WEATHER, RANGELAND PRACTICES AND NORTH CENTRAL OKLAHOMA POOR CONDITION TALLGRASS PRAIRIE REGROWTH AFTER GRAZING

By

ROBERT WOODROW HAMMOND

Bachelor of Science

California State University - Humboldt

Arcata, California

1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
Master of Science
December, 1977

WEATHER, RANGELAND PRACTICES AND NORTH CENTRAL

OKLAHOMA POOR CONDITION TALLGRASS PRAIRIE

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Thesis Approved:

J Powell
Thesis Adviser

Robert D Morrison

Jimmy F. Stritzke

Norman N. Durham
Dean of Graduate College

ACKNOWLEDGMENTS

The term "poor condition" as used in the title and throughout this manuscript does not reflect the management ability of the owner but rather a term defining an ecological successional stage. However, there is no documental evidence that the existing forage quality and annual forage consistency are not the most appropriate for the current land use of the area.

I wish to express my sincere appreciation to Mr. Rex Matthiesen and his son, Bob, as I am indebted to them for the use of their land, equipment and their interest and help during the course of this study. I also extend appreciation to Dr.'s Jim Stritzke and Robert Morrison for their guidance and constructive criticism during the course of this study and for serving on my advisory committee. To Dr. Jeff Powell I am especially grateful for his assistance, guidance and dedication as my major adviser, employment supervisor and hunting companion. The encouragement and help has enlarged my understanding in all three.

I also wish to thank my parents, Mr. and Mrs. W. T. Hammond, for their encouragement and equal thanks to my mother-in-law and father-in-law, Mr. and Mrs. Ellis Simon. I express my gratitude to Mrs. Diana Traynor for her assistance in the preparation of the rough draft and Mrs. Diane Monn for the final copy of this manuscript.

Lastly, I wish a very sincere thank you to my wife Joan and my daughters Lynne and Lori for their love and support.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Beef and wheat rate very high in the economy of Oklahoma. These two products have an important bearing on the condition of rangeland and the ways in which it is used. The state is a national leader in wheat production (Oklahoma Agriculture 1975) and the north central district produces more than twice as much as the other districts in the state. As for the number of beef cows, the same district rated fourth out of nine and the counties of Garfield, Grant, Kay and Noble are rated in the upper one-half.

Wheat pastures are used extensively to provide forage for stocker cattle during the winter months (Swafford 1967). The beef cows that help supply these stockers are maintained during most of the year on rangeland or introduced pasture if available. Within the state almost 6 million hectares of rangeland and forest-range exist (O.C.N.I. 1970). This is over 50% of the total land area in Oklahoma.

In Noble County 10% of the land operated by wheat farmers is rangeland (David Ankle. 1976. SCS Resource Conservationist. Personal Communication.). These small areas of rangeland are often used as summer and fall holding pastures and are overgrazed. This overgrazing has reduced the stand of the original tallgrasses and have been replaced by short- and midgrasses as well as unpalatable forbs.

Forage production is usually not maximal on these overgrazed areas so rangeland improvements may be necessary to increase the quantity and quality of the usable forage. Adding nutrients and controlling undesirable vegetation are frequently used to improve rangeland. These improvements have many implications and it is important that rangeland improvements be made a part of planning and directing the utilization of rangeland instead of being considered separately. They are best considered as special aids available for achieving the objective of rangeland management (Vallentine 1971).

Because rangeland in north central Oklahoma is commonly used as a holding pasture for cattle until wheat is ready for grazing, the objective of this study is to determine the regrowth of tallgrass prairie vegetation under different weather and grazing conditions and rangeland improvement practices. With a better understanding of rangeland vegetation growth responses to different conditions, rangeland managers will be better able to plan rangeland grazing and ranch management systems.

CHAPTER II

LITERATURE REVIEW

The prairie is unique, but to the early traveler a barren and desolate land. In 1934 the prairie was described by Weaver and Fitzpatrick thus . . . .

> The prairie covers a vast area. It appears almost monotonous in the general uniformity of its plant cover. The absence of trees, the paucity of shrubs and half-shrubs, the dominance of grasses, and a characteristic xeric flora constitute its main features. Neither geological formation, topography, nor soil determines the character of the flora which develops under the master hand of climate (p. 109).

Throughout the prairie region two grasses dominated the landscape. Big bluestem (*Andropogon gerardi*) occurred on the lowlands and little bluestem (*Schizachyrium scoparium*) on the upland sites. (Scientific names of plant species were taken from Gould 1968 and WSSA 1971). Overgrazing resulted in the decrease of tallgrass species like big bluestem, Indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*) while midgrass species, such as sideoats grama (*Bouteloua curtipendula*), increased. Under prolonged drought and intensive grazing pressure these were replaced by those species capable of surviving, namely blue grama (*Bouteloua gracilis*), hair grama (*Bouteloua hirsuta*) and buffalograss (*Buchloe dactyloides*) (Bruner 1931, Smith 1940, Weaver and Albertson 1943 and Weaver and Clements 1938).

Weather

Hyder et. al. (1975) recently indicated moisture and the precipitation cycle but not grazing pressure influenced the density of shortgrass species. Their study was on a single range site and the effects of repeated heavy grazing in individual months were determined. The stands of both perennial and annual plants fluctuated more with weather conditions than to heavy grazing. Grazing could not have been more severe without endangering the lives of the cattle. A serious thinning of blue grama was caused by drought, not by grazing, which on the contrary thickened the stand.

Earlier studies by Savage (1937) found that increased grazing intensities resulted in an increase in both ground cover and proportion of buffalograss with a corresponding increase in the cover of total shortgrass species. It was indicated that grazing, if not too severe, increases the ground cover of shortgrasses unless serious extremes of heat and drought prevail. High temperatures represented the most damaging climatic factor and drought, in the form of limited precipitation, ranked second.

In southwest Texas, Osborn (1950) reported that drought caused no serious change in the stand of grass but the amount of growth was reduced each year and toward the latter part of the drought, growth was one-fifth to one-half the yield of the same grass species three years earlier.

Grazing

A. W. Sampson (1913) was among the first to evaluate grazing systems. Since that time many unique and diversified grazing systems have been applied with varying degrees of success. Two types of grazing conditions applied in this study are continuous or yearlong grazing and rotating the time of grazing given a pasture during the plant growing season.

Some of the reported objectives of establishing a worthwhile grazing system are: 1) restoring vigor of forage plants; 2) allowing plants to produce seed; 3) attaining heavier and more uniform utilization; and 4) increasing animal production (Stoddart et. al. 1975). Proper grazing has been referred to as the most important and usually the least expensive way to achieve more forage production on rangeland (Anderson 1969).

This philosophy was demonstrated by Merrill (1954) on the Edwards Plateau of Texas while comparing a deferred rotation system with continuous grazing at three stocking rates; light, moderate and heavy. At the end of a four year study the greatest desirable vegetational change occurred on the moderately stocked rotated pasture and the lightly stocked continuously grazed pasture. A steady trend toward improved range condition as well as increased financial returns occurred on the rotationally grazed pastures. McIlvain and Savage (1951) reported that under moderate and heavy continual use perennial forbs decreased 50% and 67%, respectively, while an increase of 20% and 33% occurred under a rotational system at the respective stocking rates. The invader-type grasses increased most under continuous uses.

Heady (1975) suggests a rationale for seasonal grazing in that grasslands evolved under intermittent grazing pressure from migrating herbivores, for example, the buffalo in North America. These animals used a given range for a short period then moved on to new ranges when forages were depleted and perhaps established a pattern that more or less repeated itself yearly.

Fertilization

Various management techniques are often applied and a common solution to most grazing systems is to reduce the number of animal units. At current beef prices one of the greatest needs is for more forage and not fewer animal units (Rogler and Lorenz 1973).

Fertilization can assist in fulfilling such a need. In the northern Great Plains rangeland fertilization generally results in improved species composition, increased forage production and protein content (Goetz 1975, Lorenz and Rogler 1972). Two years of fertilization of a heavily grazed pasture did more to improve range condition and production than six years of complete isolation from grazing (Rogler and Lorenz 1957). In eastern Wyoming, fertilization changed the vegetative composition of a predominantly shortgrass and forbs community where the shortgrass comprised 33% of the plant population to one of cool season perennial grasses and shortgrasses. On a similar site where the shortgrasses accounted for 80% of the species composition fertilization did not alter the botanical composition. In both areas nitrogen fertilization increased forage production and crude protein yields (Cosper et. al. 1967). Rauzi et. al. (1968) found yields of warm season grasses were not significantly increased by fertilization but also stated nitrogen fertilization increased crude protein content of the grass studied. Cosper and Thomas (1961) reported nitrogen fertilizer increased production of forage and crude protein on both dryland and water-spreading sites in western South Dakota.

Fertilization studies in Texas and New Mexico have also reported increases in forage production and protein content (Dee and Box 1967, Dwyer 1971, Fulgham 1972, Herndon 1972, Kelsey et. al. 1973, and Pettit and Deering 1974).

The advantages of rangeland fertilization, where it can be successfully used, far outweigh the disadvantages. However, there are several "side effects" that should not be ignored. Warnes and Newell (1969) indicated that fertilization used to keep grass growing vigorously could also save in the cost of weed control, but timely application of fertilizers at proper rates was necessary. Otherwise, fertilization was detrimental by favoring growth of weeds which competed with warm-season grass seedlings. Goetz (1969) found that increases in total herbage production was much greater due to a higher production of forbs. Herndon (1972) reported higher rates of nitrogen produced more forage but this was due mostly to unusable forb increases at the expense of grass.

Research studies involving fertilization on short- and midgrass species have been conducted at 10 different areas in the Great Plains (Fig. 1) and the synthesized results are listed in Table 1. They are located on the western portion of the central Great Plains and occur on soils generalized as mollisols (U.S.D.A. 1975). Fertilization generally increased the yield of forage. The same trend is also shown by a positive increase in crude protein. Also, most of the favorable forage responses were during years of above normal annual precipitation.

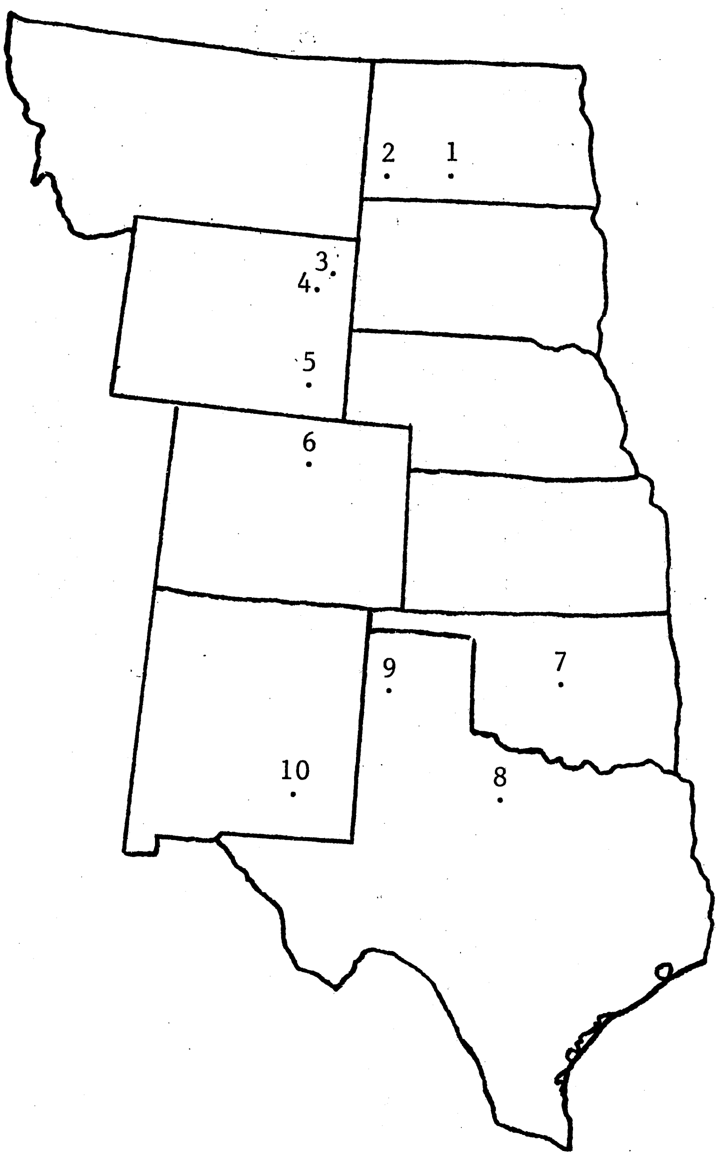

Figure 1. Location of short- and midgrass fertilization studies. (Numbers correspond to those listed under Map Loc in Table 1.)

Fertilization X Grazing

In addition to forage quality and quantity, Drawe and Box (1969) reported that cattle grazed fertilized areas more heavily than control

Table 1. Synthesis of literature reporting short and midgrass fertilization effects on herbage production (kg herbage/ kg fertilizer) and change in crude protein content (%).

State	Map Loc	Dom. Veg[1/]	Soil Texture	PPT[2/] (mm)	Kind	Actual Rate (kg/ha)	Production Compared to Control	Crude Protein	Reference
N. Dakota	1	Bogr Agsm	Silt Loam	445 406	N	34	+23	-0.28	Rogler and Lorenz (1957)
N. Dakota	2	Bogr	Silt Loam	avg + 392	N	37	+ 7.8	+0.8	Goetz (1969, 1975)
Wyoming	3	Bogr Buda Agsm	Silt Loam	254 246	N PHOS	90 + 90	+26.6	+0.14	Cosper et. al. (1967)
Wyoming	4	Bogr	Fine Sandy Loam	302 353	N	37	+ 1.5	+0.77	Rauzi et. al. (1968)
Wyoming	5	Bogr Buda	Fine Sandy Loam	356 378	N	37	+ 1.0	+1.28	Rauzi et. al. (1968)
Colorado	6	Bogr Buda	Sandy Loam	282[3/] 297	N	75	+ 0.34	+0.8	Klipple and Retzer (1959)
Oklahoma	7	Bocu	Clay Loam	589 716	N PHOS	112 + 112	- 2.1	-0.19	Huffine et. al. (1959)
Texas	8	Bocu	Fine Sandy Loam		N	34	+25.4		Herndon (1972)
Texas	9	Buda Bogr	Silty Clay Loam	295 383	N PHOS	112 + 112		+4.6	Dee and Box (1967)
N. Mexico	10	Bogr	Loamy	307 383	N SULF	45	+12.8		Dwyer (1971)
N. Mexico	10	Bogr Bohi	Loamy	295 383	UREA	45	+10.0		Dwyer and Schickendanz (1971)
N. Mexico	10	Bogr	Loamy	716 383	N	45	+11.1	+1.2	Fulgham (1972)

1/ See Nickerson, M. F. et. al. 1976 for scientific name abbreviations.

2/ Upper value represents annual precipitation during study. Lower value represents long-term annual average.

3/ Drought in 4th year only 124 mm.

areas and both percent utilization and herbage production increased with fertilization. Dwyer and Schickendanz (1971) reported animal production was increased on fertilized pastures and during their study average gain per hectare was 54 kg for nitrogen-fertilized pastures and 26 kg for unfertilized pastures. This increase was due mainly to greater number of heifers that could be grazed on fertilized pastures.

Fertilization can also be used as a tool for improving livestock distribution. A study in southeastern Wyoming on shortgrass rangeland reported cattle grazed significantly more often on areas fertilized with ammonium nitrate than they did on unfertilized areas (Samuel and Rauzi 1977). Hooper et. al. (1969) also found that rangeland adjacent to fertilized areas was utilized more frequently.

Chemical Control

The amount of forbs usually vary but they generally occur on all rangelands. Relatively few are present on good condition shortgrass rangeland and dense stands frequently occur on on poor rangeland. The density of these forbs, whether desirable or undesirable, will vary throughout the year depending on site, management system, and climatic, edaphic and other environmental factors. Diversity of species often is a desired condition, but undesirable forbs add little to usable forage production yet compete for light, fertilizer and water. Control of these undesirable species is therefore necessary on many sites before further improvement of rangeland is possible (Morton 1973).

Overgrazed pastures produce considerably less palatable forage than their potential. While many forbs may be desirable many others are low in palatability and usually ignored by livestock. Rangeland renovation work in North Dakota indicated weed control practices and fertilization combined with proper livestock management resulted in rapid improvement of abused pastures. However, while a combination of herbicide and fertilization gave the greatest yield response in total production, fertilizer alone was not effective because it stimulated vigorous weed growth at the expense of the grasses (Mitich 1973). Changes in botanical composition as a result of fertilization has been one of the chief hazards in attempting to increase yield of desirable rangeland species on poor condition rangeland (Harlan 1960).

Following its introduction as a selective herbicide following World War II, 2,4-D [(2,4-dichlorophenoxy) acetic acid] has become the most widely used chemical in the broad array of herbicides on the market today (Anderson 1973). This herbicide has proved to be very effective and most consistent in producing good ragweed control when sprayed at 0.84 kg/ha from mid-April to mid-June in Oklahoma (Elwell and McMurphy 1973).

Extensive use of 2,4-D has been made on a variety of different undesirable forbs. Rates of application have also varied from 0.56 kg/ha to 2.2 kg/ha of active ingredient (Bovey 1962, Elwell 1957, Hyder 1971, Mitich 1965, and Zahnley et. al. 1957). This herbicide has been quite effective on certain undesirable forbs. Jameson (1966) reported a reduction by weight on test plots of 90% for broom snakeweed (Gutierrezia sarothrae). Haas et. al. (1962) indicated removal of annual undesirable species did not increase the number of plants established but after two years the ground cover on sprayed plots was more than twice that of unsprayed plots and yield was significantly greater, respectively. Hurd's (1955) observation in September from a

July 1 spraying showed that cattle grazed sprayed plots much more intensively and uniformly than unsprayed plots.

Although 2,4-D has widespread applications, a few rangeland species such as silverleaf nightshade (Solanum elaegnifolium); snow-on-the-mountain (Euphorbia marginata); western yarrow (Achillea lanulosa) and some members of the genera Circium are resistant to 2,4-D (Klingman and Shaw 1971). In 1963 a new chemical, picloram (4-amino-3,5,6-trichloropicolinic acid), was introduced by Dow Chemical Company for evaluation purposes (Watson and Wiltes 1963). Since then mixtures of picloram and 2,4-D have shown distinct advantages by allowing lower rates of both chemicals to accomplish the same control (Alley 1967, Mitich 1975).

Picloram, either alone or in combination with low rates of 2,4-D, effectively controlled broom snakeweed, a species that is fairly resistant to 2,4-D (Klingman and Shaw 1971), on blue grama rangeland in southeastern Wyoming. Blue grama was initially injured by 0.56 and 1.12 kg/ha but this injury had a renovating effect and with the elimination of undesirable plants a notable improvement of the range resulted (Gesink et. al. 1973). In the same study application of 0.56 kg/ha of picloram plus 2,4-D provided 95 to 100% control and results were still apparent after 5 years. Scifres et. al. (1971) found similar results on Texas rangeland with combinations of picloram and 2,4-D controlling 94 to 100% of common broomweed (Gutierrezia dracunculoides), regardless of herbicide rate or stage of plant growth when treated.

Picloram is also quite effective when used by itself. In Nebraska, western ragweed (Ambrosia psilostachya) was effectively controlled by

1.12 kg/ha of picloram which also gave more uniform results and reliable control than did 2,4-D (McCarty and Scifres 1972). Bovey et. al. (1972) indicated the picloram sprays and granules at 2.24 kg/ha eliminated all forbs while Wiese (1967) reported that applications of 3.36 kg/ha of active ingredients have been most effective on silverleaf nightshade in northwest Texas. He also stated that applications of 2,4-D made before bud stage usually gives effective top kill but little or no root kill. In Oklahoma, application of picloram to established rangeland did not reduce forage production or desirable plant frequency but did reduce forb production (Arnold and Santelmann 1966).

The combination of 2,4-D and picloram can produce a herbicide mix capable of controlling undesirable forbs on most rangeland. An additional benefit can be seen when combining a herbicide program with one of fertilization. When undesirable forbs were eliminated by spraying, grass yields increased and nitrogen fertilization helped in reducing the forb percentages the second and third year by encouraging the growth of grass which in turn offered greater competition to the forbs (Smika et. al. 1963).

CHAPTER III

STUDY AREA

The study area is located on an upland prairie site 6 km east of Billings (latitude 36° 32' North, longitude 92° 27' West, elevation 304 m), Oklahoma in the E½, SE¼, Section 23, T24N, R2W of the Indian Meridian (Fig. 2). It lies in the northwest corner of Noble County in north central Oklahoma.

The climate is continental, warm-temperate and subhumid (Brensing 1941). The average annual precipitation is 805 mm. Most of the annual precipitation is rainfall during the growing season of April through October (Fig. 3). A uniform distribution of precipitation during the growing season is indicated by records, but dry periods of 4 to 6 weeks are very common, particularly in July and August. The winter months of November through March are the driest.

The average annual temperature is 15.7°C with the maximum recorded temperature 45°C and the lowest recorded temperature -29°C (U.S. Dept. Comm. 1976). The average frost-free period is 208 days from April 8 to October 31. The highest temperatures occur in July and August, while the lowest occur in January (Fig. 3). Relatively warm days (above 20°C) are common during any winter month, but cool nights (below 5°C) are rare during the summer.

Winds blow almost constantly throughout the year and are primarily from the southeast in the spring and southwest during the remainder of

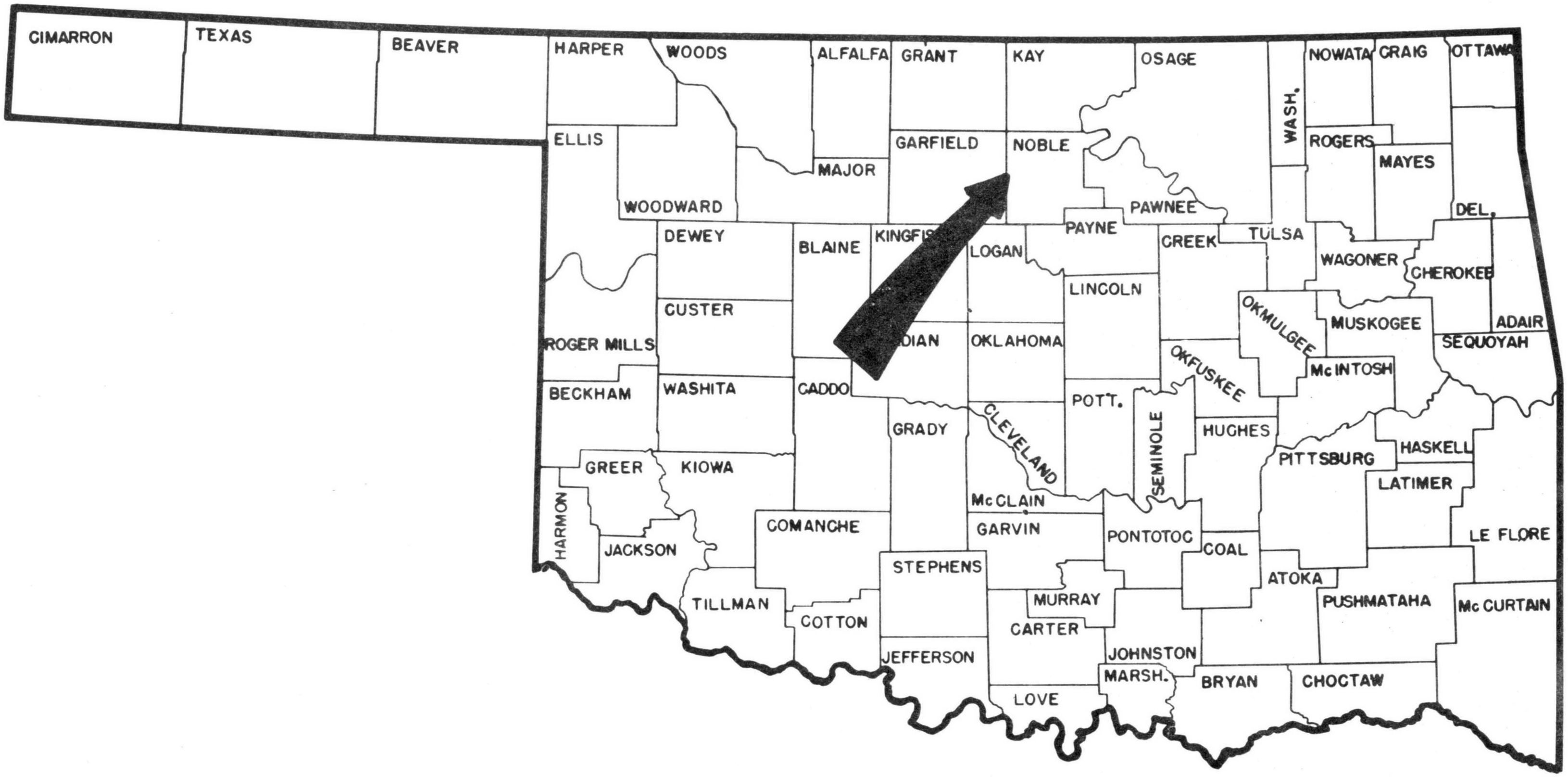

Figure 2. Location of study area in Oklahoma.

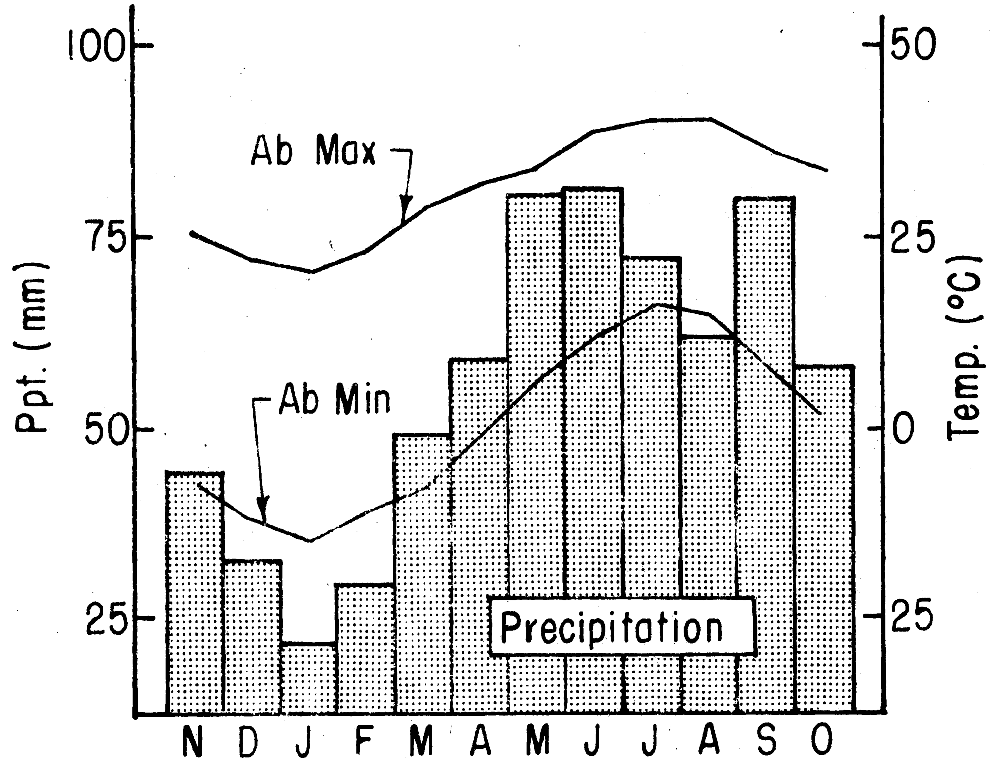

Figure 3. Longterm (1950-1975) average monthly precipitation (mm) and average absolute maximum and average absolute minimum monthly temperatures (°C) for Billings.

the year. Winds from the north occur only when cold fronts move into the area from the northwest. Wind movement is greatest in March and April and least in July, August and September (Fig. 4). The average annual 3:00 p.m. wind velocity is 22.4 kg/hr (Swafford 1967).

The average annual relative humidity is about 65% with daily highs of 80 to 90% about sunrise and daily lows of 50 to 60% about sunset. The average monthly high relative himidity is relatively constant during the year, but average low relative humidity is lowest in March and April and again in July and August (Fig. 4). The range in daily

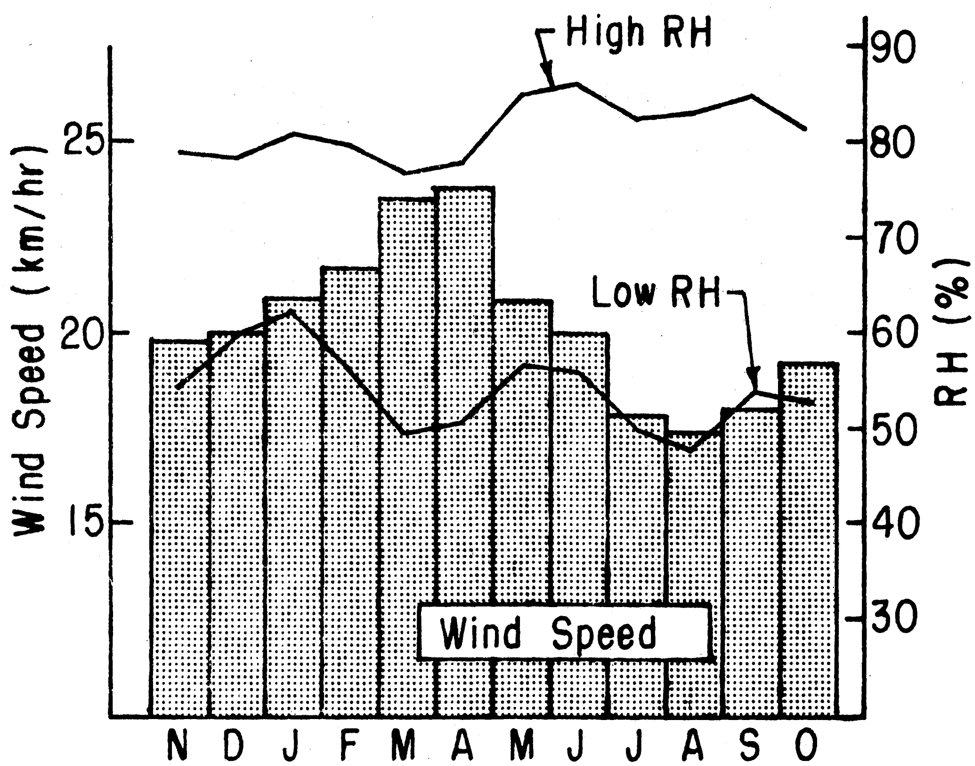

Figure 4. Longterm (1950-1975) average monthly wind speed (km/hr) and average monthly high and low relative humidity (%) for Oklahoma City, 133 km south of study area.

highs and lows is least during the coldest months and greatest during the hottest months.

Soil

The topography is undulating to rolling with the dominant soils developed under grass. The soil represented in this study is of the Kirkland series, a mollisol of the Reddish Prairie great soil group (Swafford 1967). The Kirkland series developed in alkaline reddish clays and shales, commonly of the Permian red beds. They consist of deep, dark-colored, nearly level to very gently sloping soils. Capability unit classification is IIs - 1 which defines soils in this class as being deep, medium textured or moderately fine textured on nearly level uplands that have a clayey, very slowly permeable subsoil. They are productive during years of normal or above normal precipitation but are somewhat droughty during seasons of low precipitation. The subsoil tends to restrict intake of water and penetration of roots.

The surface layer is a brown to grayish-brown friable silt loam, averaging 25 cm deep with a 17 to 35 cm range. It is underlain by a dark-brown or brown compact, very slowly permeable claypan. A description of a typical soil series is listed in Appendix A. This soil occurs on claypan prairie range sites with buffalo wallows or areas of depression present.

Vegetation

This area rests on the southern edge of the Tallgrass Prairies of the central United States. The original vegetation consisted of big bluestem, little bluestem, switchgrass, Indiangrass and sideoats grama. On some of the buffalo wallows or where the claypan is closer to the surface, blue grama and buffalograss can be found. The estimated yield of air-dry herbage on this site is 4500 kg/ha in years of favorable moisture, and 2000 kg/ha in years of unfavorable moisture (Swafford 1967).

The current dominant grass species are sideoats grama, blue grama, buffalograss ahd hairy grama. The predominant forbs are silverleaf nightshade, common broomweed, Plains coreopsis (*Coreopsis tinctoria*), daisy fleabane (Erigeron strigosus) and western yarrow. A list of these and other species encountered during the study is found in Appendix B. A view of the study area is shown in Figure 5.

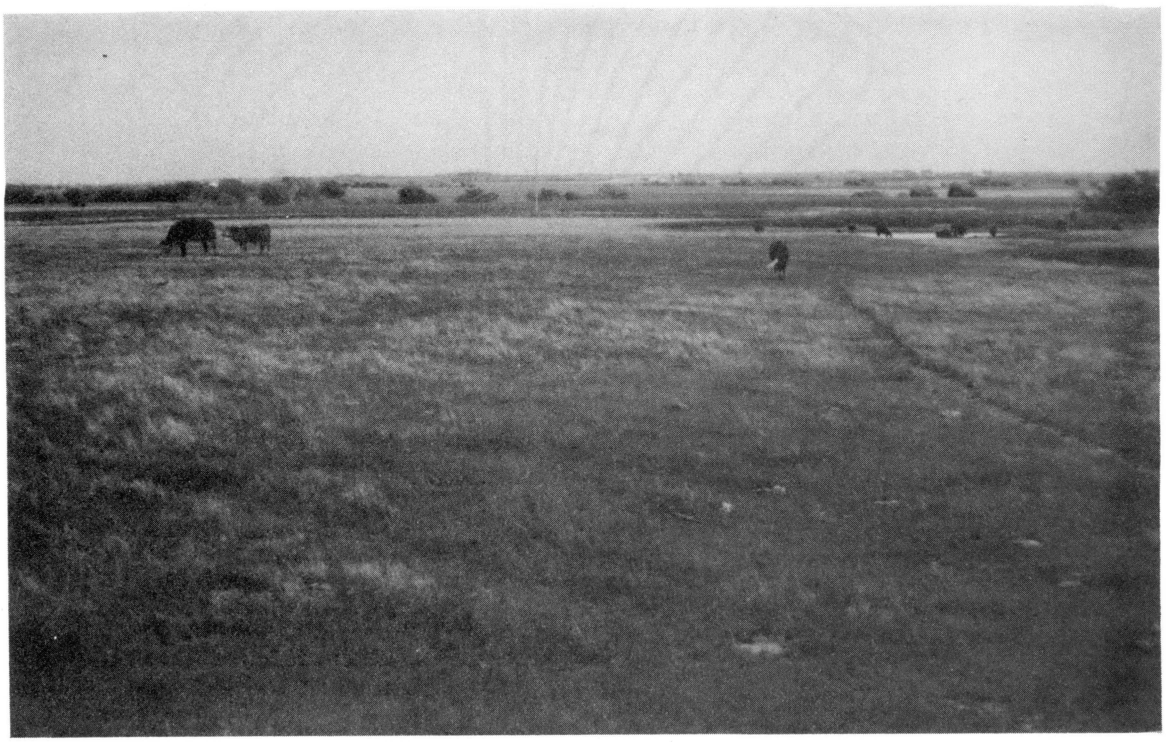

Figure 5. View of study area.

CHAPTER IV

PROCEDURES

Weather

Weather data including precipitation, temperature, relative humidity and wind movement were compiled from records at Billings and Oklahoma City. In addition to these regional data, micro-climatic data were determined on-site when vegetation was sampled. Wet and dry bulb temperatures on a sling psychrometer were determined periodically during the day. Soil temperatures approximately 10 cm below the soil surface were determined at 25 to 30 different locations on the site using dial-head soil thermometers. The gravimetric method (N.R.C. 1962) was used to determine soil water content (%) of the 0-30 cm layer at the same locations soil temperature was determined. The sample soil cores weighing about 120 gms each were taken to the Oklahoma State University, Department of Agronomy Soil and Water Testing Laboratory for drying and chemical analyses.

Grazing

The original area of 22 hectares was cross-fenced to provide two separate paddocks (Fig. 6). The smaller paddock of 4.4 ha was 20% of the total area and was grazed for 20% of the total grazing period. The small "rotation" paddock was grazed by all 17 animal units for 14 to 21

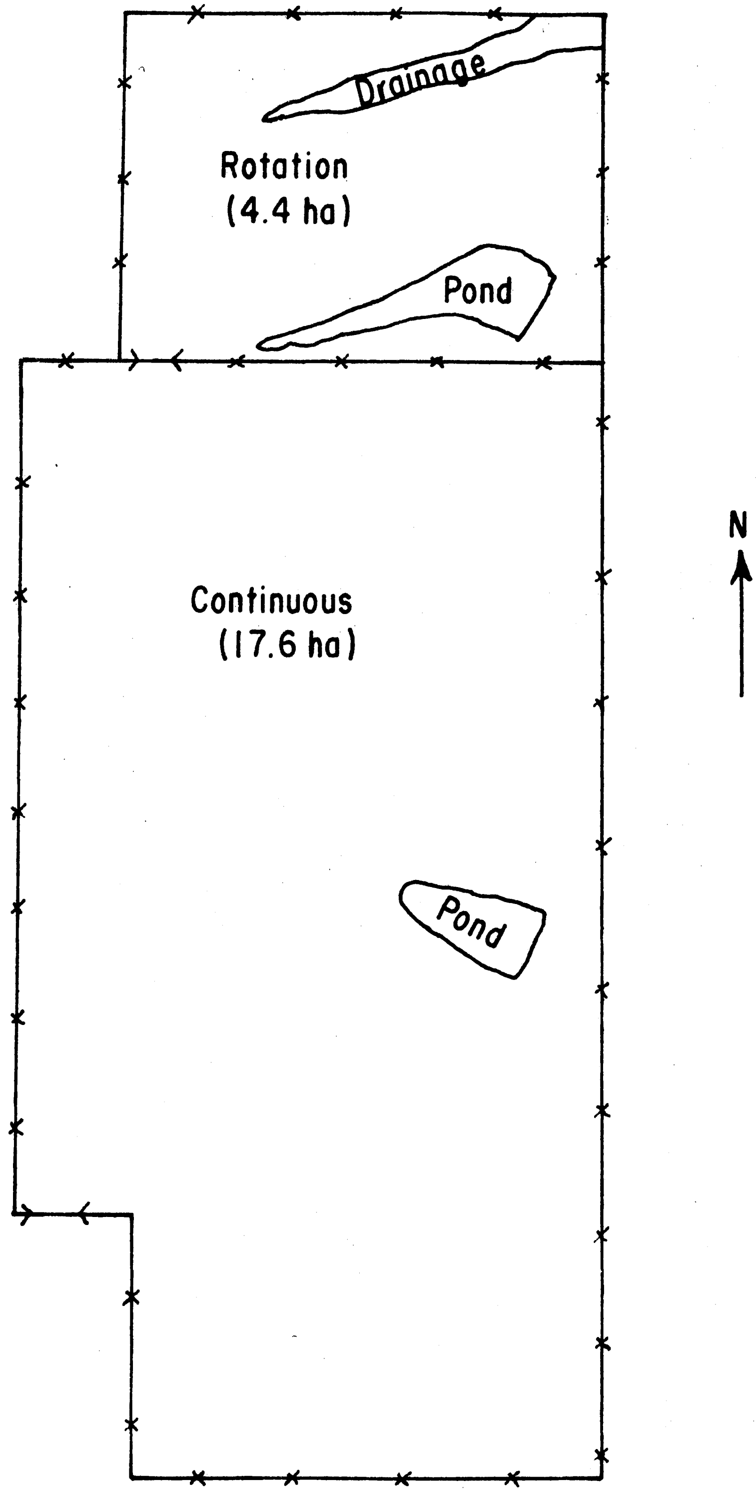

Figure 6. Livestock grazing areas.

days at the beginning of the grazing trial, rested for 40 to 60 days, grazing again for 14 days and then rested for the remainder of the growing season. The large "continuous" paddock of 17.6 ha was 80% of the total area and was grazed when the rotation paddock was rested. Water, shade and salt were available in each paddock. The cattle had access to both the continuous paddock and rotation paddock in the winter until excluded from the rotation paddock at the beginning of the growing season.

Experimental Design and Treatments

In 1973 a randomized block design was used with 24 plots, each 27 x 30 m, assigned to 3 replications in the rotation paddock (Fig. 7). Three similar plots were located in the continuous paddock near the rotation paddock. In 1975 a randomized block design was used with 12 plots, each 27 x 30 m, assigned to 3 replications in the continuous paddock.

In 1973, eight treatments were applied to plots in the rotation paddock. These treatments included 1) untreated (ONU), 2) fertilizer applied at a rate of 56-45-0 (FNU), 3) a mixture of 1.12 kg 2,4-D per hectare plus 0.56 kg picloram per hectare (OHU), 4) a broadcast seeding of plains bluestem (*Bothriochloa ischaemum*) on April 18, 1973, at a rate of 1.7 kg PLS per hectare (ONS), 5) fertilizer plus herbicide (FHU), 6) fertilizer plus seeding (FNS), 7) herbicide plus seeding (OHS), and 8) fertilizer plus herbicide plus seeding (FHS). The three plots in the continuous paddocks were untreated.

In 1974 only fertilizer was applied to appropriate plots. In 1975 fertilizer was applied for the third consecutive year at the same rate

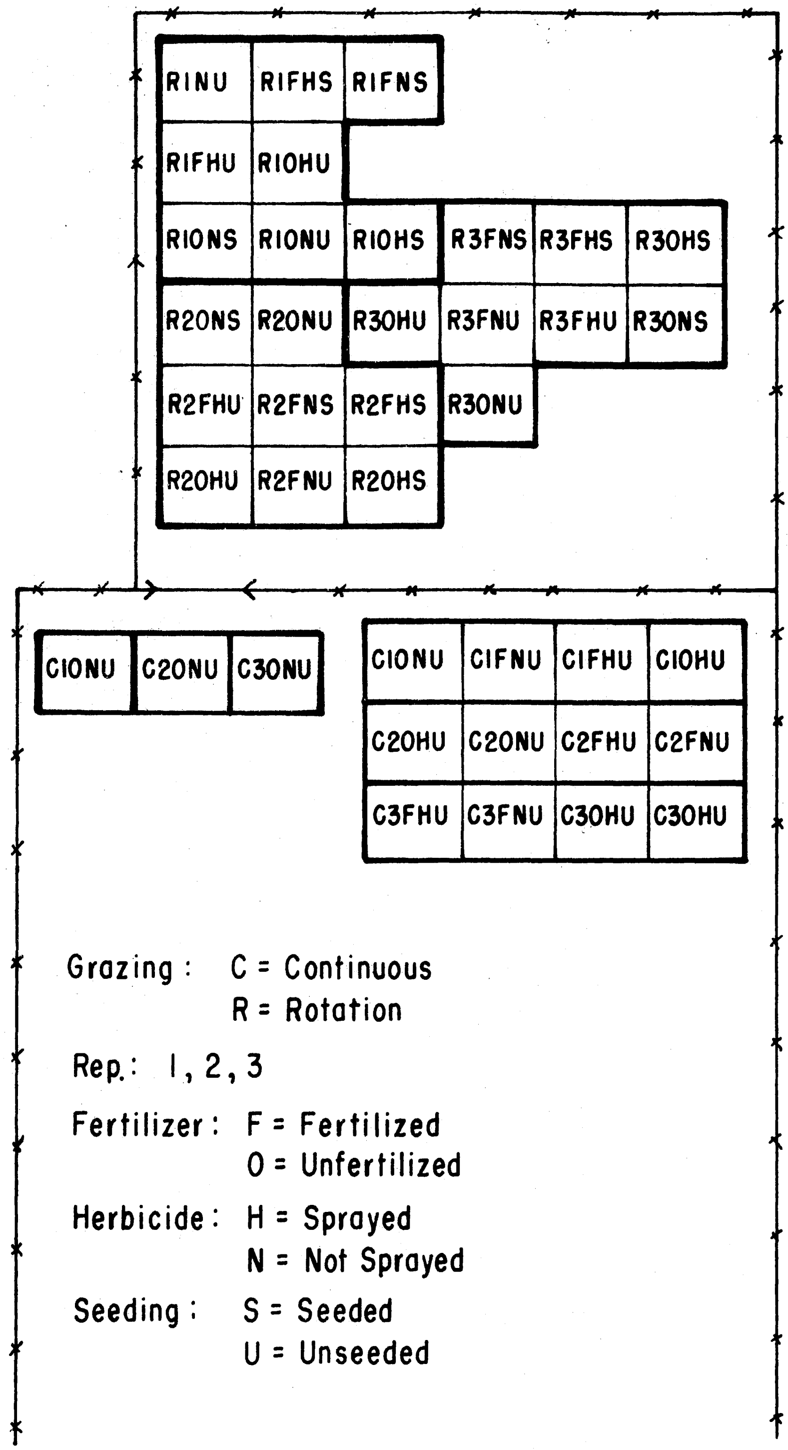

Figure 7. Location of replications and types of treatments in study area.

as before. The herbicide plots were retreated with only 2,4-D at a rate of 0.56 kg/ha. Four treatments were applied to the 12 plots in the continuous paddock. These included 1) untreated (ONU), 2) fertilizer (FNU), 3) 0.56 kg 2,4-D per hectare (OHU), and 4) fertilizer plus herbicide (FHU).

Fertilizer was applied at a rate of 56 kg nitrogen (ammonium nitrate, 33-0-0) per hectare and 45 kg phosphate (superphosphate, 0-46-0) per hectare on April 18, 1973, April 17, 1974, and May 28, 1975. The fertilizer was applied with a manually operated, crank-type mechanical spreader. Herbicides were applied using a tractor-mounted tank developing 2.82 kg/cm^2 pressure with a 6-m boom containing 12 nozzles (size 8002) spraying 112 l/ha. Herbicide application dates were May 22, 1973 and June 24, 1975 on plots in the rotation paddock and June 9, 1975 on plots in the continuous paddock. Time of herbicide application in 1975 in the rotation and continuous paddocks was adjusted so each was sprayed following removal of cattle. This procedure was initiated after research by Hammond et. al. (1974) showed grazed desirable forbs were less susceptible to 2,4-D than ungrazed forbs.

Vegetation and Soil Sampling

Two, 0.5 m^2 sub-plots were randomly selected within each plot for sampling vegetation and soil. Vegetation species composition and production was determined using the weight estimate (Pechanec and Pickford 1937) and double sampling (Wilm et. al. 1944) method. The field weight of each species within each 0.5 m^2 quadrant was estimated after an appropriate training period. The collective weight of all species present was also estimated for each sub-plot sample. One of the two sub-plots was randomly selected for clipping and the vegetation in this sub-plot was clipped at a 5-cm stubble height, bagged and weighed immediately to determine field weight of the total herbage.

Soil temperature was determined and a soil sample was collected at each of the clipped sample locations. Weather data were also determined when each vegetation sample was clipped.

Field activities and their chronological sequence are indicated in Figure 8. This figure includes all grazing, treatment applications and sampling activities performed during the three year study.

Laboratory Analyses

The clipped herbage samples were placed in a drying oven at $45^{o}C$ for 48 hours to determine the dry weight of the sample and dry matter content (%) of the sample. The dried samples were ground with a Wiley mill and 1-mm mesh screen. These samples were then analyzed for kjeldahl nitrogen content using a micro-kjeldahl digestion unit and a nitrogen analyzer (OSU Soil and Water Testing Laboratory, Unpublished procedures).

Soil samples were dried in a drying oven at $45^{o}C$ for 48 hours and ground. These samples were then analyzed by the OSU Soil and Water Testing Laboratory for pH, organic matter, extractable phosphate, potash and calcium.

Data Compilation and Statistical Analyses

Measurements of weather, soil factors, species and herbage weights were recorded on location on data forms prepared to facilitate key-punching data cards directly from the field data forms. Examples of

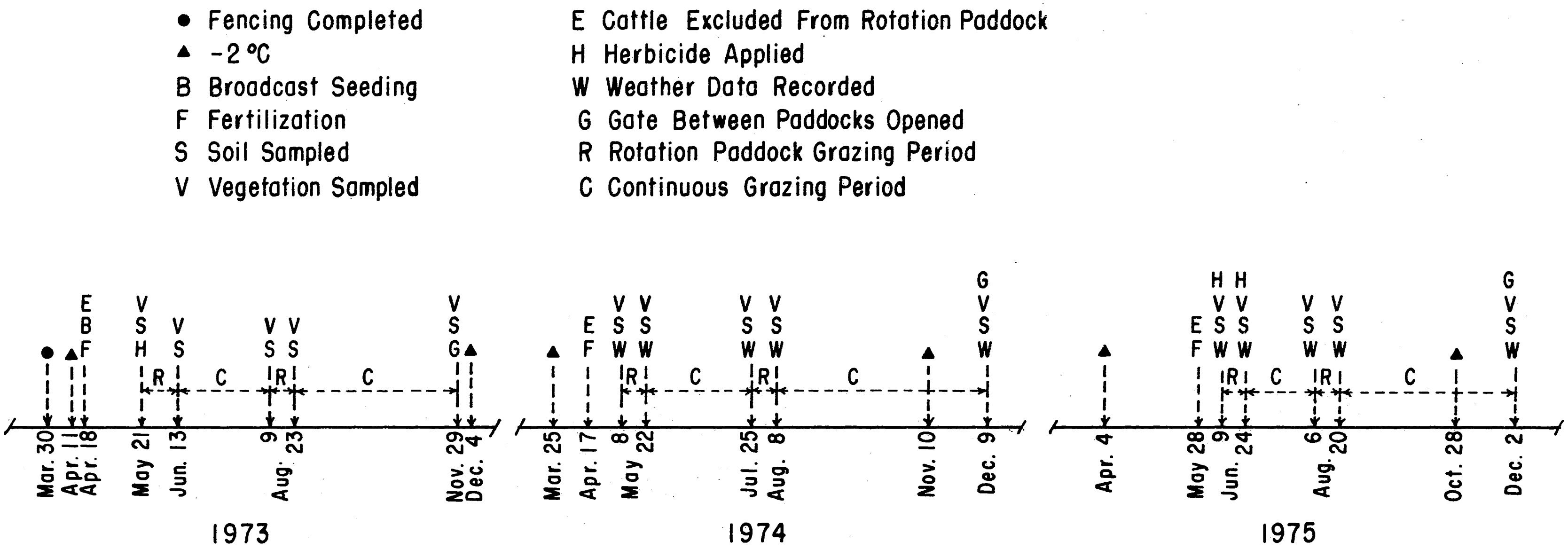

Figure 8. Chronological sequence of grazing, treatment applications and sampling activities in study area.

the data forms are shown in Appendix C. Data were stored and processed by the Oklahoma State University IBM 370/158 Computer. Statistical analyses were conducted using SAS 72 (Barr and Goodnight 1972). Computer input programs for each year are printed in Appendices D to G. The SAS 72 procedures are printed in Appendix H. Statistical comparisons (Steel and Torrie 1960) were made only for replicated treatments within the same paddock. No tests of response differences in different paddocks were made. Regrowth rates (kg/ha/day) of vegetation were determined by dividing the difference (kg/ha) in standing plant biomass at the end of one grazing period and the beginning of the next grazing period in the same area by the number of days in the regrowth or ungrazed period. The first and third regrowth periods were for the continuous paddock and the second and fourth periods were for the rotation paddocks.

Although introduced bluestem plants were established from seed on the seeded areas, all died by 1974. Therefore, data from the seeded plots were combined with data from the four comparable, but unseeded plots in 1973 and 1974. Seeded plots were not sampled in 1975, nor was broadcast seeding attempted in the continuous paddock. Whether the seedlings died because of grazing, competition from existing vegetation or natural environmental factors is unknown. Stand establishment appeared to be successful in 1973. However, the seedlings were observed to be closely grazed. Perhaps the seedlings would have survived if they had been protected from grazing for one or two growing seasons.

CHAPTER V

RESULTS AND DISCUSSION

Weather

Precipitation during the study period was very erratic in frequency and amounts (Fig. 9). The week of greatest rainfall (200+ mm) occurred in September, 1973. Heavy rains fell the last of May and second week in August, 1974 with very little rain in June and July. Except for May and June, most of the growing season in 1975 was dry with no weeks of very high rainfall.

Each year of the study period was progressively drier than the year before. In 1973, 24 weeks had 10 mm or less rainfall and 29 weeks had less than 20 mm. In 1974, 30 weeks had 10 mm or less and 35 weeks had less than 20 mm. In 1975, 33 weeks had 10 mm or less and 38 weeks had less than 20 mm.

Temperature during the spring and fall of the growing period was also more favorable in 1973 than 1974 and more favorable in 1974 than in 1975 (Fig. 9). The absolute minimum temperature was generally greater than $0^{o}C$ from March 1 through October with more than average rainfall in March. This allowed warm season plants to begin growth earlier than usual. Rainfall was also greater than average in March, 1974, but mid-March temperatures were much below $0^{o}C$. The absolute maximum temperature was also very low for a short period in late March

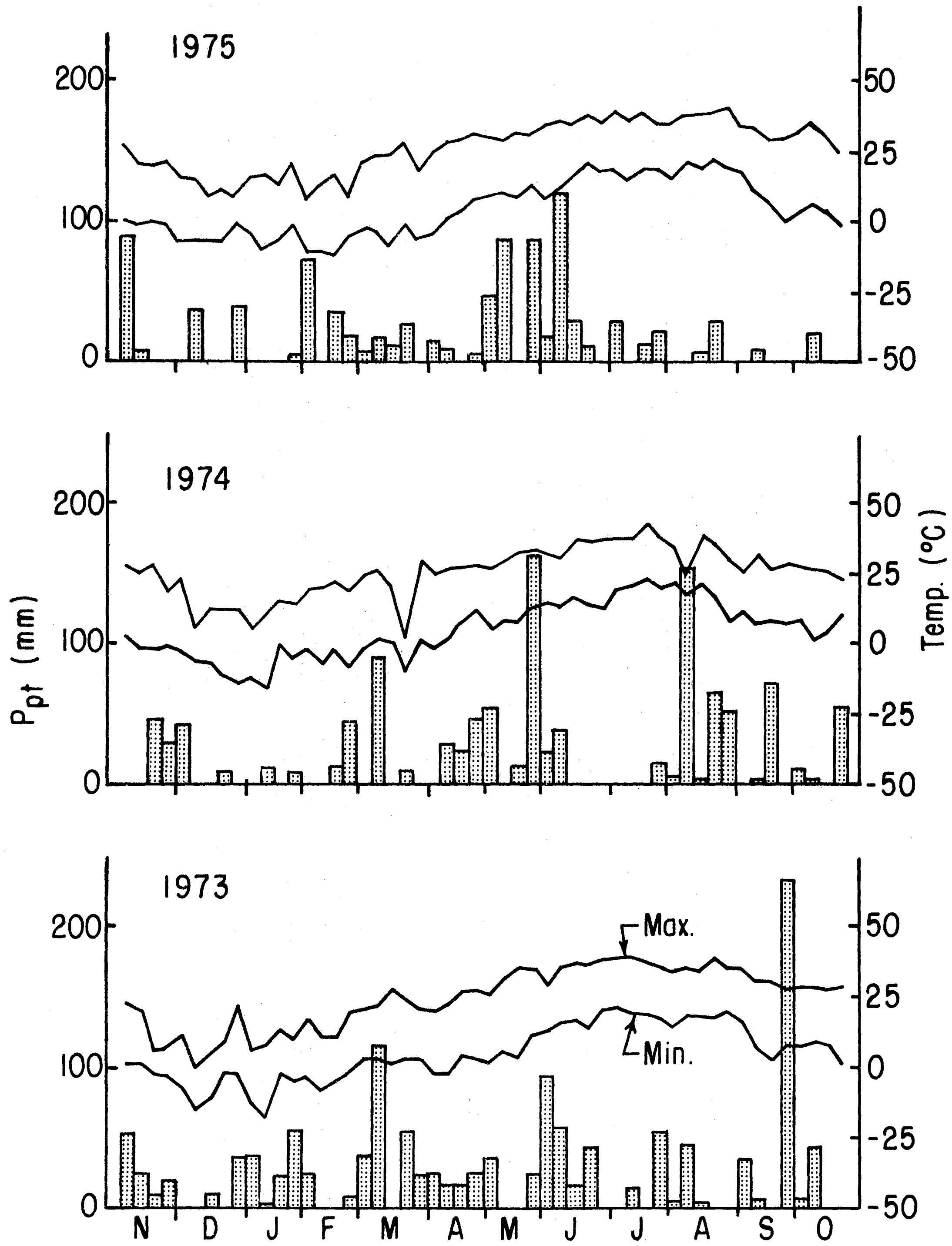

Figure 9. Weekly precipitation (mm) and absolute maximum and absolute minimum temperatures (°C) for study area.

of 1974. The absolute minimum temperature did not remain above $9^{o}C$ until mid-April in 1975 and decreased again to $0^{o}C$ in late September.

Wind conditions during the study period were about average except during 1975 when spring winds were greater than average, and summer winds were less than average (Fig. 10). Relative humidity conditions, especially the average minimum, were more erratic between months and years. In general the relative humidity reflected periods of high or low precipitation. Examples of this relationship are evident in September of 1973, July of 1974, and summer and fall of 1975 (Fig. 9 and Fig. 10).

Poor growing conditions caused by low rainfall during the growing season are further compounded by high winds, high temperature and low humidity. Rainfall amounts may not accurately reflect growing conditions if soil moisture from adequate rainfall is rapidly lost because high winds and temperature and low humidity cause excessive evapotranspiration.

Precipitation class distribution. - In an effort to better understand the precipitation distribution during the study period, the amount of precipitation contributed by all precipitation events within each week was summed to derive weekly precipitation. The 52 weeks in each year were then assigned to different weekly precipitation classes. Each class had a range of 10 mm. Since factors such as temperature, wind movement, relative humidity, rainfall intensity, antecedent soil water content, infiltration rate, interception, ground cover and soil texture influence the difference between precipitation and effective soil water used by rangeland plants (Branson et. al. 1972, Brown 1977), the distribution of annual precipitation by precipitation classes is an

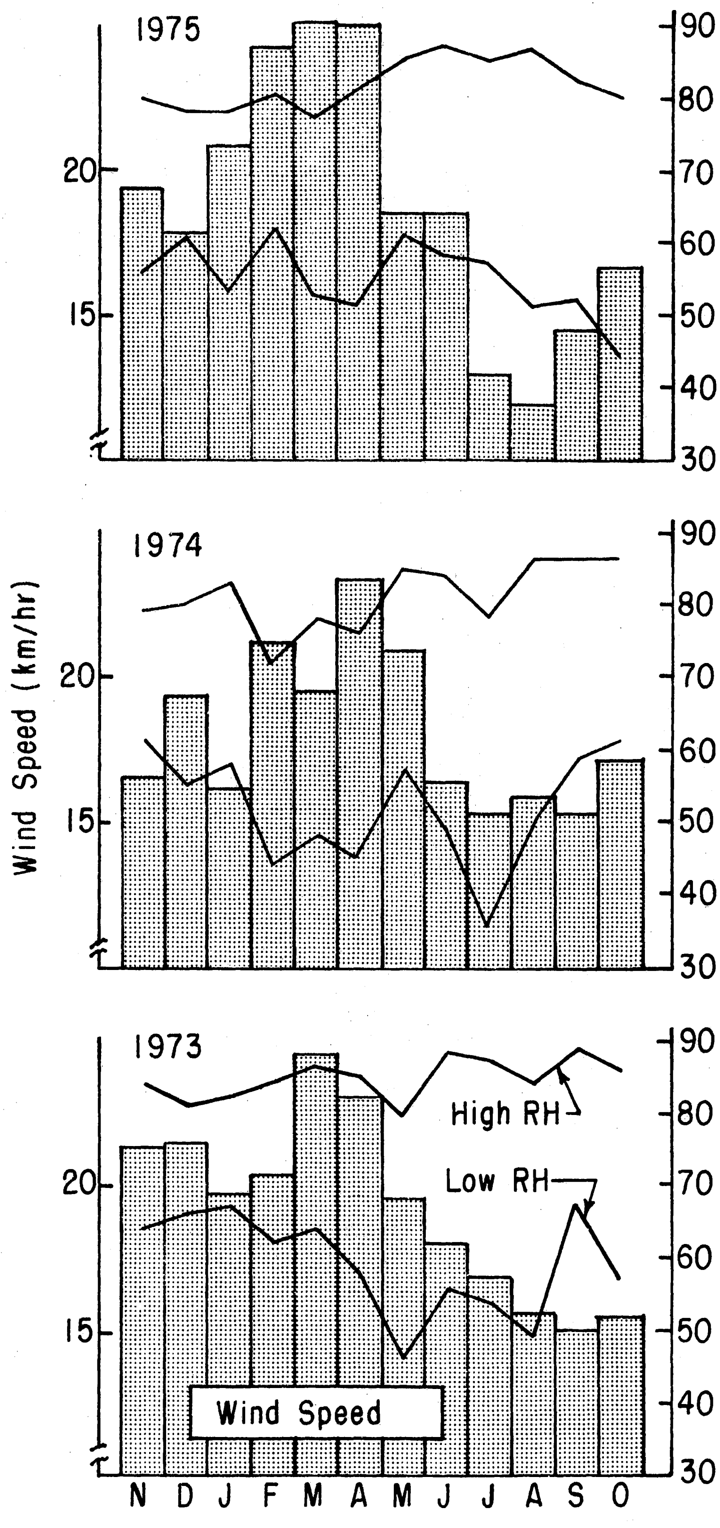

Figure 10. Monthly average wind speed (km/hr) and monthly high and low relative humidity (%) for Oklahoma City, 133 km south of study area.

important consideration. Weekly rather than daily amounts were arbitrarily chosen to facilitate presentation and discussion of data.

Less than 10 mm of precipitation fell during almost half or more of the weeks during each year of the study period (Fig. 11). The number of "dry" weeks varied each year from 24 in 1973 to 33 in 1975. All three years had five weeks with 11-20 mm precipitation and from 4 to 7 weeks with 21-30 mm precipitation.

Except for the three weeks receiving more than 100 mm precipitation, the distribution of 20-, 30-, 40-, 50- and 60-mm precipitation classes was relatively uniform in 1973. The greatest amount of precipitation received in a single week was 232 mm in 1973, 162 mm in 1974 and 118 mm in 1975. In general, weather conditions causing convection or frontal storms were most common in 1973 and least common in 1975.

The effect of precipitation in different precipitation classes on total annual precipitation is shown in Figure 12. The total amount of moisture contributed by precipitation classes of 50-mm or less (440-600 mm) was similar for all three years. The large difference in annual precipitation between the three years was primarily because of the number of weeks with more than 50 mm of precipitation and the amounts received during these weeks.

In 1973, five weeks with 51-60 mm contributed 280 mm and three weeks with over 60 mm contributed 450 mm precipitation. In 1974, three weeks with 51-60 mm contributed 165 mm and five weeks with over 60 mm contributed 550 mm precipitation. In 1975, only five weeks had over 50 mm and the total amount added during these weeks was 425 mm.

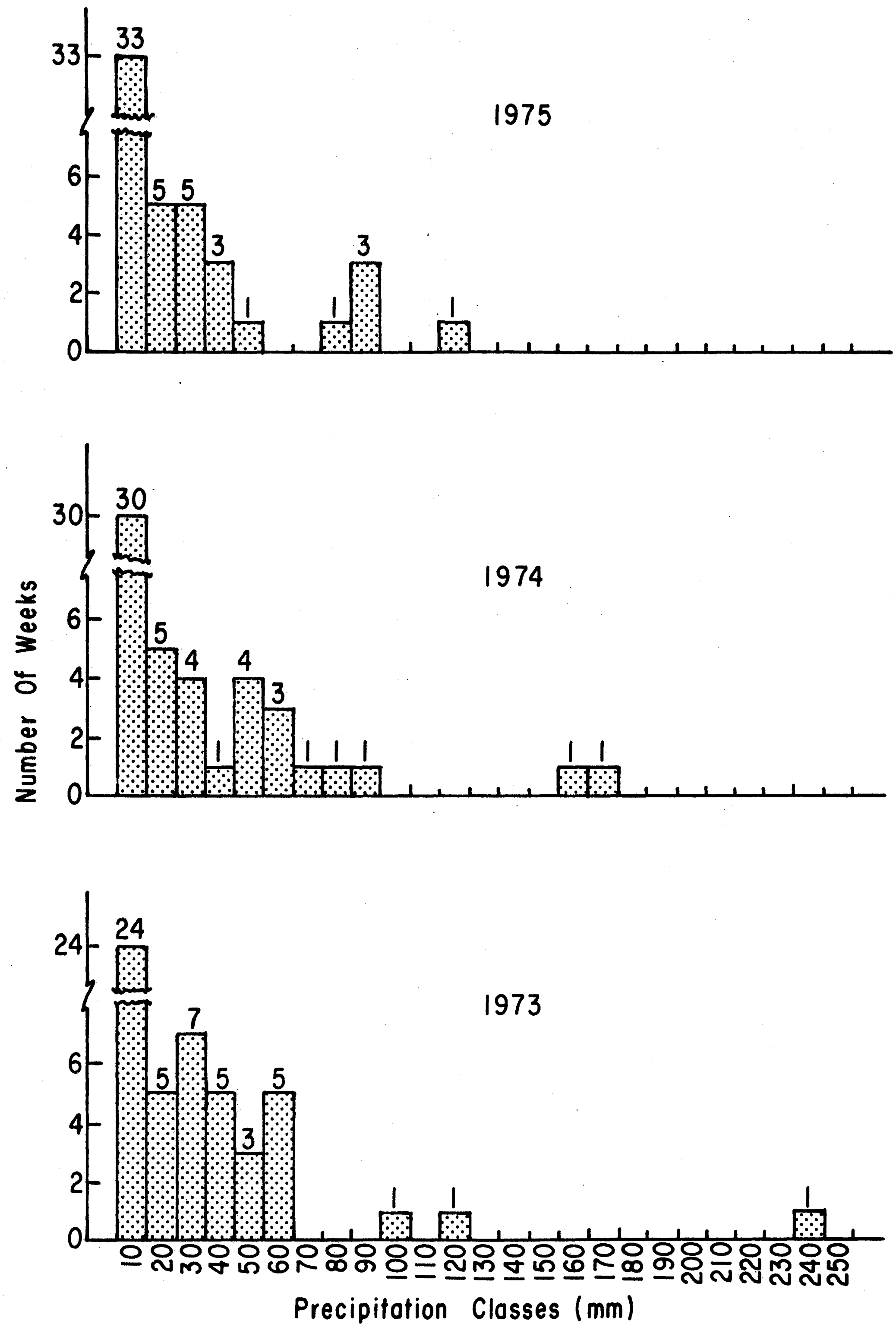

Figure 11. Distribution of annual precipitation by weekly precipitation classes.

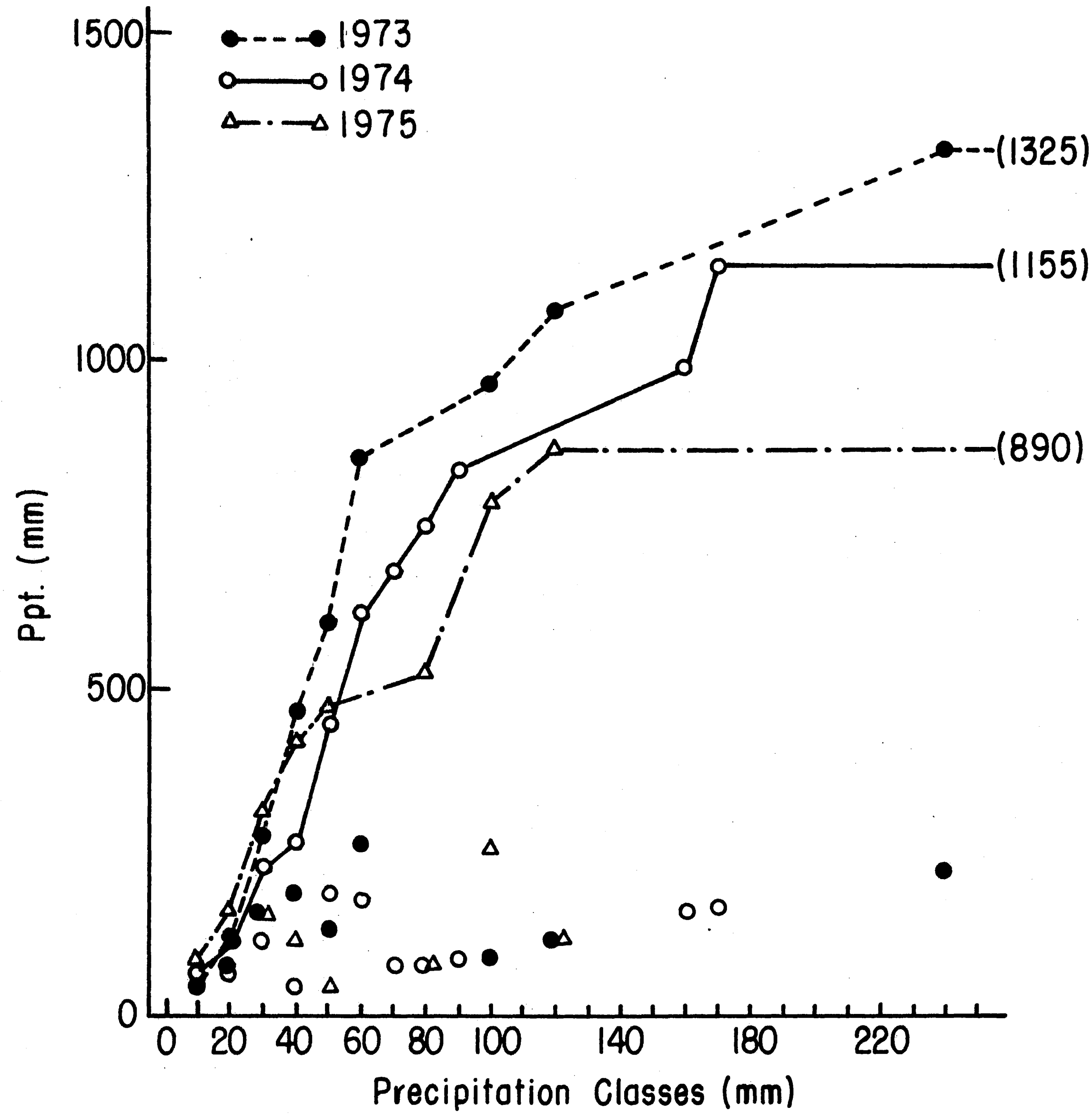

Figure 12. Annual accumulative precipitation (mm) and amounts contributed by different weekly precipitation classes.

Although the precipitation classes are arbitrary and could be defined in other combinations of precipitation events, it is evident a small number of periods or events contribute a significant portion of total precipitation. Additional research should be conducted to determine the effects of different amounts of precipitation within various periods on plant growth rate, subsoil water recharge, and the proportion of precipitation retained as available soil water. This information would greatly facilitate interpretation of rangeland vegetation responses to different grazing and range improvement treatments.

Soil water content. - The soil water content during the study was closely related to season and rainfall distribution (Table 2). In all three years soil water content was relatively high in the spring and very low at some time during the summer.

Table 2. Soil water content (%) for untreated areas on different sampling dates, Billings.

1973		1974		1975	
Date	Soil Water	Date	Soil Water	Date	Soil Water
May 21	11 b[1/]	May 8	21 b	June 9	28 d
June 13	18 c	May 22	22 b	June 24	19 c
Aug. 9	20 d	July 25	6 a	Aug. 6	5 a
Aug. 23	6 a	Aug. 8	8 a	Aug. 20	6 a
Nov. 29	31 e	Dec. 9	29 c	Dec. 2	11 b

[1/] Those values in the same column followed by the same letter are not different at the 5% level of significance.

In 1973 the soil water content was only 11% on May 21, but was greater on the next two sampling dates, June 13 and August 9. The potential high rate of soil water extraction by evapotranspiration was indicated by the large difference in soil water content in the surface 3 dm of soil at the beginning and end of a 14-day period in August. The soil water content in the surface 3 dm of soil decreased from 20% on August 9 to 6% on August 23.

The rapid decrease in soil water may have occurred during other months in 1973 and in 1974 and 1975. However, determination of soil water content was too infrequent to detect in 1974 and 1975 the rapid decrease that occurred in August, 1973. In 1974 soil water content was 22% on May 22 and 6% on July 25. The soil water decrease due to evapotranspiration during this 64-day period effectively included most of the soil water in the surface 3 dm on May 22 and all of the soil water recharge in the surface 3 dm from rainfall during this period. In 1975 a similar decrease in soil water content occurred during the 43-day period between June 24 and August 6. In order to better understand the relationships between soil water content, vegetation growth, evapotranspiration loss and soil water recharge from precipitation during the growing season, frequent monitoring (e.g., weekly) of soil water content and live plant biomass should be conducted for different weather-soil-vegetation combinations.

Untreated Areas

Spring production and species composition. - Herbage production and species composition determined in the rotation grazing area before the first grazing period was similar in 1973 and 1974, but not in 1975

(Fig. 13). In 1975 growth was relatively late; however, once rapid growth began, it was much more rapid than expected. Consequently, the vegetation was sampled 10-14 days later than the phenological stage sampled in 1973 and 1974. The date of range readiness in 1975 was probably between May 28 and June 1.

Visual assessment was used to estimate phenology and "range readiness" (Society for Range Management 1974) in the spring of each year. Range readiness in this study was considered to be the amount of green forage available to sustain the cattle for a 14-day grazing period with a 300-500 kg/ha residue after grazing. The residue was based on recommendations of Bement (1969) and adjusted upward because of the greater expected herbage production on the study area.

The variation in range readiness dates during this study was a good example of the need to closely monitor range readiness when seasonal grazing is planned. Additional research is needed to determine the optimum amount of forage production for initiation of spring grazing and the optimum amount of grazing residue to maintain on an area for maximum growth and forage quality during all seasons.

At the time of range readiness, grasses produced 70 to 75% of the total herbage. Cool season annual grasses, primarily Japanese brome (Bromus japonicus) and little barley (Hordeum pusilium), were the most abundant grasses. They produced about one-half of the total herbage when sampled on May 8, 1974 and about one-third when sampled on June 9, 1975. Although grasses were not sampled by species in 1973, cool season annual grasses were the most abundant plants in all three years. Since the forage quality of cool season annual grasses is high during their vegetative stage and their growth period is relatively brief,

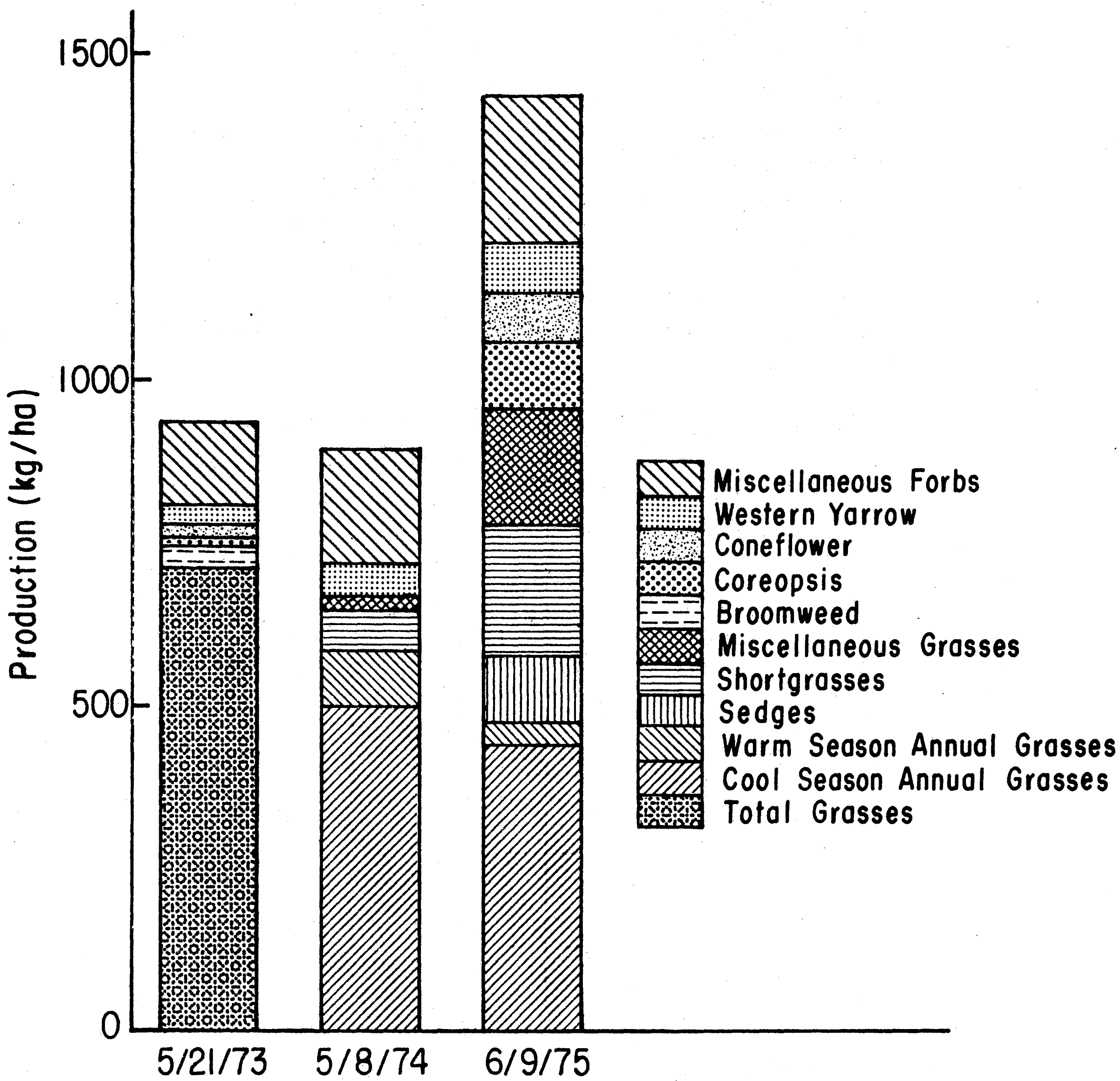

Figure 13. Spring dry matter production (kg/ha) by species classes on untreated areas. Grass species were not differentiated in 1973.

optimum utilization of cool season annual grasses requires frequent monitoring of plant growth and livestock utilization.

Spring herbage production contained 8 to 10% sedges (Carex spp.) and were observed to be utilized by the cattle. Production by shortgrasses was much greater in June, 1975 than in May, 1974. It is not clear how much of the difference was due to temperature and soil water conditions and how much was due to differences in daylength.

The most abundant spring forbs were common broomweed, plains coreopsis, prairie coneflower (Ratibida columnifera), and western yarrow. The relative abundance of the various species varied each year. Broomweed was common in 1973, but rare in 1974 and 1975. Plains coreopsis and prairie coneflower were much more abundant in 1975 than in 1973 and 1974. At least one-half or more of the spring forb production was produced by a multitude of short-lived spring forbs.

Regrowth. - The rate (kg/ha/day) of herbage regrowth after grazing was relatively similar in the spring, early summer and fall of the three years and variable during mid and late summer (Fig. 14). Although the grazing system produced only four separate regrowth periods each year, a comparison of regrowth in all periods and all years indicates spring and early summer regrowth rates are more predictable than those in mid and late summer. The first two regrowth periods in 1973 and 1974 produced from 20 to 25 kg additional herbage per hectare per day. In 1975 the regrowth rate was 29 kg/ha/day during the first period (mid-June) and 15 kg/ha/day during the second period (late June to early August).

The third regrowth period was in late July or August all three years and varied from 59 kg/ha/day in 1973 to -6 kg/ha/day in 1974. A

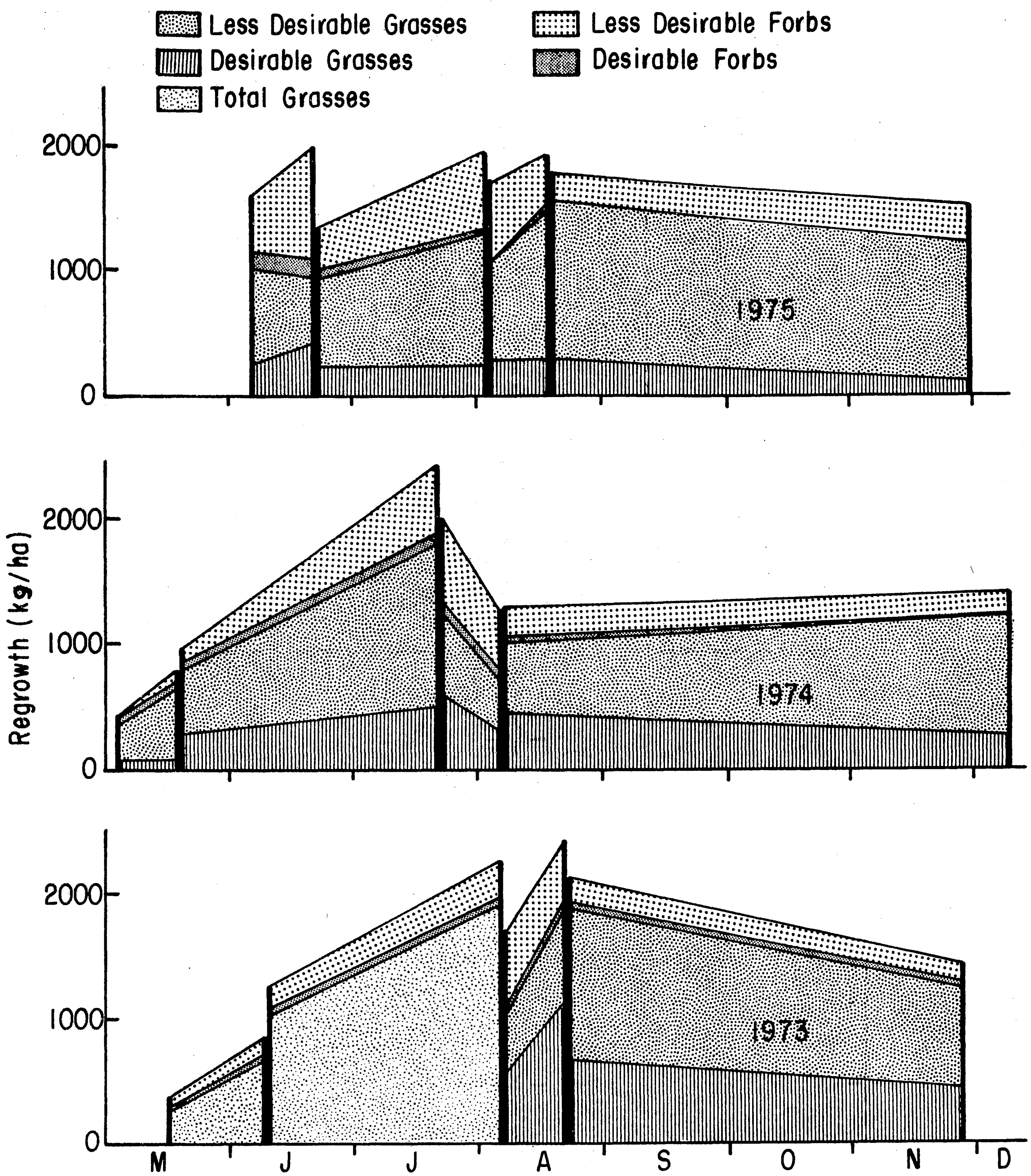

Figure 14. Herbage growth (kg/ha) of the different species classes on untreated areas during four regrowth periods in the three years of the study. Grass species were not differentiated for the first two periods in 1973.

review of Figure 9 indicates that late summer regrowth rates were closely related to rainfall amounts and distribution. The difference in plant biomass at the beginning and end of the fourth regrowth period was negligible. Either little or no regrowth occurred or the regrowth that was produced by some species or at some time was negated by deterioration of other species or at other times during the long period.

Although these results were determined under variable grazing and growing conditions, they do indicate certain relationships that warrant additional research. A longer (6-10 years) study utilizing more and shorter regrowth periods and determining regrowth rates for key species during the growing season would provide useful information for rangeland grazing managers. This kind of information would allow grazing plans to be formulated with greater confidence in their success than now exists.

The regrowth rate of each species class in the first and second periods in 1973 and 1974 was relatively consistent. The highest regrowth during these periods and years was for less desirable grasses, primarily because these plants were most abundant at the beginning of each period. In May the less desirable grasses were predominantly cool season annual grasses. After mid-June most of the less desirable grasses were the lower successional warm season annuals, such as threeawn (*Aristida* spp.) and perennials, such as silver bluestem (*Bothriochloa saccharoides*).

During the third period the regrowth rates of both desirable and less desirable grasses were positive and high in 1973 and negative in 1974. The regrowth rate for less desirable forbs was negative during this period all three years with the greatest decrease (-16 kg/ha/day) in 1975.

In 1975, the regrowth rates varied widely between species classes and for each species class between different regrowth periods. Desirable grasses increased (11 kg/ha/day) the first period, but very little in succeeding periods. Regrowth rates between the first and third period for less desirable grasses was equal in magnitude but opposite in trend for those of less desirable forbs. The regrowth rate for less desirable grasses was -16 kg/ha/day in the first period and 31 kg/ha/day in the third period. Conversely, the regrowth rate for less desirable forbs was 32 kg/ha/day in the first period and -16 kg/ha/day in the third period. Apparently growing conditions favorable for plants in one species class were not favorable for plants in the other species class.

Crude protein and plant water content. - As expected, both crude protein and plant water contents decreased all years as the growing season progressed (Fig. 15). However, the interrelationships between protein, plant water and time were not consistent all years.

Protein content declined rapidly in the spring and early summer of 1973 and 1974. The decline between August and December, 1973 was much more gradual. Protein determinations were not made for the December, 1974 samples. Protein content declined in June, 1975, increased slightly between June and August, and then decreased between August and December. The winter herbage protein content in 1973 (5.1%), a relatively wet year was lower than that in 1975 (6.5%), a relatively dry year. Protein contents in mid and late season, 1975 were generally higher than those on similar dates in 1973 and 1974.

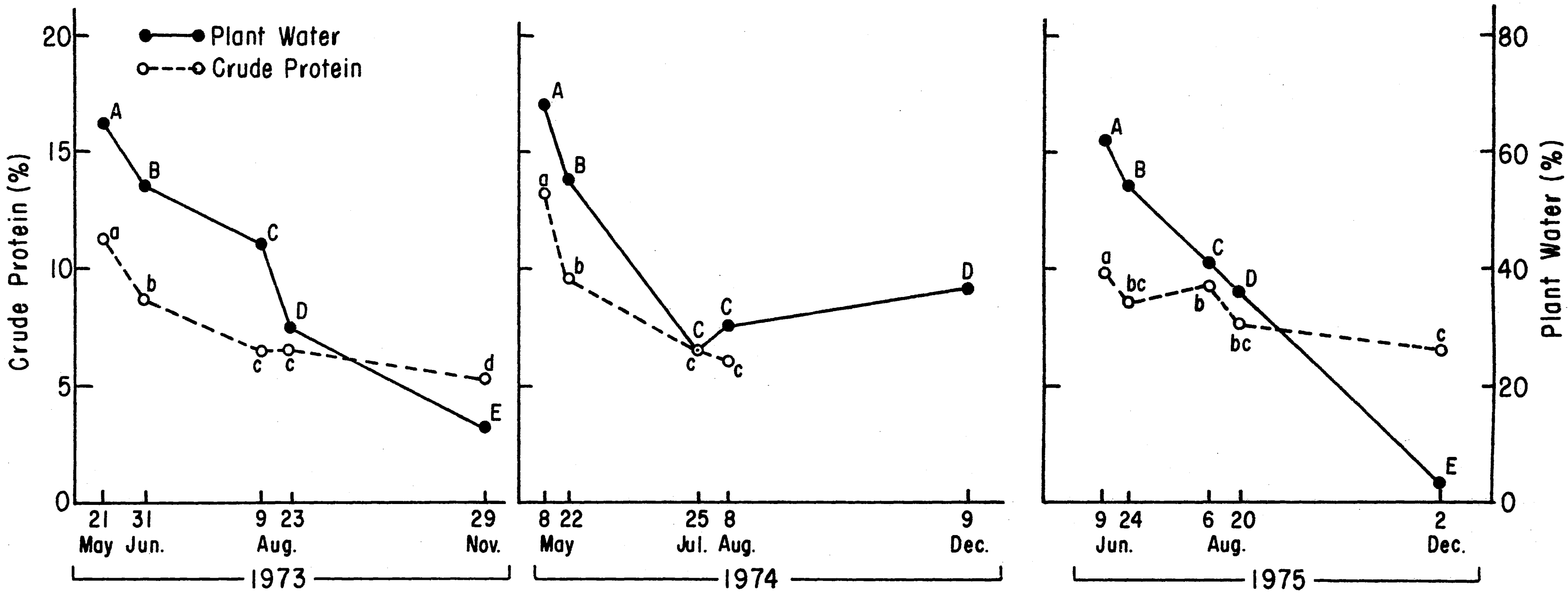

Figure 15. Crude protein (%) and plant water content (%) in herbage on untreated areas, Billings. Within each year, those values for crude protein or plant water content with the same letter are not different at the 5% level of significance.

Decrease in plant water content with time was very consistent in 1973 and 1975. In 1974 plant water content decreased between May 8 and July 25 then increased slightly between July 25 and December 9. The increase in plant water content between late July and early December coincided with several weeks of moderate (50-75 mm) or high (100+ mm) precipitation amounts during this time. After the mid-summer drought, the shortgrass vegetation responded with additional succulent growth in late summer and fall.

Although results from this study indicate certain general trends in crude protein and plant water contents during the growing season, it is also evident weather conditions during this time can significantly modify these trends. Plant water contents were very similar on the first sampling date. Crude protein contents were variable on the first sampling date, but more consistent on the final sampling date.

Treatment Effects

Spring production and species composition. - Fertilization was the only treatment evaluated in regard to spring production because herbicides were applied after grazing. Fertilization greatly increased production of all species classes in 1973 and 1974 (Fig. 16). For most species classes, production was doubled by fertilization. In 1975 there was little or no difference in production for any species class.

The production response to fertilization was determined 33 days after fertilization in 1973, 20 days after in 1974 and 11 days after in 1975. Even though the response time was less in 1974 than in 1973 the relative production response rate was greater in 1974. The difference in production (840 kg/ha) between fertilized and unfertilized areas in

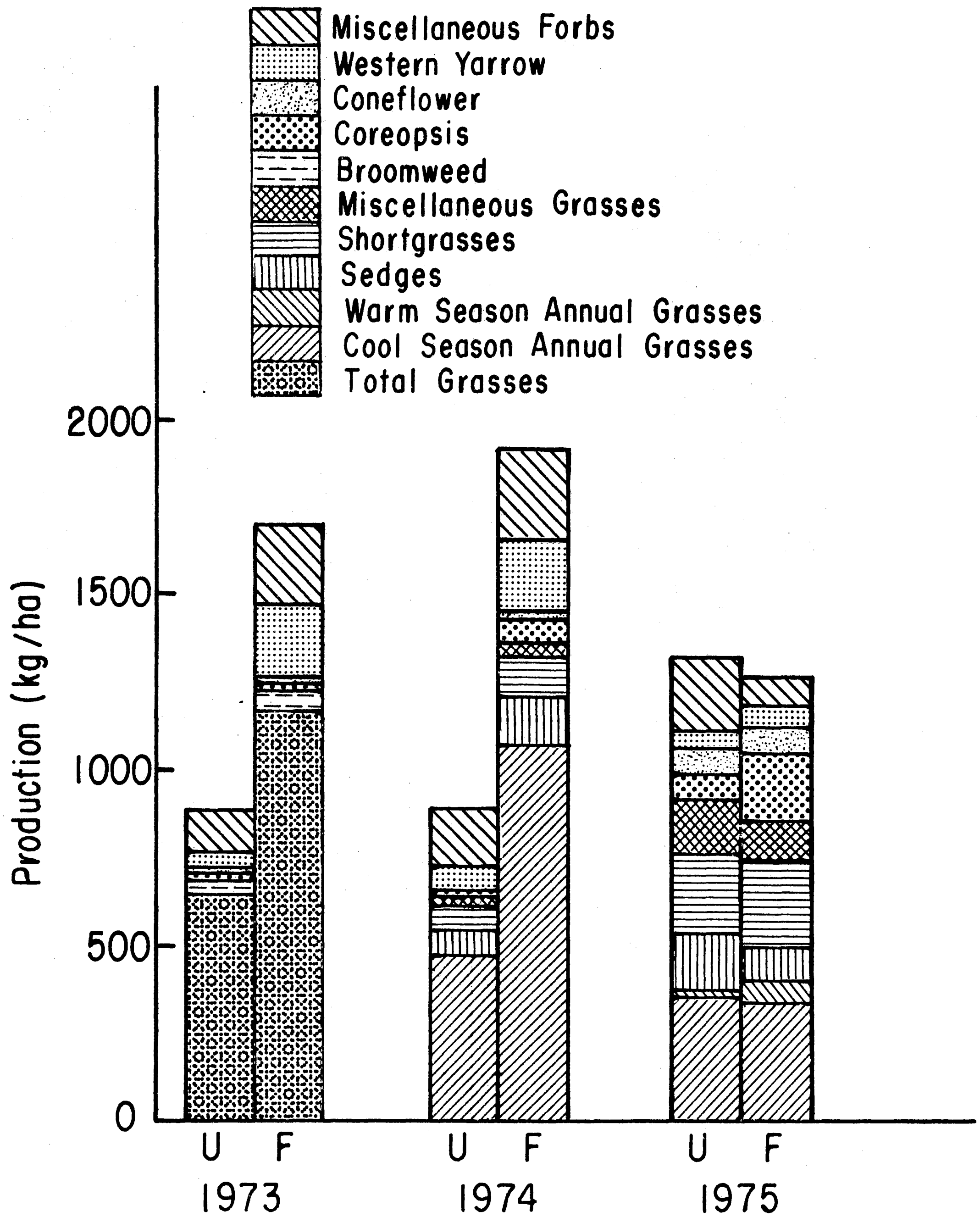

Figure 16. Spring herbage production (kg/ha) and species composition response to unfertilized (U) and fertilized (F) areas.

1973 was produced at a rate of 25 kg/ha/day, while that (1020 kg/ha) in 1974 was produced at a rate of 51 kg/ha/day. There was no response to fertilization in the 11-day period in 1975.

These results indicate a very great response potential of rangeland plants to fertilization in the spring when growing conditions are favorable. Although the 1975 plant production response to fertilization in the relatively short 11-day period was negligible, it does accentuate the need to determine "favorable" growing conditions. If favorable growing conditions, including daylength, air and soil temperature, soil water content, and plant carbohydrate reserves, were known or could be predicted, the economics and management opportunities would be greatly improved. Since spring forage quality is very high, it might be advantageous to fertilize and graze a relatively small unit of rangeland and defer the remainder of the unfertilized area until later in the season when proper use of the fertilized area was attained.

The lack of spring plant production response to fertilization in 1975 also raises the questions of which conditions are favorable for root activity and are these conditions also favorable for plant top growth. Rainfall and soil water between the date of fertilizer application and production determination were high and seemed to be favorable. Root absorption of fertilizer nutrients was apparently active because the fertilized plants had a much darker green to blue color, characteristic of fertilized plants. The crude protein content of the fertilized plants was also much higher than that of the unfertilized plants. Perhaps fertilization research under controlled greenhouse or growth chamber conditions would answer some of the questions.

Soil chemical composition. - There was a trend for fertilization and herbicide applications to reduce pH but the degree of reduction and level of probability varied among years (Table 3). Some of the inconsistency may have been caused by sampling at different seasons in different years. All sampling dates in five consecutive years with the corresponding values ($\bar{X} \pm$ sd) for different soil factors are presented in Table 4.

Soil pH was lower in the areas receiving a fertilizer treatment in 1975 ($P < .01$) and a herbicide application in 1973 ($P < .04$) and 1976 ($P < .06$). The lower soil pH after fertilization with nitrate fertilizer was as expected since similar results have been obtained by Black and Wright (1972) and Smika et. al. (1961). The lower soil pH after application of 2,4-D and picloram in 1973 may have been a direct effect of herbicide chemicals on the soil or an indirect effect caused by changes in root chemical composition during or after the death or injury of forbs.

Fertilizer and herbicide application had little or no effect on soil organic matter content. However, the data indicate a slight increase in organic matter content in soil receiving either fertilization or herbicide treatments. Soil organic matter content was slightly higher ($P < .17$) on those areas that received a herbicide application in 1974 and slightly higher ($P < .17$) in 1976 by fertilization. In these two years soil samples were collected for analyses only in early spring when soils were cool and contained a relatively high soil water content.

Soil phosphorus content was more than twice as great on fertilized areas as on unfertilized areas in the spring of 1976. Repeated

Table 3. Effects of fertilization and herbicide application on soil factors, Billings.

Factors	Year	Treatments[1/] ON	OH	FN	FH	Signif.[4/]	Treatments[2/] O	F	Signif.	Treatments[3/] N	H	Signif.
pH	1973	6.53	6.24	6.50	6.43	.09	6.45	6.47	.60	6.52	6.34	.04
	1974	6.17	6.22	6.22	6.07	.20	6.19	6.14	.60	6.19	6.14	.60
	1975	6.40	6.19	6.10	6.19	.06	6.30	6.14	.01	6.25	6.19	.57
	1976	6.29	6.20	6.17	6.12	.35	6.25	6.14	.32	6.23	6.16	.06
	$\bar{X}$	6.33	6.20	6.17	6.19	.18	6.28	6.18	.05	6.27	6.20	.15
Organic matter (%)	1973	2.38	2.50	2.38	2.33	.15	2.42	2.36	.94	2.38	2.42	.30
	1974	1.90	1.97	1.87	2.03	.79	1.93	1.95	.67	1.88	2.00	.17
	1975	2.26	2.16	2.29	2.21	.96	2.21	2.25	.57	2.27	2.18	.54
	1976	2.58	2.62	2.85	2.77	.63	2.60	2.81	.17	2.70	2.70	.89
	$\bar{X}$	2.28	2.25	2.35	2.30	.68	2.27	2.33	.15	2.31	2.28	.60
Phosphorus (ppm)		-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-
	1976	5.0	4.9	11.5	10.0	.12	5.0	10.8	.01	8.1	7.6	.68

1/ ON - Untreated; OH - Herbicide only; FN - Fertilizer only; FH - Fertilizer plus herbicide.

2/ O - (ON + OH)/2; F - (FN + FH)/2.

3/ N - (ON + FN)/2; H - (OH + FH)/2.

4/ Level of significance.

Table 4. Chemical composition ($\bar{X}$ ± sd) of study area soil during different sampling periods.

Year	Sampling Date	Sample Depth (cm)	No. of Samples	Fertilization Rate[1/]	Fertilization Date	pH	Organic Matter (%)	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)
1972	11/12	0-10	10	0	-	6.1±0.3	- [2/]	3.0±0.8	217±73	-
1973	5/21	0-30	9	0	-	6.4±0.4	2.2±0.2	4.1±1.2	199±28	1145±217
	5/21	0-30	6	F	4/18	6.4±0.3	2.2±0.2	6.5±3.2	192±31	1294±567
	11/29	0-30	9	0	-	6.5±0.5	2.7±0.5	11.1±19.4	257±41	1020 ± 56
	11/29	0-30	6	F	4/18	6.5±0.2	2.5±0.1	6.0±0.9	214±36	-
1974	5/8	0-30	15	0	-	6.2±0.2	1.9±0.2	-	-	-
	5/8	0-30	12	F	4/17	6.1±0.2	1.9±0.3	-	-	-
1975	6/9	0-30	12	0	-	6.2±0.4	2.4±0.2			
	6/9	0-30	12	F	5/28	6.2±0.3	2.3±0.4			
	6/24	0-30	12	0	-	6.5±0.7	2.3±0.3			
	6/24	0-30	12	F	5/28	6.1±0.1	2.3±0.3			
	8/6	0-30	12	0	-	6.3±0.4	2.1±0.3			
	8/6	0-30	12	F	5/28	6.2±0.1	2.2±0.4			
	8/20	0-30	12	0	-	6.3±0.5	2.2±0.2			
	8/20	0-30	12	F	5/28	6.0±0.2	2.2±0.3			
	12/2	0-30	12	0	-	6.2±0.5	2.1±0.3			
	12/2	0-30	12	F	5/28	6.2±0.2	2.1±0.3			
1976	4/26	0-10	18	0	-	6.2±0.2	2.6±0.3	5.0±1.2	266±53	1279±254
	4/26	0-10	18	F	-	6.1±0.2	2.8±0.4	10.8±5.1	280±58	1323±383
Average			111	0		6.3±0.4	2.3±0.3	5.8±5.6	235±49	1148±176
(1973-1976)			102	F		6.2±0.2	2.3±0.3	7.8±3.1	229±42	1309±475

[1/] 0 - Unfertilized; F - Fertilized. [2/] Not determined.

applications of phosphate fertilizer during the three preceeding years caused an accumulation of phosphorus in the soil. Differences in residual soil phosphorus content due to a fertilizer X herbicide interaction ($P < .12$) indicated less residual phosphorus on areas receiving both fertilizer and herbicide than on areas receiving only fertilizer. No explanation of this difference is apparent. A similar study involving both plant and soil analyses for phosphorus might determine if plant uptake of phosphorus affects residual phosphorus content since species composition was affected by fertilization and herbicide application.

Regrowth. - No treated areas were continuously grazed in 1973 and 1974 so regrowth values were not obtained in these years. However, both the continuous and rotation grazing areas were treated in 1975 and regrowth values were determined for all treatments and regrowth periods.

The fertilized vegetation regrowth rate during the 1973 second regrowth period (22 kg/ha/day) was slightly higher than that (19 kg/ha/day) for unfertilized vegetation (Fig. 14 and 17). The regrowth rates for fertilized and unfertilized grasses was similar, but the regrowth rate (10 kg/ha/day) of fertilized, less desirable forbs was more than twice that (4 kg/ha/day) of unfertilized, less desirable forbs. Whether the increased forb production during this period was additional growth on ungrazed forbs or regrowth on grazed plants, the fertilized forbs were more vigorous and made more efficient use of the added nutrients and soil water.

A similar difference in regrowth rates for unfertilized (7 kg/ha/day) and fertilized (11 kg/ha/day) forbs was evident in 1974

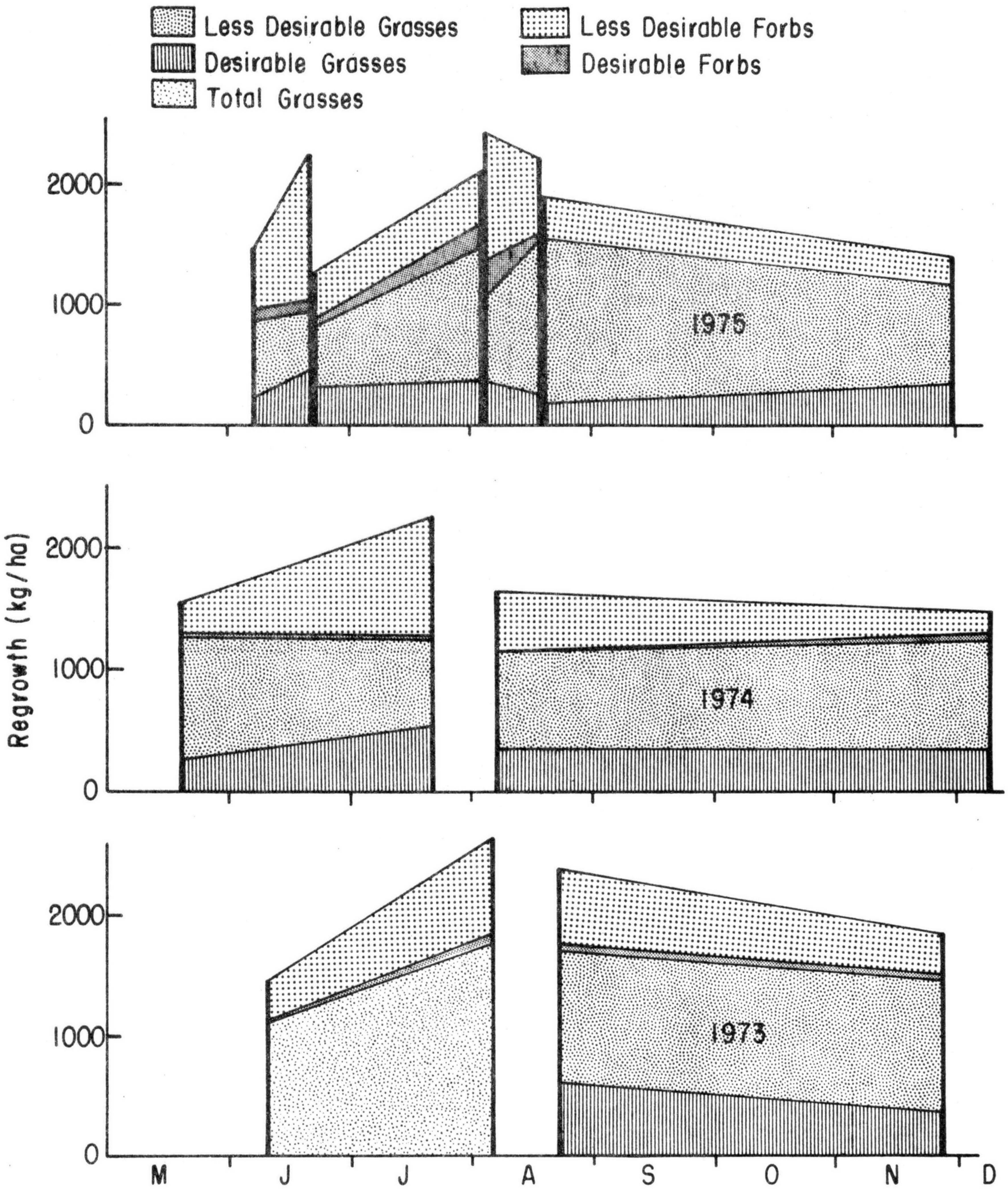

Figure 17. Herbage growth (kg/ha) of the different species classes on fertilized areas during four regrowth periods in the three years of the study. Grass species were not differentiated for the second period in 1973.

during the second period, but to a lesser extent than in 1973. Almost all of the regrowth during the second period was due to forbs because the additional herbage from desirable grasses (4 kg/ha/day) was offset by a decline in less desirable grass production (-4 kg/ha/day).

In 1975, the regrowth rates for each species class was more consistent across treatments than from one regrowth period to the following regrowth period. The regrowth rates for total herbage in fertilized areas were 53, 18, -16 and -4 kg/ha/day for the first, second, third and fourth periods, respectively. The relationships between regrowth rates for different species classes in different periods was very similar to those for unfertilized plants. However, fertilization accentuated the differences. When regrowth rates were positive, the values for fertilized plants were higher than those for unfertilized plants. Similarly a decline in production of a particular species class was greater for fertilized plants than unfertilized plants. Apparently fertilizer was being utilized by short-lived forbs in June and by warm season grasses in July and August.

The major effect of herbicide application was a reduction in forbs during all regrowth periods (Fig. 18). However, the reduction in forb competition did not increase the grass regrowth rate even though forbs were relatively abundant during the first three periods on untreated plots in 1975. In fact the net regrowth of all grasses for all years and all periods was less on herbicide treated areas than on untreated areas. There were no observable signs of direct damage to grass plants from herbicide and the literature generally reports an increase in grass production after a reduction in forb competition by herbicide application.

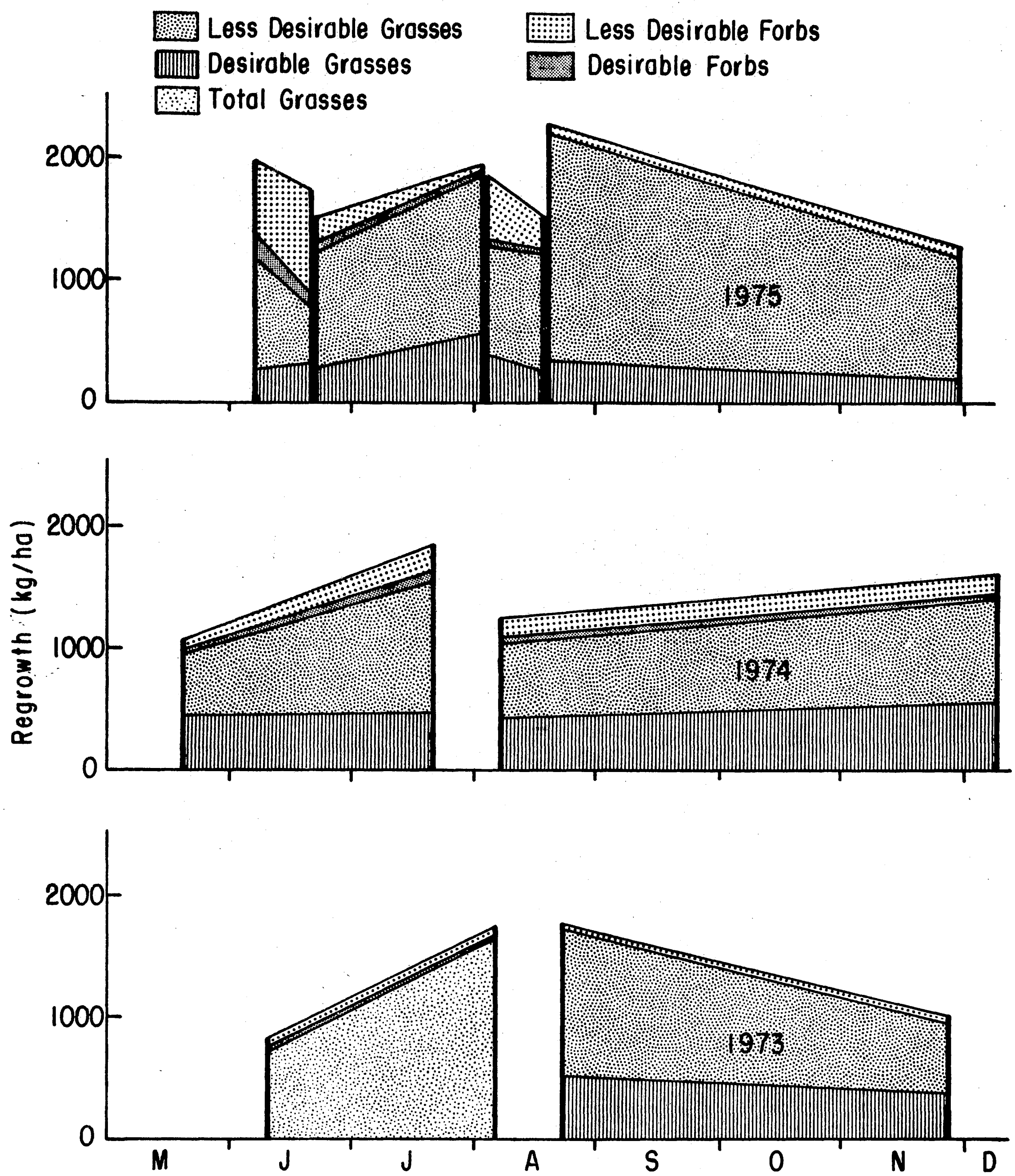

Figure 18. Herbage growth (kg/ha) of the different species classes on herbicide applied areas during four regrowth periods in the three years of the study. Grass species were not differentiated for the second period in 1973.

The combination of fertilizer and 2,4-D increased grass regrowth rates during the second regrowth period in 1973 and 1974 (Fig. 19). The regrowth rates of less desirable forbs on areas treated with fertilizer and 2,4-D were lower than those for untreated forbs. During the fourth period of all three years there was a low forb population on areas treated with 2,4-D and fertilizer.

In 1975 regrowth rates of different species classes on areas treated with 2,4-D plus fertilizer were averages between those rates on fertilized areas and those on areas treated with 2,4-D. For example, the regrowth rates during the first period for desirable grasses on untreated, fertilizer, herbicide, and herbicide plus fertilizer areas were 11, 15, 3 and 7 kg/ha/day, respectively. Regrowth rates for less desirable grasses for the same areas were -16, -12, -33 and -22 kg/ha/day, respectively.

The response of grass to the combination of fertilizer and 2,4-D may be different when forbs produce significant competition with grasses. In this study increases in production by one species class was generally offset by decreases in production by another species class resulting in relatively little total herbage regrowth during any period. More information is needed to understand plant competition, environmental conditions affecting competition between associated species and which plant communities are least competitive internally and most efficient in terms of plant and livestock production.

Crude protein. - The crude protein contents of fertilized and unfertilized herbage were very similar on all sampling dates in 1973 (Fig. 20). The lack of protein response to fertilizer, especially in the spring, was unusual.

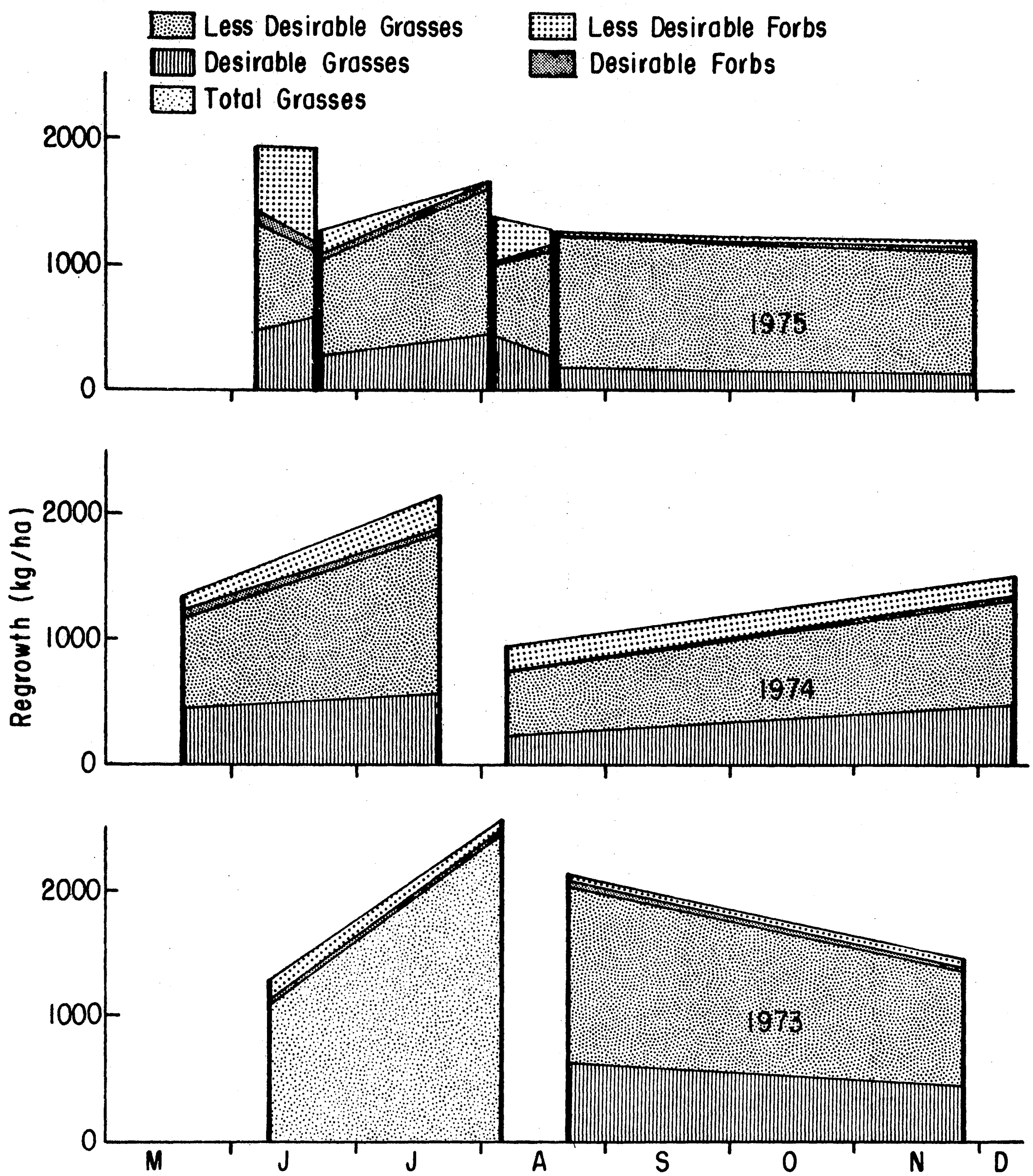

Figure 19. Herbage growth (kg/ha) of the different species classes on fertilized and herbicide applied areas during four regrowth periods in the three years of the study. Grass species were not differentiated for the second period in 1973.

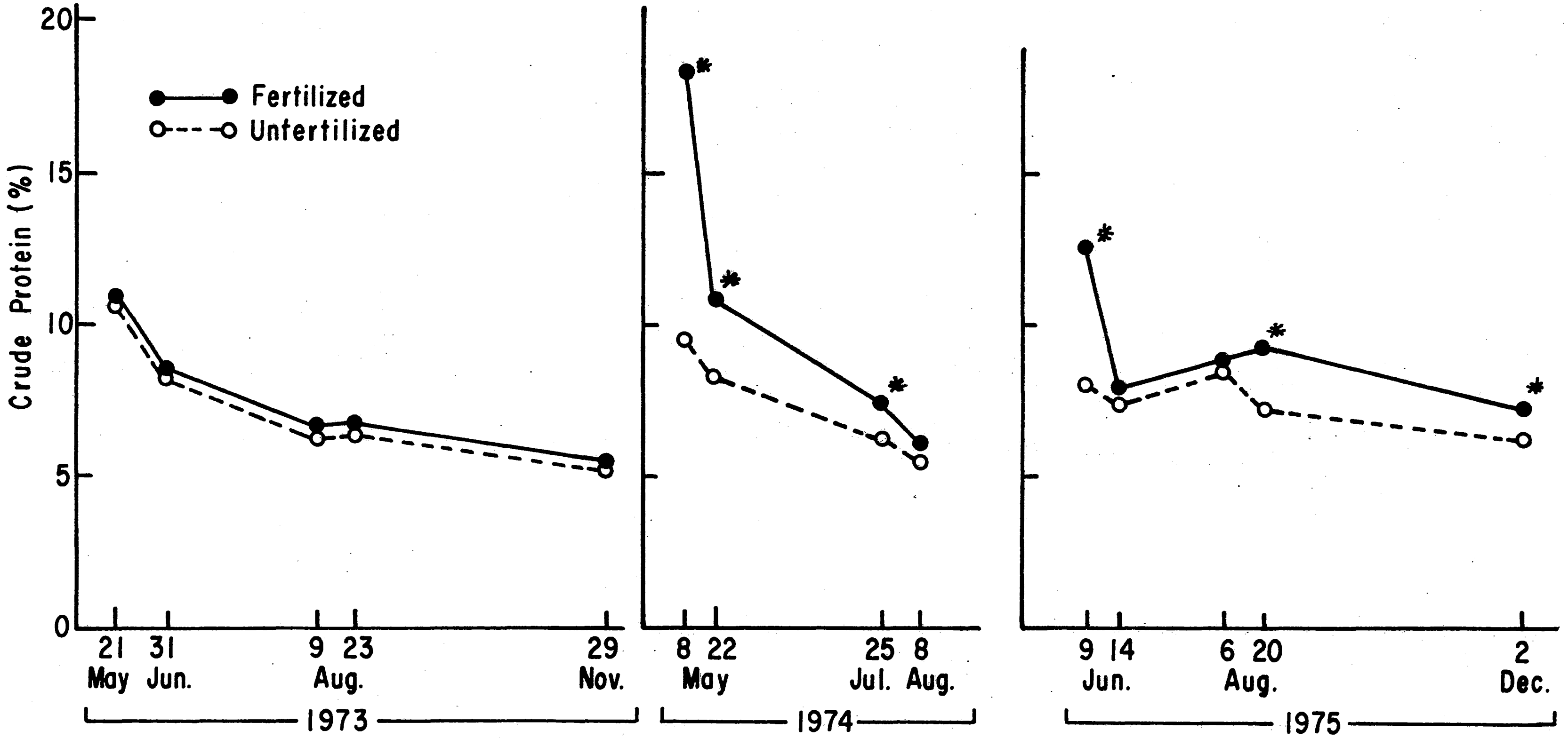

Figure 20. Crude protein content (%) in fertilized and unfertilized herbage, Billings. The two values for the same dates and indicated by a "*" are different at the 5% level of significance.

The greatest difference in crude protein content was on the May 8, 1974 sampling date. Cool season annual grasses were the dominant plants at this time and apparently had absorbed a significant amount of fertilizer nutrients in the 20 days between fertilizer application and sampling. Although fertilized herbage contained more protein than unfertilized herbage the difference decreased with plant growth and maturity. By August 8, the difference of 0.6% was not significant at the 5% level of probability.

In 1975, a second period of fertilizer nutrient absorption by plant roots was evident when plants responded to late summer rains with additional growth. This response has significant implications for increasing late summer crude protein content. If sufficient rain falls in mid or late summer to initiate significant new growth or root activity, fertilizer could be applied immediately to obtain increased protein and forage quality. Another alternative would be to fertilize in early spring the grazing areas with an abundance of cool season annual grasses and forbs. Other grazing areas dominated by shortgrasses would be fertilized in early or mid-summer. Fertilizer could be applied in different pastures or on different areas within one large pasture. Animals would utilize the fertilized cool season annuals when they are most nutritious in the spring and then the fertilized shortgrasses when they are nutritious in the summer and fall.

CHAPTER VI

SUMMARY

Northcentral Oklahoma is located on the southern boundary of the tallgrass prairie. This area is now being used almost extensively for wheat production and during winter months provides a valuable grazing resource. Cattle that are not sold are kept the remainder of the year on rangeland. The limited number of tallgrass species found on this rangeland has lead to the classification of poor condition tallgrass prairie. The inherent production capabilities still exist although not by the original climax species.

In 1973 rangeland improvement practices were implemented on a poor condition tallgrass prairie site. The area had been overgrazed but had never been plowed. Improvement practices consisted of fertilizing, spraying a herbicide and a combination of fertilizing and spraying. The amount of precipitation was recorded as was temperature and soil moisture. Grazing was permitted on a rotational basis but only to serve as a condition under which vegetation could be measured after it had been grazed.

Shortgrass species appear to respond to precipitation more directly than to artificial improvement practices. Herbage production was high during the first year of the study and precipitation was also above normal. During the second and third year the difference in herbage production between the control areas and those receiving fertilization was not as great. Precipitation was above normal in 1974 but periods of low precipitation and high temperature occurred during the summer months. The annual precipitation recorded for 1975 was slightly above average but even with the annual application of fertilizer and another herbicide spraying the measured herbage production did not differ significantly between treatments.

Species composition changed during the different seasons of plant growth. Cool season annuals comprised a significant percentage of the herbage in the spring and fall whereas, warm season annuals dominated the summer months. The effect of low precipitation and high temperatures during the summer of 1974 may have affected the growth of the cool season annuals during 1975 as lower percent composition of these species were recorded with very little change occurring between the different treatment areas. Soil water content by weight was extremely low during August in 1974 and this may also have contributed to a decline of cool season annuals in 1975.

Fertilization increased the percent crude protein of herbage but did not increase herbage production consistently during all three years. Herbicide application reduced forb production, but did not increase grass production. Forbs did not comprise a major portion of the total herbage and reduced competition from forbs may have been insignificant compared to the variable effects of growing conditions.

Weather should be a major consideration when planning improvements on poor condition tallgrass prairie sites. Fertilization will increase crude protein but for increased herbage production, above average amounts of precipitation may be necessary. During years of adequate precipitation when fertilizers are applied, changes in the number of animal units may be needed to harvest the additional plant growth.

The beneficial effects of herbicides may depend on the degree of competition by the undesirable forbs present. Forbs respond readily to fertilization so a combination of fertilizer plus herbicide may be the most effective improvement practice. During periods of low precipitation herbicides may not be as effective as during periods of above normal precipitation.

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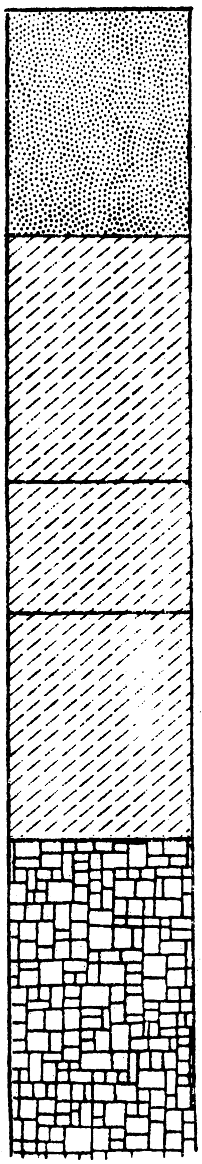
APPENDIXES

APPENDIX A

KIRKLAND SOIL PROFILE DESCRIPTION

Typical Series taken approximately 40 km to the southwest of study area. The profile is from a nearly level cultivated field (23 m south of the northwest corner of the southwest quarter of Section 26, T21N., R5W) in Garfield County.



A1 -- 0 - 30 cm -- Dark Brown (7.5YR 4/2) silt loam, dark brown (7.5YR 3/2) when moist; weak, fine granular structure; friable when moist, slightly hard when dry; slightly acid, pH 6.5; abrupt boundary.

B21t -- 30 - 62.5 cm -- Dark brown (7.5YR 4/2) clay, dark brown (7.5YR 3/2) when moist; very firm when moist; weak, medium to coarse, blocky structure; very hard when dry; neutral, pH 7.0; gradual boundary.

B22t -- 62.5 - 80 cm -- Dark brown (7.5YR 4/4) clay, dark brown (7.5YR 3/4) when moist; weak, coarse, blocky structure to massive, very firm when moist, extremely hard when dry; moderately alkaline, pH 8.0; a few, fine distinct red (2.5YR 5/8) specks; gradual boundary.

B3 -- 80 - 110 cm -- Dark brown (10YR 4/3) clay, dark brown (10YR 3/3) when moist; massive; very firm when moist, extremely hard when dry; moderately alkaline, pH 8.0; many fine and some large calcium concretions, a few, small, black iron concretions, and a few, distinct, coarse and fine red (2.5YR 5/8) specks; clear boundary.

C -- 110 - 150 cm -- Yellowish red (5YR 5/6) clay, yellowish red (5YR 4/6) when moist; massive; firm when moist, hard when dry; moderately alkaline, pH 8.0.

The A horizon ranges from 10YR to 7.5YR in hue. It is 20 to 35 cm thick. In some places there is a 5 cm horizon of silty clay loam or clay loam just above the B2 horizon. The depth to the C horizon ranges from 105 to 120 cm.

APPENDIX B

PLANT SPECIES RECORDED ON STUDY AREA

Common Name	Scientific Names
Grasses and Grass-like	
Big Bluestem	*Andropogon gerardi* Vitman
Prairie Threeawn	*Aristida oligantha* Michx.
Arrowfeather Threeawn	*Aristida purpurascens* Poir.
Old World Bluestem	*Bothriochloa ischaemum* var *ischaemum*
Silver Bluestem	*Bothriochloa saccharoides* (Swartz) Rydb.
Sideoats Grama	*Bouteloua curtipendula* (Michx.) Torr.
Blue Grama	*Bouteloua gracilis* (Willd. ex H.B.K.) Lag. ex Griffiths
Hairy Grama	*Bouteloua hirsuta* Lag.
Japanese Brome	*Bromus japonicus* Thunb.
Buffalograss	*Buchloe dactyloides* (Nutt.) Engelm.
Sedge	*Carex* spp.
Windmillgrass	*Chloris verticillata* Nutt.
Plains Lovegrass	*Eragrostis intermedia* Hitchc.
Little Barley	*Hordeum pusilium* Nutt.
Fall Witchgrass	*Leptoloma cognatum* (Schult.) Chase
Scribner's Panicum	*Panicum oligosanthes* Schult. var *scribnerianum* (Nash) Fern.
Kentucky Bluegrass	*Poa pratensis* L.
Tumblegrass	*Schedonnardus paniculatus* (Nutt.) Trel.
Tall Dropseed	*Sporobolus asper* (Michx.) Kunth.
Forbs	
Western Yarrow	*Achillea lanulosa* Nutt.
Western Ragweed	*Ambrosia psilostachya* DC.
Hemp Dogbane	*Apocynum cannabinum* L.
Heath Aster	*Aster ericoides* L.
Purple Poppymallow	*Callirhoe involucrata* (T. & G.) Gray
Showy Partridgepea	*Cassia fasciculata* Michx.
Wavyleaf Thistle	*Cirsium undulatum* (Nutt.) Spreng.
Plains Coreopsis	*Coreposis tinctoria* Nutt.
Texas Croton	*Croton texensis* (Klotzsch) Muell. Ang.
Rough Fleabane	*Erigeron strigosus* Muhl.
Snow-on-the-Mountain	*Euphorbia marginata* Pursh.
Carolina Geranium	*Geranium carolinianum* L.
Common Broomweed	*Gutierrezia dracunculoides* (DC.) Blake
Virginia Pepperweed	*Lepidium virginicum* L.
Wooly Plantain	*Plantago purshii* Roem. & Schult.
Scurfpea	*Psoralea tenuiflora* Pursh.
Prairie Coneflower	*Ratibida columnifera* (Nutt.) Woot. & Standl.
Hairy Coneflower	*Rudbeckia hirta* L.
Silverleaf Nightshade	*Solanum elaeagnifolium* Cav.
Missouri Goldenrod	*Solidago missouriensis* Nutt.
Western Ironweed	*Veronia baldwinii* Torr.

APPENDIX C

EXAMPLES OF FIELD DATA WORKSHEETS

Card 1

- NAME
- YEAR
- DAY
- GRAZE / REP / FERT / HERB / SEED
- SAMP NO.
- CARD NO. — 1
- OWB
- ANG
- ERA
- PAN
- SPO
- LECO
- DSGR
- LDGS
- ARI
- BOU
- BRJA HOPU
- BOSA
- CHVE
- AR
- EST WT
- REMARKS

Card 2

- NAME
- YEAR
- DAY
- GRAZE / REP / FERT / HERB / SEED
- SAMP NO.
- CARD NO. — 2
- AMPS
- APO
- ASER
- CIR
- ERST
- MAL
- PLPU
- SOEL
- SOL
- LEVI
- ALCA
- GUDR
- RACO
- COTI
- OTH
- REMARKS

Card 3

- NAME
- YEAR
- DAY
- GRAZE / REP / FERT / HERB / SEED
- SAMP NO.
- CARD NO. — 3
- TIME
- DRY BULB
- WET BULB
- SOIL TEMP
- WIND SPEED
- WIND DIR.
- CLOUD
- DEW
- RELATIVE HUM.
- EST WT
- FLD WT
- DRY WT
- SL WET WT
- SL DRY WT
- ESTIMATOR

Card 4

- NAME
- YEAR
- DAY
- CONDITION / REP / FERT / HERB / SEED
- SAMP NO.
- CARD NO. — 4
- PH
- BI
- OM
- #/A P
- #/A K
- #/A CA
- N
- P
- CP
- DMD

APPENDIX D

COMPUTER COMMENT STATEMENTS

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COMMENT
  STUDY AREA LOCATED IN NORTH CENTRAL OKLAHOMA NEAR BILLINGS
    6 KM EAST IN EAST ONE-HALF OF THE SOUTHEAST ONE-QUARTER OF
    SECTION 23  RANGE 2 WEST TOWNSHIP 24 NORTH
  NAME
    ALTERATIVES FOR OVERGRAZED HOLDING PASTURE MANAGEMENT
  INITIATED IN SPRING OF 1973
  TREATMENTS
     FERT  56 KG/HA AMMONIUM NITRATE  34-0-0
           45 KG/HA SUPERPHOSPHATE  0-46-0
        APPLIED IN SPRING EACH OF THREE YEARS
     HERB  CHEMICAL SPRAY OF 1.12 KG/HA OF 2,4-D AND 0.56 KG/HA OF PICLORAM
        APPLIED IN  MIDJUNE
     SEED 8.4 KG/HA OF 20 PERCENT PLS OF OLD WORLD BLUESTEM MIXTURE
        APPLIED 18 APR 73 WITH 10 MM RAIN SAME EVENING
  DATA SHEETS
     GRAZE = R OR G AND REPRESENTS THE NORTH GRAZING AREA OR ROTATION
             C FOR LARGE PASTURE SOUTH WHICH HAD CONTINUOUS USE
     REP = REPLICATION
     FERT = F IF PLOT RECEIVED FERTILIZER O IF NO FERT
     HERB = H IF PLOT RECEIVED CHEMICAL N IF NO CHEM
     SEED = S IF PLOT RECEIVED SEED U IF NO SEED
     SAMPNO = RANDOM SAMPLE ON PLOTS 1 ON WEST HALF 2 ON EAST HALF
     CARDNO = DATA SHEET CARD NUMBER
     SPECIES
       OWB = OLDWORLD BLUESTEMS
       ANGE = BIG BLUESTEM
       ERA = LOVEGRASS SPECIES
       PAN = PANICUM SPECIES
       SPO = DROPSEED
       LECO = FALL WITCHGRASS
       DSGR = DESIRABLE GRASS
       LDGR = LESS DIRABLEGRASS
       ARI = THREEAWN SPECIES
       BOU = BLUE GRAMA HAIRY SIDEOATS BUFFALO GRASS
       BRJA-HOPU = JAPANESE BROME AND LITTLE BARLEY
       BOSA = SILVER BLUESTEM
       CHVE = WINDMILL GRASS
       CAR = CAREX SPECIES
       ESTWT = ESTIMATED WEIGHT OF PLOTS SAMPLED
       AMPS = WESTERN RAGWEED
       APO = HEMP DOGBANE AND SNOW-ON-THE-MOUNTAIN
       CIR = THISTLES
       ERST = DAISY FLEABANE
       MAL = PURPLE POPPY MALLOW
       PLPU = WOOLY PLANTAIN
       SOEL = SILVERLEAF NIGHTSHADE
       SOL = SOLIDAGO OR GOLDENROD
       LEVI = PEPPERGRASS
       ACLA = WESTERN YARROW
       GUDR = ANNUAL BROOMWEED
       RACO = PRAIRIE CONEFLOWER
       COTI = PLAINS COREOPSIS
       OTH = OTHER FORB SPECIES
     WEATHER INFORMATION
       DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
       WET BULB = WET THERMOMETER READING ON SLING PSYCHROMETER
       SOILTEMP = TEMPERATURE OF SOIL AT TIME ESTIMATE
       WIND SPEED = WIND VELOCITY
       WIND DIR = DIRECTION OF WIND
       CLOUD = COVER 1-CLEAR 2-BROKEN 3-SCATTERED 4-OVERCAST 5-HEAVY OVERCAST
       DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
     ESTWT = ESTIMATED WEIGHT OF SAMPLE WITHIN .5 SQ METER FRAME
     FLDWT = ACTUAL WEIGHT OF SAMPLE AS CLIPPED IN FIELD (NET WEIGHT)
     DRYWT = ACTUAL WEIGHT OF SAMPLE AFTER BEING OVEN DRIED (60 DEG CENT)
     SLWETWT = WET WEIGHT OF SOIL SAMPLE
     SLDRYWT = DRY WEIGHT OF SOIL SAMPLE
     ESTR = INDIVIDUAL ESTIMATING HERBAGE
```

APPENDIX E

COMPUTER INPUT PROGRAM FOR 1973

```
DATA GRAZE_73;
  INPUT NREC = 3
    NAME $ 1-9 YR 10-11 DAY 13-15 CON $ 17 REP 18 FERT $ 19 HERB $ 20
      SEED $ 21 TRT $ 19-21 CD 23 OWB 24-25 ANGE 27-28 ERA 30-31
      PAN 33-34 SPO 36-37 ARI 39-41 BOU 43-45 CHVE 47-49 ANUL 51-53 BOSA 55-57
      CAR 59-61 LECO 63-65 DSGR 67-69 LDGS 71-73 TOTGRS 77-79
        AMPS #2 25-26 APO #2 28-29 ASER #2 31-32 CIR #2 34-35 ERST #2 37-38
        MAL #2 40-41 PLPU #2 43-44 SOEL #2 46-47 SOLI #2 49-50 LEVI #2 52-53
        ACLA #2 55-57 GUDR #2 59-61 RACO #2 63-65 COTI #2 67-69 OTH #2 71-73
ESTWT #3 27-29 FLDWT #3 33-35 DRYWT #3 39-41 WETSLWT #3 45-47 DRYSLWT #3 51-53
  YR2 #2 10-11 DAY2 #2 13-15 COND2 #2 $ 17 REP2 #2 18 FERT2 #2 $ 19
  YR3 #3 10-11 DAY3 #3 13-15 COND3 #3 $ 17 REP3 #3 18 FERT3 #3 $ 19
    HERB2 #2 $ 20 SEED2 #2 $ 21 TRT2 #2 $ 19-21 CD2 #2 23
    HERB3 #3 $ 20 SEED3 #3 $ 21 TRT3 #3 $ 19-21 CD3 #3 23;
IF YR = 73 AND CON = 'C' THEN COND = 'C';
IF YR = 73 AND CON = 'R' THEN COND = 'G';
IF CD ¬= 1 OR CD2 ¬= 2 OR CD3 ¬= 3 THEN PUT YR DAY COND REP TRT CD;
DROP YR2 YR3 DAY2 DAY3 COND2 COND3 REP2 REP3 FERT2 FERT3 HERB2 HERB3
     SEED2 SEED3 TRT2 TRT3 CD2 CD3;
  IF DRYWT > FLDWT THEN PUT YR DAY COND REP TRT;
OUTPUT; CARDS


 120 OBSERVATIONS IN DATA SET GRAZE_73      46  VARIABLES

PROC SORT DATA=GRAZE_73; BY YR DAY COND REP TRT;


DATA A573ALL; SET GRAZE_73;
  OWB=OWB+0; ANGE=ANGE+0; ERA=ERA+0; PAN=PAN+0; SPO=SPO+0; LECO=LECO+0;
  DSGR=DSGR+0; LDGS=LDGS+0; ARI=ARI+0; BOU=BOU+0; ANUL=ANUL+0; BOSA=BOSA+0;
  CHVE=CHVE+0; CAR=CAR+0; AMPS=AMPS+0; APO=APO+0; ASER=ASER+0; CIR=CIR+0;
  ERST=ERST+0; MAL=MAL+0; PLPU=PLPU+0; SOEL=SOEL+0; SOLI=SOLI+0; LEVI=LEVI+0;
  ACLA=ACLA+0; GUDR=GUDR+0; RACO=RACO+0; COTI=COTI+0; OTH=OTH+0;
BOUT=BOU+0; TOTGRS=TOTGRS+0;
IF FLDWT >0 THEN MFTR1 = (DRYWT/ESTWT) * 20.18;
IF FLDWT ¬>0 THEN MFTR2 = 0; MF = (MFTR2 = 0) * MFTR1;
  OWB=OWB*MF; ANGE=ANGE*MF; ERA=ERA*MF; PAN=PAN*MF; SPO=SPO*MF; LECO=LECO*MF;
  DSGR=DSGR*MF; LDGS=LDGS*MF; ARI=ARI*MF; BOU=BOU*MF; ANUL=ANUL*MF;
  BOSA=BOSA*MF; CHVE=CHVE*MF; CAR=CAR*MF; AMPS=AMPS*MF; APO=APO*MF;
  ASER=ASER*MF; CIR=CIR*MF; ERST=ERST*MF; MAL=MAL*MF; PLPU=PLPU*MF;
  SOEL=SOEL*MF; SOLI=SOLI*MF; LEVI=LEVI*MF; ACLA=ACLA*MF; GUDR=GUDR*MF;
  RACO=RACO*MF; COTI=COTI*MF; OTH=OTH*MF; TOTGRS=TOTGRS*MF;
DESGRS = OWB + ANGE + PAN + BOU + LECO + DSGR;
LESGRS = ERA + SPO + ARI + ANUL + BOSA + CHVE + CAR + LDGS;
GRASS = DESGRS + LESGRS + TOTGRS;
DESFBS = OTH;
LESFBS = AMPS + APO + ASER + CIR + ERST + MAL + PLPU + SOEL
       + SOLI + LEVI + ACLA + GUDR + RACO + COTI;
FORBS = DESFBS + LESFBS;
FORAGE = GRASS + FORBS;
HERBAGE = FORAGE;
  PCSLM = DIV((WETSLWT-DRYSLWT),DRYSLWT);
  IF PCSLM ¬> 0 THEN PCSLM = MISS(PCSLM);
PF = FORAGE;
PCOWB=OWB/PF; PCANGE=ANGE/PF; PCPAN=PAN/PF; PCBOU=BOU/PF; PCLECO=LECO/PF;
PCDSGR=DSGR/PF; PCERA=ERA/PF; PCSPO=SPO/PF; PCARI=ARI/PF; PCANUL=ANUL/PF;
PCBOSA=BOSA/PF; PCCHVE=CHVE/PF; PCCAR=CAR/PF; PCLDGS=LDGS/PF; PCCOTI=COTI/PF;
  PCAMPS=AMPS/PF; PCAPO=APO/PF; PCASER=ASER/PF; PCCIR=CIR/PF; PCERST=ERST/PF;
  PCMAL=MAL/PF; PCPLPU=PLPU/PF; PCSOEL=SOEL/PF; PCSOLI=SOLI/PF; PCOTH=OTH/PF;
  PCLEVI=LEVI/PF; PCACLA=ACLA/PF; PCGUDR=GUDR/PF; PCRACO=RACO/PF;
  PCDESGRS=DESGRS/PF; PCLESGRS=LESGRS/PF; PCTOTGRS=TOTGRS/PF; PCGRASS=GRASS/PF;
  PCDESFBS=DESFBS/PF; PCLESFBS=LESFBS/PF; PCFORBS=FORBS/PF;
TITLE 'ALTERNATIVES FOR HOLDING PASTURE MANAGEMENT IN 1973';


 120 OBSERVATIONS IN DATA SET A573ALL      96  VARIABLES
```

APPENDIX F

COMPUTER INPUT PROGRAM FOR 1974

```
DATA GRAZE_74;
  INPUT NREC = 3
    NAME $ 1-9 YR 10-11 DAY 13-15 COND $ 17 REP 18 FERT $ 19 HERB $ 20
      SEED $ 21 TRT $ 19-21 SAMP 23 CD 25 OWB 27-29 ANGE 30-32 ERA 33-35
      PAN 36-38 SPO 39-41 LECO 42-44 DSGR 45-47 LDGS 48-50 ARI 51-53 BOU 54-56
      ANUL 57-59 BOSA 60-62 CHVE 63-65 CAR 66-68 ESWT 69-71
        AMPS #2 27-29 APO #2 30-32 ASER #2 33-35 CIR #2 36-38 ERST #2 39-41
        MAL #2 42-44 PLPU #2 45-47 SOEL #2 48-50 SOLI #2 51-53 LEVI #2 54-56
        ACLA #2 57-59 GUDR #2 60-62 RACO #2 63-65 COTI #2 66-68 OTH #2 69-71
          TIME #3 27-30 DRYBULB #3 32-34 WETBULB #3 36-38 SOILTEMP #3 40-42
          WDSPEED #3 44-46 WINDDIR #3 48-50 CLOUD #3 52 DEW #3 54 REHU #3 56-57
          ESTWT #3 59-61 FLDWT #3 63-65 DRYWT #3 67-69 WETSLWT #3 71-73
          DRYSLWT #3 75-77 ESTR #3 $ 79-80
  YR2 #2 10-11 DAY2 #2 13-15 COND2 #2 $ 17 REP2 #2 18 FERT2 #2 $ 19
  YR3 #3 10-11 DAY3 #3 13-15 COND3 #3 $ 17 REP3 #3 18 FERT3 #3 $ 19
   HERB2 #2 $ 20 SEED2 #2 $ 21 TRT2 #2 $ 19-21 SAMP2 #2 23 CD2 #2 25
   HERB3 #3 $ 20 SEED3 #3 $ 21 TRT3 #3 $ 19-21 SAMP3 #3 23 CD3 #3 25;
IF CD ¬= 1 OR CD2 ¬= 2 OR CD3 ¬= 3 THEN PUT YR DAY COND REP TRT CD;
DROP YR2 YR3 DAY2 DAY3 COND2 COND3 REP2 REP3 FERT2 FERT3 HERB2 HERB3
     SEED2 SEED3 TRT2 TRT3 SAMP2 SAMP3 CD2 CD3 ESWT;
  IF DRYWT > FLDWT THEN PUT YR DAY COND REP TRT;
  SAMPLE = (FLDWT¬>0)*10*SAMP + (FLDWT>0);
OUTPUT; CARDS


 240 OBSERVATIONS IN DATA SET GRAZE_74      56  VARIABLES

PROC SORT DATA=GRAZE_74; BY YR DAY COND REP TRT SAMPLE;

DATA A574ALL; SET GRAZE_74;
  OWB=OWB+0; ANGE=ANGE+0; ERA=ERA+0; PAN=PAN+0; SPO=SPO+0; LECO=LECO+0;
  DSGR=DSGR+0; LDGS=LDGS+0; ARI=ARI+0; BOU=BOU+0; ANUL=ANUL+0; BOSA=BOSA+0;
  CHVE=CHVE+0; CAR=CAR+0; AMPS=AMPS+0; APO=APO+0; ASER=ASER+0; CIR=CIR+0;
  ERST=ERST+0; MAL=MAL+0; PLPU=PLPU+0; SOEL=SOEL+0; SOLI=SOLI+0; LEVI=LEVI+0;
  ACLA=ACLA+0; GUDR=GUDR+0; RACO=RACO+0; COTI=COTI+0; OTH=OTH+0;
IF FLDWT >0 THEN MFTR1 = (DRYWT/ESTWT) * 20.18;
IF FLDWT ¬>0 THEN MFTR2 = 0; MF = (MFTR2 = 0) * MFTR1;
  OWB=OWB*MF; ANGE=ANGE*MF; ERA=ERA*MF; PAN=PAN*MF; SPO=SPO*MF; LECO=LECO*MF;
  DSGR=DSGR*MF; LDGS=LDGS*MF; ARI=ARI*MF; BOU=BOU*MF; ANUL=ANUL*MF;
  BOSA=BOSA*MF; CHVE=CHVE*MF; CAR=CAR*MF; AMPS=AMPS*MF; APO=APO*MF;
  ASER=ASER*MF; CIR=CIR*MF; ERST=ERST*MF; MAL=MAL*MF; PLPU=PLPU*MF;
  SOEL=SOEL*MF; SOLI=SOLI*MF; LEVI=LEVI*MF; ACLA=ACLA*MF; GUDR=GUDR*MF;
  RACO=RACO*MF; COTI=COTI*MF; OTH=OTH*MF;
DESGRS = OWB + ANGE + PAN + BOU + LECO + DSGR;
LESGRS = ERA + SPO + ARI + ANUL + BOSA + CHVE + CAR + LDGS;
GRASS = DESGRS + LESGRS;
DESFBS = OTH;
LESFBS = AMPS + APO + ASER + CIR + ERST + MAL + PLPU + SOEL
       + SOLI + LEVI + ACLA + GUDR + RACO + COTI;
FORBS = DESFBS + LESFBS;
FORAGE = GRASS + FORBS;
HERBAGE = FORAGE;
  PCSLM = DIV((WETSLWT-DRYSLWT),DRYSLWT);
  IF PCSLM ¬> 0 THEN PCSLM = MISS(PCSLM);
PF = FORAGE;
PCOWB=OWB/PF; PCANGE=ANGE/PF; PCPAN=PAN/PF; PCBOU=BOU/PF; PCLECO=LECO/PF;
PCDSGR=DSGR/PF; PCERA=ERA/PF; PCSPO=SPO/PF; PCARI=ARI/PF; PCANUL=ANUL/PF;
PCBOSA=BOSA/PF; PCCHVE=CHVE/PF; PCCAR=CAR/PF; PCLDGS=LDGS/PF; PCCOTI=COTI/PF;
  PCAMPS=AMPS/PF; PCAPO=APO/PF; PCASER=ASER/PF; PCCIR=CIR/PF; PCERST=ERST/PF;
  PCMAL=MAL/PF; PCPLPU=PLPU/PF; PCSOEL=SOEL/PF; PCSOLI=SOLI/PF; PCOTH=OTH/PF;
  PCLEVI=LEVI/PF; PCACLA=ACLA/PF; PCGUDR=GUDR/PF; PCRACO=RACO/PF;
  PCDESGRS=DESGRS/PF; PCLESGRS=LESGRS/PF;                    PCGRASS=GRASS/PF;
  PCDESFBS=DESFBS/PF; PCLESFBS=LESFBS/PF; PCFORBS=FORBS/PF;
TITLE 'ALTERNATIVES FOR HOLDING PASTURE MANAGEMENT 1974';


 240 OBSERVATIONS IN DATA SET A574ALL       104  VARIABLES
```

APPENDIX G

COMPUTER INPUT PROGRAM FOR 1975

```
DATA GRAZE_75;
  INPUT NREC = 3
    NAME $ 1-9 YR 10-11 DAY 13-15 COND $ 17 REP 18 FERT $ 19 HERB $ 20
      SEED $ 21 TRT $ 19-20 SAMP 23 CD 25 OWB 27-29 ANGE 30-32 ERA 33-35
      PAN 36-38 SPO 39-41 LECO 42-44 DSGR 45-47 LDGS 48-50 ARI 51-53 BOU 54-56
      ANUL 57-59 BOSA 60-62 CHVE 63-65 CAR 66-68 ESWT 69-71
        AMPS #2 27-29 APO #2 30-32 ASER #2 33-35 CIR #2 36-38 ERST #2 39-41
        MAL #2 42-44 PLPU #2 45-47 SOEL #2 48-50 SOLI #2 51-53 LEVI #2 54-56
        ACLA #2 57-59 GUDR #2 60-62 RACO #2 63-65 COTI #2 66-68 OTH #2 69-71
          TIME #3 27-30 DRYBULB #3 32-34 WETBULB #3 36-38 SOILTEMP #3 40-42
          WDSPEED #3 44-46 WINDDIR #3 48-50 CLOUD #3 52 DEW #3 54 REHU #3 56-57
          ESTWT #3 59-61 FLDWT #3 63-65 DRYWT #3 67-69 WETSLWT #3 71-73
          DRYSLWT #3 75-77 ESTR #3 $ 79-80
  YR2 #2 10-11 DAY2 #2 13-15 COND2 #2 $ 17 REP2 #2 18 FERT2 #2 $ 19
  YR3 #3 10-11 DAY3 #3 13-15 COND3 #3 $ 17 REP3 #3 18 FERT3 #3 $ 19
   HERB2 #2 $ 20 SEED2 #2 $ 21 TRT2 #2 $ 19-20 SAMP2 #2 23 CD2 #2 25
   HERB3 #3 $ 20 SEED3 #3 $ 21 TRT3 #3 $ 19-20 SAMP3 #3 23 CD3 #3 25;
IF CD ¬= 1 OR CD2 ¬= 2 OR CD3 ¬= 3 THEN PUT YR DAY COND REP TRT CD;
DROP YR2 YR3 DAY2 DAY3 COND2 COND3 REP2 REP3 FERT2 FERT3 HERB2 HERB3
     SEED2 SEED3 TRT2 TRT3 SAMP2 SAMP3 CD2 CD3 ESWT;
  IF DRYWT > FLDWT THEN PUT YR DAY COND REP TRT;
  SAMPLE = (FLDWT¬>0)*10*SAMP + (FLDWT>0);
OUTPUT; CARDS


 120 OBSERVATIONS IN DATA SET GRAZE_75       56  VARIABLES

PROC SORT DATA=GRAZE_75; BY YR DAY COND REP TRT SAMPLE;

DATA A575ALL; SET GRAZE_75;
  OWB=OWB+0; ANGE=ANGE+0; ERA=ERA+0; PAN=PAN+0; SPO=SPO+0; LECO=LECO+0;
  DSGR=DSGR+0; LDGS=LDGS+0; ARI=ARI+0; BOU=BOU+0; ANUL=ANUL+0; BOSA=BOSA+0;
  CHVE=CHVE+0; CAR=CAR+0; AMPS=AMPS+0; APO=APO+0; ASER=ASER+0; CIR=CIR+0;
  ERST=ERST+0; MAL=MAL+0; PLPU=PLPU+0; SOEL=SOEL+0; SOLI=SOLI+0; LEVI=LEVI+0;
  ACLA=ACLA+0; GUDR=GUDR+0; RACO=RACO+0; COTI=COTI+0; OTH=OTH+0;
IF FLDWT >0 THEN MFTR1 = (DRYWT/ESTWT) * 20.18;
IF FLDWT ¬>0 THEN MFTR2 = 0; MF = (MFTR2 = 0) * MFTR1;
  OWB=OWB*MF; ANGE=ANGE*MF; ERA=ERA*MF; PAN=PAN*MF; SPO=SPO*MF; LECO=LECO*MF;
  DSGR=DSGR*MF; LDGS=LDGS*MF; ARI=ARI*MF; BOU=BOU*MF; ANUL=ANUL*MF;
  BOSA=BOSA*MF; CHVE=CHVE*MF; CAR=CAR*MF; AMPS=AMPS*MF; APO=APO*MF;
  ASER=ASER*MF; CIR=CIR*MF; ERST=ERST*MF; MAL=MAL*MF; PLPU=PLPU*MF;
  SOEL=SOEL*MF; SOLI=SOLI*MF; LEVI=LEVI*MF; ACLA=ACLA*MF; GUDR=GUDR*MF;
  RACO=RACO*MF; COTI=COTI*MF; OTH=OTH*MF;
DESGRS = OWB + ANGE + PAN + BOU + LECO + DSGR;
LESGRS = ERA + SPO + ARI + ANUL + BOSA + CHVE + CAR + LDGS;
GRASS = DESGRS + LESGRS;
DESFBS = OTH;
LESFBS = AMPS + APO + ASER + CIR + ERST + MAL + PLPU + SOEL
       + SOLI + LEVI + ACLA + GUDR + RACO + COTI;
FORBS = DESFBS + LESFBS;
FORAGE = GRASS + FORBS;
HERBAGE = FORAGE;
  PCSLM = DIV((WETSLWT-DRYSLWT),DRYSLWT);
  IF PCSLM ¬> 0 THEN PCSLM = MISS(PCSLM);
PF = FORAGE;
PCOWB=OWB/PF; PCANGE=ANGE/PF; PCPAN=PAN/PF; PCBOU=BOU/PF; PCLECO=LECO/PF;
PCDSGR=DSGR/PF; PCERA=ERA/PF; PCSPO=SPO/PF; PCARI=ARI/PF; PCANUL=ANUL/PF;
PCBOSA=BOSA/PF; PCCHVE=CHVE/PF; PCCAR=CAR/PF; PCLDGS=LDGS/PF; PCCOTI=COTI/PF;
  PCAMPS=AMPS/PF; PCAPO=APO/PF; PCASER=ASER/PF; PCCIR=CIR/PF; PCERST=ERST/PF;
  PCMAL=MAL/PF; PCPLPU=PLPU/PF; PCSOEL=SOEL/PF; PCSOLI=SOLI/PF; PCOTH=OTH/PF;
  PCLEVI=LEVI/PF; PCACLA=ACLA/PF; PCGUDR=GUDR/PF; PCRACO=RACO/PF;
  PCDESGRS=DESGRS/PF; PCLESGRS=LESGRS/PF;                      PCGRASS=GRASS/PF;
  PCDESFBS=DESFBS/PF; PCLESFBS=LESFBS/PF; PCFORBS=FORBS/PF;
TITLE 'ALTERNATIVES FOR HOLDING PASTURE MANAGEMENT 1975';


 120 OBSERVATIONS IN DATA SET A575ALL      104  VARIABLES
```

APPENDIX H

COMPUTER ANALYSIS PROCEDURE

STATISTICAL ANALYSIS SYSTEM
YR=75

```
DATA ALLHERB; SET TOTHERB;
IF COND = 'G';
HERBAGE = FORAGE;
DM = DIV(DRYWT,FLDWT);
IF DM¬> 0 THEN DM = MISS(DM);
PCSLM = DIV((WETSLWT-DRYSLWT),DRYSLWT);
IF PCSLM ¬> 0 THEN PCSLM = MISS(PCSLM);
```

120 OBSERVATIONS IN DATA SET ALLHERB   107 VARIABLES

```
PROC ANOVA DATA=ALLHERB; BY YR;
  CLASSES REP FERT HERB DAY;
MODEL DESGRS LESGRS DESFBS LESFBS HERBAGE =
 REP FERT|HERB REP*FERT|HERB DAY DAY*FERT|HERB REP*DAY
     REP*DAY*FERT|HERB; MEANS DAY FERT|HERB DAY*FERT|HERB;
  POOL 'R*F|H' REP*FERT|HERB/FERT;
  POOL 'R*H|F' REP*FERT|HERB/FERT*HERB;
  POOL 'R*D+R*D*F|H' REP*DAY REP*DAY*FERT|HERB/DAY;
  POOL 'R*D+R*D*H|F' REP*DAY REP*DAY*FERT|HERB/FERT*DAY;
  POOL 'D*R+R*D*H|F' REP*DAY REP*DAY*FERT|HERB/FERT*HERB*DAY;
TEST FERT|HERB BY 'R*F|H';
TEST  DAY  DAY*FERT|HERB BY 'R*D+R*D*F|H';
```

DATA SET ALLHERB

CLASSES	VALUES
REP	1 2 3
FERT	F 0
HERB	H N
DAY	221 236 279 293 397

VITA

Robert Woodrow Hammond

Candidate for the Degree of

Master of Science

Thesis: WEATHER, RANGELAND PRACTICES AND NORTH CENTRAL OKLAHOMA POOR CONDITION TALLGRASS PRAIRIE REGROWTH AFTER GRAZING

Major Field: Agronomy

Biographical:

Personal Data: Born in Portland, Oregon, May 27, 1945, the son of Mr. and Mrs. Woodrow T. Hammond. Married Joan Marie Simon September 16, 1967.

Education: Graduated from Yucaipa High School, Yucaipa, California in June 1963; received Bachelor of Science degree in Range Management from California State University - Humboldt in 1968; completed requirements for the Master of Science degree at Oklahoma State University in December, 1977.

Professional Experience: Range Research Technician, Oklahoma State University, 1971-present.

Professional Organization: Society for Range Management
Weed Science Society of America