RESPONSE OF OKLAHOMA RANGELAND TO ATRAZINE, 2,4-D, AND FERTILIZER

By

ROGER LYNN BAKER

Bachelor of Science in Agriculture
Kansas State University
Manhattan, Kansas
1969

Master of Science
Texas Tech University
Lubbock, Texas
1972

Submitted to the Faculty of the Graduate College
Of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1978

RESPONSE OF OKLAHOMA RANGELAND TO

ATRAZINE, 2,4-D, AND FERTILIZER

Thesis Approved:

Jeff Powell
Thesis Adviser

E. H. McIlvain

J. F. Stritzke

Robert D. Morrison

J. J. Crockett

Norman D. Durham
Dean of the Graduate College

PREFACE

The science of rangeland management is based on a continuing supply of usable herbage for animal production. There is a great need to develop rangelands and better utilize their potential. Poor management and production practices combined with limiting factors usually results in decreased rangeland production. Limiting factors such as climatic effects and soil properties are readily evident. We know little about others such as herbage utilization by various fauna (insects, rodents, birds, nematodes, etc.) and allelopathic reactions. Range scientists must find ways to overcome the limiting factors, but to accomplish this the basic reactions of all ecosystem participants must be studied. Those individuals that represent rangeland management and are inflexible to changes and unreceptive to new ideas and innovations can only deter the growth and development of rangeland management.

Rangeland is a diverse community of species with many interspecific and intraspecific relationships to be considered. Herbicides and fertilizers have successfully increased field crop production and they also hold a key to increases in rangeland productiveness. The present solution for increased production on rangeland is a continual research program, and the challenge will continue to be met through innovative rangeland managers.

The purpose of this study was to evaluate the response of Oklahoma rangeland to the application of atrazine, 2,4-D, and fertilizer. This

was measured through herbage production, species changes and crude protein changes of the herbage.

Financial assistance for the study was provided through Oklahoma Agricultural Experiment Station funds plus a grant from CIBA-Geigy Corporation. Land for the study was provided through the courtesy of Mr. Jim Williams of Stillwater.

My appreciation to my major adviser, Dr. Jeff Powell, cannot be fully expressed in words, but his guidance and patience will help me share with others the knowledge, love, and understanding I have gained for rangeland management. My graduate committee members, Drs. Robert Morrison, Jerry Crockett, and Jim Stritzke, and Mr. E. H. McIlvain have been an invaluable reference in their specialities and in their constructive criticism of my professional development.

I thank Mr. Bob Hammond for his patience, guidance, and help in the development of my field techniques, vegetation identification, computer knowledge, and general common sense. I believe this research could not have developed as it did if it were not for Bob. Mrs. Ann Williams is acknowledged for the tolerance and understanding she possessed during the preparation of this manuscript.

At the culmination of my formal education I thank my parents for their love and understanding through the years of reaching this goal, and my mother and father-in-law who have helped keep our morale from sinking.

To my wife, Debbie, who has sacrificed her own goals, and our children, Patrick and Marie, who have loved their father patiently, you have tolerated all my troubles and shared my love. I pray that the future will make me a father worthy of such a faithful and wonderful family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

One economic value of rangeland can be measured by its forage production potential and by the performance of the grazing animal harvesting the forage. A rangeland animal's performance is influenced by animal preference, species present for grazing, and the herbage dry matter content, nutrient composition, digestibility, and palatability. A simultaneous decline in nutrient content and digestibility is characteristic of range grasses as they mature (Burzlaff 1971, Cogswell and Kamstra 1976). Therefore, the performance of grazing animals on mature range forage is less than that on the same actively growing forage (Rao et al. 1973, Sneva et al. 1973). Animal performance could be improved and supplemental feed costs reduced by slowing the decline in herbage protein content throughout the growing season and into the winter.

Several herbicides were recently used in the attempt to increase yield, crude protein (CP) content, and digestibility of forage species. On Wyoming subalpine rangeland 2,4-D[(2,4-dichlorophenoxy) acetic acid] did not change In Vitro dry matter digestibility (IVDMD) of grasses or forbs (Thilenius and Brown 1976). Application of 2,4-D and picloram (4-amino-3, 5, 6-trichloropicolinic acid) used for control of *Artemisia tridentata* was followed by application of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] to control

Bromus tectorum and enhance perennial grass seedling growth (Evans and Young 1977). Simazine [2-chloro-4, 6-bis(ethylamino)-s-triazine] increased CP and dry matter yield of *Phleum*, *Festuca*, and *Lolium* species in a greenhouse study (Allinson and Peters 1970), and rates less than 0.56 kg/ha increased yield and CP in *Lolium*, *Oryza*, *Avena*, and *Medicago* in Michigan and Costa Rica (Ries et al. 1968).

Single applications of 1.1 kg/ha simazine depressed CP, dry matter yield and IVDMD of *Phalaris arundinacea* while split applications of the same treatment did not decrease yields (Allison 1972). Atrazine, simazine, and metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one] controlled *Bromus tectorum* and increased forage production in Nebraska (Morrow et al. 1977). Grass dry matter yields increased up to 6-fold on atrazine and simazine treated areas in California (Kay 1971). CP increased 4% but nitrate levels in forage approached critical livestock poisoning levels. Broadleaf forb control in Nebraska increased forage production while additional forage increases resulted from nitrogen (N) fertilization (Morrow and McCarty 1976). S-triazine herbicide treatments (1.1 and 3.4 kg/ha) consistantly resulted in increased CP content in eastern Colorado range herbage for three years, but overall herbage yields were not affected. CP increases on herbicide treated areas were additive to increases from N fertilization (Houston and van der Sluijs 1975).

Many increases in production of rangeland dry matter after herbicide application result from decreases in interspecific competition among species (Peters and Lowance 1969). Decreases in grass roots and rhizomes of 60% have been related to natural competition from several rhizomatous range forbs (Dwyer 1958). Removal of grasses

does not always create the same response in forb growth as the removal of forbs on grass growth (Pinder 1975).

Sublethal, or non-toxic, concentrations of s-triazine herbicides can influence plant growth independently of any benefit gained from decreases in competition (Ebert 1976). Stimulations and inhibitions of plant growth are recorded. Growth stimulations after s-triazine treatment affect shoot length, leaf blade surface, stem thickness, and root growth (Ebert 1976). The s-trazine herbicides inhibit the Hill reaction of photosynthesis where herbicidal action is thought to be located during the early steps in the photochemical conversion of energy during photosynthesis but before biosynthesis of saccharides occurs (Von Assche and Ebert 1976).

Changes in plant chemical composition caused by sublethal s-triazine herbicide additions are not fully understood. The effect of s-triazines on N-metabolism has been studied for many plant species. Increases in N occur predominately in the aerial parts of plants (Dumford and Ebert 1976). Previous research with atrazine indicates uptake and translocation of foliar applications of atrazine by many members of the *Poaceae* (*Gramineae*) is through the roots (Minshall 1975). Phytotoxicity in *Setaria* may be restricted to unrolled leaves unless some atrazine is absorbed by the roots (Thompson and Slife 1969). Translocation of atrazine from *Sorghum* and *Digitaria* leaves dipped in labeled atrazine shows very little basipetal movement of the herbicide (Dexter et al. 1966).

Chemical fertilizers generally increase yields of tallgrass prairie forage and CP content (Ball 1965, Senter 1973). However, if not fully utilized by warm season species, N may be used by cool season

species (Owensby et al. 1970), and many undesirable forbs may become sinks for large amounts of N (Harper et al. 1933). The timing of fertilizer application and the response of individual species are important (Wight 1976). On tallgrass prairie fertilizer may be more effectively utilized when applied after native, warm season species have started growth.

This study was conducted to investigate plant species responses to the application of atrazine, 2,4-D, and fertilizer, and the importance of these chemicals in Oklahoma rangeland management practices. Another study objective was to determine if tallgrass prairie responses to atrazine were similar to those in shortgrass plains.

CHAPTER II

STUDY AREA

The study area is 2.25 ha of east-facing, loamy upland rangeland, 11 km north of Stillwater, Oklahoma. The elevation is about 280 m (900 ft). Stillwater has a continental climate with average absolute maximum temperatures exceeding 40° C from June through September, and average absolute minimum temperatures below -20° C from December through March. Annual precipitation averages 820 ± 250 mm and its distribution during the 210 day growing season is 21% (April-May), 28% (June-August), 17% (September-October), plus 34% (November-March) in winter.

The topography is rolling with smooth areas confined to broad interstream divides (Gray and Galloway 1959). The slope of the land varies from 2 to 6% eastward. The soils are predominately fine-loamy, mixed, thermic Udic Arguistolls. The range site is good condition, loamy prairie which has been used as a native hay meadow or grazed moderately for more than 10 years. The area is part of a rotational grazing system with introduced pastures; grazing is during July to September and during the winter months as necessary.

Major species in the study area include *Schizachyrium scoparium* (SCSC), *Sorghastrum nutans* (SONU), *Panicum virgatum* (PAVI), *Andropogon gerardi* (ANGE), *Panicum scribnerianum* (PASC), *Ambrosia psilostachya* (AMPS), and *Carex* spp. (CAREX). Other species mentioned in the

discussion are *Manisuris cylindrica* (MACY), *Aristida oligantha* (AROL), *Amorpha canescens* (AMCA), *Asclepias viridis* (ASVI), *Gaura filiformis* (GAFI), plus the category, tallgrass (ANGE, PAVI, SONU). Scientific names are from Waterfall (1972), and Appendix A lists species found on the study area. Plant species will be discussed in the text using the previous abbreviations.

CHAPTER III

METHODS

A randomized block experimental design was used in 1975 with three replications of 15 treatments (Table 1). Randomly selected 12 x 15 m plots were treated with foliar sprays of atrazine (1.1 and 3.4 kg/ha) and 2,4-D (0.8 kg/ha) on June 27 or July 16 with a tractor-powered boom-type sprayer using 187 liters water/ha at 2.81 kg/cm^2. Fertilizer (N-P-K) was broadcast June 7 at the rate of 67-45-45 kg/ha. The 15 treatments and the experimental areas are shown in figure 1.

Standing herbage biomass was extimated for each species in June, July, August, and November, 1975, using a modified weight-estimate (Pechanec and Pickford 1937) and double sampling method (Wilm et al. 1944). Species production on six, 0.5 m^2 sample areas were estimated for each treatment in each of the three replications, and two of the six samples were clipped at a 5-cm stubble height and dried at 60^{o} C to a comstant weight to determine the estimation correction factor and dry matter content. To insure against vegetation being clipped twice during the experiment each treatment plot was divided into 32 individual sampling areas and sampling dates were randomly assigned (Fig. 2). Soil samples were taken at 0-30 cm and 30-60 cm depths with a split-tube soil sampler or a Veihmeyer soil tube at each clipped sample site to determine percent soil water using the gravimetric method (National Academy of Science 1962).

Table 1. Treatments, treatment codes, and month of application.

Treatment code	Treatment and month of application
C	Untreated or control.
N	67 kg N/ha, June.
NP	67 kg N/ha, 45 kg P_2O_5/ha, June.
NPK	67 kg N/ha, 45 kg P_2O_5/ha, 45 kg K_2O/ha, June.
DNPK	0.8 kg 2,4-D/ha plus 67 kg N/ha, 45 kg P_2O_5/ha, 45 kg K_2O/ha, June.
A61	1.1 kg atrazine/ha, June.
A71	1.1 kg atrazine/ha, July.
A63	3.4 kg atrazine/ha, June.
A73	3.4 kg atrazine/ha, July.
AN	3.4 kg atrazine/ha plus 67 kg N/ha, June.
ANP	3.4 kg atrazine/ha plus 67 kg N/ha, 45 kg P_2O_5/ha, June.
ANPK	3.4 kg atrazine/ha plus 67 kg N/ha, 45 kg P_2O_5/ha, 45 kg K_2O/ha, June.
ADNPK	3.4 kg atrazine/ha, 0.8 kg 2,4-D/ha plus 67 kg N/ha, 45 kg P_2O_5/ha, 45 kg K_2O/ha, June.
6D	0.8 kg 2,4-D/ha, June.
7D	0.8 kg 2,4-D/ha, July.

C - Untreated
A - Atrazine
6 - June Application
7 - July Application
1 - 1.1 kg/ha
3 - 3.4 kg/ha
N - 67 kg/ha N
P - 45 kg/ha P
K - 45 kg/ha K
D - 0.8 kg/ha 2,4-D

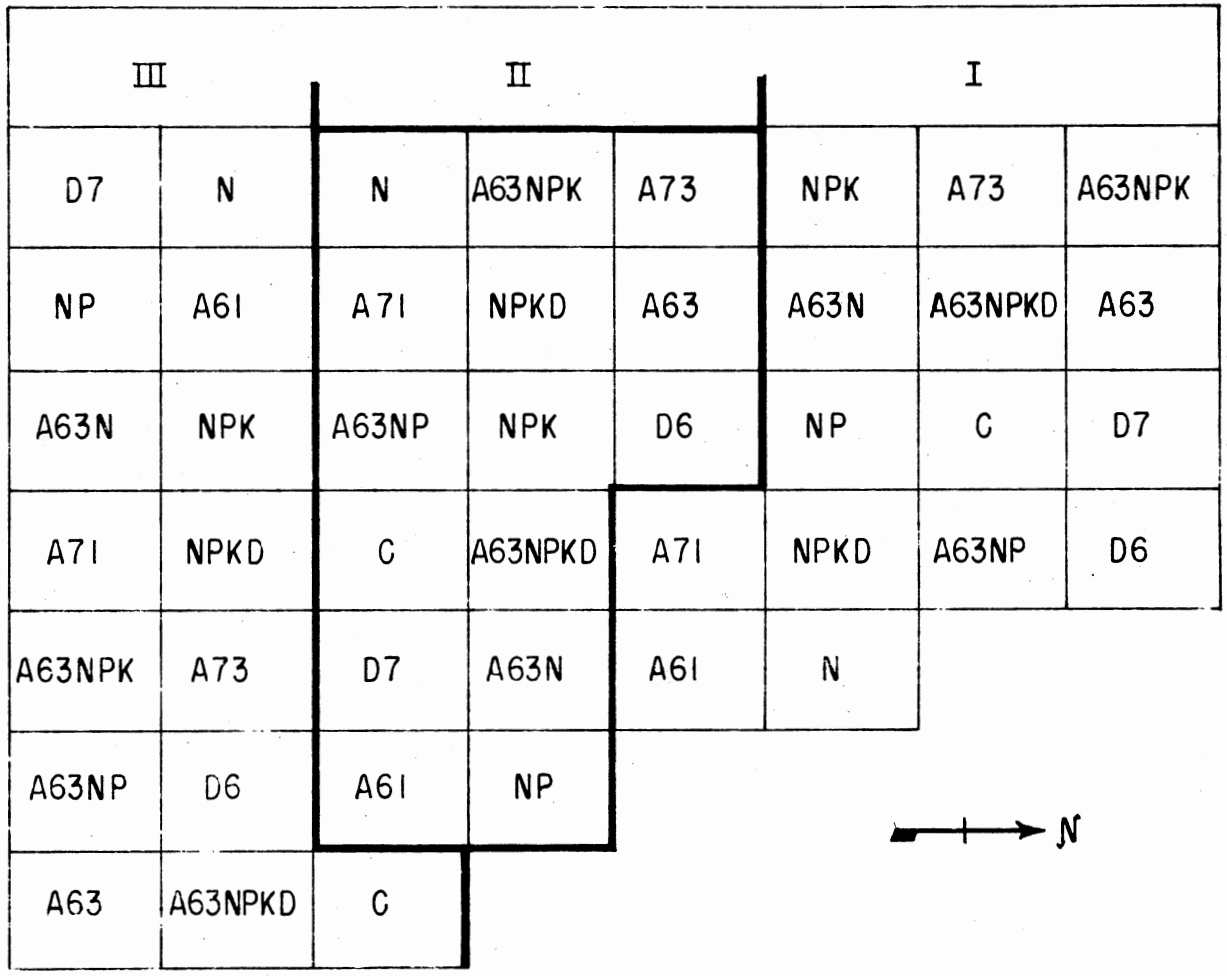


Fig. 1. Location of replications and treatments in study area.

1975 Sampling

	Jun.	Nov.	Aug.	Jul.		Jul. Clip	Jul.
Nov.	Jun.	Aug. Clip	Jul.		Aug.		Nov.
	Nov. Clip	Jul. Clip	Jul.	Jun.		Aug.	Jun. Clip
Aug.			Aug. Clip	Nov.	Jun.	Jun. Clip	Nov. Clip

Fig. 2. Location of samples for each sampling date for a treatment area in 1975 (Each treatment area was sampled similarly).

All standing vegetation was mowed to a 10-cm height with a rotary blade lawn mower in March, 1976, and left on plots as ground litter. A split-plot design was superimposed on the randomized block design in 1976. One-half of each plot received the same treatment as in 1975, while the other half remained untreated to measure residual effects. Sampling times were again randomly assigned (Fig. 3). In 1976, fertilizer was broadcast May 10, and herbicides were applied as in 1975 on June 4 and July 8. Herbage yields were estimated in June, July, August, and November to coincide with similar phenological growth stages in 1975. Four estimates per treatment area were recorded with one estimated sample clipped. Other sampling procedures were unchanged from 1975.

Forage samples were mixed by hammermilling and then ground with a Wiley Mill to pass a 2-mm screen. Samples were sent to the Oklahoma State University Soil Testing Lab for nitrogen determination. The 1975 nitrogen analyses were by the micro-Kjedahl and nitrogen analyzer procedure (OSU Soil and Water Testing Laboratory, Stillwater, Unpublished procedures) while 1976 analyses were by the macro-Kjeldahl procedure (AOAC 1970).

Data were analyzed using an IBM 370/158 computer and the ANOVA procedure of the Statistical Analysis System (Barr and Goodnight 1972). Statistically significant differences among treatment means were determined using the least significant differences (LSD) from the analysis of variance, and all discussion is based on differences at the 95% level of probability unless otherwise indicated. Examples of data forms prepared to facilitate keypunching data cards are shown in Appendix C and D. Examples of computer input and analysis programs are shown in Appendix E, F, and G.

1976 Sampling

Aug. Clip	Jul.	Jul.	Jun.	Aug.	Jun. Clip	Nov.	Nov.
Residual							
Jun.	Nov.	Aug.	Nov. Clip	Aug.	Jun.	Jul.	Jul. Clip
Aug.	Jul.	Jul.	Nov.	Aug. Clip	Jul.	Nov. Clip	Nov.
Retreated							
Jun.	Jul. Clip	Jun.	Nov.	Aug.	Jun. Clip	Aug.	Jan.

Fig. 3. Location of samples for each sampling date for a treatment area in 1976 (Each treatment area was sampled similarly).

CHAPTER IV

RESULTS AND DISCUSSION

Weather

Precipitation during the study period was very erratic in frequency and amount (Fig. 4, 5). The week of greatest rainfall (142 mm) occurred in October, 1974, followed by another week with 132 mm. These two rainfall periods plus other periods of precipitation during the winter provided abundant soil water in spring, 1975. Only one other week during the study period received 100+ mm precipitation. Heavy rains (281 mm in three weeks) fell in May, 1975. Precipitation became progressively less during each of the following months in 1975 with generally one week of precipitation and three weeks of little or no precipitation. On June 13, 1975, a tornado struck Stillwater with 30 mm rainfall plus hail (H. E. Myers, personal communcation). At the same time the study area received an undetermined amount of hail. The effect on the vegetation is unknown although broken leaves and stems were noted. After June, 1975, only March, 1976, precipitation was above average during the remainder of the study. From May through September, 1976, weekly precipitation was above 20 mm during only two weeks and above 10 mm for five weeks.

A species survey done on similar rangeland five miles from this study area in March, 1976, revealed that the abundance of cool season

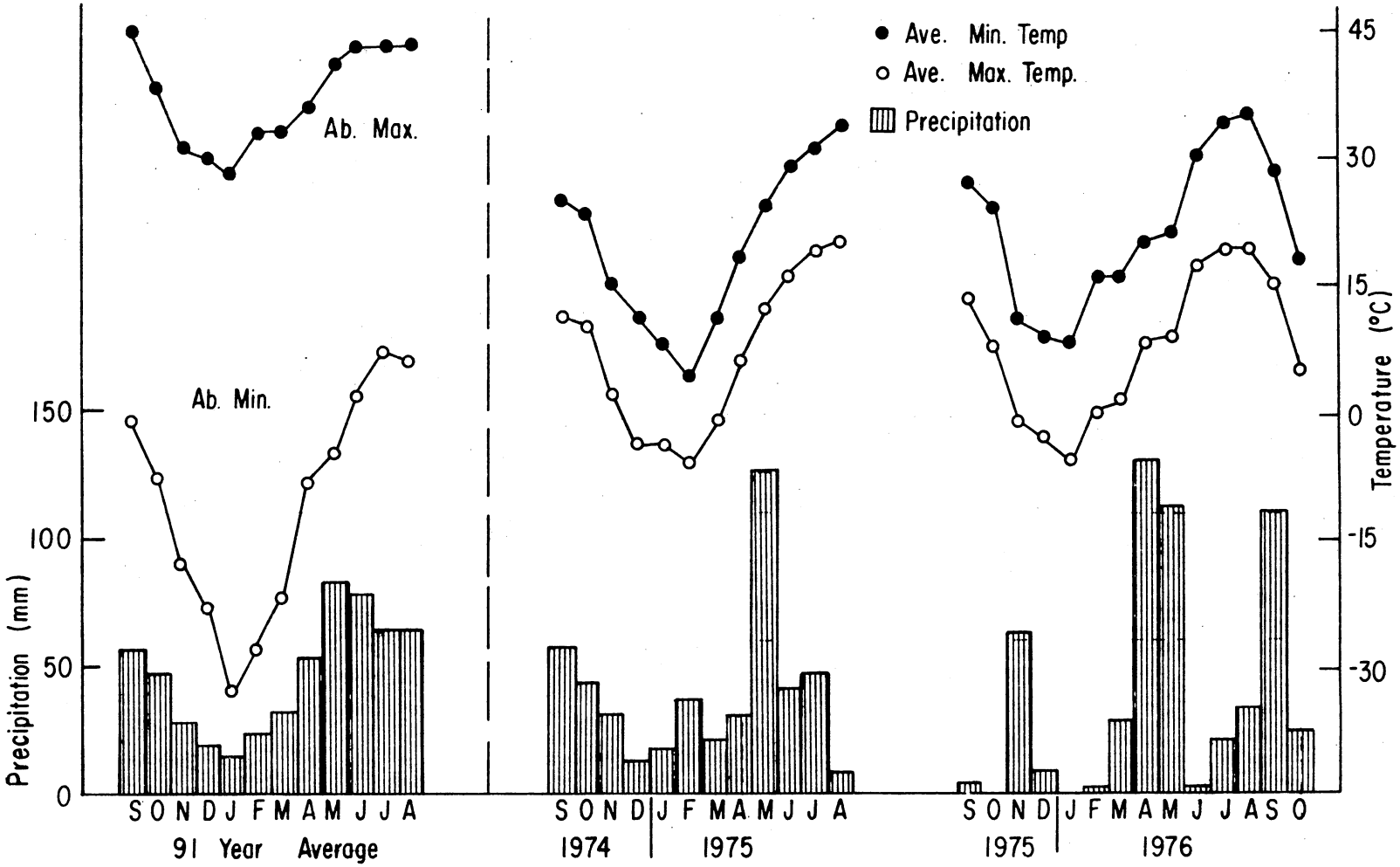


Fig. 4. Longterm (1893-1975) average monthly precipitation, absolute maximum, and absolute minimum temperatures; monthly precipitation, average maximum and average minimum temperatures during study period, Stillwater.

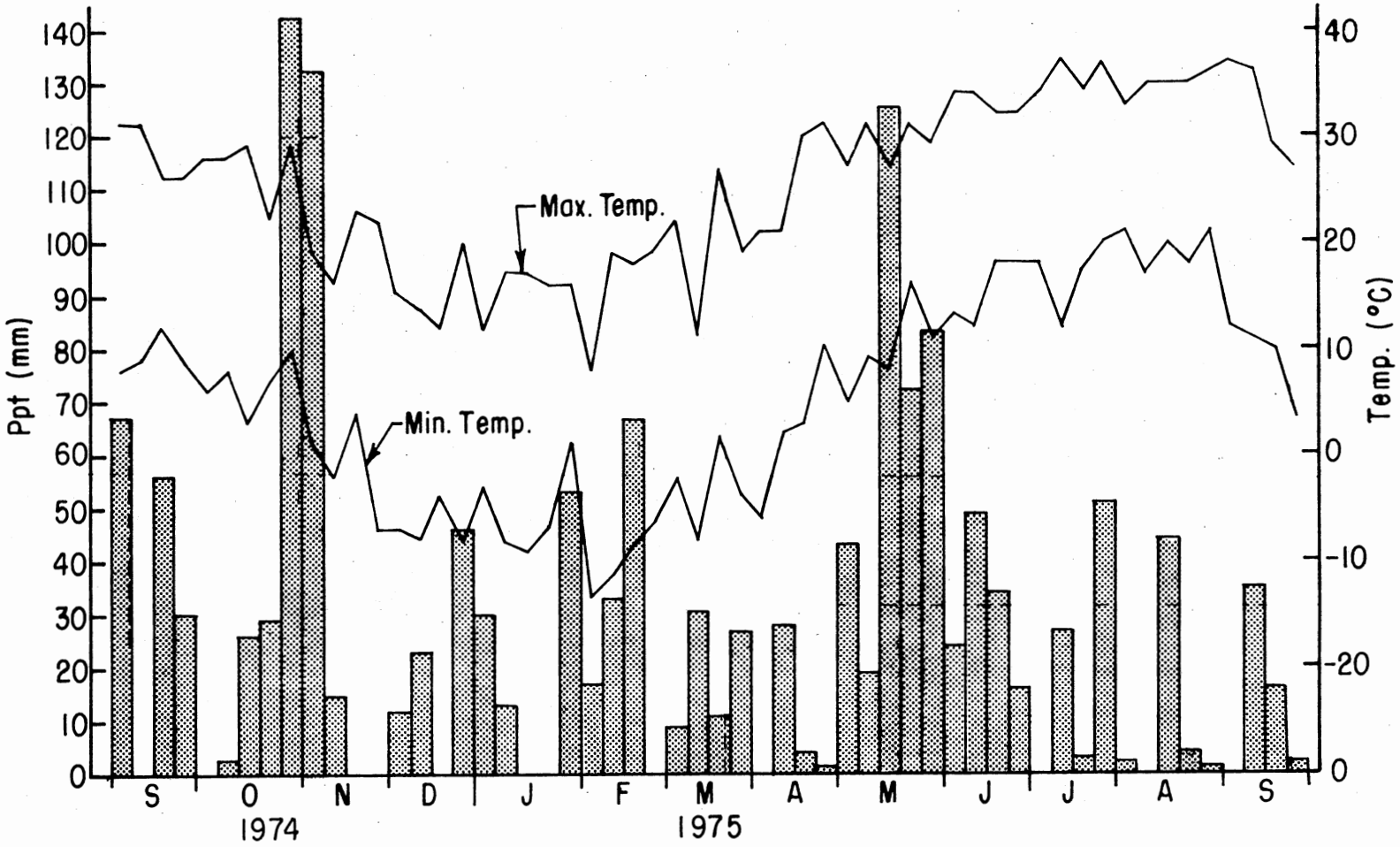


Fig. 5. Weekly precipitation (mm) and absolute maximum and absolute minimum temperatures (°C) for study area, Sep. 1974 - Sep. 1975.

grasses and forbs was far below normal presumable because of dwindling soil water (Powell et al. 1978). This may also have decreased the occurrence of some cool season species in this study.

Average temperatures during March, 1975 were below normal. Absolute maximum and minimum temperatures were often below normal through July (Fig. 4, 5, 6). Temperatures were above average during March and April, 1976, while May and June temperatures were again below normal. Absolute maximum temperatures in 1976 reached 38° C five times in July and 11 times in August. To emphasize extremes in weather, on August 2, 1976, the temperature reached 39° C and 70 mm of precipitation was recorded.

Herbage Production on Untreated Areas

Herbage production in July, 1975, was 61% greater than production in June on untreated areas. Total herbage dry matter remained relatively constant in August and November (Table 2). In June, 1976, herbage production was 50% greater than in June, 1975. Herbage in 1976 was 65% greater in July than June. Growth of warm season species started earlier in 1976 than in 1975, so herbage sampling was earlier in 1976 to coordinate phenological stages between the two years. August and November herbage was less than the July herbage. In 1975 the study area received a full year's rest from grazing so that in 1976 plants were more vigorous even though water loss is sometimes greater from an ungrazed plant (Brown 1977, Stoddart et al. 1975). Soil water was less in 1976 due to increased transpiration from larger plants and to less precipitation (Table 3). March and April temperatures were higher in 1976 than in 1975. Warm season species' growth started earlier in the season resulting in an advanced phenological stage in May, June, and

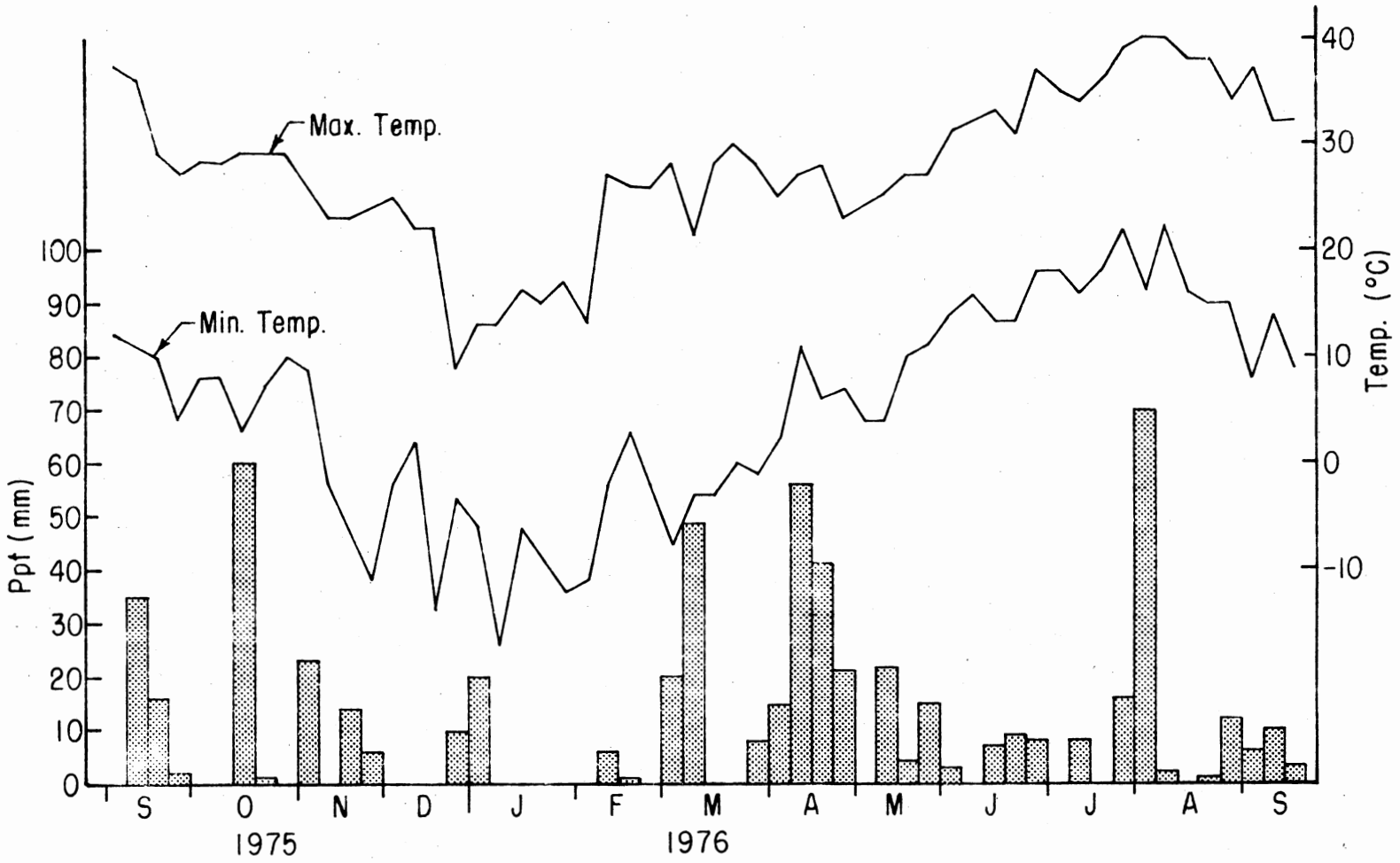


Fig. 6. Weekly precipitation (mm) and absolute maximum and absolute minimum temperatures (°C) for study area, Sep. 1975 - Sep. 1976.

Table 2. Dry matter production (kg/ha) by species classes on untreated areas.

Species Class	1975 June	1975 July	1975 Aug.	1975 Nov.	1976 June	1976 July	1976 Aug.	1976 Nov.
Herbage	1350	2200	2000	2050	2000	3100	2600	2600
Grasses and grasslike	850	1750	1600	1850	1550	2550	1850	2050
Tallgrass	300	700	600	600	450	1050	700	950
SCSC	100	150	350	400	300	650	500	350
CAREX	100	500	300	150	300	350	150	100
Other	350	400	350	700	500	500	500	650
Forbs	500	450	400	250	500	550	750	550
AMPS	150	250	300	150	100	150	250	150
Other	350	200	100	100	400	400	500	400

Yields are rounded to nearest 50 kg.

Table 3. Soil water content (%) for untreated areas on different sampling dates (0-60 cm depth).

1975 Date	1975 Soil Water	1976 Date	1976 Soil Water
June 5	27	June 1	12
July 23	11	June 30	5
Aug. 21	9	July 28	4
Nov. 22	17	Oct. 25	13

July. Differences in herbage production between 1975 and 1976 are related to the previously mentioned factors. A decrease in daily growth with approaching maturity, the breaking of leaves and stems by wind, and the grazing and breaking of leaves and stems by insects, rodents, and birds decreases standing herbage biomass (Heady 1975). These reductions in biomass vary with phenological stage, weather, and species present (Wiegert and Evans 1964, Bement 1969, Wiegert and McGinnis 1975).

Grass increased from 64% to 80% of the total herbage from June to July, 1975. Grass was 78% and 82% of the June and July, 1976, total herbage, respectively. August grass in both years was slightly less than in July or in November. The greater decline was between July and August. Additional dry matter production of grass after July was not great enough to offset losses of plant material to other factors, so grass production generally showed no increase.

Tallgrasses (ANGE, PAVI, SONU) and SCSC produced about half of the total grass in June, 1975. SONU was the most abundant species. Carex and PASC were also relatively abundant in June, 1975. The tallgrass plus SCSC production doubled from June to July, 1975, and was composed of 17% ANGE, 34% PAVI, 30% SONU, and 19% SCSC in July. August and November tallgrasses were slightly less than in June but SCSC was greater. The June, 1976, tallgrass plus SCSC was 750 kg/ha, and was about half of the total grass as in June, 1975. SCSC production was equal to that of SONU in June. Tallgrass plus SCSC was 1700 kg/ha in July, 1976, composed of 10% ANGE, 22% PAVI, 31% SONU, and 37% SCSC. CAREX and PASC were again abundant in 1976, primarily in June and July. August tallgrass plus SCSC production was less than in July and decreased

by the same percentage as total grass, while the November production was 3% ANGE, 41% PAVI, 29% SONU, and 27% SCSC.

More forb species were recorded in June than in any other month. Forb production in 1975 was the largest in June (480 kg/ha), and decreased at each subsequent sampling. The June, 1976, forb production was the same as in July, 1975; however, production continued to increase through August, 1976. Other Oklahoma studies indicate that forb production gradually increases into August (Hammond 1977, Broyles 1978). As spring forbs mature and deteriorate, summer forbs increase. AMPS was the most abundant forb, and the greatest AMPS production was in July and August, 1975. The AMPS production followed the same seasonal growth pattern as total forbs in 1976.

First Year Treatment Responses

Total herbage production was different due to the effects of treatments on forbs (Table 4). Total herbage was greater on the NP, NPK, and DNPK areas than on untreated areas. Herbage was greater on 1.1 kg atrazine only areas (A61, A71), and less on 3.4 kg atrazine only areas (A63, A73) than on untreated areas. Total herbage was not greater on atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) than on untreated areas.

Differences in grass production among the 15 treatments in 1975 were significant at the 10% level of probability. Forb production was equal on fertilizer only (N, NP, NPK) and untreated areas. However, total forb production was less on atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) than on untreated areas and fertilizer only areas

Table 4. Average total production (kg/ha dry matter) of July, August, and November herbage and grass from 15 treatment areas in 1975.

Treatments[1]	Herbage	Grass
Untreated	2100	1750
N	2650	2200
NP	3150	2700
NPK	3150	2650
DNPK	2900	2800
A61	2450	2300
A71	2450	2150
A63	1850	1800
A73	1950	1750
AN[2]	2400	2350
ANP[2]	2200	2100
ANPK[2]	2200	2150
ADNPK[2]	2600	2550
6D	2400	2300
7D	2550	2350
Probability level	.02	.10
$LSD_{.05}$	710	740

[1]A = atrazine, 6 = June application, 7 = July application, 1 = 1.1 kg/ha, 3 = 3.4 kg/ha, N = 67 kg/ha N, P = 45 kg/ha P_2O_5, K = 45 kg/ha K_2O, D = 0.8 kg/ha 2,4-D.

[2]Atrazine was applied in June at the rate of 3.4 kg/ha.

(N, NP, NPK). Therefore, atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) contained a larger percentage of grass than other areas.

Three common grass species (AROL, PAVI, SONU) presented three different responses to the treatments. AROL, a warm season annual grass susceptible to atrazine, produced 120 kg/ha on untreated areas. Production of AROL did not change on the fertilizer only (N, NP, NPK) or on 2,4-D plus fertilizer (DNPK) areas, but AROL production was less on all areas treated in June with 3.4 kg atrazine (A63, AN, ANP, ANPK, ADNPK) than on untreated areas. AN, ANP, and ADNPK areas produced less AROL than their respective fertilizer only areas (N, NPK, DNPK). AROL did not benefit significantly from fertilizer during the first year.

PAVI production was greater on AN and ADNPK areas than on untreated areas, and greater on ADNPK areas than on DNPK areas. SONU production was greater on NP, NPK, DNPK, ADNPK, 6D, and A61 areas than on the untreated areas. PAVI increased its greatest production on atrazine plus fertilizer areas, and SONU increased its greatest production on fertilizer only areas.

The major forb present, AMPS, averaged 240 kg/ha on untreated areas, and production was less on all areas treated with herbicide in July (A61, A63, AN, ANP, ANPK, 6D) than that on untreated areas. AMPS production on fertilizer only areas (N, NP, NPK) was not greater than on untreated areas, but was greater on these areas than on the respective atrazine plus fertilizer treatments (AN, ANP, ANPK).

Second Year Residual Treatment Responses

Areas treated with 1.1 kg atrazine or N in June, 1975, produced more grass and total herbage in 1976 than did untreated areas (Table 5).

Table 5. Average total production (kg/ha dry matter) of July, August, and November herbage and grass from 15 residual treatment areas in 1976.

Treatments[1]	Herbage	Grass
Untreated	2900	2200
N	3650	2900
NP	3250	2550
NPK	3350	2600
DNPK	3250	2800
A61	3500	3050
A71	3100	2650
A63	2850	2350
A73	2800	2450
AN[2]	3700	3400
ANP[2]	3800	3350
ANPK[2]	3600	3150
ADNPK[2]	3600	3300
6D	3100	2650
7D	2800	2500
Probability level	.01	.01
$LSD_{.05}$	560	640

[1]A = atrazine, 6 = June application, 7 = July application, 1 = 1.1 kg/ha, 3 = 3.4 kg/ha, N = 67 kg/ha N, P = 45 kg/ha P_2O_5, K = 45 kg/ha K_2O, D = 0.8 kg/ha 2,4-D.

[2]Atrazine was applied in June at the rate of 3.4 kg/ha.

In addition all atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) also produced more grass and herbage than did untreated areas. Grass production was greater on areas treated with 1.1 kg atrazine in June than on areas treated with 3.4 kg atrazine in June. The rate of June applied atrazine for maximum grass production was therefore less than 3.4 kg atrazine per hectare. Total herbage production was greater on all treatments in 1976 than in 1975, although all differences were not statistically significant at the 5% level.

The residual effect of fertilizer influenced herbage production in 1976 more than any residual effect of atrazine. Atrazine would not be expected to remain in the soil in toxic quantities one year after application (Le Baron 1970). The measurable residual effect of atrazine would be in species changes remaining from the first year of application. Forb production increased 6-fold or more on atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) from 1975 to 1976. Only the AN and ADNPK areas had less forb production than the untreated areas and the N and NPK areas. AMPS was the only forb with less production in 1976 than in 1975. These results support previous research that reduced competition from forbs allows increased grass production (Elwell and McMurphy 1973, Morrow and McCarty 1976).

Individual species again responded differently to residual effects of treatments. MACY, a grass maturing in June and July, is normally not abundant on Oklahoma rangelands. However, as a result of drought, protection from grazing, or treatments applied, MACY production was as much as 15% of the total grass (350 kg/ha on A63 areas). MACY has been classified as a bunchgrass characteristically found in association with SCSC on overgrazed areas subject to sheet erosion or gullying. MACY

may also occur on lower ground in association with ANGE and SCSC. Once established MACY may become a permanent part of the community (Carpenter 1937). MACY production was less on the untreated areas than on all areas treated with atrazine except A71 areas (A61, A63, A73, AN, ANP, ANPK, ADNPK), and on N and 6D areas. Increased MACY production may have resulted from residual fertilizer stimulation and less competition from various spring and early summer (May, June) forbs.

ANGE production was greater only on ANPK and ADNPK areas when compared to untreated, NPK and DNPK areas. Increased soil fertility and reduced competition may have caused the differences in ANGE production. PAVI production was greater on AN and ADNPK areas than untreated, N and DNPK areas. Increases in plant stem numbers on *Andropogon hallii* and PAVI have been related to growth of rhizomes and axillary buds (Sims et al. 1971, Sims et al. 1973). Much root growth and rhizome and axillary bud formation for additional shoot growth occurs in August, September, and October of the previous year (Sims et al. 1973, E. H. McIlvain, personal communication). Increased soil fertility and less interspecific competition with forbs in 1975 may have benefited ANGE and PAVI growth.

AMPS, the major forb present, was decreased by herbicides and generally increased on fertilizer only areas. AMPS production was less on 6D, 7D, A73, ANP, ANPK, DNPK, and ADNPK areas and greater on N and NP areas than on untreated areas.

Second Year Retreatment Responses

Total herbage on retreated areas was greater on areas receiving fertilizer (AN, ANP, ANPK, ADNPK, N, NP, NPK, DNPK) than on untreated

areas. Production on ANP areas was 1050 kg/ha more than on AN areas indicating the value of P in this case. Grass production was greater on A71, AN, ANP treated areas and on all areas treated with NPK fertilizer (NPK, ANPK, DNPK, ADNPK) than on untreated areas (Table 6). Throughout the study total grass yields tended to decrease on the 3.4 kg atrazine areas (A63, A73) while 1.1 kg atrazine did not decrease yields. This was the same response observed in Colorado (Houston and van der Sluijs 1975). ANP treated areas were the only atrazine plus fertilizer areas in which grass production was greater than on the corresponding fertilizer areas.

All treated areas contained less AROL than untreated areas. This decrease was expected on atrazine treated areas, but a decrease was not expected on fertilizer only (N, NP, NPK) areas. Two years of fertilization possibly increased soil fertility levels sufficiently to create an unsuitable environment for AROL (Rice et al. 1960, Hyder and Bement 1972, Leuck and Rice 1976). A decrease in AROL production on 6D and 7D areas cannot be explained except that poor germination and survivability during the dry summer decreased the total AROL population. PAVI production was greater on AN, ANP, ADNPK areas than on untreated areas, and greater on AN and ADNPK areas than on N and DNPK areas, respectively. MACY showed no definite pattern of response, and production was greater on A63, A73, and ANPK areas than on untreated areas. On AN and ANP areas MACY production was 53% lower than on A63 areas, but was not significantly lower. Rodent damage was evident on MACY culms in June and July. Some culms had been cut at ground level and the caryopses eaten. All areas treated with 3.4 kg atrazine (A63,

Table 6. Average total production (kg/ha dry matter) of July, August, and November herbage and grass from 15 retreated areas in 1976.

Treatments[1]	Herbage	Grass
Untreated	2650	2050
N	3650	2900
NP	4100	2800
NPK	4600	3400
DNPK	4750	4500
A61	3150	3000
A71	3400	3100
A63	2800	2650
A73	2800	2500
AN[2]	3700	3600
ANP[2]	4750	4600
ANPK[2]	4450	4300
ADNPK[2]	5150	5050
6D	2900	2700
7D	2800	2550
Probability level	.01	.01
$LSD_{.05}$	980	990

[1]A = atrazine, 6 = June application, 7 = July application, 1 = 1.1 kg/ha, 3 = 3.4 kg/ha, N = 67 kg/ha N, P = 45 kg/ha P_2O_5, K = 45 kg/ha K_2O, D = 0.8 kg/ha 2,4-D.

[2]Atrazine was applied in June at the rate of 3.4 kg/ha.

A73, AN, ANP, ANPK, ADNPK) and 2,4-D (6D, 7D) produced less than 10 kg/ha AMPS.

Production Changes, July to November

Peak standing production on rangeland depends on the major species present (Kamstra 1972, Conant and Risser 1974, Bradbury and Hofstra 1976). Early grass growth is predominately the result of leaf blade elongation, while later growth may be from reproductive tissue and structures such as flowering culms (Sims et al. 1971, Sims et al. 1973). This growth was evident within the 15 treatments of this study. Peak standing herbage production was recorded in July, August, and November depending on the year and treatment. Few changes in production from July to November were found to be significant (Table 7).

July to November changes in 1975 were different for AMPS ASER, and combined forbs. An increase in forbs on A61 areas probably resulted from partial herbicide dissipation by July. Forb production decreased from July to November on N, NP, and NPK areas as a result of the decrease in AMPS. Forbs also decreased 50% on untreated areas from combined decreases of AMPS, AMCA, and various perennial forbs. AMPS decreased from July to November on fertilizer only areas (N, NP, NPK) but did not change on remaining areas. A reduction in plant water content due to maturity resulted in lower herbage weights.

Only tallgrasses were increased on residual treatment areas in 1976. SONU increased 119% from July to November on A61 areas. Increases in production on ANP, ANPK, NPK, and DNPK were a result of individual increases in PAVI or SONU or both depending upon treatment. This

indicates that both species responded more favorably on areas with N and P treatments.

The second year of herbicide and fertilizer treatment created differences in July to November production for ANGE, SONU, tallgrasses, total grass, and total herbage. ANGE decreased from July to November on ANPK, ADNPK, DNPK, and untreated areas. However, ANPK, ADNPK, and DNPK areas produced, at peak ANGE production, the most ANGE of all 15 treatments, and the greatest standing biomass of ANGE was produced in July and August. SONU increased on DNPK and 6D areas and decreased on ADNPK areas. Tallgrass production increased on ADNPK, NPK, and 6D areas. Increases on ANPK and NPK retreated areas were attributed to both PAVI and SONU as on 1976 residual areas; however, the increase on 6D areas was a result of a 216% increase in SONU. Grass increased only on the ADNPK areas, as a result of the increase in tallgrasses. Total herbage increased on the ADNPK areas but decreased on NP areas. A 47% decrease in total herbage resulted from reductions of SONU, SCSC, MACY, GAFI, and *Asclepias viridis*. All other changes in minor species were not related to season or treatment.

Treatment Response by Month

July

Rangeland in the Great Plains is commonly grazed during the summer growing period (season-long) and in winter after seed maturity in year-long, rotational, or deferred grazing systems (Broyles 1978). The range manager needs to know the response and production capabilities of rangeland for grazing during both periods. July production values are

Table 7. Total grass and herbage production (kg/ha dry matter) from 15 treatment areas on July and November sampling dates, 1975, and from residual and retreated areas on July and November sampling dates, 1976.

Treatment[1]	1975				1976							
					Residual				Retreated			
	July		Nov.		July		Nov.		July		Nov.	
	Grass	Herbs	Grass	Herbs	Grass	Herbs	Grass	Herbs	Grass	Herbs	Grass	Herbs
Untreated	1750	2200	1850	2050	2700	3450	2150	2600	2350	2750	1950	2600
N	1650	2250	2600	2900	3000	3950	3200	3850	2850	3650	3600	4250
NP	2550	3000	2400	2600	2600	3300	2550	3150	3150	4550	2150	3050
NPK	2450	3100	2800	3050	2400	3000	3150	3750	2850	4250	3850	4500
DNPK	2200	2350	2800	2800	2650	3150	3200	3500	3600	3900	4450	4550
A61	1750	1900	2800	2950	3300	3800	3300	3700	2800	2900	3150	3250
A71	1800	2400	2400	2450	2650	3150	3150	3500	3350	3900	3400	3550
A63	1200	1300	2250	2250	2400	2800	2400	2700	2500	2650	3300	3350
A73	1450	1900	2000	2100	2900	3250	2450	2700	2500	2950	2500	2750
AN[2]	1950	2050	2400	2450	3900	4250	2900	3200	3500	3650	3100	3200
ANP[2]	1550	1600	2700	2700	3050	3400	3850	4250	3900	4050	5150	5200
ANPK[2]	1600	1700	2450	2450	2750	3300	3800	4000	4250	4550	4550	4650
ADNPK[2]	2100	2150	2500	2550	3800	4200	2950	3050	6000	6050	3800	3850
6D	1900	2050	2400	2450	2500	2900	3000	3350	2150	2450	3250	3300
7D	1950	2350	2600	2650	2700	2950	2450	2600	2700	3050	2750	2850
Probability Level	.10	.01	.85	.82	.30	.21	.01	.01	.01	.01	.01	.02
LSD .05	800	770	1040	1070	1190	1110	860	800	1320	1290	1450	1450

[1]A = atrazine, 6 = June application, 7 = July application, 1 = 1.1 kg/ha, 3 = 3.4 kg/ha, N = 67 kg/ha N, P = 45 kg/ha P_2O_5, K = 45 kg/ha K_2O, D = 0.8 kg/ha 2,4-D

[2]Atrazine was applied in June at the rate of 3.4 kg/ha

representative of production for summer grazing and November values are representative of standing production for winter grazing.

The first year of treatment differences in July grass yields were significant at the .10 level of probability; however, treatments created greater differences in total herbage (Table 7). Total herbage was 900 kg/ha less on A63 areas than on untreated areas. This decrease was similar to that of herbage treated with 3.4 kg atrazine in eastern Colorado (Houston and van der Sluijs 1973). Total herbage increased on NP and NPK areas compared to untreated, ANP, and ANPK areas. In July, 1975, herbage was 80% grass on untreated areas, 76% grass on fertilizer only (N, NP, NPK) areas, and 95% grass on fertilizer plus atrazine areas (AN, ANP, ANPK, ADNPK).

Residual areas in 1976 produced no significant differences in grass or total herbage among treatments. However, untreated and fertilizer only areas (N, NP, NPK) were 78% grass, while atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK) were 89% grass.

In July, 1976, areas retreated with ANP, ANPK, and ADNPK produced more grass than untreated areas. PAVI and SONU produced more herbage than any other species. Production of over 3000 kg/ha on native rangeland by a single species may not be attainable under average growing conditions and moderate grazing. At that high a level of production, intraspecific competition, drought stress and grazing pressures could decimate the community in dry years (Harlan 1960, Dwyer et al. 1963, E. H. McIlvain, personal communication).

Total herbage was greater on ANP, ANPK, ADNPK, NP, and NPK retreated areas than on untreated areas. Tallgrasses and SCSC accounted for the increases on atrazine treated areas (ANP, ANPK, ADNPK), while larger

increases of AMPS combined with tallgrasses and SCSC produced the increases on NP and NPK areas. Total herbage was 85% grass on untreated areas, 71% grass on fertilizer only areas (N, NP, NPK), and 96% grass on atrazine plus fertilizer areas (AN, ANP, ANPK, ADNPK).

November

Grass and herbage production was smallest on untreated areas in 1975 and 1976. Differences among treatments for grass and herbage production in November, 1975, were relatively small and inconsistant between replications. The average production for all treatments was 2450 kg/ha grass and 2550 kg/ha herbage. Variations in grass and herbage production within treatments was generally less on November, 1976, residual areas than November, 1975, areas. The result was lower LSD's and probability levels in 1976 than in 1975.

SONU production was slightly greater than PAVI on areas without atrazine in 1976. PAVI was generally the most productive species on atrazine treated areas. This may be a result of some abiility of PAVI to vegetatively increase ground cover where other species were removed, or it may be a direct physiological response to atrazine. SCSC was generally the third most productive species present.

The ANP treated areas had the largest grass and herbage production in November, 1976. These areas were consistantly greater in production than AN areas which indicates a production increase due to the addition of P.

Differences in grass and herbage production on residual areas were probably caused more by species changes in 1975 than by residual effects of herbicide or fertilizer. Visual observations in May

indicated that there were residual fertilizer elements available. I believe that continued retreatment with atrazine and fertilizer would continue to increase tallgrass and SCSC production for three to five years if soil water were available. These treatments would probably favor PAVI over other species, and the area would become dominated by PAVI. I would not expect large yearly increases in production after about five years.

Protein Yield

Protein yield is determined by multiplying herbage crude protein content times herbage yield. Protein yield represents the amount of protein available per unit area. A treatment producing large amounts of low protein herbage may have the same protein yield as a treatment producing limited amounts of high protein herbage.

July

Protein yield in July, 1975, averaged 195 kg/ha and ranged from 120 kg/ha (A63) to 295 kg/ha (NP, NPK) (Table 8). The protein yield was greater in 1975 on NP, NPK, and ADNPK areas than on untreated areas. Herbage on these treated areas had a greater crude protein content (9.5-11.7%) than herbage on untreated areas (6.5%). Protein yield was greater on NPK areas than on DNPK areas, but crude protein content was not different. Grass production on these areas was nearly equal, but the NPK areas contained 400 kg/ha more forbs, the majority AMPS. Therefore, this difference in protein yield was due largely to forb production with and without 2,4-D.

Table 8. Protein yield of herbage (kg/ha) from 15 treatment areas on July and November sampling dates, 1975, and from residual and retreated areas on July and November sampling dates, 1976.

Treatment[1]	1975		1976			
			Residual		Retreated	
	July	Nov.	July	Nov.	July	Nov.
Untreated	145	115	210	110	155	130
N	205	155	235	160	295	235
NP	295	160	190	115	440	150
NPK	295	180	190	180	385	215
DNKP	200	165	185	140	325	260
A61	175	140	220	135	200	115
A71	175	150	155	135	220	140
A63	120	130	155	115	180	145
A73	175	135	185	115	155	120
AN[2]	205	130	250	105	345	145
ANP[2]	165	175	185	180	415	315
ANPK[2]	180	135	185	195	455	255
ADNPK[2]	245	125	235	125	480	185
6D	190	125	165	125	150	110
7D	180	155	155	95	170	95
Probability level	.03	.64	.10	.01	.01	.01
$LSD_{.05}$	93	62	66	42	80	74

[1]A = atrazine, 6 = June application, 7 = July application, 1 = 1.1 kg/ha, 3 = 3.4 kg/ha, N = 67 kg/ha N, P = 45 kg/ha P_2O_5, K = 45 kg/ha K_2O, D = 0.8 kg/ha 2,4-D.

[2]Atrazine was applied in June at the rate of 3.4 kg/ha.

Protein yield differences were significant at the 10% level of probability on residual areas in July, 1976. Mean protein yield was 195 kg/ha and ranged from 155 kg/ha (A71, A63, 7D) to 250 kg/ha (AN), while the mean crude protein was 5.7% ranging from 4.9% (A71) to 6.4% (NPK).

Protein yields were greater on all areas treated with fertilizer (AN, ANP, ANPK, ADNPK, N, NP, NPK, DNPK) than on untreated areas in July, 1976. The mean protein yield was 290 kg/ha. The highest protein yield was 480 kg/ha (ADNPK), while the lowest was 150 kg/ha (6D). This was more than a 200% difference between the highest and lowest yield.

Mean crude protein content was 7.7% and ranged from 10.3% (ANP) to 5.4% (A73). Herbage crude protein content on A61 and A63 areas was greater than on untreated areas (7.0% vs 5.6%); however, herbage production on A61 and A63 areas was not greater than on untreated areas and protein yields were not greater.

Additional data analysis was attempted on both crude protein and protein yield data. Both CORR (correlation) and REGR (regression) procedures (Barr and Goodnight 1972) were used in an attempt to correlate percent composition of major species classes to crude protein content (%) and protein yield, and to build an equation for predicting crude protein (%) and protein yield using percent species composition and production data. No significant correlations or predictions were obtained. If crude protein content of individual species were known these statistical methods might have been better utilized.

November

Protein yield in November, 1975, averaged 145 kg/ha, and differences between treatments were significant at the 64% level of probability (Table 8). Crude protein content averaged 5.7% and ranged from 4.7% (A61) to 6.5% (ANP).

Protein yields in November, 1976, from residual areas were greater on ANP, ANPK, N, and NPK treated areas than on untreated. Mean protein yield was 135 kg/ha with the greatest yield on ANPK areas (195 kg/ha) and least on 7D areas (95 kg/ha). Crude protein differences were significant at the 28% level of probability. Crude protein content was greatest on ANPK areas (4.9%) and least on AN areas (3.3%). Protein yield differences were therefore related more to differences in herbage production than to crude protein content of herbage.

CHAPTER V

COMPETITION, INTERACTIONS, AND INTERFERENCES

The response of the tallgrasses (ANGE, PAVI, SONU), SCSC, and AMPS to atrazine and fertilizer treatments indicates why this region is considered "Tallgrass Prairie". Production of tallgrasses, SCSC, and AMPS was increased on fertilizer areas both years of application. Residual fertilizer or residual effects of fertilizer appeared to increase tallgrass production. However, what factors that were not measured could have had a bearing on the results? I stated in the introduction that the exact effect of the s-triazines on N-metabolism in the plant is not fully understood. Therefore, I cannot say that atrazine with or without fertilizer directly increased herbage production and protein content in this study. Usable forage on atrazine plus fertilizer areas was greater than on fertilizer only areas just as in eastern Colorado (Houston and van der Sluijs 1975). A discussion of other possible factors that could have interacted with the treatments is necessary to better understand the results.

Large application rates of another s-triazine herbicide, simazine, (300 kg/ha) caused no direct depression in the overall biological activity of the soil (Kaiser et al. 1970). However, when a decrease in CO_2 evolution (a measure of microbial respiration) from the soil was noted after simazine application, those soils with the largest organic matter content had the highest levels of respiration. Usually,

s-triazines (including atrazine) have had little effect on soil nitrate levels (Kaiser et al. 1970).

Cropland data indicates that no more than 3.4% of the labeled N^{15} applied in fertilizer the first year could be recovered in that year's crop. After the first year most soil N is not in nitrate form, but in organic forms as a result of immobilization by microorganisms and incorporation into organic forms (Black 1968). Fertilizer stimulates the biological activity of the soil. Soil retention of N in the ammonium (NH_4^+) form is considered to be beneficial to soil N levels. Ammonium-N is adsorbed by the exchange complex and is not subject to loss from oxidation and leaching (Black 1969). Soils supporting climax grassland vegetation are low in nitrates because of nitrification inhibition by climax plants (Rice 1974). The inhibition of nitrification in later stages of old-field succession aids in the increase of NH_4^+-N which enables climax species with higher N requirements to dominate (Rice 1974). The NH_4^+ form of N is also more efficient in the nitrogen cycle from uptake to amino acids. Therefore, fertilization, especially with NH_4NO_3 fertilizer, should benefit climax species.

Competition may be considered as simultaneous demands for the same resources in a common environment when demands are in excess of the immediate supply. Competition is a reaction in which one species may reduce the level of a necessary factor to the detriment of another species sharing the same habitat (Risser 1969, Rice 1974). Competition changes were evident on 6D and 7D areas where AMPS decreased. There was no extremely large increase in production, but AMPS was replaced by the desirable grasses (tallgrasses and SCSC) in both space and production.

Allelopathy refers to the direct or indirect harmful effect by one plant (or microorganism) on another through the production of chemical compounds that escape into the environment (Rice 1974). Allelopathy exists in grassland ecosystems, and may be responsible for results reported in literature as effects of competition (Risser 1969); however, there is limited data to determine what specific roles allelopathy plays. Many biologists consider allelopathy to be a part of competition, so the term interference has been suggested to encompass the overall deleterious effects of one plant on another, including both allelopathy and competition (Rice 1974).

The suppression of invader species in an undisturbed prairie has been attributed to mechanical effects of the mulch layer or competition. However, fire, which removes much of the mulch layer may also strengthen the dominance of the tallgrass species if fire occurs at a desirable time. The probable mechanism of suppression is one of competition or mechanical effects; although, no specific suppression mechanism has been advanced (Still 1976). Allelopathy can be a potent force influencing the composition of plant communities, and either competition or allelopathy or some combination could account for the observed resistance to invasion (Still 1976).

The increased production of desirable species on fertilized areas is not a result of just allelopathy or a reduction in competition. Ammonium nitrate fertilizer supplies 50% of its N in the NH_4^+ form which is readily adsorbed by the soil exchange complex and readily utilized by climax species. Assimilation of inorganic substances, such as N, is an important means of immobilization, a mechanism by which microorganisms reduce the quantity of plant available nutrients in the soil

(Alexander 1961). The magnitude of immobilization is proportional to the net quantity of microbial tissue formed. The efficiency of cell synthesis is governed by environmental conditions. Nitrification and its results are affected by soil pH, aeration, temperature, and water. Even then organisms may liberate various end products depending on their timing and environmental situation (Alexander 1961).

These previous facts raise several questions that must be considered in rangeland herbicide and fertilizer research. Using atrazine as an example the questions are:

1. When a herbicide is used to control species, what effect is there on the remaining species, and how are the interactions among the remaining species affected?
2. When fertilizers and herbicides are added to a range ecosystem do they directly affect any allelopathic chemicals without affecting the plant producing them?
3. Is a resulting increase in production a result of an interaction within the plant or a result of decreased interference (competition and allelopathy)?

Probably the greatest problem in answering these questions is that we do not know exactly what allelopathic responses and actions actually occur in the rhizosphere. Much of the data now amassed is from work using leachates and extracts, grown and cultivated in sterile mediums of sand or water. However, a rangeland soil is a highly complex, dynamic community of organisms, organic matter, and soil minerals which is a living, biologic system. Soil organisms under one set of circumstances may liberate an end product not produced in another situation (Alexander 1971, Clark 1969). When plant species are changed in a

grassland ecosystem, what is the effect on organic matter distribution in the soil, and has the uptake of soil minerals been changed? Increasing the plant biomass increases standing vegetation and ground litter. But how much has the root system changed and are roots distributed throughout the solum in the same proportions as before the species changes?

We cannot be certain if every plant species or only certain species produce allelopathic substances. It is evident that when a species or group of species are removed, other species are available to utilize the space in the community formerly occupied by the controlled species. Tallgrasses and SCSC appear to be compatable; any allelopathic compounds produced by one species apparently do not reduce the growth of another.

Atrazine alone generally did not significantly increase herbage production. The species composition of the rangeland did change, but were allelopathic substances affected? I cannot be certain that it was totally a decrease in competition from AMPS and AROL that allowed an increase in certain species and not a change in some plant exudant.

Fertilization increased the amount of N available for plant growth. Since 50% of the N was already in NH_4^+ form I must conclude that this would benefit climax species (tallgrasses, SCSC) the most. I cannot be certain that NH_4^+ would not also increase production of other species, especially if competition was less due to atrazine. However, AROL production did not increase in 1976 on any fertilized area. This could be in response to an increase in soil fertility which benefited climax species not AROL. I believe interaction is occurring between atrazine and fertilizer within some plants. This physiological action may or may not be linked to competition and allelopathy. However, large

numbers of microorganisms require the presence of available forms of P for cell synthesis. In environments where P is limiting, its addition will stimulate microbial activities (Alexander 1961).

The path and fate of added fertilizer elements and herbicides in rangeland are unknown and much more research is needed before reliable and economic recommendations can be made. Further research is needed to provide an understanding of competition and allelopathy on rangeland and what effects herbicides have on them. How can we measure the microbial response to herbicides and fertilizer in situ and can we determine differences in populations and responses of microorganisms?

CHAPTER VI

CONCLUSIONS

Atrazine alone was effective in controlling many forbs and grasses, especially AMPS, regardless of the rate and date of application. Control of susceptible species was the same in July as in June; however, the July date allowed one month longer for growth of those species controlled. Initially, 3.4 kg atrazine alone decreased total production slightly after application, but herbage recovered by August or November. A larger percentage of forbs was controlled with the 3.4 kg rate. Otherwise there was no difference between the 1.1 and 3.4 kg atrazine rate.

Fertilizer generally increased herbage production. The largest increases were from NPK areas. Much of this additional herbage resulted from increases in forbs and less desirable grasses. AMPS was able to double production on fertilizer areas and was the most common forb.

Atrazine plus fertilizer increased total herbage, especially grasses. Residual effects of fertilizer from species changes by atrazine were noted the second year. Retreatment of areas with atrazine and fertilizer further decreased forbs and susceptible grasses, while tallgrasses, especially PAVI, and SCSC doubled in production compared to untreated areas.

Protein yield was greater in July than in November on nearly all treatments, and it was highly dependent upon herbage production. The

only significant increases in protein yield were on fertilized areas. Areas treated with both atrazine and fertilizer contained a greater percentage of desirable herbage due to the decrease of undesirable AMPS. The results indicate that fertilization of tallgrass prairie may be highly successful in increasing total herbage and herbage quality if less desirable species are controlled with a herbicide. Atrazine was considered more successful in accomplishing this than was 2,4-D because of its physiological effect on the grasses and ability to increase plant protein content.

The combination of atrazine and fertilizer should be further investigated to learn how tallgrass rangeland can be utilized for various management objectives. Intra- and interspecific competition for soil water, fertilizer nutrients, and other factors may greatly affect species response to some treatments. My results showed a high production potential of tallgrass prairie vegetation in relatively dry years, and the opportunity for using various combinations of chemicals may provide many management alternatives.

LITERATURE CITED

Alexander, M. 1961. Introduction to soil microbiology. John Wiley and Sons, Inc. New York. 472pp.

Allinson, D. W. 1972. Influence of simazine on yield and quality components of reed canarygrass. Agron. J. 64:530-535.

Allinson, D. W., and R. A. Peters. 1970. Influence of simazine on crude protein and cellulose content and yield of forage grasses. Agron. J. 62:246-250.

AOAC. 1970. Methods of analysis. 11th ed. Assoc. Official Agr. Chemists. Washington, D. C. 1015pp.

Ball, L. F., Jr. 1965. Fertilization of a native hay meadow in southeastern Oklahoma. M.S. Thesis. Okla. State Univ. 29pp.

Barr, A. J., and J. H. Goodnight. 1972. A users guide to the statistical analysis system. Sparks Press, Raleigh, N.C. 260pp.

Bement, R. E. 1969. Dynamics of standing dead vegetation on the shortgrass plains. Pages 221-240 in R. L. Dix and R. G. Beidleman, eds. The grassland ecosystem. Range Sci. Dep. Sci. Ser. no. 2. Colo. State Univ., Ft. Collins. 437pp.

Black, C. A. 1968. Soil-plant relationships. John Wiley and Sons, Inc. New York. 792pp.

Bradbury, I. K., and G. Hofstra. 1976. Vegetation death and its importance in primary production measurements. Ecology 57:209-211.

Brown, R. W. 1977. Water relations of range plants. Pages 97-140 in R. E. Sosebee, ed. Rangeland plant physiology. Range Sci. Ser. No. 4. Society for Range Manage., Denver, Colo. 290pp.

Broyles, P. J. 1978. Oklahoma tallgrass prairie species composition and production responses to rotation fertilization on different range sites. M.S. Thesis. Okla. State Univ. 70pp.

Burzlaff, D. F. 1971. Seasonal variations of the in vitro dry-matter digestibility of three sandhill grasses. J. Range Manage. 24:60-63.

Carpenter, J. R. 1937. Fluctuations in biotic communities, III. Aspection in a ravine sere in central Oklahoma. Ecology 18:80-92.

Clark, F. E. 1969. The microflora of grassland soils and some microbial influences on ecosystem functions. Pages 361-376 in R. L. Dix and R. G. Beidleman, eds. The grassland ecosystem. Range Sci. Dep. Sci. Ser. no. 2. Colo. State Univ., Ft. Collins. 437pp.

Cogswell, C., and L. D. Kamstra. 1976. The stage of maturity and its effect upon the chemical composition of four native range species. J. Range Manage. 29:460-463.

Conant, S., and P. G. Risser. 1974. Canopy structure of a tall-grass prairie. J. Range Manage. 27:313-318.

Dexter, A. G., O. C. Burnside, and T. L. Lavy. 1966. Factors influencing the phytotoxicity of foliar applications of atrazine. Weeds. 14:222-228.

Dumford, S. W., and E. Ebert. 1976. Plant constituents. Pages 21-35 in F. A. Gunther and J. D. Gunther, eds. Residue reviews, Vol. 65. Effects of triazine herbicides on the physiology of plants. Springer-Verlag, New York. 103pp.

Dwyer, D. D. 1958. Competition between forbs and grasses. J. Range Manage. 11:115-118.

Dwyer, D. D., W. C. Elder, and G. Singh. 1963. Effects of height and frequency of clipping on pure stands of range grasses in northcentral Oklahoma. Okla. Agr. Exp. Sta. Bull. B-614. 10pp.

Ebert, E. 1976. Morphology and plant growth. Pages 40-48 in F. A. Gunther and J. D. Gunther, eds. Residue reviews, Vol. 65. Effects of triazine herbicides on the physiology of plants. Springer-Verlag, New York. 103pp.

Elwell, H. M., and W. E. McMurphy. 1973. Weed control with phenoxy herbicides on native grasslands. Okla. Agr. Exp. Sta. Bull. B-706. 23pp.

Evans, R. A., and J. A. Young. 1977. Weed control-revegetation systems for big sagebrush-downy brome rangelands. J. Range Manage. 30:331-336.

Gray, F., and H. M. Galloway. 1959. Soils of Oklahoma. Okla. Agr. Exp. Sta. Misc. Publ. MP-56. 65pp.

Hammond, R. W. 1977. Weather, rangeland practices and northcentral Oklahoma poor condition tallgrass prairie regrowth after grazing. M.S. Thesis. Okla. State Univ. 83pp.

Harlan, J. R. 1960. Production characteristics of native range. Okla. Agr. Exp. Sta. Bull. B-547. 34pp.

Harper, H. J., H. A. Daniel, and H. L. Murphy. 1933. Total nitrogen, phosphorus, and calcium content of common weeds and native grasses in Oklahoma. Proc. Okla. Acad. Sci. 14:36-41.

Heady, H. F. 1975. Rangeland management. McGraw-Hill Book Co., N.Y. 460pp.

Houston, W. R., and D. H. van der Sluijs. 1973. Increasing crude protein content of forage with atrazine on shortgrass range. U.S. Dep. Agr., Prod. Res. Rep. No. 153. 10pp.

Houston, W. R., and D. H. van der Sluijs. 1975. S-triazine herbicides combined with nitrogen fertilizer for increasing protein on short-grass range. J. Range Manage. 28:372-376.

Hyder, D. N., and R. E. Bement. 1972. Controlling red threeawn on abandoned cropland with ammonium nitrate. J. Range Manage. 25:443-446.

Kaiser, P., J. J. Pochon, and R. Cassini. 1970. Influence of triazine herbicides on soil microorganisms. Pages 211-233 in F. A. Gunther and J. D. Gunther, eds. Residue reviews. Vol. 32. The triazine herbicides. Springer-Verlag, New York. 413pp.

Kamstra, L. D. 1973. Seasonal changes in quality of some important range grasses. J. Range Manage. 26:289-291.

Kay, B. L. 1971. Atrazine and simazine increase yield and quality of range forage. Weed Sci. 19:370-372.

LeBaron, H. M. 1970. Ways and means to influence the activity and the persistence of triazine herbicides in soils. Pages 311-353 in F. A. Gunther and J. D. Gunther, eds. Residue reviews, Vol. 32, The triazine herbicides. Springer-Verlag, New York. 413pp.

Leuck, E. E., and E. L. Rice. 1976. Effect of rhizosphere bacteria of *Aristida oligantha* on *Rhizobium* and *Azotobacter*. Bot. Gaz. 137:160-164.

Minshall, W. H. 1975. Translocation of atrazine: accumulation versus passage through the petioles. Weed Sci. 23:97-99.

Morrow, L. A., and M. K. McCarty. 1976. Effect of weed control on forage production in the Nebraska sandhills. J. Range Manage. 29:140-143.

Morrow, L. A., C. R. Fenster, and M. K. McCarty. 1977. Control of downy brome on Nebraska rangeland. J. Range Manage. 30:293-296.

National Academy of Sciences, Subcommittee on Range Research Methods. 1962. Basic problems and techniques in range research. Nat. Res. Council. Washington, D.C. 341pp.

Ownsby, C. E., R. M. Hyde, and K. L. Anderson. 1970. Effects of clipping and supplemental nitrogen and water on loamy upland bluestem range. J. Range Manage. 23:341-346.

, J. F., and G. D. Pickford. 1937. A weight estimate method ne determination of range or pasture production. J. Amer. Soc. n. 29:894-904.

ers, E. J., and S. A. Lowance. 1969. Gains in timothy forage from goldenrod control with 2,4-D, 2,4-DB, and picloram. Weed Sci. 17:473-474.

Pinder, John E., III. 1975. Effects of species removal on an old-field plant community. Ecology. 56:747-751.

Powell, J., R. L. Baker, and D. Holbert. 1978. Plant, soil, and site interactions in the Oklahoma tallgrass prairie. Page 19. Abstract of paper presented at 31st Annual Meeting. Soc. for Range Manage. San Antonio, TX. Feb. 1978.

Rao, M. R., L. H. Harbers, and E. F. Smith. 1973. Seasonal change in nutritive value of bluestem pastures. J. Range Manage. 26:419-422.

Rice, E. L. 1974. Allelopathy. Academic Press, New York. 353pp.

Rice, E. L., W. T. Penfound, and L. M. Rohrbaugh. 1960. Seed dispersal and mineral nutrition in succession in abandoned fields in central Oklahoma. Ecology 41:224-228.

Ries, S. K., C. J. Schweizer, and H. Chmiel. 1968. The increase in protein content and yield of simazine-treated crops in Michigan and Costa Rica. BioScience 18:205-208.

Risser, P. G. 1969. Competitive relationships among herbaceous plants and their influences on the ecosystem function in grasslands. Pages 153-171 in R. L. Dix and R. G. Beidleman, eds. The grassland ecosystem. Range Sci. Dep. Sci. Ser. no. 2. Colo. State Univ.,Ft. Collins. 437pp.

Senter, W. R. 1975. Establishment of warm and cool season grass pastures of wooded sites in east central Oklahoma after aerial spraying and burning. M.S. Thesis. Okla. State Univ. 63pp.

Sims, P. L., L. J. Ayuko, and D. N. Hyder. 1971. Developmental morphology of switchgrass and sideoats grama. J. Range Manage. 24:357-360.

Sims, P. L., R. K. Lang'at, and D. N. Hyder. 1973. Developmental morphology of bluegrama and sand bluestem. J. Range Manage. 26:340-344.

Sneva, F. A., R. J. Raleigh, and H. A. Turner. 1973. Paraquat cured herbage for late season grazing. J. Animal Sci. 36:107-113.

Still, K. R. 1976. Allelopathic inhibition of weed invasion by *Andropogon scoparius* Michx. in climax prairies. Ph.D. Dissertation Okla. State Univ. 148pp.

Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range management. 3rd edition. McGraw-Hill Book Co., New York. 532pp.

Thilenius, J. F., and G. R. Brown. 1976. Effect of 2,4-D on digestibility and production of subalpine herbage. J. Range Manage. 29:63-65.

Thompson, L., Jr., and F. W. Slife. 1969. Foliar and root absorption of atrazine applied postemergence to giant foxtail. Weed Sci. 17:251-256.

Van Assche, C. J., and E. Ebert. 1976. Photosynthesis. Pages 2-19 in F. A. Gunther and J. D. Gunther, eds. Residue reviews, Vol. 65. Effects of triazine herbicides on the physiology of plants. Springer-Verlag, New York. 103pp.

Waterfall, U. T. 1972. Keys to the flora of Oklahoma. Okla. St. Univ. Bookstore. Okla. St. Univ., Stillwater. 246pp.

Wiegert, R. G., and F. C. Evans. 1964. Primary production and the disappearance of dead vegetation on an old field in southeastern Michigan. Ecology 45:49-63.

Wiegert, R. G., and J. T. McGinnis. 1975. Annual production and disappearance of detritus on three South Carolina old fields. Ecology 56:129-140.

Wight, J. R. 1976. Range fertilization in the northern great plains. J. Range Manage. 29:180-185.

Wilm, H. G., D. E. Costello, and G. E. Klipple. 1944. Estimating forage yield by the double-sampling method. J. Amer. Soc. Agron. 36:194-203.

APPENDIX

APPENDIX A

PLANT SPECIES RECORDED ON STUDY AREA

Scientific Name[1]	Common Name[2]
Grasses and grass-like	
Agrostis hiemalis	winter bentgrass
Andropogon gerardi	big bluestem
Andropogon ternarius	splitbeard bluestem
Andropogon virginicus	broomsedge
Aristida longiseta	red threeawn
Aristida oligantha	prairie threeawn
Bothriochloa saccharioides	silver bluestem
Bouteloua curtipendula	sideoats grama
Bouteloua gracilis	blue grama
Bromus japonicus	Japanese brome
Cynodon dactylon	bermudagrass
Cyperus ovularis	globe flatsedge
Digitaria ischaemum	smooth crabgrass
Digitaria sanguinalis	crabgrass
Eragrostis intermedia	plains lovegrass
Eragrostis oxylepis	red lovegrass
Leptoloma cognatum	fall witchgrass
Manisuris cylindrica	Carolina jointtail
Panicum anceps	beaked panicum
Panicum capillare	common witchgrass
Panicum scribnerianum (oligosanthes)	scribner panicum
Panicum sphaerocarpon	roundseed panicum
Panicum virgatum	switchgrass
Paspalum floridanum	Florida paspalum
Paspalum setaceum (stramineum)	sand paspalum
Schizachyrium scoparium	little bluestem
Scirpus americanus	American bulrush
Setaria geniculata	knotroot bristlegrass
Sorghastrum nutans	indiangrass
Sphenopholis obtusata	prairie wedgescale
Sporobolus asper	tall dropseed
Sporobolus cryptandrus	sand dropseed
Tridens flavus	purpletop
Vulpia octoflora	sixweeks fescue
Forbs	
Achillea lanulosa	western yarrow
Ambrosia artemisiifolia	common ragweed
Ambrosia psilostachya	western ragweed
Amorpha canescens	leadplant
Apocynum cannabinum	hemp dogbane
Artemisia ludoviciana	Louisiana sagewort
Asclepias viridis	green antelopehorn
Aster ericoides	heath aster
Baptisia australis (minor)	blue wildindigo
Buchnera americana	American bluehearts
Cassia fasciculata	showy partridge pea
Chrysopsis pilosa	soft goldaster
Conyza canadensis	horseweed (marestail)
Daucus pusillus	southwestern carrot

Scientific Name	Common Name
Erigeron strigosus	daisy fleabane
Euphorbia corollata	flowering spurge
Euphorbia supina	prostrate spurge
Gaillardia lanceolata	Indian blanket
Gaura filiformis	gaura
Haplopappus ciliatus	wax goldenweed
Helianthus mollis	ashy sunflower
Hymenopappus scabiosaeus	whitebract hymenopappus
Krameria lanceolata	trailing krameria
Lespedeza capitata	roundhead lespedeza
Lespedeza cuneata	sericea lespedeza
Linum rigidum	stiffstem flax
Mirabilis linearis	narrowleaf four-o'clock
Monarda clinopodioides	basil beebalm
Neptunea lutea	neptune
Oenothera serrulata	serrateleaf eveningprimrose
Petalostemum purpureum	purple prairieclover
Plantago purshii	woolly plantain
Plantago virginica	paleseed plantain
Polygala incarnata	pink milkwort
Psoralea tenuiflora	slimflower scurfpea
Pyrrhopappus carolinianus	Carolina falsedandelion
Ratibida columnifera	upright prairieconeflower
Rudbeckia hirta	blackeyedsusan
Ruellia humilis	fringeleaf ruellia
Sabatia campestris	prairie rosegentian
Salvia azurea (pitcheri)	pitcher sage
Schrankia uncinata	catclaw sensitivebriar
Sisyrinchium angustifolium	common blue-eyed grass
Solanum elaeagnifolium	silverleaf nightshade
Solidago missouriensis	Missouri goldenrod
Specularia perfoliata	clasping venuslookingglass
Stylosanthes biflora	pencil flower
Vernonia baldwini	baldwin ironweed

[1]Scientific names from Waterfall, U. T. 1972. Keys to the flora of Oklahoma. Okla. State Univ. Student Union Bookstore. Stillwater. 246pp.

[2]Common names from Barkley, T. M. 1968. A manual of the flowering plants of Kansas. Kansas State Univ. Endowment Assoc. Manhattan. 402pp. and Anderson, K. L., and C. E. Owensby. 1969. Common names of a selected list of plants. Kansas Agr. Exp. Sta. Tech. Bull. 117. 62pp.

APPENDIX B

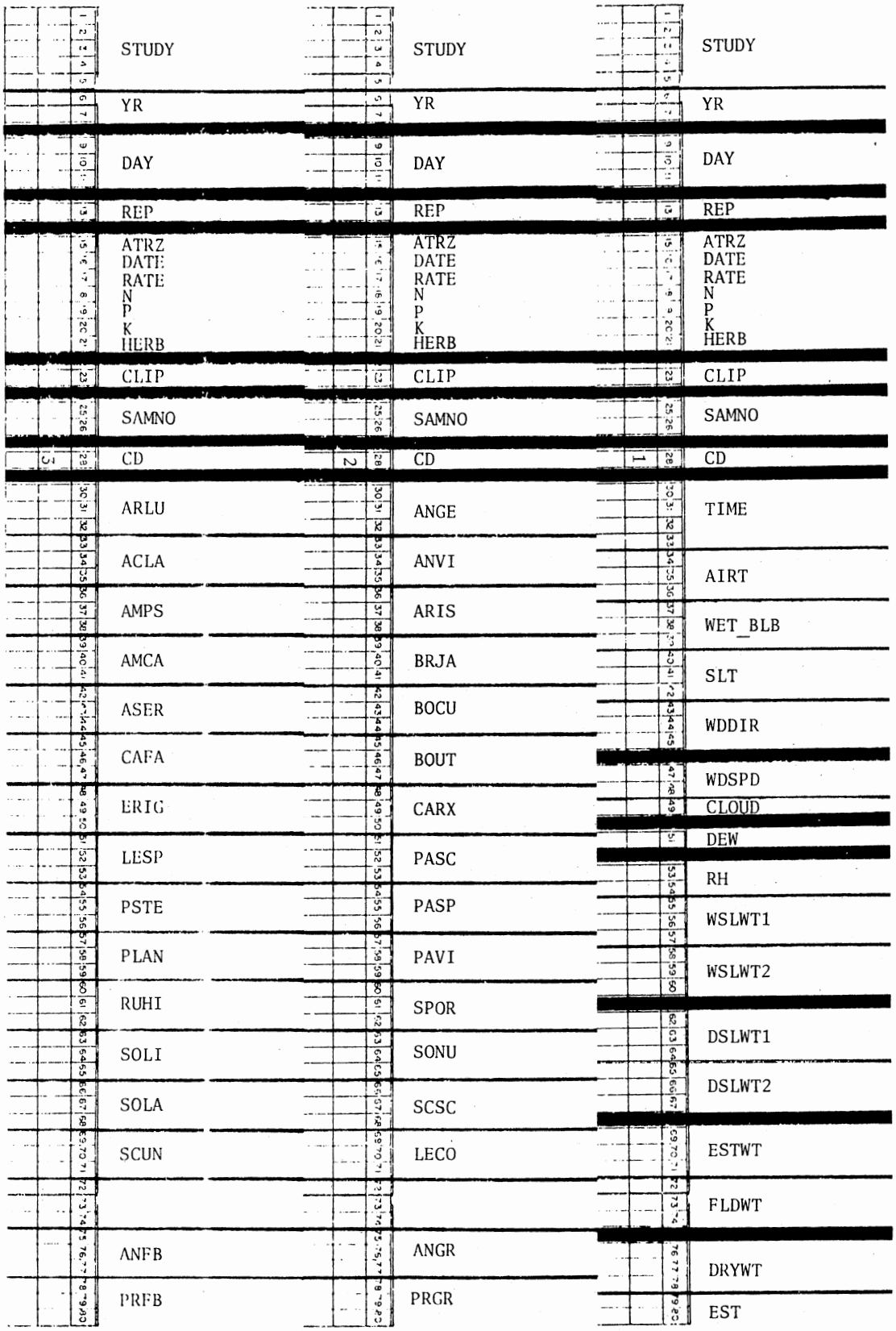
SPECIES KEY TO FIELD DATA WORKSHEET

Computer Species Abbreviation	Scientific Name	Species Symbol[1]
Grasses and grass-like		
ANGE	*Andropogon gerardi*	ANGE
ANTE	*Andropogon ternarius*	ANTE
ANVI	*Andropogon virginicus*	ANVI
ARIS	*Aristida* spp.	ARIST
BOCU	*Bouteloua curtipendula*	BOCU
BOUT	*Bouteloua* spp.	BOUTE
BRJA	*Bromus* spp.	BROMU
CARX	*Carex* spp.	CAREX
LECO	*Leptoloma cognatum*	LECO
MACY	*Manisuris cylindrica*	MACY
PASC	*Panicum scribnerianum*	PASC
PASP	*Paspalum* spp.	PASPA
PAVI	*Panicum virgatum*	PAVI
SCSC	*Schizachyrium scoparium*	SCSC
SONU	*Sorghastrum nutans*	SONU
SPOR	*Sporobolus* spp.	SPORO
Forbs		
ACLA	*Achillea lanulosa*	ACLA
AMCA	*Amorpha canescens*	AMCA
AMPS	*Ambrosia psilostachya*	AMPS
ARLU	*Artemisia ludoviciana*	ARLU
ASER	*Aster ericoides*	ASER
CAFA	*Cassia fasciculata*	CAFA
ERIG	*Erigeron* spp.	ERIGE
LESP	*Lespedeza* spp.	LESPE
PLAN	*Plantago* spp.	PLANT
PSTE	*Psoralea tenuiflora*	PSTE
RUHI	*Rudbeckia hirta*	RUHI
SCUN	*Schrankia uncinata*	SCUN
SOLA	*Solanum* spp.	SOLAN
SOLI	*Solidago* spp.	SOLID

[1]Species symbols are from National list of scientific plant names. 1971. U.S. Dep. Agr. Soil Conserv. Service 281 pp.

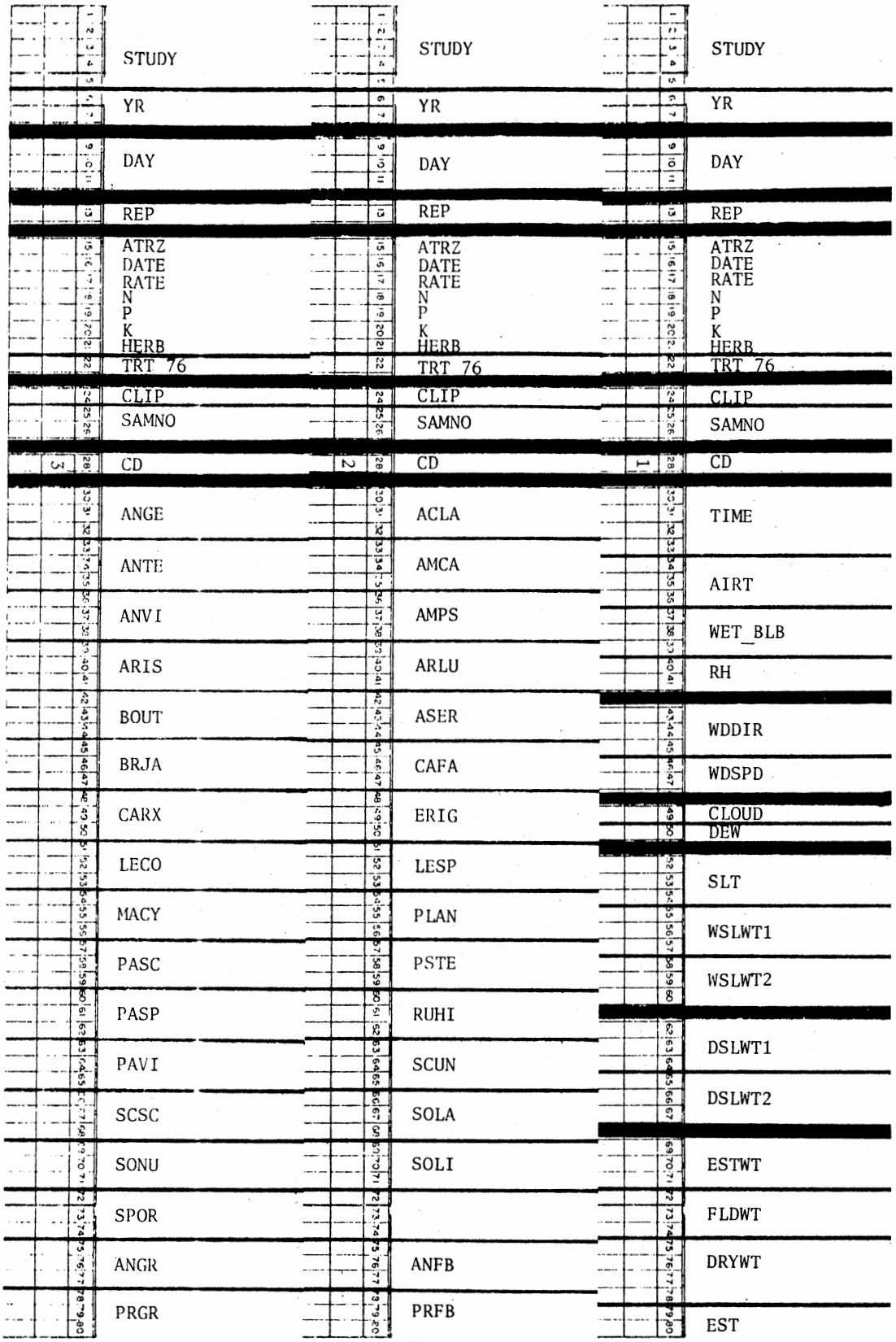
APPENDIX C

FIELD DATA WORKSHEETS - 1975


STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
CLIP
SAMNO
CD
ARLU
ACLA
AMPS
AMCA
ASER
CAFA
ERIG
LESP
PSTE
PLAN
RUHI
SOLI
SOLA
SCUN
ANFB
PRFB
STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
CLIP
SAMNO
CD
ANGE
ANVI
ARIS
BRJA
BOCU
BOUT
CARX
PASC
PASP
PAVI
SPOR
SONU
SCSC
LECO
ANGR
PRGR
STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
CLIP
SAMNO
CD
TIME
AIRT
WET_BLB
SLT
WDDIR
WDSPD
CLOUD
DEW
RH
WSLWT1
WSLWT2
DSLWT1
DSLWT2
ESTWT
FLDWT
DRYWT
EST

APPENDIX D

FIELD DATA WORKSHEETS - 1976


STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
TRT 76
CLIP
SAMNO
CD
3
ANGE
ANTE
ANVI
ARIS
BOUT
BRJA
CARX
LECO
MACY
PASC
PASP
PAVI
SCSC
SONU
SPOR
ANGR
PRGR
STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
TRT 76
CLIP
SAMNO
CD
2
ACLA
AMCA
AMPS
ARLU
ASER
CAFA
ERIG
LESP
PLAN
PSTE
RUHI
SCUN
SOLA
SOLI
ANFB
PRFB
STUDY
YR
DAY
REP
ATRZ
DATE
RATE
N
P
K
HERB
TRT 76
CLIP
SAMNO
CD
1
TIME
AIRT
WET_BLB
RH
WDDIR
WDSPD
CLOUD
DEW
SLT
WSLWT1
WSLWT2
DSLWT1
DSLWT2
ESTWT
FLDWT
DRYWT
EST

APPENDIX E

COMPUTER COMMENT STATEMENTS

COMMENT
STUDY AREA LOCATED IN NORTH-CENTRAL OKLAHOMA NORTH OF STILLWATER. NORTHWEST ONE-QUARTER OF THE NORTHWEST ONE-QUARTER OF SECTION 7, RANGE 2 EAST, TOWNSHIP 20 NORTH.

STUDY NUMBER- 3AS.
STUDY NAME- RESPONSE OF OKLAHOMA RANGELAND TO ATRAZINE, 2,4-D, AND FERTILIZER.
INITIATED IN SPRING OF 1975.

TREATMENTS
HERBICIDE-
FOLIAR SPRAY OF ATRAZINE, 1.1 OR 3.4 KG PER HA.
USING 187 LITERS WATER PER HA AT 2.81 KG PER SQUARE CM PRESSURE.
FOLIAR SPRAY OF 2,4-D, 0.8 KG PER HA.
APPLIED 27 JUNE AND 16 JULY 1975, 4 JUNE AND 8 JULY 1976.
FERTILIZER- BROADCAST 67 KG PER HA N AS AMMONIUM NITRATE 34-0-0.
45 KG PER HA SUPERPHOSPHATE 0-46-0.
45 KG PER HA MURIATE OF POTASH 0-0-62.
APPLIED 7 JUNE 1975 AND 10 MAY 1976.

SAMPLING
SAMPLES WERE COLLECTED 5 JUNE, 21 JULY, 21 AUGUST, 18 NOVEMBER, 1975 AND 2 JUNE, 30 JUNE, 28 JULY, 27 OCTOBER 1976.
EACH TREATMENT PLOT WAS DIVIDED INTO 4 ROWS OF 8 SIX FT BY SIX FT SAMPLING POINTS. THE ROWS WERE NEXT TO THE PATHWAY OF THE TRACTOR-SPRAYER. SAMPLING POINTS WERE RANDOMLY SELECTED FOR SAMPLING AND CLIPPING. A SAMPLE POINT WAS TO BE CLIPPED ONLY ONCE DURING THE STUDY AND ESTIMATED ONLY ONCE DURING A YEAR. IN 1976 SAMPLE POINTS 1 THROUGH 16 WERE NOT RETREATED AND SAMPLE POINTS 17 THROUGH 32 WERE RETREATED.

DATA SHEETS
STUDY - INCLUDES NAME, EXPERIMENT, AND LOCATION.
EXP - EXPERIMENT NUMBER- 3A.
LOC - LOCATION- STILLWATER.
YR - YEAR
DAY - JULIAN DAY WITH 1 NOVEMBER CONSIDERED THE START OF A NEW PLANT YEAR.
REP - REPLICATION
ATRZ - ATRAZINE (A) NO ATRAZINE (0)
DATE - MONTH HERBICIDE APPLIED- JUNE (6) JULY (7) OR FOR FERTILIZER ONLY (6), CONTROL TREATMENT IS (0).
RATE - APPLICATION RATE OF ATRAZINE- 1.1 KG PER HA (1), 3.4 KG PER HA (3), NO ATRAZINE (9).
N - NITROGEN (N), NO NITROGEN (0).
P - PHOSPHORUS (P), NO PHOSPHORUS (0).
K - POTASSIUM (K), NO POTASSIUM (0).
HERB - 2,4-D (D), NO 2,4-D (U).
TRT76 - SAMPLE RETREATED IN 1976 (T), NOT RETREATED IN 1976 (N).
TRT - COMBINATION OF TREATMENTS FROM COLUMNS 15 TO 22.
CLIP - SAMPLE WAS CLIPPED (C), OR ESTIMATED (E).
SAMP - SAMPLE POINT NUMBER THAT WAS SAMPLED.
CD - DATA SHEET CARD NUMBER.
TIME - TIME OF SAMPLING.
AIRT - AIR TEMPERATURE AT TIME OF SAMPLING.
WET-BLB - WET THERMOMETER READING ON SLING PSYCHROMETER.
RH - RELATIVE HUMIDITY AT TIME OF SAMPLING.
WDDIR - DIRECTION OF WIND- 1 TO 360 DEGREES.
WDSPD - SPEED OF WIND MOVEMENT.
CLOUD - CLOUD COVER, 1-CLEAR 2-BROKEN 3-SCATTERED 4-OVERCAST 5-HEAVY OVERCAST.
DEW - WETNESS OF VEGETATION 1-DRY 2-DAMP 3-WET.
SLT - TEMPERATURE OF SOIL AT TIME OF ESTIMATE.
WSLWT1 - WET WEIGHT OF SOIL SAMPLE- 0 TO 30 CM.
WSLWT2 - WET WEIGHT OF SOIL SAMPLE- 30 TO 60 CM.
DSLWT1 - DRY WEIGHT OF SOIL SAMPLE- 0 TO 30 CM.
DSLWT2 - DRY WEIGHT OF SOIL SAMPLE- 30 TO 60 CM.
ESTWT - ESTIMATED WEIGHT OF HERBAGE WITHIN .5 SQ METER FRAME.
FLDWT - ACTUAL WEIGHT OF HERBAGE IN .5 SQ METER-FRAME AS CLIPPED IN FIELD.
DRYWT - ACTUAL WEIGHT OF HERBAGE AFTER OVEN DRYING (60 DEGREES CELSIUS).
EST - INITIALS OF INDIVIDUAL ESTIMATING HERBAGE.

SPECIES ABBREVIATIONS USED ARE LISTED SEPARATELY BY SCIENTIFIC NAME AND SPECIES SYMBOL.

APPENDIX F

COMPUTER INPUT PROGRAM FOR DATA

```
TITLE 'BAS,1976 ORIGINAL DATA';

DATA A3S76;
INPUT NREC=3
NAME $ 1-2 EXP $ 3-4 LOC $ 5 YR 6-7 DAY 9-11 REP 13 ATRZ $ 15 DATE 16 RATE 17
 N $ 18 P $ 19 K $ 20 HERB $ 21 TRT76 $ 22 TRT $ 15-22 CLIP $ 24 SAMNO 25-26
 CD 28 TIME 30-33 AIRT 34-36 WET_BLB 37-39 RH 40-41 WDDIR 43-45 WDSPD 46-47
 CLOUD 49 DEW 50 SLT 52-54 WSLWT1 55-57 WSLWT2 58-60 DSLWT1 62-64 DSLWT2 65-67
 ESTWT 68-71 FLDWT 72-75 DRYWT 76-78 EST $ 79-80
NAME2 #2 $ 1-2 EXP2 #2 $ 3-4 LOC2 #2 $ 5 YR2 #2 6-7 DAY2 #2 9-11 REP2 #2 13
 ATRZ2 #2 $ 15 DATE2 #2 16 RATE2 #2 17 N2 #2 $ 18 P2 #2 $ 19 K2 #2 $ 20
 HERB2 #2 $ 21 TRT762 #2 $ 22 TRT2 #2 $ 15-22 CLIP2 #2 $ 24 SAMNO2 #2 25-26
 CD2 #2 28 ACLA #2 30-32 AMCA #2 33-35 AMPS #2 36-38 ARLU #2 39-41
 ASER #2 42-44 CAFA #2 45-47 ERIG #2 48-50 LESP #2 51-53 PLAN #2 54-56
 PSTE #2 57-59 RUHI #2 60-62 SCUN #2 63-65 SOLA #2 66-68 SOLI #2 69-71
 WOODY #2 72-74 ANFB #2 75-77 PRFB #2 78-80
NAME3 #3 $ 1-2 EXP3 #3 $ 3-4 LOC3 #3 $ 5 YR3 #3 6-7 DAY3 #3 9-11 REP3 #3 13
 ATRZ3 #3 $ 15 DATE3 #3 16 RATE3 #3 17 N3 #3 $ 18 P3 #3 $ 19 K3 #3 $ 20
 HERB3 #3 $ 21 TRT763 #3 $ 22 TRT3 #3 $ 15-22 CLIP3 #3 $ 24 SAMNO3 #3 25-26
 CD3 #3 28 ANGE #3 30-32 ANTE #3 33-35 ANVI #3 36-38 ARIS #3 39-41
 BOUT #3 42-44 BRJA #3 45-47 CARX #3 48-50 LECO #3 51-53 MACY #3 54-56
 PASC #3 57-59 PASP #3 60-62 PAVI #3 63-65 SCSC #3 66-68 SONU #3 69-71
 SPOR #3 72-74 ANGR #3 75-77 PRGR #3 78-80;


IF DAY2 ¬=DAY OR DAY3 ¬=DAY OR REP2 ¬=REP OR REP3 ¬=REP OR TRT2 ¬=TRT OR
 TRT3 ¬=TRT OR SAMNO2 ¬=SAMNO OR SAMNO3 ¬=SAMNO OR CD ¬=1 OR CD2 ¬=2 OR CD3 ¬=3
 THEN ERROR
     DAY DAY2 DAY3 REP REP2 REP3 TRT TRT2 TRT3 SAMNO SAMNO2 SAMNO3 CD CD2 CD3;

IF DSLWT1>WSLWT1 THEN ERROR
     DAY DAY2 DAY3 REP REP2 REP3 TRT TRT2 TRT3 SAMNO SAMNO2 SAMNO3 CD CD2 CD3;

IF DSLWT2>WSLWT2 THEN ERROR
     DAY DAY2 DAY3 REP REP2 REP3 TRT TRT2 TRT3 SAMNO SAMNO2 SAMNO3 CD CD2 CD3;

IF DRYWT>FLDWT THEN ERROR
     DAY DAY2 DAY3 REP REP2 REP3 TRT TRT2 TRT3 SAMNO SAMNO2 SAMNO3 CD CD2 CD3;

ANGE= (ANGE+0);     ANVI= (ANVI+0);     ARIS= (ARIS+0);     BRJA= (BRJA+0);
ANTE= (ANTE+0);    BOUT= (BOUT+0);     CARX= (CARX+0);     PASC= (PASC+0);
PASP= (PASP+0);     PAVI= (PAVI+0);     SPOR= (SPOR+0);     SONU= (SONU+0);
SCSC= (SCSC+0);     LECO= (LECO+0);     ANGR= (ANGR+0);     PRGR= (PRGR+0);
ARLU= (ARLU+0);     ACLA= (ACLA+0);     AMPS= (AMPS+0);     AMCA= (AMCA+0);
ASER= (ASER+0);     CAFA= (CAFA+0);     ERIG= (ERIG+0);     LESP= (LESP+0);
PSTE= (PSTE+0);     PLAN= (PLAN+0);     RUHI= (RUHI+0);     SOLI= (SOLI+0);
SOLA= (SOLA+0);     SCUN= (SCUN+0);     ANFB= (ANFB+0);     PRFB= (PRFB+0);
MACY= (MACY+0);      WOODY= (WOODY+0);

IF DAY=214 THEN DAY=213;  IF DAY=215 THEN DAY=213;
IF DAY=241 THEN DAY=240;  IF DAY=242 THEN DAY=240;
IF DAY=269 THEN DAY=268;  IF DAY=270 THEN DAY=268;  IF DAY=271 THEN DAY=268;
IF DAY=354 THEN DAY=356;  IF DAY=359 THEN DAY=356;  IF DAY=366 THEN DAY=356;
IF DAY=368 THEN DAY=356;  IF DAY=361 THEN DAY=356;  IF DAY=370 THEN DAY=356;
CARDS



1440 OBSERVATIONS IN DATA SET A3S76          105  VARIABLES

DATA A3S76C; SET A3S76; IF CLIP='C';
  DM=DIV(DRYWT,FLDWT);  ESTFTR=DIV(ESTWT,FLDWT);    HFTR=(DIV(DRYWT,ESTWT))*20;
 SLWTR1=DIV((WSLWT1-DSLWT1),DSLWT1); SLWTR2=DIV((WSLWT2-DSLWT2),DSLWT2);
SLWTR12=DIV(((WSLWT1-DSLWT1)+(WSLWT2-DSLWT2)),(DSLWT1+DSLWT2));


360 OBSERVATIONS IN DATA SET A3S76C          111  VARIABLES

PROC SORT OUT= A3S76CST DATA=A3S76C; BY DAY REP TRT SAMNO;
```

```
DATA A3S76E; SET A3S76; IF CLIP='E';

1080 OBSERVATIONS IN DATA SET A3S76E        105  VARIABLES

PROC SORT OUT=A3S76EST DATA=A3S76E; BY DAY REP TRT SAMNO;


DATA S3A76; MERGE A3S76CST A3S76EST; BY DAY REP TRT SAMNO;

1440 OBSERVATIONS IN DATA SET S3A76         111  VARIABLES

PROC SORT OUT=S3A76ST DATA=S3A76; BY DAY REP TRT CLIP;


PROC MEANS NOPRINT OUT=S3A76X DATA=S3A76ST; BY DAY REP TRT;
 VAR DM ESTETR HETR SLWTR1 SLWTR2 SLWTR12 ANGE ANVI ARIS BRJA ANTE BOUT CARX
  PASC PASP PAVI SPOR SONU SCSC LECO ANGR PRGR ARLU ACLA AMPS AMCA ASER CAFA
  ERIG LESP PSTE PLAN RUHI SOLI SOLA SCUN ANFB PRFB MACY WOODY;


DATA S3A76XX; SET S3A76X; IF DAY>1;
 ANGE= ANGE*HETR;  ANVI= ANVI*HETR;  ARIS= ARIS*HETR;  BRJA= BRJA*HETR;
 ANTE= ANTE*HETR;  BOUT= BOUT*HETR;  CARX= CARX*HETR;  PASC= PASC*HETR;
PASP= PASP*HETR;  PAVI= PAVI*HETR;  SPOR= SPOR*HETR;  SONU= SONU*HETR;
 SCSC= SCSC*HETR;  LECO= LECO*HETR;  ANGR= ANGR*HETR;  PRGR= PRGR*HETR;
 MACY= MACY*HETR;     WOODY= WOODY*HETR;
 ARLU= ARLU*HETR;  ACLA= ACLA*HETR;  AMPS= AMPS*HETR;  AMCA= AMCA*HETR;
 ASER= ASER*HETR;  CAFA= CAFA*HETR;  ERIG= ERIG*HETR;  LESP= LESP*HETR;
 PSTE= PSTE*HETR;  PLAN= PLAN*HETR;  RUHI= RUHI*HETR;  SOLI= SOLI*HETR;
 SOLA= SOLA*HETR;  SCUN= SCUN*HETR;  ANFB= ANFB*HETR;  PRFB= PRFB*HETR;
PERGRS=ANGE+ ANVI+ ANTE+ BOUT+ CARX+ PASC+ PASP+ PAVI+ SPOR+ SONU+ SCSC+ LECO+
   MACY+ PRGR;
ANNGRS=ARIS+ BRJA+ ANGR;
GRASS=PERGRS+ ANNGRS;
TALGRS=ANGE+ PAVI+ SONU;
BNCHGRS=SCSC+ ANTE;
PERFBS=ARLU+ ACLA+ AMPS+ AMCA+ ASER+ LESP+ PSTE+ RUHI+ SOLI+ SOLA+ SCUN+ PRFB;
ANNFBS=CAFA+ ERIG+ PLAN+ ANFB;
DECRSR=TALGRS+ SCSC+ AMCA+ LESP+ SCUN;
FORBS=PERFBS+ ANNFBS;
HERBS=GRASS+ FORBS;


 360 OBSERVATIONS IN DATA SET S3A76XX       121  VARIABLES

DATA S3A76PC;SET S3A76XX;IF DAY >1;
PCANGE=(ANGE/HERBS)*100;      PCANVI=(ANVI/HERBS)*100;
PCARIS=(ARIS/HERBS)*100;      PCBRJA=(BRJA/HERBS)*100;
PCANTE=(ANTE/HERBS)*100;      PCBOUT=(BOUT/HERBS)*100;
PCCARX=(CARX/HERBS)*100;      PCPASC=(PASC/HERBS)*100;
PCPASP=(PASP/HERBS)*100;      PCPAVI=(PAVI/HERBS)*100;
PCSPOR=(SPOR/HERBS)*100;      PCSONU=(SONU/HERBS)*100;
PCSCSC=(SCSC/HERBS)*100;      PCLECO=(LECO/HERBS)*100;
PCANGR=(ANGR/HERBS)*100;      PCPRGR=(PRGR/HERBS)*100;
PCARLU=(ARLU/HERBS)*100;      PCACLA=(ACLA/HERBS)*100;
PCAMPS=(AMPS/HERBS)*100;      PCAMCA=(AMCA/HERBS)*100;
PCASER=(ASER/HERBS)*100;      PCCAFA=(CAFA/HERBS)*100;
PCERIG=(ERIG/HERBS)*100;      PCLESP=(LESP/HERBS)*100;
PCPSTE=(PSTE/HERBS)*100;      PCPLAN=(PLAN/HERBS)*100;
PCRUHI=(RUHI/HERBS)*100;      PCSOLI=(SOLI/HERBS)*100;
PCSOLA=(SOLA/HERBS)*100;      PCSCUN=(SCUN/HERBS)*100;
PCANFB=(ANFB/HERBS)*100;      PCPRFB=(PRFB/HERBS)*100;
PCPERGRS=(PERGRS/HERBS)*100;      PCANNGRS=(ANNGRS/HERBS)*100;
PCGRASS=(GRASS/HERBS)*100;
PCTALGRS=(TALGRS/HERBS)*100;      PCPERFBS=(PERFBS/HERBS)*100;
PCANNFBS=(ANNFBS/HERBS)*100;      PCFORBS=(FORBS/HERBS)*100;
 PCMACY= (MACY/HERBS)*100;     PCBNCGRS= (BNCHGRS/HERBS)*100;
PCDECRSR= (DECRSR/HERBS)*100;


 360 OBSERVATIONS IN DATA SET S3A76PC       163  VARIABLES
```

APPENDIX G

ANALYSIS OF VARIANCE TABLE

FROM ANOVA PROGRAM

```
TITLE '3AS HERBAGE YIELDS- AOVS ON RETREATED PLOTS- 1976';
DATA S3A; SET S3A76XX; IF TRT76='T';
MACRO SPECIE76 ANGE ANVI ARIS BRJA ANTE BOUT CARX PASC PASP PAVI SPOR SONU SCSC
  LECO ANGR PRGR ARLU ACLA AMPS AMCA ASER CAFA ERIG LESP PSTE PLAN RJHI SOLI
  SOLA SCUN ANFB PRFB MACY %
MACRO SOIL76   SLWTR1 SLWTR2 SLWTR12 %
MACRO HERBS76 DM ESTETR HETR PERGRS ANNGRS GRASS TALGRS BNCHGRS PERFBS
  ANNFBS DECRSR FORBS HERBS %


 180 OBSERVATIONS IN DATA SET S3A          121  VARIABLES


PROC SORT OUT=S3AS DATA=S3A; BY DAY REP TRT;



PROC ANOVA DATA=S3AS;
CLASSES DAY REP TRT;
MEANS REP TRT DAY REP*DAY REP*TRT;
MODEL SPECIE76
                SOIL76
                      HERBS76
                              =
     REP|TRT DAY TRT*DAY REP*DAY REP*TRT*DAY;
POOL 'RT' REP*TRT/TRT;
POOL 'RD+RTD' REP*DAY REP*TRT*DAY/DAY;
POOL 'RD+RDT' REP*DAY REP*DAY*TRT/TRT*DAY;
TEST TRT BY 'RT';
TEST DAY TRT*DAY BY 'RD+RTD';



DATA SET S3AS

CLASSES         VALUES

DAY             213 240 268 356

REP             1 2 3

TRT             A61000UT A63NPKHT A63NPKUT A63NP0UT A63N00UT A63000UT A71000UT A73000UT
                D09000UT D69NPKHT D69NPKUT D69NP0UT D69N00UT D69000HT D79000HT
```

3AS HERBAGE YIELDS- AOVS ON RETREATED PLOTS- 1976

ANALYSIS OF VARIANCE FOR VARIABLE ANGE MEAN 115.766971

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	LSD .01	LSD .05	DIVISOR
REP	2	20236.30	10118.151			
TRT	14	1240102.96	88578.783			
REP*TRT	28	1290589.59	46092.485			
DAY	3	384195.63	128065.208			
DAY*TRT	42	1590403.89	37866.759			
DAY*REP	6	50177.67	8362.945			
DAY*REP*TRT	84	2701860.21	32165.002			
RT	28	1290589.59	46092.485	242.194336	179.536240	12
RD+RTD	90	2752037.87	30578.199	97.0123444	73.2391357	45
RD+RDT	90	2752037.87	30578.199	375.727051	283.653809	3
CORRECTED TOTAL	179	7277566.25	40656.795			

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	TRT	14	1240102.96	88578.783	1.92176	0.0686
DENOMINATOR:	RT	28	1290589.59	46092.485		
NUMERATOR:	DAY	3	384195.63	128065.208	4.18812	0.0082
DENOMINATOR:	RD+RTD	90	2752037.87	30578.199		
NUMERATOR:	DAY*TRT	42	1590403.89	37866.759	1.23836	0.1983
DENOMINATOR:	RD+RTD	90	2752037.87	30578.199		

```
PROC ANOVA DATA=SAS; BY DAY;
CLASSES REP TRT;
MODEL SPECIES
                SOIL76
                        HERBS76  OTHRGRS OTHRFBS= REP|TRT;
POOL 'RT' REP*TRT/TST;
TEST TRT BY 'RT';
```

SAS HERBAGE YIELDS= ADV ON RETREATED PLOTS= 1976
DAY=213

ANALYSIS OF VARIANCE FOR VARIABLE ANGE MEAN 72.2732206

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	LSD .01	LSD .05	DIVISOR
REP	2	515.279	257.6395			
TRT	14	302529.174	21609.2267			
REP*TRT	28	616101.154	22003.6127			
RT	28	616101.154	22003.6127	334.677002	248.092743	3
CORRECTED TOTAL	44	919145.608	20889.6729			

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	TRT	14	302529.174	21609.2267	0.98208	0.5051
DENUMINATOR:	RT	28	616101.154	22003.6127		

VITA

Roger Lynn Baker

Candidate for the Degree of

Doctor of Philosophy

Thesis: RESPONSE OF OKLAHOMA RANGELAND TO ATRAZINE, 2,4-D, AND FERTILIZER

Major Field: Crop Science

Biographical:

Personal Data: Born in Holton, Kansas, August 14, 1946, the son of Mr. and Mrs. J. Wendell Baker. Married Deborah Ann Griffin August 1, 1970.

Education: Graduated from Eskridge High School, Eskridge, Kansas, in May, 1964; received Bachelor of Science degree in Agronomy from Kansas State University in 1969; received Master of Science degree in Range Science from Texas Tech University in 1972; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1978.

Professional Experience: Graduate research assistant, Department of Range and Wildlife Management, Texas Tech University. 1969-70; commissioned into the U.S. Air Force, 1969 and served on active duty at Grand Forks AFB, N.D. from 1971 to 1974; graduate research assistant, Department of Agronomy, Oklahoma State University, 1974-present.

Professional Organizations: Society for Range Management; American Society of Agronomy; Soil Science Society of America; Toastmasters International.