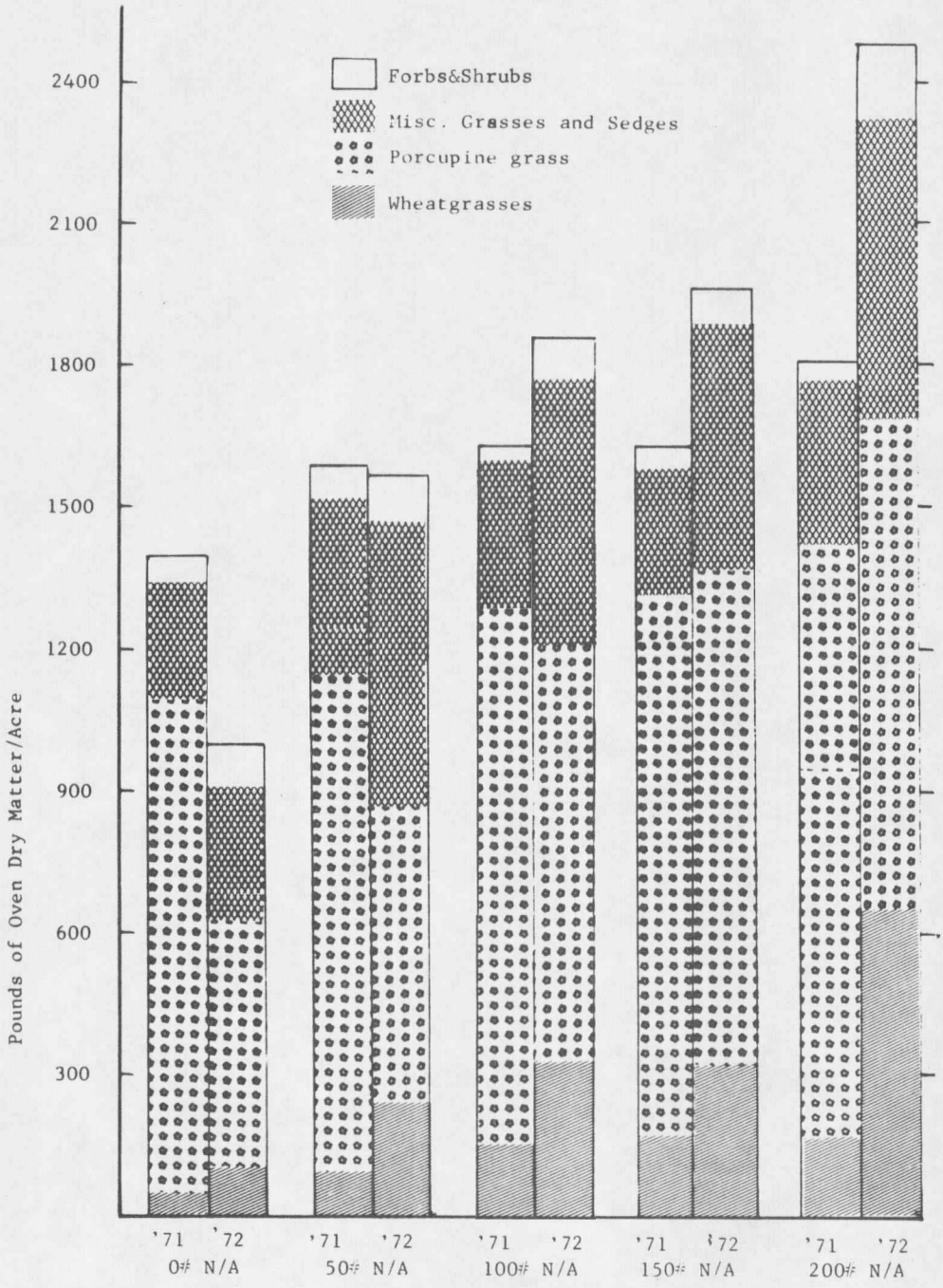


FIGURE 10 Vegetational response to fertilization of porcupine grass community with deferment in 1971 and 1972.

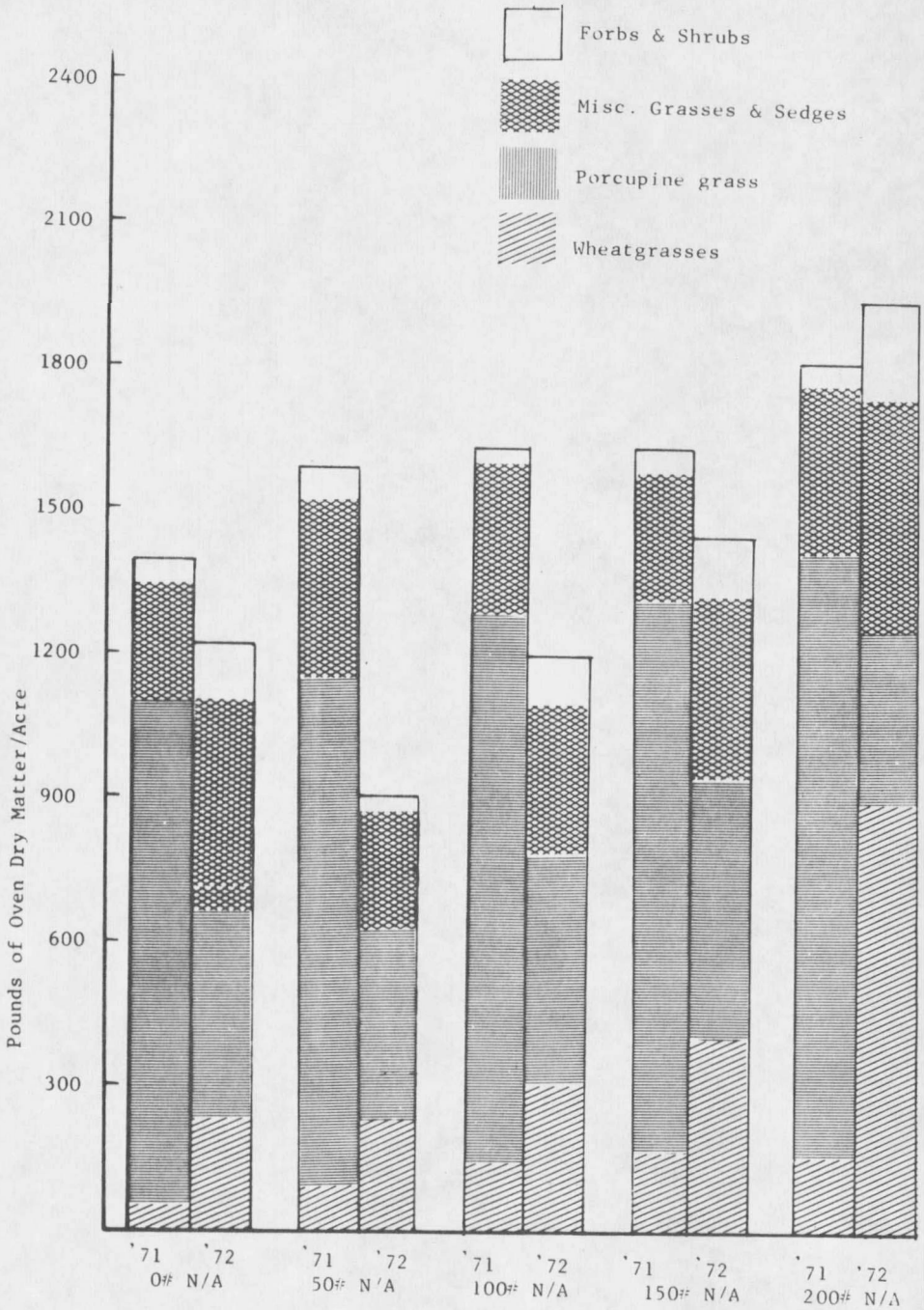


FIGURE 11 Vegetational response to fertilization of porcupine grass communities with deferment 1971 and grazing 1972.

have been due to a competitive advantage of rhizomatous wheatgrasses in obtaining water in a nitrogen enriched environment.

Utilization.

Utilization estimates, taken in April, 1973, revealed that the utilization of porcupine grass was relatively low. The 0, 50, and 100 pounds of nitrogen per acre fertilizer treatments had less than five percent utilization, while the 150 and 200 pounds of nitrogen per acre had 10 and 50 percent utilization, respectively (Figure 12).

Two probable causes for low utilization were (1) the area had received far above normal precipitation (Table 2), causing a flush of growth and an abundance of forage; (2) the nitrogen effect on palatability had likely declined because of relatively low amounts of residual nitrogen remaining after the 1971 growing season. The 200 pounds of nitrogen per acre fertilizer treatment was still manifesting signs of nitrogen effect on palatability, with substantial utilization.

Plant Height.

Plant heights of ungrazed porcupine grass were taken in April of 1972. The means derived from those heights were subjected to a t-test to determine if a nitrogen treatment effect was displayed. The means and the results of the t-test are shown in Table 14.

The mean height for 0 and 50 pounds of nitrogen per acre are significantly different from means of 100, 150 and 200 pounds of nitrogen per acre. There was no difference among the means of the 100, 150 or

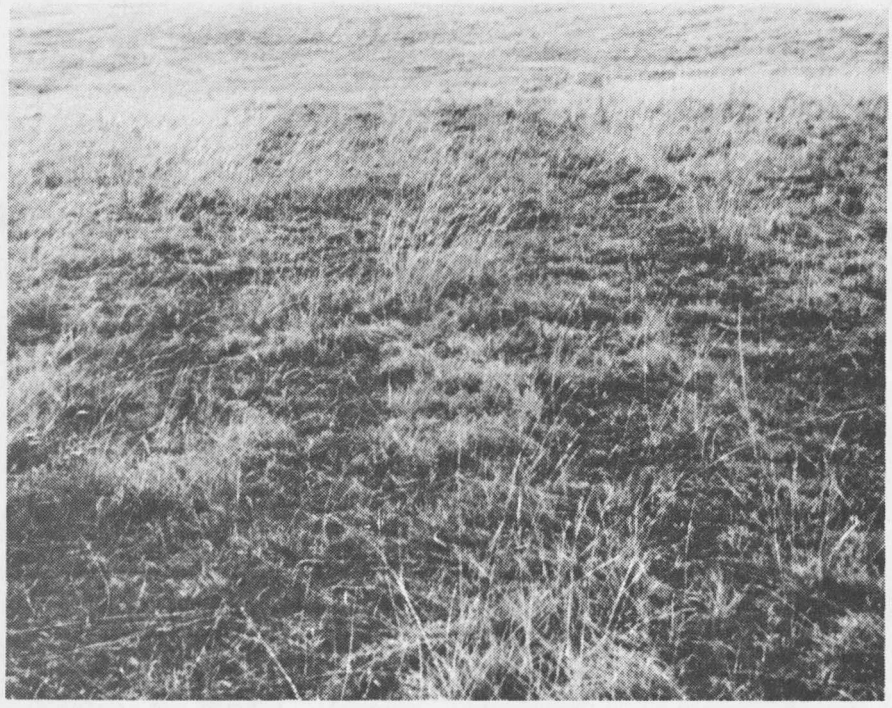


FIGURE 12 Livestock utilization on the 200 lbs. of N/A treatment, in 1972.

TABLE 14 Average height measurements of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County, taken in March, 1973.

	DEFERRED 1971, 1972, 1973				
Lbs. N/A	Rep I	Rep II	Rep III	Rep IV	Mean
0	22.1	21.1	20.7	23.7	21.9 a 2/
50	23.1	21.2	17.4	28.3	22.5 a
100	27.5	27.4	24.6	25.9	26.4 b
150	26.7	25.8	24.8	26.9	26.1 b
200 1/	27.4	30.4	28.1	28.2	28.5 b

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

2/ Unlike letters indicate a significant difference.

the 200 pounds of nitrogen per acre treatments. The residual nitrogen effect was not apparent in the 0 and 50 pounds of nitrogen per acre treatment.

Vegetational Response in 1973

Production.

The yield data from the porcupine grass communities for the year 1973 are presented in Tables 15, 16, and 17.

The perennial grass yields from the deferred 1971, 1972, 1973 treatment (Table 15) showed a trend of increased herbage production with increasing rates of applied fertilizer. Wheatgrasses, a prominent vegetational component of the perennial category, seemed to be the major contributor in the creation of the trend. Porcupine grass was the major component of perennial grasses but did not reflect this trend. Porcupine grass yields in response to rates of applied fertilizer were erratic. Other vegetational components, green needlegrass and miscellaneous grasses, had small yields. Miscellaneous grasses had fairly constant yields across fertilizer rates in all three grazing treatments (Tables 16, 17).

The porcupine grass yields from the grazed 1971, deferred 1972, 1973 treatment (Table 16) were well below those from the deferred 1971, 1972, 1973 treatment (Table 15). These low yields were probably due to a negative response of porcupine grass to grazing pressure in 1971. The apparent trend of decreasing porcupine grass yields with increasing

TABLE 15 Vegetation response to fertilization (applied Fall, 1970) of porcupine grass communities in 1973, Rohde-Langen Ranch (3 year deferment).

VEGETATION SEPARATES	FERTILIZER LEVELS				
	Check	50# N/A	100# N/A	150# N/A	200# N/A[1/]
	lbs/A	lbs/A	lbs/A	lbs/A	lbs/A
WHEATGRASS	110	149	163	228	416
PORCUPINE GRASS	1101	791	1226	1185	959
GREEN NEEDLE-GRASS	4	5	1	23	20
MISCELLANEOUS GRASSES	335	515	248	237	398
TOTAL PEREN-NIAL GRASSES	1459	1469	1638	1674	1793
FORBS	9	9	14	13	7
FRINGED SAGEWORT	7	25	6	10	14
TOTAL YIELD	1475	1495	1658	1697	1814

1/ Applied at 600 lbs. N/A on 1 foot strips placed on 3 foot centers.

TABLE 16 Vegetation response to fertilizer (applied Fall, 1970) of porcupine grass communities, grazed 1971, deferred 1972, 1973 on Rohde-Langen Ranch.

VEGETATION SEPARATES	FERTILIZER LEVELS				
	Check	50# N/A	100# N/A	150# N/A	200# N/A[1/]
	lbs/A	lbs/A	lbs/A	lbs/A	lbs/A
WHEATGRASS	203	203	200	287	455
PORCUPINE GRASS	681	611	526	466	445
GREEN NEEDLE-GRASS	1	0	6	0	0
MISCELLANEOUS GRASSES	463	338	396	470	497
TOTAL PEREN-NIAL GRASSES	1347	1151	1128	1223	1397
FORBS	25	30	14	14	23
FRINGED SAGEWORT	15	12	2	4	16
TOTAL YIELD	1387	1194	1145	1241	1435

1/ Applied at 600 lbs. N/A on 1 foot strips placed on 3 foot centers.

TABLE 17 Vegetational response to fertilizer (applied Fall, 1970) of porcupine grass communities, grazed in 1971, 1972, deferred 1973 on Rohde-Langen Ranch.

VEGETATION SEPARATES	FERTILIZER LEVELS				
	Check	50# N/A	100# N/A	150# N/A	200# N/A[1/]
	lbs/A	lbs/A	lbs/A	lbs/A	lbs/A
WHEATGRASS	135	421	569	252	313
PORCUPINE GRASS	405	212	151	228	499
GREEN NEEDLE-GRASS	9	0	30	0	9
MISCELLANEOUS GRASSES	320	325	361	461	413
TOTAL PEREN-NIAL GRASSES	869	957	1112	941	1234
FORBS	23	13	31	33	48
FRINGED SAGEWORT	18	13	8	8	9
TOTAL YIELD	910	984	1151	982	1290

1/ Applied at 600 lbs. N/A on 1 foot strips placed on 3 foot centers.

fertilizer rates may not be real. The data from 1972 and the other grazed treatment in 1973 do not reflect a similar trend.

The wheatgrass yields showed no visible response to grazing effects or deferment in 1973. There was an apparent residual nitrogen effect on wheatgrass yields in the deferred 1971, 1972, 1973 and the grazed 1971, deferred 1972, 1973 treatments. The residual nitrogen effect was especially pronounced in the 150 and 200 pounds of nitrogen per acre fertilizer treatments (Tables 15, 16).

The wheatgrass yields from the grazed 1971, 1972, deferred 1973 treatment demonstrated a unique response pattern. The yields from the 50 and 100 pounds of nitrogen per acre treatments were unpredictably high. These high yields appear to be anomalies with no apparent biological explanation. In contrast, the wheatgrass yields from the 150 and 200 pounds of nitrogen per acre fertilizer treatments show a decrease in yield. This was probably a negative response of physically and physiologically overextended plants from an enriched environment, to below average precipitation (Table 2). This reaction was probably enhanced by extreme water use in production of herbage in 1972 and by the dry 1973 winter, preventing build-up of ground water reserves.

Statistical Analysis.

Bartlett's Test for Homogeneity of Variance. Bartlett's test for homogeneity (Tables 18, 19, 20) revealed that two vegetational component groups, wheatgrasses and miscellaneous grasses, showed lack of homogen-

TABLE 18 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety curtiseta) communities, deferred 1971, 1972, 1973, on the Rohde-Langen Ranch, North Valley County in 1973.

	DEFERRED 1971, 1972, 1973		
Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	23.282**	13.371**	1.740
50	2.200	10.321	2.160
100	7.979*	9.976*	7.939*
150	3.440	0.377	0.660
200 1/	2.238	9.330*	0.582

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

* Different at the 0.05 level or probability.

** Different at the 0.01 level of probability.

TABLE 19 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety curtiseta) communities, grazed 1971, deferred 1972, 1973, on the Rohde-Langen Ranch, North Valley County in 1973.

	GRAZED 1971, DEFERRED 1972, 1973		
Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	17.520**	1.734	0.342
50	16.378**	0.459	5.556
100	5.430	2.675	6.360
150	3.029	1.707	1.684
200 1/	4.466	1.809	6.773

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

** Different at the 0.01 level of probability.

TABLE 20 Bartlett's test (X^2 values) from porcupine grass (Stipa spartea, variety curtiseta) communities, grazed 1971, 1972, deferred 1973, on the Rohde-Langen Ranch, North Valley County in 1973.

	GRAZED 1971, 1972, DEFERRED 1973		
Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass
0	3.726	1.726	2.218
50	4.428	4.136	0.296
100	3.486	4.467	3.530
150	5.178	0.895	2.601
200 1/	0.546	2.064	11.708*

1/ Applied in one foot strips two feet apart. Fertilizer applied at a rate of 600 lbs. N/A on the strips which is equivalent to 200 lbs. N/A on an over-all application.

* Different at the 0.05 level of probability.

eity. Therefore, these were not considered in an analysis of variance.

Porcupine grass yield data displayed heterogeneity of variance in two cases. Those cases were 100 pounds of nitrogen per acre fertilizer treatment from the deferred 1971, 1972, 1973 treatment, and the 200 pounds of nitrogen per acre fertilizer treatment from the grazed 1971, 1972, deferred 1973 grazing treatment. Because of this innate heterogeneity, the analysis of variance will be interpreted while taking into account this variance.

Analysis of Variance. The analysis of variance of porcupine grass data (Table 21) revealed that again there was a significant block effect. A test of the main effect, grazing treatments, showed a highly significant difference between treatments. This effect appears to be due mostly to the severe utilization on vegetation in 1971 with a slight compounding effect by 1972 utilization.

The fertilizer effects on porcupine grass were non-significant as was the grazing fertilizer interaction.

Comparisons Among Years.

Wheatgrasses. A comparison of wheatgrass yields over a three year period for each fertilizer treatment and each combination of grazing treatments revealed a general trend of increasing yield with increasing rates of applied fertilizer (Figures 13, 14, 15). This general trend was especially evident in the continuously deferred treatment (Figure 13).

TABLE 21 Split block analysis of variance of vegetational components of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, North Valley County in 1973.

	PORCUPINE GRASSES			
SOURCE OF VARIATION	Sum of Squares	Degrees of Freedom	Mean Square	F
Total	25150.0	59		
Blocks	3413.3	3	1137.8	6.57**
Fert.	955.6	4	238.9	1.38
Error A	1332.5	12		
Grazing	14145.7	2	7072.8	40.8 **
Error B	356.1	6		
G*Fert.	1827.4	14	130.5	0.75
Error C	3119.4	18	173.3	

** Different at the 0.01 level of probability.

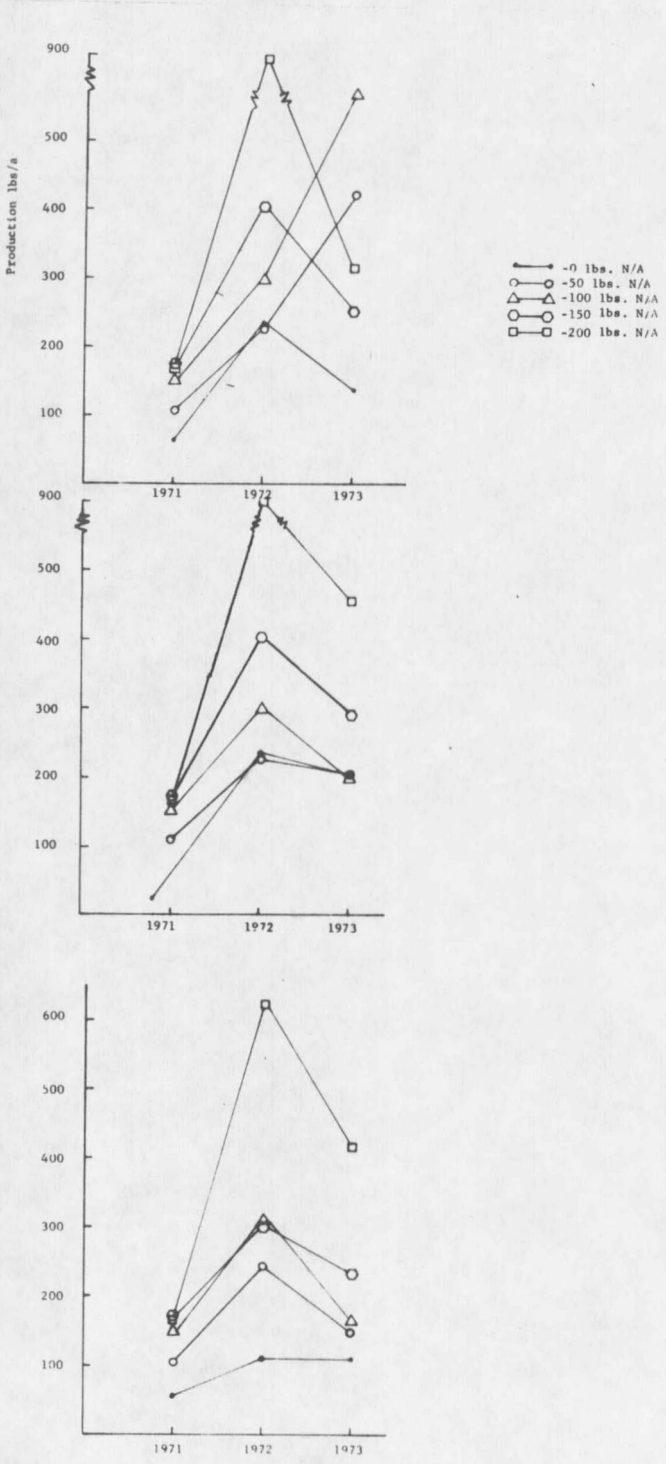


FIGURE 13 Wheatgrass response to N fertilization (applied fall, 1970 only) of the porcupine grass community with grazing and deferment 1971-1973, on Rohde-Langen Ranch.

1971 - deferred
1972 - grazed 1971, deferred 1972
1973 - grazed 1971, 1972, deferred 1973

FIGURE 14 Wheatgrass response to N fertilization (applied fall, 1970 only) of the porcupine grass community with grazing and deferment 1971-1973, on Rohde-Langen Ranch.

1971 - deferred
1972 - grazed 1971, deferred 1972
1973 - grazed 1971, deferred 1972, 1973

FIGURE 15 Wheatgrass response to N fertilization (applied fall, 1970 only) of the porcupine grass community with continuous deferment (1971, 1972, 1973) on Rohde-Langen Ranch.

The yields in 1972 demonstrated an apparently positive response to above average precipitation and higher fertility levels, causing the production to peak. The response was relatively less at lower fertilizer rates and in the continuously deferred treatment.

The 1973 wheatgrass yields were substantially below the 1972 yields in all except two cases. These were the 50 and 100 pounds of nitrogen per acre fertilizer treatments which were subjected to the grazed 1971, 1972, deferred 1973 grazing treatment. Both treatments were assumed anomalous. The yield depression in 1973 was probably due to lower levels of residual nitrogen and below average precipitation (Table 2).

Porcupine Grass. The yields of porcupine grass for the deferred 1971, 1972, 1973 treatment showed a sharp depression in the year 1972 (Figure 16). The depression of yield was proportionately less with increasing fertilizer rates. The reason for this depression is obscure. One possible cause could be that below average precipitation in the fall and winter (Table 2) prevented a normal amount of available ground water from accumulating. This probably did not provide sufficient moisture for normal phytomer elongation. In addition to low fall and winter precipitation, the early spring temperatures were below normal (Table 1). The low production of porcupine grass is emphasized in Figure 10, which shows the total yields of the 0 and 50 pounds of nitrogen per acre fertilizer treatments were below those of 1971.

The yield depression in porcupine grass evident in Figures 17 and

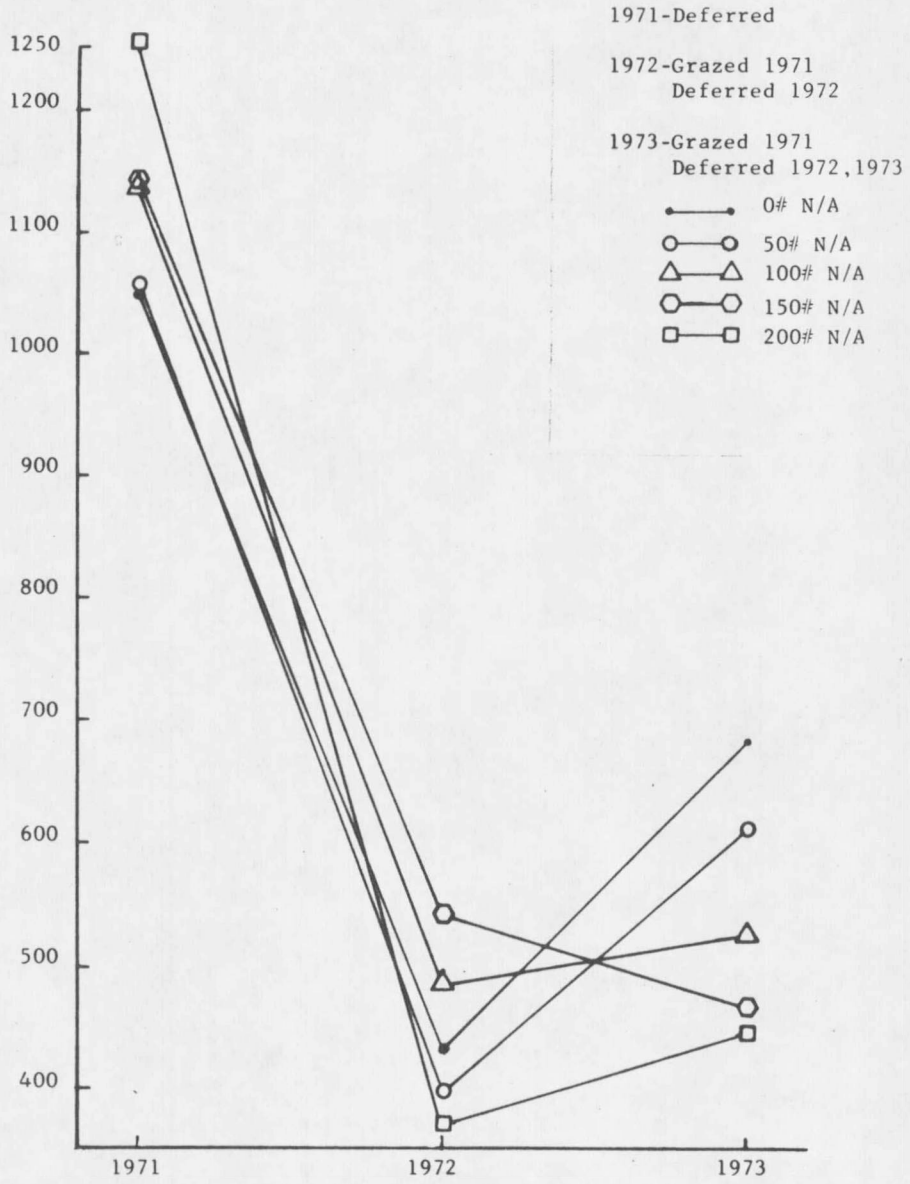


FIGURE 16 Porcupine grass response to N fertilization (applied 1970 only) with continuous deferment (1971, 1972, 1973) on the Rohde-Langen Ranch (N applied at 600 lbs. N/A on 1 foot strips placed on 3 foot centers).

18 probably was partially affected by the same factors causing the yield depression in the deferred 1971, 1972, 1973 treatment.

The rebound of porcupine grass yields in 1973 could have been due to additional stored moisture in the spring of 1973 and warm spring temperatures. It was observed in March of 1973 that soil moisture below the six inch level, beneath the 150 and 200 pounds of nitrogen per acre fertilizer treatments, was appreciably less than beneath the other fertilizer treatments. This condition could be an indication of increased root length and bulk caused by nitrogen stimulation of the plant.

The increases in yield in 1973 (Figure 17) for the grazed 1971, deferred 1972, 1973 treatment were very likely responses to the same biological factors causing the increase in yields in the deferred 1971, 1972, 1973 treatment. The residual grazing effect from 1971 probably changed the magnitude of the response. The yields from the grazed 1971, 1972, deferred 1973 treatment (Figure 18) did not show the same response as the grazed 1971, deferred 1972, 1973 treatment even though the 0 - 150 pounds of nitrogen per acre fertilizer treatments had low utilization in 1972. The magnitude of yield increase of the 200 pounds of nitrogen per acre treatment was greater in the treatment grazed in 1972 than the treatment deferred in 1972. This was an apparent anomaly.

Statistical Comparisons.

Analysis of Variance. No analysis of variance was performed between years because each grazing treatment each year must be considered

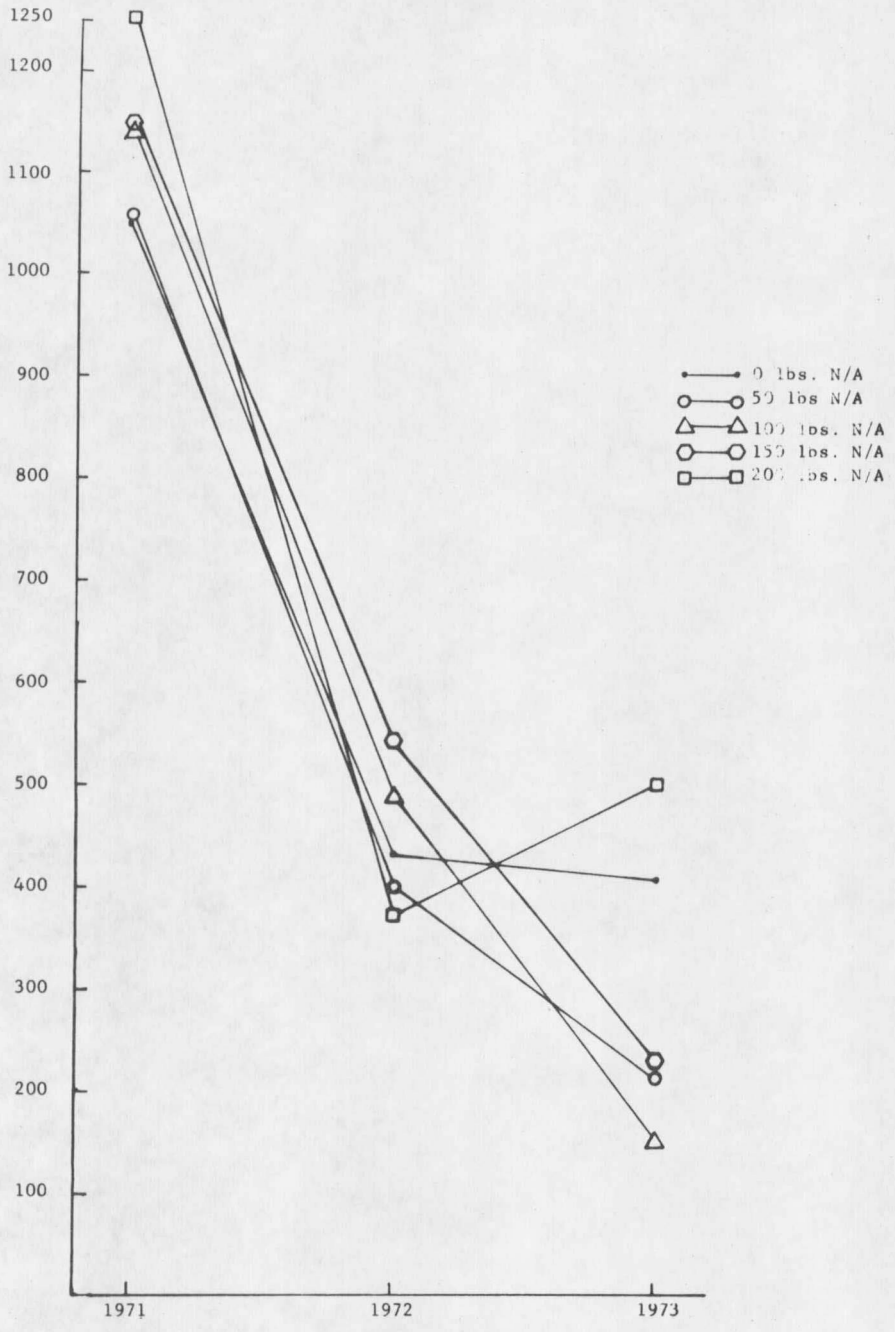


FIGURE 17 Porcupine grass response to N fertilization (applied fall, 1970 only) with grazing and deferment for the 1971 - 1973 years on the Rohde-Langen Ranch.

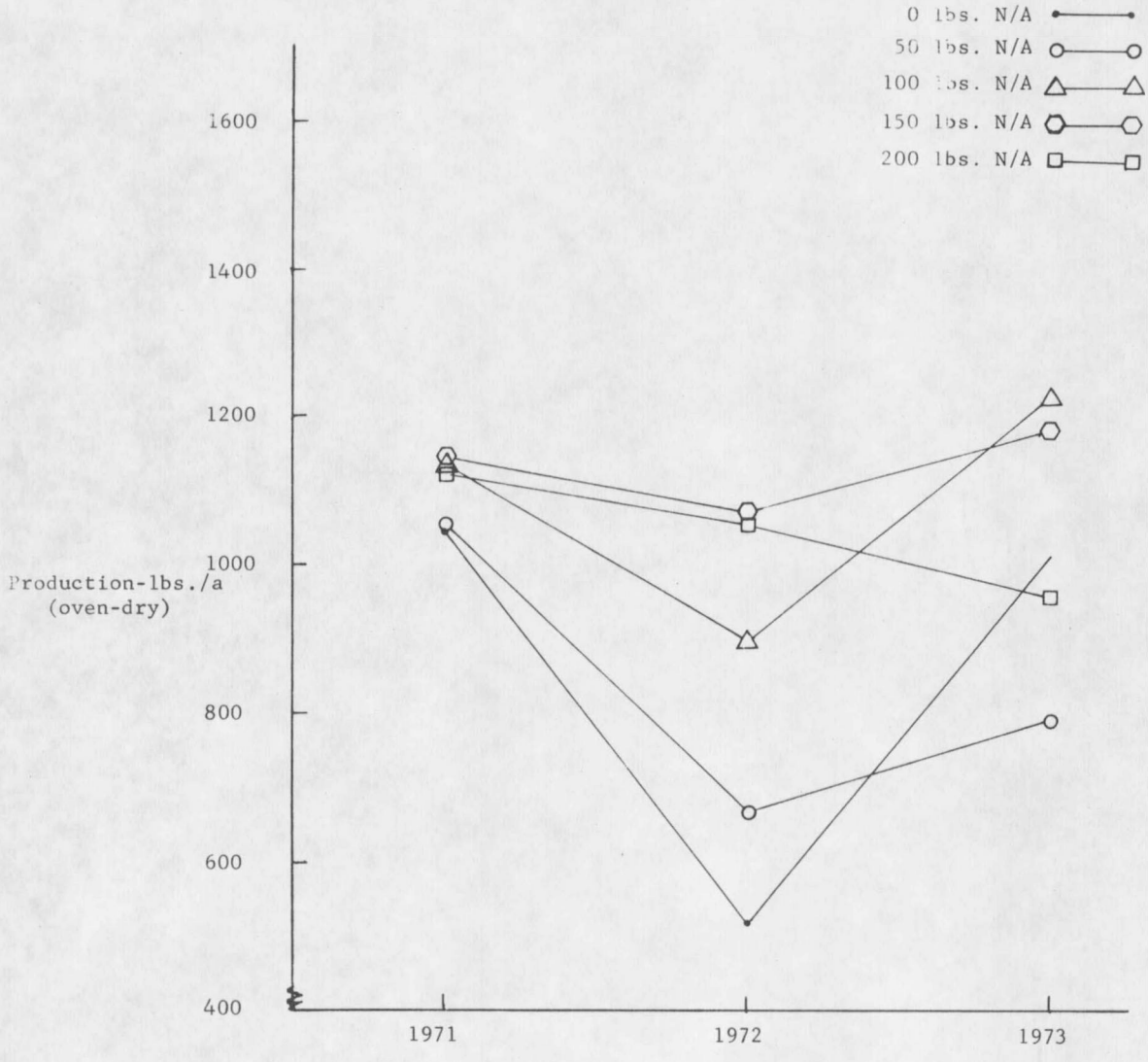


FIGURE 18 Porcupine grass response to N fertilization (applied fall, 1970 only) with grazing and deferment for 1971 - 1973 on Rohde-Langen Ranch.

as an individual treatment. Each treatment must be considered separately because each year an additional grazing treatment was included. This made each treatment an entity due to the fact that every treatment was not represented every year. In this way, those treatments receiving the same length of deferment were confounded with year effects.

Sample Size. Proper sample size for the analysis of variance was computed using a simple t-test. This method requires a variance from samples, the smallest expected resolution from an analysis of variance, and a T-value. The T-value is determined by the tabular value from the degree of freedom of the maximum feasible number of samples.

Variances used were from actual calculation of variances from the five clip samples. Large variances, 1705 and 1948, were chosen to allow for high vegetational variation. One hundred pounds per acre was chosen as the smallest expected resolution between means. A tabular T-value for four degrees of freedom was chosen because the relatively large value allowed for maximization of calculated sample size.

The calculated number of samples was three. This was sufficient to resolve a one hundred pound per acre difference. However, the figure of three samples will only adequately sample the major vegetational components. The minor components were established as heterogeneous. Therefore, an infinite number of samples would not adequately evaluate their yields.

Basal Area Cover. In many instances basal area cover may be a more

sensitive indicator of vegetational composition changes than yield data. This method can be used to gain additional insight regarding vegetational trends caused by a treatment or combinations of treatments.

Basal area cover estimates, taken summer 1973, were used to compare the effects of fertilizer and grazing treatments on the porcupine grass community (Table 22). The estimates revealed that total basal area cover for the deferred 1971, 1972, 1973 treatment was variable across fertilizer treatments. The intermediate rates of applied fertilizer showed the highest percent basal cover with the 200 pounds of nitrogen per acre fertilizer treatment showing the lowest. The low cover value on the high nitrogen plot could be partially due to a greater concentration of rhizomatous grasses, principally western wheatgrass.

Wheatgrasses: The species cover values are probably more indicative of change than the total basal area cover. There were slight increases in the 150 and 200 pounds of nitrogen per acre treatments. The small increases in basal cover probably did not indicate the actual magnitude of change in composition, characterized by increases in rhizomatous wheatgrasses.

Miscellaneous Grasses: The miscellaneous grass cover was probably influenced by changes occurring in the two component grasses. Therefore the change in basal cover would not yield any important information about the overall composition changes.

Porcupine Grass: The porcupine grass basal area values demonstra-

TABLE 22 Percent basal area cover of vegetation in the porcupine grass communities on the Rohde-Langen Ranch in August, 1973.

DEFERRED 1971, 1972, 1973

Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass	Total
0	1.1	2.6	5.8	9.9
50	1.1	3.2	5.6	10.6
100	1.1	2.0	9.0	12.3
150	1.2	2.2	6.3	10.0
200	1.8	2.0	4.4	8.2

GRAZED 1971, DEFERRED 1972, 1973

Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass	Total
0	.9	3.9	5.3	10.2
50	.9	2.9	3.8	8.2
100	1.0	2.6	4.9	7.9
150	1.5	3.2	3.7	9.0
200	2.0	2.8	2.5	7.5

GRAZED 1971, 1972, DEFERRED 1973

Lbs. N/A	Wheatgrasses	Miscellaneous Grasses	Porcupine Grass	Total
0	1.1	3.0	3.5	7.3
50	1.3	5.3	2.6	10.0
100	0.6	5.0	4.2	10.1
150	1.1	4.4	2.4	8.4
200	1.8	3.9	2.9	9.1

ted a definite trend across grazing treatments. A decrease in basal cover was evident with each additional year of grazing. These results compare quite favorably with those of Coupland et al. (1960), who showed a net decrease in basal area cover of porcupine grass grazed over a seven year period.

No trend in basal cover was indicated by comparing values across fertilizer treatments. However, the 100 pounds of nitrogen per acre fertilizer treatment displayed consistently higher basal area cover values. The biological implications of the result are not understood.

It would appear that utilization caused a general decrease in basal area cover of porcupine grass. This decrease may not indicate a decrease in the number of plants. No data were taken on relative plant numbers per unit surface area. Therefore, no conclusion can be made as to whether the decrease in basal area was an indication of plant loss or reduction of plant basal diameter.

Ordination. Ordination procedures were performed on yield weight data from the 1973 samples, to elucidate any separations of data that were not revealed by more standard statistical analysis.

The procedure is based on maximum differences between variances. Ordination of yield data accounted for 99.34 percent of the total variation in three axes. The x axis accounted for 83.67 percent of the variation, while the y and z axes accounted for 11.71 percent and 3.96 percent of the total variation, respectively.

The method seemed to indicate a separation of groups of grazing treatments, but reveals no separation of fertilizer treatments (Figure 19). The distribution of grazing treatments on the x axis leads to the conclusion that most of the variation was associated with grazing treatments. This variation tends to indicate that grazing treatments had the more dramatic effect on the vegetation.

Soils

All soils data presented in this section were from the 200 pounds of nitrogen per acre treatment. The data collected were from two replications, one of which had the calcium carbonate layer at 16 inches and the second at 24 inches. The variation in the depth of the calcium carbonate layer is characteristic of this soil series (Southard, 1969).

Vertical Movement of Soil Nitrates.

The nitrate values taken from the 200 pounds of nitrogen per acre treatment ranged from 0.0 parts per million to 3.3 parts per million, with most of the values averaging about 0.5 parts per million. This means for depths are presented in Table 23. The pattern of nitrate distribution seems to show a decrease of nitrates in the 4 - 8 inch depth and a slight accumulation in the 8 - 12 inch depth in both replications (Figure 20).

Lateral Movement of Soil Nitrates.

Samples were taken in four inch increments from the center of one

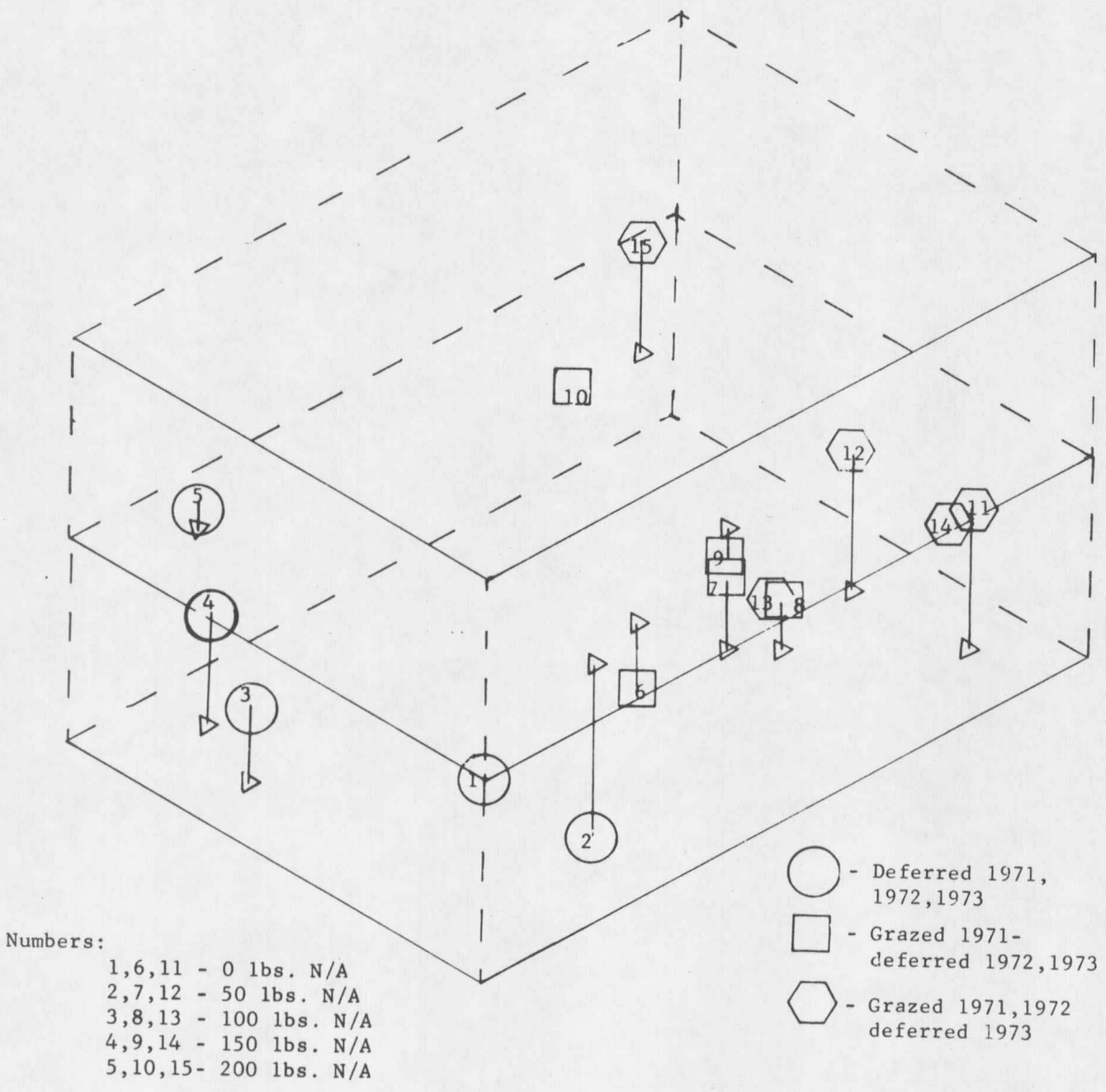


FIGURE 19 Ordination of 1973 weight data from the porcupine grass community on the Rohde-Langen Ranch.

TABLE 23 Average nitrate (PPM) present in soil profile from 200 lbs. N/acre treatment of porcupine grass (Stipa spartea, variety curtiseta) communities on the Rohde-Langen Ranch, taken at depth increments of four inches.

DEPTH	REP. I	REP. II
4 in.	0.50	0.93
8 in.	0.15	0.25
12 in.	0.50	0.55
16 in.	0.50	0.33
20 in.		0.33
24 in.		0.50

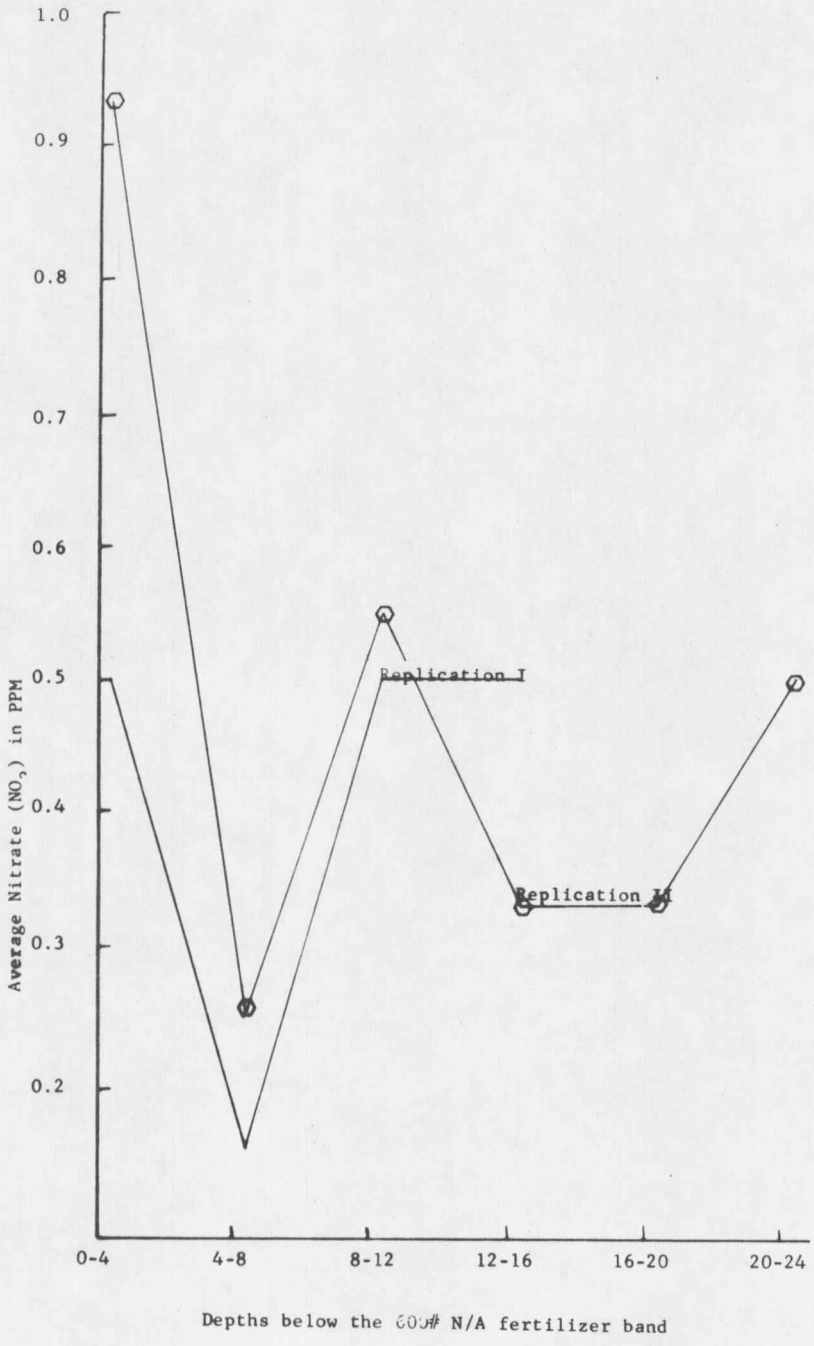


FIGURE 20 Average soil nitrate below the 600 lbs. N/A fertilizer band on the porcupine grass community on the Rohde-Langen Ranch.

600 pounds of nitrogen per acre band to the next (Table 24). The pattern of nitrate distribution in these samples was erratic (Figure 21).

Because of the very low nitrate values under the high nitrogen plots, the lower rate plots were not tested for nitrates.

Nitrogen Assimilation. Burt et al. (1971) presented a theoretical formula for nitrogen uptake in crested wheatgrass. This method used a constant and the square of March through June precipitation for the current year divided by the average March through June precipitation. Using Burt's formula, the calculated residual nitrogen for the porcupine grass community after the 1971 and 1972 growing seasons is 13.61 pounds per acre (calculationl, Appendix D).

$$R_{fert.} = 0.3 + \left(\frac{\text{Mar - June precip.}}{\bar{x}\text{Mar-June precip.}}\right)^2 \text{ (fert. applied lb. N/A)}$$

A similar formula developed at Havre, Montana, allows for seventy percent recovery per year on crested wheatgrass. Crested wheatgrass has a higher biological potential for yield than most native range grasses. At the present time no one has worked out a formula for nitrogen uptake on porcupine grass communities.

Assuming a uniform distribution of nitrate calculation 2 (Appendix D) shows a theoretical concentration of nitrates under one square foot of grassland, if all applied nitrates remained in nitrate form. Taking nitrate concentrations in one foot depths below that square foot, the values are 342 ppm, 171 ppm, and 114 ppm for the first, second, and

TABLE 24 Average nitrate (PPM) present in the surface four inches of soil. Samples taken from center of the 600 lbs. of N/Acre band to the center of an adjacent band crossing the intervening non-fertilized area.

	DISTANCE									
Rep. I										
	0	4	8	12	16	20	24	28	32	36
Ave.	.125	1.00	.125	.875	.250	.500	.500	.375	.125	.250
Rep. II										
Ave.	.250	1.00	.417	.417	.417	.333	.883	.083	.500	.083

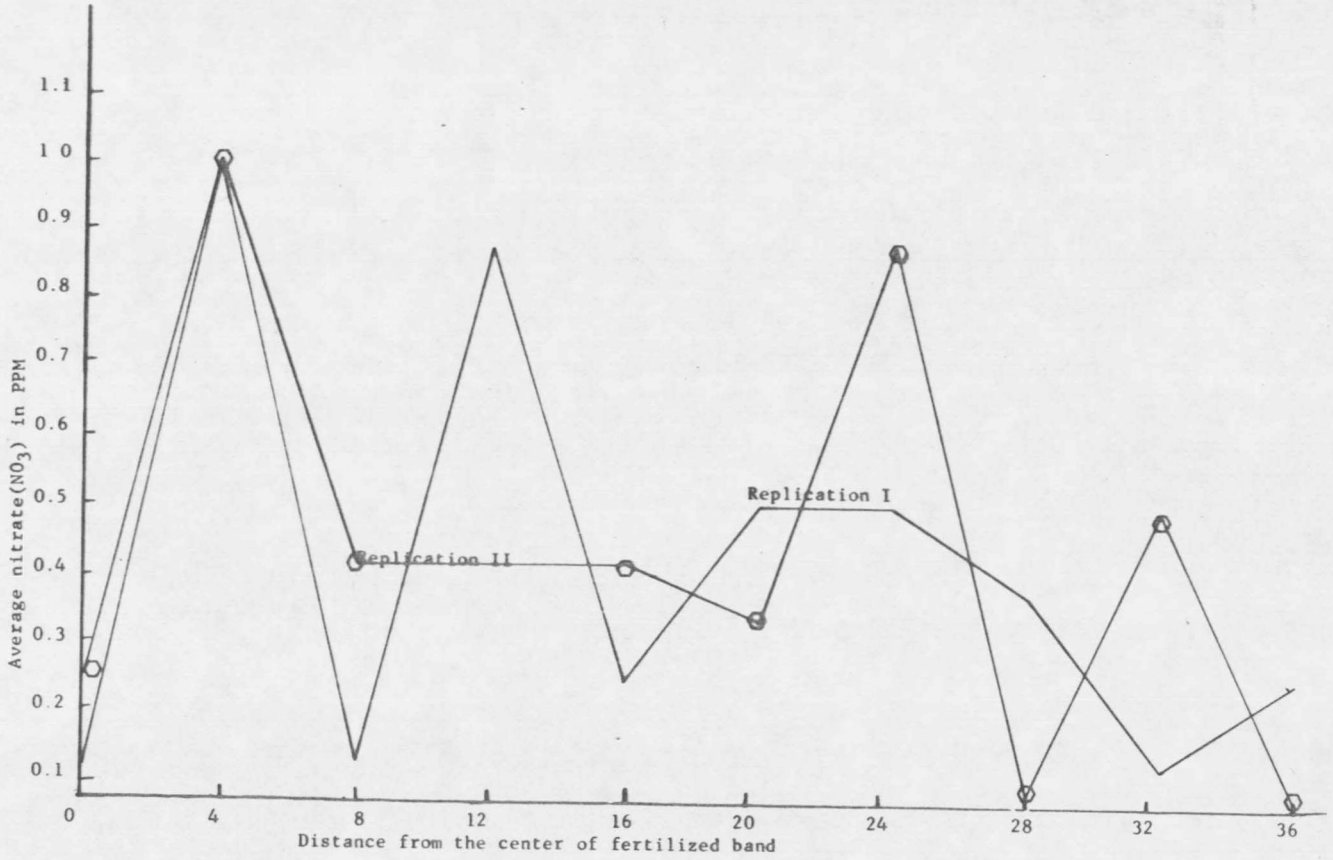


FIGURE 21 Average soil nitrate for distance away from the center of the one foot 600 lbs. N/A band on the porcupine grass community on the Rohde-Langen Ranch.

third foot respectively.

A calculation of total nitrate in vegetation (calculation 2) revealed a maximum nitrate yield of 0.665 grams of nitrate in the forage for two years (1971, 1972). The calculation was done using 1.5 percent nitrate on a dry weight basis as a maximum non-toxic level.

The determination from calculation 2 estimated a total of 13.89 grams of original nitrate per foot that was no longer in the nitrate form. Other forms of nitrogen are present in the plants or soil.

The other forms of nitrogen that cannot be accounted for can be divided into several categories: (1) nitrogen "sink", (2) non-nitrate nitrogen in vegetation, (3) volatilized nitrogen loss, and (4) non-nitrate nitrogen forms in soil and nitrogen leached from the sampling zone. The amounts accounted for in each specific group cannot be evaluated.

Power (1968) describes the nitrogen "sink" as the amount of nitrogen needed to satisfy the needs of soil fauna, micro-organisms, and decomposing humus.

An important loss was the nitrogen in plants harvested and the total nitrogen in unharvested vegetation.

A small part of missing nitrates could have been a loss through volatilization of nitric acid (Wallenstein et al., 1964).

The major part of the unaccountable nitrate was probably a readily mobilized nitrogen form involved with the soil clay particles and or-

ganic matter complex. The apparent nitrogen response of vegetation in the third year after fertilization, in spite of very low measured nitrate values, seems to support this viewpoint.

Cosper et al. (1961) in a study area similar to the present study site, reported 1.16 percent total nitrogen in vegetation after addition of 160 pounds of nitrogen per acre. Using the total production from the study area for two years the calculated recovery of nitrogen was only 24.75 percent, which was very low compared to the calculated value (70 percent) from Burt et al. (1971) (calculation 3). The actual nitrogen recovery was probably between the two figures.

SUMMARY AND CONCLUSIONS

A nitrogen fertilization study on a porcupine grass community was initiated on the Rohde-Langen Ranch, in North Valley County, Montana, in the fall of 1970. The primary objectives were to determine if nitrogen fertilization would increase the palatability of porcupine grass, and to evaluate the effects of five nitrogen treatments on herbage yields and vegetation species composition.

Data and observations were recorded for three years following fertilization, terminating in September of 1973. Based on these observations and data the following conclusions were formulated:

1. There was a positive yield response of western wheatgrass to the application of nitrogen fertilizer. Wheatgrasses demonstrated general increases in yield with increasing nitrogen application rates.

Porcupine grass showed no trend in yield increases due to fertilization.

Total vegetation yield response was not tested because of variation of means.

2. The palatability of all vegetation was apparently greatly increased by nitrogen. The increased palatability was reflected by increased utilization. Porcupine grass was adversely affected by increases in utilization. Wheatgrasses showed no difference in yield due to different grazing treatments.

3. The 200 pounds of nitrogen per acre treatment (600 pounds of

nitrogen per acre applied on one foot bands placed on three foot centers) showed a uniform distribution of vegetation, but displayed higher palatability of vegetation in the fertilized bands in the second season after fertilization.

4. The abundance of soil water was substantially less under the 150 and 200 pounds of nitrogen per acre fertilizer treatments, implying greater water use in those treatments.

5. Previous to the third growing season soil nitrate values were very low. Vegetation demonstrated nitrogen responses in that season, indicating readily mobile non-nitrate nitrogen supplies in the soil.

6. The purpose of this thesis was not to prove or disprove economic feasibility of range fertilization. No conclusion was reached.

7. To more fully understand the trend in vegetation composition changes and residual effects of nitrogen fertilization, an annual evaluation would be necessary for at least three to five additional seasons. In addition, observation and evaluation techniques could be improved by taking more intensive soils data and performing a complete study of soils and vegetation before the application of treatments. The pre-initiation data would be extremely beneficial in evaluation and interpretation of treatment effects.

8. A change in plot size might sample some portions of the vegetation more accurately.

APPENDIX

APPENDIX A PLANTS FOUND ON THE STUDY AREA

Scientific Name [1]	Common Name
Achillea lanulosa	western yarrow
Allium spp.	wild onion
Agropyron albicans	Montana wheatgrass
Agropyron dasystachyum	thickspike wheatgrass
Agropyron smithii	western wheatgrass
Antennaria spp.	pussytoes
Aristida longiseta	red threeawn
Arnica fulgens	arnica
Artemisia frigida	fringed sagewort
Aster spp.	aster
Astragalus spp.	milk vetch
Bouteloua gracilis	blue grama
Bromus tectorum	cheatgrass brome
Calamogrostis montanensis	plains reedgrass
Carex eleocharis	needleleaf sedge
Carex heliophila	sun sedge
Dodecatheon spp.	shooting star
Gaura coccinea	scarlet gaura

[1] All plant identification according to Booth, (1959) and Booth and Wright (1959).

Appendix A, continued

Scientific Name	Common Name
Grendelia squarosa	curlycup gumweed
Helianthella uniflorus	oneflower heliathella
Helianthus spp.	sunflower
Koeleria cristata	prairie junegrass
Liatris punctata	purple blazingstar
Lomatium spp.	biscuitroot
Lupinus spp.	lupine
Musineon divaricatum	musineon
Opuntia polycantha	plains pricklypear cactus
Oxytropis spp.	pointloco
Phlox hoodii	Hood's phlox
Poa secunda	Sandberg bluegrass
Potentilla spp.	cinquefoil
Psoralea argophylla	silver scurfpea
Psoralea tenuiflora	slimflower scurfpea
Schedonnardus paniculatus	tumblegrass
Selaginella densa	dense clubmoss
Senecio spp.	groundsel
Solidago spp.	goldenrod
Stipa comata	needle-and-thread
Stipa spartea	porcupine grass

Appendix A, continued

Scientific Name	Common Name
Stipa viridula	green needlegrass
Taraxicum spp.	dandelion
Tragopogon dubius	salsify
Vicia americanna	American vetch
Zygadenus spp.	death camas

APPENDIX B WEATHER DATA, 1971 - 1973 [1]

TEMPERATURE IN °C

YEAR	S	O	N	D	J	F	M	A	M	J	J	A
1970-1971	11.7	4.9	-4.3	-13.1	-16.4	-10.5	-5.1	6.0	11.9	17.1	18.7	23.2
1971-1972	12.2	6.2	-0.3	-13.4	-16.4	-13.4	-2.0	5.6	12.2	17.2	16.6	20.3
1972-1973	10.7	4.2	-0.7	-14.6	- 7.7	- 4.7	3.9	5.3	13.4	18.7	21.0	22.7

PRECIPITATION IN MM.

YEAR	S	O	N	D	J	F	M	A	M	J	J	A
1970-1971	57.6	11.4	13.5	4.8	18.8	2.0	3.3	8.9	28.2	52.6	19.3	20.8
1971-1972	24.5	17.5	0.3	7.1	12.7	15.5	14.7	16.2	75.7	112.8	58.7	24.1
1972-1973	24.1	5.8	0.5	13.5	0.5	3.3	6.6	40.1	19.8	77.5	22.6	26.4

ACCUMULATED PRECIPITATION IN INCHES

YEAR	S	O	N	D	J	F	M	A	M	J	J	A
1970-1971	1.48	1.93	2.46	2.65	3.39	3.47	3.60	3.95	5.06	7.13	7.89	8.71
1971-1972	0.97	1.66	1.67	1.95	2.45	3.06	3.64	4.67	7.65	12.09	14.40	15.35
1972-1973	0.95	1.18	1.20	1.73	1.75	1.88	2.14	3.72	4.50	7.59	8.44	9.48
Normal	0.94	1.78	2.25	2.70	3.18	3.59	4.15	5.16	6.65	9.63	10.96	12.45

[1] National Oceanic and Atmospheric Administration.

APPENDIX C COEFFICIENTS OF VARIATION FOR YIELD DATA IN 1972

Coefficients of Variantion from Data Season 1972		REP I						REP II					
		Wheat-grass	Miscel-laneous Grasses	Forbs	Fringed Sage-wort	Porcu-pine Grass	Green Needle-grass	Wheat grass	Miscel-laneous Grasses	Forbs	Fringed Sage-wort	Porcu-pine Grass	Green Needle-grass
	01_	18	18	92	224	51	223	72	61	127	70	109	
Con-tin-uous	02_	64	61	35		69		60	53	55	224	83	
	03_	97	51	48		60	163	61	88	144	144	48	
Defer-ment	04_	52	26	66		36	224	102	69	81	197	50	213
	05_	61	78	71		52	210	54	53	70	143	72	223
	01_	59	69	67		28	12	52	46	52		10	197
	02_	34	30	53	38	14	144	26	72	79		20	
Grazed	03_	59	23	36		24	224	28	48	68		82	27
1 Year	04_	28	55	40		24	155	28	41	86		25	154
	05_	18	29	42		16		19	41	120		56	171

Appendix C, continued

Coefficients of Variation from Data Season 1972		REP III						REP IV					
		Wheat-grass	Miscel-laneous Grasses	Forbs	Fringed Sage-wort	Porcu-pine Grass	Green Needle-grass	Wheat-grass	Miscel-laneous Grasses	Forbs	Fringed Sage-wort	Porcu-pine Grass	Green Needle-grass
Con-tin-uous Defer-ment	01	125	61	97	224	39		126	66	127	188	37	223
	02	73	79	83	218	91	156	100	61	115	112	34	
	03	99	32	98		41		44	69	76	135	68	
	04	93	81	77	224	48		40	84	93	152	91	
	05	59	89	85		31		97	53	127	202	44	223
Grazed 1 Year	01	41	49	102	222	37		104	50	70	116	61	220
	02	45	58	123	137	32		58	26	101	111	57	
	03	67	38	106	75	113	224	50	40	54		43	
	04	43	36	68	91	7	188	57	18	143	148	68	
	05	95	47	74	88	48		72	41	99	199	177	

APPENDIX D CALCULATION OF SOIL DATA

CALCULATION 1

$$R_{fert} = \left[.3 + \left(\frac{\text{Mar - June precip.}}{\bar{x}\ \text{Mar - June precip.}}\right)^2\right] \text{(fert. applied N lb./A)}$$

$$R_{1971} = \left[.3 + \left(\frac{3.92}{6.04}\right)^2\right] (200)$$

$$= \left[.3 + (.649)^2\right] (200)$$

$$= \left(\frac{.3}{.4212}\right) (200)$$

$$= (.71)\ (200)$$

$$= 142 \text{ lb. residual N/A.}$$

$$R_{1972} = \left[.3 + \left(\frac{10.69}{6.04}\right)^2\right] (142 \text{ lb. N})$$

$$= \left(\frac{.3}{3.13}\right) (142 \text{ lb. n})$$

$$= 13.6 \text{ lb. residual N/A.}$$

Glasgow 15 NW

1971 3.56"

1972 11.54"

$\bar{x}$ 1971 = 3.92"
1972 = 10.69"

1971 - 1797 lb. forage/A

1972 - 2462 lb. forage/A

Opheim 12 SSE

1971 4.29" Mar-June precip.

1972 9.85" Mar-June precip.

20 year average = 6.04" Mar-June

Appendix D, continued

CALCULATION 2

600 lb. N/A = 1800 lb. of NH_4NO_3/A

(1800 lb. fert./A) (.775 NO_3 available) = 1395 lb. NO_3/A

$\frac{1395 \text{ lb. } NO_3/A}{43{,}500 \text{ ft.}^2/A}$ = .032 lb. $NO_3/ft.^2$

= 14.55 g $NO_3/ft.^2$

(62.4 lb./$ft.^3$ H_2O) (1.5*B.D. soil) = 93.6 lb./$ft.^3$

*Estimated bulk density = 42.54 Kg/$ft.^3$

= 42545 g/$ft.^3$

$\frac{14.55 \text{ g } NO_3\text{-}(ft.^3}{42545 \text{ g/ft.}^3}$ = 3.42×10^{-4} gNO_3/g soil

= 342 ppm NO_3 for 1 $ft.^3$

$\frac{342 \text{ ppm}}{2}$ = 171 ppm for 2 $ft.^3$

$\frac{342 \text{ ppm}}{3}$ = 114 ppm for 3 $ft.^3$

(2464 lb. veg/A) (1.5% $NO_{3(max)}$) = 36.93 lb. NO_3 in Veg/A

= 8.4×10^4 lb. $NO_3/ft.^2$

= .385 g $NO_3/ft.^2$

(1797 lb. veg/A) (1.5% NO_3) = 26.95 lb. NO_3 in Veg/A

= .28 g $NO_3/ft.^2$

Total = .665 g NO_3 in Veg/$ft.^2$

for 2 years (Max.)

14.55 g/$ft.^2$ - .665 g NO_3 in Veg/$ft.^2$ = 13.89 g NO_3 remaining

Appendix D, continued

CALCULATION 3

(1.16% total N) (2462 lb. forage/A) = 28.56 lb. N/A

(1.16% total N) (1797 lb. forage/A) = 20.84 lb. N/A

Total = 49.40 lb. N/A for 1971 and 1972

= 24.7% N recovery in 2 years.

CALCULATION 4

70% N recovery in 2 years = 140 lb. N/A recovered.

140 lb. N/A = (4259 lb. forage) (X)

3.05% N = Present in vegetation

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