BURNING AND FERTILIZATION
FOR RANGE IMPROVEMENT
IN CENTRAL OKLAHOMA

By

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CHAPTER I

INTRODUCTION

There are more acres of pasture and rangeland in the United States than all other crops combined. Much of these native rangelands, of which there are 22,000,000 acres in Oklahoma alone, has been misused and overgrazed so severely that they can no longer give an economical return to the rangeman. Throughout history it has always been assumed well managed rangelands were an economical source of livestock feed. As the world population increases, it becomes more and more important to obtain optimum production from every acre of land available. Any increase in production and efficiency of this great natural resource will be of great value.

The efficiency of these depleted ranges can be improved by various methods. The two most common being deferment, relying upon natural succession, and reseeding.

Natural succession, by itself, is a very slow process frequently covering a span of many years to approach climax. Reseeding is costly and risky since failure to establish a stand of any kind is too common.

It has been established by many researchers that the application of nitrogen fertilizer to forages usually increases yield. The quality of this forage has been variable when nutritive value was checked.

Fire has been a controversial subject among most rangemen. Burning of native ranges has been condemned by many rangemen while others have advocated using fire as a tool for range improvement.

Much of the older literature was written to extoll the hazards and damage from fire. Only in recent years have researchers begun to try to understand more about fire and how to use it as a tool in range improvement.

This study was conducted primarily to determine the effects of fire in combination with different rates and combinations of nitrogen, phosphorus and potassium on plant succession of depleted native rangeland in central Oklahoma.

It was hoped that some results would be obtained revealing how burning and fertilizers could be used to help rangemen increase the production of our native rangelands.

CHAPTER II

LITERATURE REVIEW

Bruner (1931) described the true tall grass prairie of Oklahoma. He reported that the dominant plant was little bluestem (Andropogon scoparius),[1/] and it was most usually associated with big bluestem (Andropogon gerardi), switchgrass (Panicum virgatum) and indiangrass (Sorghastrum nutans) or with species from the mixed prairie and short grass plains.

Little bluestem was listed as the most abundant decreaser species in north central Oklahoma (Sims, 1962). Big bluestem was next in importance with indiangrass and switchgrass being of somewhat lesser importance as decreasers. Blue grama (Bouteloua gracilis), sideoats grama (Bouteloua curtipendula) and hairy grama (Bouteloua hirsuta) were the most important increaser grasses. The most important invader grass reported by Sims (1962) was buffalograss (Buchloe dactyloides).

Grasslands in the Great Plains are promoted by periods of dry weather which limits the invasion of trees. Saur (1950) reported the occurrance of grasslands around the world points to the one known factor that operates effectively across such surfaces--fire. Intermittent fires sweeping across surfaces of low relief are capable of suppressing woody vegetation. He knew of no basis for a climatic

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1/ Scientific names follow Waterfall, U.T. 1960. Keys to the Flora of Oklahoma.

grassland climax, but only of a fire grass "climax" for soils permitting deep rooting. Fires have long been recognized as instrumental in maintaining the former treeless conditions of our grasslands (Stewart, 1953).

Bray (1901) stated that under the open prairie regime, the equilibrium was apparently maintained by more or less regular recurrence of prairie fires. This idea is supported by the fact that grass vegetation is tolerant of fires and the woody vegetation is not.

In writing about the Great Plains regions and giving reasons for their status as grasslands, Shantz (1924) stated that in the eastern portion of the area fires have, in all probability, protected the grasslands from the encroachment of the forests. Aided by high winds, these fires swept with great rapidity across the grasslands of the prairies and plains. Trees and shrubs were often killed by fires and, as a consequence, the grasses were able to maintain themselves on land which would support a good forest growth if the trees were adequately protected.

According to Ehrenreich (1959) it is very important, in native range management, to know how burning, mowing, grazing, complete protection or combinations thereof, will affect individual plants and communities of plants. He found that vegetation on burned areas began growing earlier, matured earlier and produced more flowerstalks than on unburned areas on the native prairies of Iowa.

Speed of succession is very important in going from a depleted range to a climax vegetation. Booth (1941) found that succession on abandoned fields in central Oklahoma showed four stages: (1) ruderal weeds, lasting 2 to 3 years; (2) annual grass, predominantly prairie threeawn (Aristida obligantha), lasting 9 to 13 years; (3) perennial bunch grass, predominantly little bluestem, persisting for at least 30 years; and (4) true prairie, in which the dominant species were little bluestem, big bluestem, indiangrass and switchgrass. In a study of succession on abandoned fields in the Southern Great Plains of the United States, Savage and Runyon (1937) emphasized the very slow invasion of these areas by climax grasses. Even after 40 years, no fields possessed a cover comparable in composition to climax.

Climax may be defined as the highest point, or culmination, of plant succession on a particular soil development under a given climatic condition (Dyksterhuis 1949). Range condition is expressed as the percentage of the present vegetation which is climax vegetation for the site. Range condition is classified according to percentage of decreasers, increasers and invader species of plants. These species are classified into such categories according to their response to grazing. Decreaser species are those which decrease in relative amounts with continued overuse. Increaser species are those which increase in relative amounts for a period of time with overuse.

The invader species are those species which were absent in undisturbed portions of the original vegetation and will invade under continued overuse.

Penfound (1964) made a study on succession of a moderately grazed tall grass prairie and found that the vegetation changed from midgrass to midgrass-tallgrass to midgrass-tallgrass-woody plants in just 13 years with complete protection. This would indicate that this tall grass prairie was headed for a woody plant climax.

Harper et al (1934) found that almost all the annual and perennial "weeds" (forbs) which come in during the early stages of succession had much higher contents of nitrogen and phosphorus than did any of the grasses analyzed. Apparently, many of the forbs are deep rooted and thus bring minerals from the deeper layers of the soil to the surface.

It appears possible that forbs influence succession by increasing the availability of nitrogen and phosphorus in the surface layers of the soil. Consequently, plants with successively higher requirements for these elements gradually become established in the order of their increasing needs for nitrogen and phosphorus.

Theory tends to equate nitrogen content with fertility. Therefore, Roux and Warren (1963) suggested that grasses occurring early in the succession have a competitive advantage over climax grasses because their nitrogen requirements are relatively low. Conversely, climax grasses coming at the end of succession are able to more effectively utilize high nitrogen concentrations. In central Oklahoma, Rice et al (1960) found that the requirements for nitrogen and phosphorus of prairie threeawn, little bluestem, and switchgrass increase in that order. This is also the relative order in which these three species invade abandoned fields and occur in succession on depleted rangeland. Soils in abandoned fields and depleted ranges in Oklahoma are usually low in nitrogen and phosphorus. Soils in later stages of the succession contained increased amounts of these elements (Roux and Warren, 1963).

Aldous (1934) observed that succession was affected by burning. There were fewer plants in the plots burned in late spring than those burned in the fall. With late spring burning the number of grasses stayed fairly constant, but there was a measurable decrease in the number of weeds and sedges present. Little bluestem population decreased while sideoats grama and indiangrass increased under late spring burning. He found that late spring burning increased the protein content of little bluestem. Smith and Young (1959) reported an increase in crude protein, ash and calcium content in little bluestem under burning, but a decrease in ether extract content.

Burning of native rangeland in the Central and Southern Great Plains area is very controversial. However, it is felt by many researchers that fire is a tool that can be used successfully in certain instances. Their opinion is supported by the work of Voge (1965). Spring burning of brush prairie savannah in Northwestern Wisconsin produced a three-fold increase in grass and forb yield. In this particular instance, periodic burning was found to be important in retarding the woody growth which otherwise enables savannah to succeed to forest. Fire at the wrong time of year can be detrimental to certain grasses. Launchbaugh (1964) found that the tillers of buffalograss were killed by a wildfire in early spring (March 18) on an upland range site supporting a mixture of shortgrasses. This fire occurred at a time when the soil and the dormant vegetation were extremely dry, which could account for the detrimental effects.

McMurphy and Anderson (1965) found that late spring burning (May 1) in the Flint hills increased big bluestem production and reduced the production of Kentucky bluegrass (*Poa pratensis*), Japanese brome (*Bromus japanicus*), and buckbrush (*Symphoricarpos orbiculatus*). Burning seemed detrimental to little bluestem. Total beef production and individual animal gains were increased by the late spring burning. Burning also reduced the overall forage yield, possibly because of reduced soil moisture and infiltration rate.

Anderson (1965) pointed out that burning reduced forage yields. The greatest reduction came from early burning and the least reduction came from late burning. The greatest reductions in soil moisture were caused by early burning. Burning should be employed no more than is necessary for good management.

Vlamis and Gowans (1961) determined that there was a release of nitrogen, phosphorus and sulfur when brush was burned. Burning released some soluble salts and nitrogen in the soil according to Reynolds and Bohning (1956) who conducted a study on southern Arizona grass-shrub range.

Kay (1960) reported that hardinggrass (*Phalaris tuberosa*) in California was very fire tolerant under controlled burning. A 7-year old stand of hardinggrass increased from 13% ground cover before burning to 16% ground cover the year following burning.

The effects of burning plus fertilization were studied for one year by Gay and Dwyer (1965). Burning alone did not significantly increase forage yield, but when burning and fertilizer were combined, a significant increase in forage yield was observed. Big bluestem and indiangrass yield was doubled with 50 pounds of nitrogen per acre when combined with burning. Little bluestem and switchgrass did not respond as well as the two other grasses, but reached their peak production at the 50 pound per acre level of nitrogen with burning.

Fertility of native rangeland is very important for sustained production. Miles (1958) stated that nonsymbiotic fixation is a possible source of range nitrogen. He also feels that prolonged production on the range under good management proves there is a source of range fertility. A constant nutrient cycle for adequate fertility is necessary for adequate root and top growth. Applications of commercial nitrogen are thought to enhance root replacement and nitrogen fixation.

Vigorous range plants need nitrogen, phosphorus, and potassium (McGinnies and Retzer, 1948). These elements are usually available in adequate quantities on ranges in good condition. Good condition ranges were associated with high fertility.

According to a study conducted in the Northern Great Plains by Cosper et al (1967) a single application of nitrogen fertilizer to a deteriorated range site changed the botanical composition from predominantly forbs and shortgrass species to a western wheatgrass (Agropyron smithii) and shortgrass composition. Nitrogen also increased both the forage yield and crude protein. Forage yields were increased by the increased number of midgrasses as well as with the nitrogen applied.

It has been shown by Reardon and Huss (1965) that little bluestem responded to nitrogen only under conditions of sufficient moisture, while phosphorus had more of an effect than nitrogen on little bluestem production under droughty conditions.

Fertilization of native ranges is a controversial subject. On the tableland in the extreme northeastern corner of California it was observed that in no instance did the increase in forage yield justify the cost of the fertilizer used on a mixed stand of cheatgrass (Bromus secalinus) and intermediate wheatgrass (Agropyron intermedium) (Kay and Evans, 1965).

Fertilization appeared to be generally uneconomical in a semidesert grassland, under all but the best moisture conditions in a five year study (Herbal, 1963). However, under certain conditions, ranchers could profitably fertilize flood plain sites with 60 to 90 pounds of nitrogen and up to 13.1 pounds of phosphorus per acre.

In a study conducted by Woolfolk and Duncan (1962) on a California annual-type range, fertilizer minimized the effects of weather on vegetative composition. This study indicated that forage production, range use, and weight gains can be effectively increased by fertilization. Fertilizer brought about earlier plant growth and prolonged growth.

In studying the effects of fertilizer on native rangeland in Oklahoma, Huffine and Elder (1960) found that total grass yield for a two year period was slightly higher for the non-fertilized pastures, primarily because of the increase in weed production on the fertilized plots.

Studies by Huffine and Elder (1960), and Elder and Murphy (1958) have shown that weeds were increased in native grassland by repeated applications of fertilizer.

Holt and Wilson (1961) found that even under 14.34 inches of rainfall, there was a marked response in desert grassland vegetation of Southern Arizona to 25, 50 and 100 pounds of nitrogen per acre. Even at the lowest rates of nitrogen, the forage production was almost double that of non fertilized. Fertilizer extended the green feed period of the forage up to six weeks and the livestock utilization went up 3, 4 and 5 times respectively with 25, 50 and 100 pounds of nitrogen per acre over check plots.

Wullstein and Gilmour (1964) determined that if range fertilization becomes a common practice, range managers may encounter gaseous nitrogen losses of economic significance.

Lorenz and Rogler (1967) stated that root development is important to good range condition. They found that nitrogen significantly increased root weight.

Rogler and Lorenz (1957) reported that two years of fertilization with 90 pounds of nitrogen did more to improve range conditions and increase production than six years of complete isolation from grazing. The applied nitrogen increased the supply of accumulated organic matter by stimulating growth. With increased organic matter, nitrogen fixation increased.

On Oregon meadow land, Nelson and Castle (1958) found that 50 pounds of nitrogen gave the highest return of hay per pound of nitrogen although it was still profitable to fertilize these meadows at the 200 pound per acre rate.

CHAPTER III

MATERIALS AND METHODS

Study Area

The study was initiated in June, 1964 on a poor condition loamy prairie range site[1] north of Boomer Lake at Stillwater, Oklahoma.

The loamy prairie range sites of this area are gently rolling with deep, loamy, upland soils. The soils are neutral to slightly acid, with medium to slow permeability (U.S.D.A. Soil Conserv. Serv., 1961).

The prevailing climate of the study area is relatively temperate but of continental origin with hot, often dry, summers, mild autumns, mild to cold winters, and cool springs. Average annual precipitation is 32.2 inches. Approximately 80 per cent of the total precipitation occurs from April to October, which is favorable for the warm season grasses of the area.

Rainfall for the study area was 16 to 22 per cent below normal for the years 1964, 1965, 1966 and 1967 (Appendix Table XV).

1/ In the southeast quarter (SE^4), of the northwest quarter (NW^4), of section thirty-five (35), township twenty (20), north (N) range two (2), east (E) of the Indian meridian.

Treatments

The experimental design was a split plot with four replications. The main plot treatments were burned versus not burned. The sub plots were the fertility treatments at twelve different levels and combinations, randomized within each main plot (Table I).

Burning was performed under controlled conditions in the spring, on or about April 1, just before new growth was being initiated. The areas were burned when the soil was moist so the crowns of the native grass would not be damaged. The burning was done against a 5 to 10 mile per hour wind so all residue would be burned and the fire would not get out of control. The unburned areas were mowed earlier in the spring to remove all residue so that the forage yields measured on both burned and unburned plots could be attributed to the current years growth.

The fertilizer was applied after the desirable vegetation had started to grow each year. This was done so the undesirable annuals that initiate growth earlier in the spring would be favored less by the fertilizer, thus reducing their competitive use of the available moisture and nutrients.

All three fertilizer elements applied were broadcast at the same time. The fertilizer elements were applied as amonium nitrate (33-0-0), super phosphate (0-45-0), and murate of potash (0-0-63).

Species Composition and Forage Yield

Species composition was determined with a meter transect, using eight readings per plot in late summer of each year. The meter transect is a rod approximately one fourth inch in diameter, one meter long,

TABLE I

LEVELS OF EACH FERTILIZER ELEMENT
AT TWELVE DIFFERENT COMBINATIONS

Fertilizer Element	Treatments											
	1	2	3	4	5	6	7	8	9	10	11	12
Nitrogen	0	0	0	0	40	40	40	40	80	80	80	80
Phosphorus	0	0	18	18	0	0	18	18	0	0	18	18
Potassium	0	33	0	33	0	33	0	33	0	33	0	33

and is inserted into the vegetative growth at ground level. Everytime the rod touched a plant, a recording of that particular species was made. This was done at eight different randomly chosen locations within each plot.

Forage production was determined by clipping an 18" x 36" quadrat from each plot in the fall of each year after all noticeable growth had stopped. The samples were clipped at ground level and taken from a different site within the plot from year to year. The forage yield represented the full season's growth. The samples were oven dried, weighed, and yields converted to total dry weight per acre.

Common names of plants often vary from place to place thus, those plants described as decreasers, increasers and invaders are listed in Appendix Table VI by scientific names with the corresponding common names acceptable in Central Oklahoma.

Forb frequencies were determined in 1967 using 20 quadrats, each one foot square, per plot and recording the presnece or absence of foliage.

The statistical procedure utilized was that of Steel and Torrie (1960).

CHAPTER IV

RESULTS AND DISCUSSION

Botanical composition of the range was taken in 1964 shortly after the experiment was started, to establish a basis of comparison. Forage yields in 1964 were undoubtedly adversly influenced because the pasture was closely grazed until June 13. No botanical composition data were collected in 1965 because no visual difference was apparent. Dry matter yields were taken but the species composition was still dominated by increasers and invaders to the extent that the forage value was very low.

Early in 1966 it became obvious that species composition changes were occurring. The burned plots had more of the desirable decreaser species and fewer of the undesirable annuals.

Potassium had no appreciable effect on either forage yield or species composition. Soil tests indicated 270 pounds of available potassium per acre. This amount apparently provided adequate potassium for all plots.

Species Composition

There were no appreciable differences in species compositions in 1964 (Appendix Tables VII and VIII). These data were taken shortly after the experiment was initiated and before any burning was done. The percentage increasers varied from 28.6 to 47.0 and the percentage of invaders varied from 31.7 to 58.8 across all fertility and burning treatments.

The improvement which can be credited to the burning treatment was apparent in 1966 (Figure 1). The decreaser precentage was significantly higher on the burned plots. The invader percentage averaged 15 percent for the burned plots and 30 percent for the unburned ones. No significant difference in increaser percentages occurred in 1966 as a result of burning.

By 1967 there was no significant difference in decreaser percentage attributable to burning (Figure 1). Thus, it appears that controlled burning accelerated the succession of decreaser species by about one year over the four year period. The percentage of invaders was being reduced each year, but the unburned plots still contained greater percentages of invaders in 1967. These differences were statistically significant.

The burned plots contained more increasers in 1967 (Appendix Tables XI and XII). These differences were also statistically significant. The increasers were dominated by sideoats grama, which is one of the more desirable increasers.

The total improvement in decreaser percentage is worthy of note. From 1964 thru 1967 the decreasers averaged 17.9 percent to 45.9 percent on all the burned plots. On the unburned plots, the decreasers improved from an average of 17.2 to 47.9 percent during the same period.

Prairie threeawn was the dominant invader species in the unburned plots for 1966 and 1967 (Table II and Appendix Tables VII thru XII). The 1964 data indicate that all plots had less than two percent prairie threeawn. These data were taken in July. The plots had all been

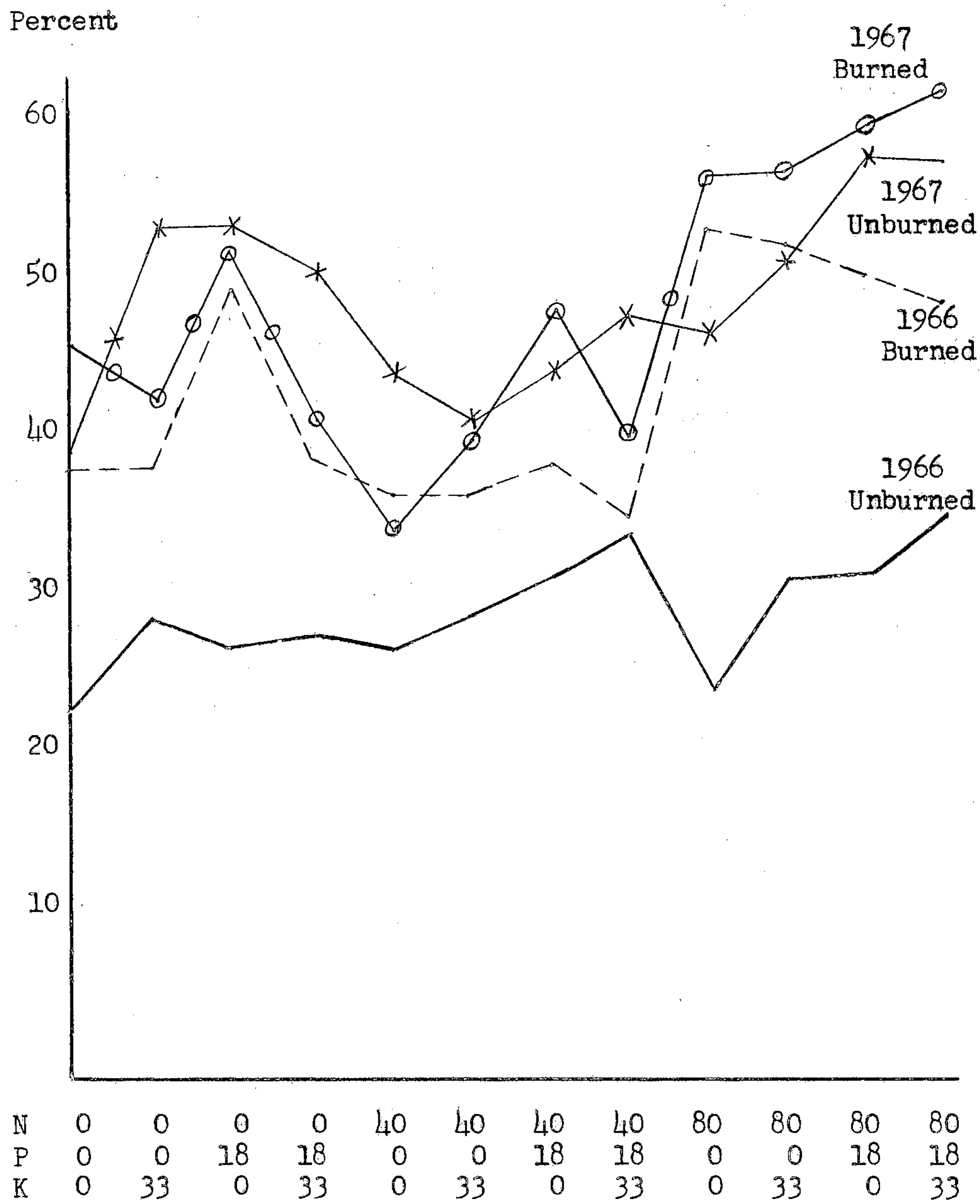

Figure 1. Decreaser Percentage in 1966 and 1967. Difference Between Burned and Unburned Were Significant (P = .05) in 1966 but Not In 1967

TABLE II

PRAIRIE THREEAWN, PERCENTAGE OF TOTAL VEGETATION*

	Years					
	1964		1966 1/		1967 1/	
Treatment	Burned	Unburned	Burned	Unburned	Burned	Unburned
0-0-0	1.2	1.2	6.0	10.4	.2	7.5
0-0-33	1.9	1.0	2.1	10.5	1.2	6.6
0-18-0	0.0	0.0	2.2	16.9	.4	5.6
0-18-33	1.5	1.8	1.2	13.1	.1	9.0
40-0-0	.1	1.0	1.4	17.6	.2	11.1
40-0-33	.4	1.1	.5	20.9	1.0	8.4
40-18-0	.5	1.6	.2	12.1	0.0	6.0
40-18-33	.8	1.0	1.5	5.5	.2	4.1
80-0-0	.4	.8	.2	44.0	.2	16.2
80-0-33	.9	.5	.5	11.4	0.0	6.4
80-18-0	.2	.8	.5	1.9	0.0	.8
80-18-33	.9	1.0	0.0	3.2	.2	1.5

1/ Significant difference (P = .05) between burned and unburned.

* Determined by the meter transect technique.

closely grazed and it was very dry at the time. Following the heavy August precipitation, prairie threeawn became abundant on all plots that fall. Prairie threeawn was also visibly abundant in all plots in 1965. By the end of 1966, after 2 controlled burnings and 2 1/2 years of grazing deferment, prairie threeawn was well under control in all burned plots. A significant reduction in prairie threeawn had been achieved (Table II).

The most abundant undesirable forbs were western yarrow (Achillea lanulosa), western ragweed (Ambrosia psilostachya), and Louisiana sagewort (Artemisia ludoviciana). The meter transect procedure which measured basal area covered was inadequate for measuring forb content because topgrowth seemed to vary. Therefore, in 1967, square foot quadrats were used and presence or absence of western yarrow, western ragweed and Louisiana sagewort were recorded. The controlled burning could be credited with causing a significant reduction of these undesirable forbs (Table III). Visually, there appeared to be a tendency for the combination fertility treatment of nitrogen with phosphorus to stimulate a more rank growth of forbs. The meter transect and square foot quadrats were either inadequate for measuring the fertility effects on forb production or the differences indicated were not true ones.

Previous research (Elder and Murphy, 1958; Huffine and Elder, 1960) on range fertilization had been plagued by the response of undesirable cool season species. Burning has been shown to control cool season species (McMurphy and Anderson, 1965). Therefore, burning was included to control the expected invasion of cool season species, primarily Japanese brome (Bromus japonicus). The expected invasion never materialized. In the spring of 1966, it was noted that blackeyedsusan

TABLE III

PERCENT FREQUENCY OF THE FORBS (WESTERN YARROW, WESTERN RAGWEED AND LOUISIANA SAGEWORT) IN SPRING OF 1967 USING FT.^{2} QUADRATS

Treatment	Burned	Unburned	Difference
0-0-0	27	38	11 +
0-0-33	25	40	15 +
0-18-0	21	49	28 +
0-18-33	27	46	19 +
40-0-0	22	43	21 +
40-0-33	28	50	22 +
40-18-0	29	50	21 +
40-18-33	29	51	22 +
80-0-0	28	46	18 +
80-0-33	17	42	25 +
80-18-0	34	49	15 +
80-18-33	27	58	31 +

(Rudbeckia hirta) and daisy fleabane (Erigeron strigosus) flowered profusely on the unburned plots, but were absent on burned plots. These species had matured and disappeared by late summer when the meter transects were read.

The effect of the different fertility treatments on improving species composition was inconclusive. The variability between plots was so large that differences observed were not statistically significant. It can be concluded that the undesirable species will grow profusely if they are well fertilized.

Range Condition

Species composition is used to determine range condition. In this case, the percentage basal composition from the meter transects was used instead of actual dry weight of the species. Dry weight determination would have required a hand separation of the forage by species.

Range condition is usually based upon the percentage of original or climax vegetation (Dyksterhuis, 1949). Using the meter transect data, the percent range condition would include the total for decreasers plus the allowable percent of increasers. For this loamy prairie site studied, the allowable percentage of each increaser was sideoats grama, 5; tall dropseed, 5; fall witchgrass, 5; and scribner panicum, 5. The different range condition classes and the corresponding percentage variation allowable for the original vegetation are shown in Table IV.

By 1966, all burned plots had an average range condition of 51 percent while all unburned plots had an average range condition of 39 percent. This places the range condition in the good category for

TABLE IV

RANGE CONDITION EXPRESSED AS
PERCENT OF CLIMAX SPECIES

Range Condition	Percent of Climax
Poor	0-25
Fair	26-50
Good	51-75
Excellent	76-100

burning and only fair for unburned plots. An accelerated improvement was achieved by burning.

By 1967, the average range condition for all burned plots was 55 percent and for all unburned plots was 57 percent. Thus, after 3 years of controlled burning and 3 1/2 years of deferment, there was no significant difference in range condition.

Forage Production

The term "forage production" is inappropriate for much of the yield data obtained, because of the high content of prairie threeawn, forbs, and other low quality vegetation. For example, one unburned plot receiving 80 pounds of nitrogen per acre produced over 3 tons of dry matter. The botanical composition of this plot was 70.5 percent prairie threeawn. Three tons of prairie threeawn should not be called forage. The example probably represents an extreme case, but it does present the problem.

Total dry matter yields are presented in Appendix Table XIII without statistical analysis, because 3 tons of prairie threeawn has no particular value. The forage produced on the burned plots in 1966 and 1967 was primarily of desirable, high quality grasses. Therefore, only these two years' quality forage production was analyzed for presentation as "forage yield" (Appendix Table XIV).

Nitrogen fertilizer gave the greatest response in forage production (Table V). Significant increases in production occurred at each increased level of nitrogen fertilizer. The most important aspect was the increase in forage yield per pound of applied nitrogen. In 1966 the 40N and 80N levels produced 44 and 37 pounds of forage per pound of

TABLE V

EFFECT OF NITROGEN ON FORAGE PRODUCTION FROM BURNED PLOTS[1]

Year		Pounds of Nitrogen Per Acre		
		0	40	80
1966	Production[2]	3235c	5011b	6122a
	Pounds Forage/Pound Nitrogen		44	37
1967	Production	3263c	5256b	6987a
	Pounds Forage/Pound Nitrogen		50	47

1/ Pounds of oven dry forage per acre.

2/ Means within a year followed by the same letter, are not significantly different (P = .05).

nitrogen applied, respectively. In 1967 production increased to 50 and 47 pounds of forage produced per pound of applied nitrogen at the 40N and 80N rates, respectively. These outstanding responses to nitrogen fertilizer are higher than those from any previous research in Oklahoma. The best obtained previously was 28 pounds of forage per pound of nitrogen. This was, however, from a burned plot (Gay and Dwyer, 1965).

Phosphorus produced a significant increase in forage yields, averaging 667 pounds per acre in 1967. No significance was attributed, but there was a significant nitrogen x phosphorus interaction (Appendix Table XIV). The nitrogen x phosphorus interaction occurred with the additions of phosphorus at the high nitrogen level. This is an unexplainable interaction.

Potassium did not significantly affect forage production.

CHAPTER V

SUMMARY AND CONCLUSIONS

Burning and fertilization were used on a poor condition range to evaluate their effect on range improvement and forage production.

Burning improved species composition by controlling blackeyed susan, daisy fleabane, western yarrow, western ragweed and Louisiana sagewort. The most significant difference was the elimination of prairie threeawn, which fire controlled, and the resulting increased growth of decreaser species. The percentage decreasers in the burned plots was significantly improved over unburned plots in 1966. However, by 1967, the improvement in the unburned areas was equal to that in the burned plots.

Range condition improved from an average poor to good on all plots by 1967. However, in 1966, the burned plots were classed as good while the unburned plots were classed as only fair.

Dry matter production was determined each year. The abundance of prairie threeawn resulted in low quality forage except for the last two years on the burned plots. Significant forage yield increases in the last two years were attributed to nitrogen fertilization. The increase in forage production ranged from 37 to 50 pounds of additional forage per pound of applied nitrogen. Phosphorus produced a significant increase in yield in 1967.

Potassium had no effect on forage yield or species composition.

Fertilizer had no measurable effect on increasing the speed of range improvement. It was observed that phosphorus plus nitrogen seemed to encourage the growth of broadleaf weeds.

A future study of this type, using fire, fertilizer and 2,4-D for the control of broadleaf weeds deserves consideration.

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APPENDIX

TABLE VI

DECREASER, INCREASER AND INVADER SPECIES BY SCIENTIFIC AND COMMON NAMES

Scientific Name	Abbreviation	Common Name
	Decreaser Species	
Andropogon gerardi	Age	big bluestem
Andropogon scoparius	Asc	little bluestem
Panicum virgatum	Pvi	switchgrass
Sorghastrum nutans	Snu	indiangrass
	Increaser Species	
Andropogon ternarius	Ate	splitbeard bluestem
Bouteloua curtipendula	Bcu	sideoats grama
Bouteloua gracilis	Bgr	blue grama
Bouteloua hirsuta	Bhi	hairy grama
Sporobolus asper	Sas	tall dropseed
Eragrostis spectabilis	Esp	purple lovegrass
Leptoloma cognatum	Lco	fall witchgrass
Paspalum stramineum	Pst	sand paspalum
Panicum scribnerianum	Psc	scribner panicum
Carex spp.	Csp	sedges
Sporobolus cryptandrus	Scr	sand dropseed
	Invaders	
Setaria geniculata	Sge	knotroot bristlegrass
Buchloe dactyloides	Bda	buffalograss
Andropogon saccharoides	Asa	silver bluestem
Andropogon virginicus	Avi	broomsedge bluestem
Paspalum floridanum	Pfl	Florida paspalum
Chloris verticillata	Cve	windmill grass
Aristida oligantha	Aol	prairie threeawn
Eragrostis intermedia	Ein	plains lovegrass
Cynodon dactylon	Cda	bermuda grass

TABLE VII

SPECIES COMPOSITION OF BURNED PLOTS 1964 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE-METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age[1]	4.9	10.7	11.0	10.1	5.7	15.2	10.6	13.3	8.5	11.2	7.3	11.8
Asc	7.0	2.7	6.2	3.9	5.2	6.9	4.8	4.5	4.8	7.2	6.5	5.1
Pvi	.7			.2		.8						
Snu	3.5	1.1	5.9	4.3	4.5	1.1	1.1	1.3	.2	1.5	2.3	3.5
Dec	16.1	14.5	23.1	18.6	15.4	22.0	16.4	19.1	13.5	19.9	16.2	20.4
Bcu	20.5	18.5	26.7	28.1	19.1	28.9	22.5	11.5	15.8	11.6	20.6	17.9
Bgr	6.2	7.6	1.3	2.3	6.3	5.5	3.5	8.6	1.1	11.0	3.4	1.5
Bhi	2.6	2.5	3.5	1.0	3.7	2.1	.9	3.5	4.1	4.0	3.7	3.2
Sas											.2	
Esp			.2							.4		
Lco	2.4	1.2	.9	.8	1.2	2.1	1.9	.8	3.0	2.3	2.4	1.3
Pst	12.1	6.1	6.6	8.3	6.1	7.5	8.9	8.2	7.8	6.8	6.4	5.0
Psc	.2	1.0		1.0	.4	.2	.4	.8	.2	.4	.2	
Csp												
Inc	44.0	36.9	39.2	41.5	36.8	46.3	38.0	33.5	32.1	36.6	36.8	28.9
Sge												
Bda	2.6	17.2	2.9	10.1	13.4	1.9	17.1	12.7	16.3	10.6	19.2	26.5
Asa												
Avi	.9	2.9	1.8	1.9	4.1	1.3	1.1	.4	.4	1.7		.8
Pdi									.9			
Cve	22.5	17.4	25.3	20.1	19.5	15.9	17.1	21.2	23.4	18.2	15.7	15.6
Aol	2.2	2.9		2.5	.2	.6	.9	1.2	.7	1.5	.4	1.3
Ein	11.7	8.2	7.7	5.2	10.6	12.0	9.5	11.9	12.8	11.6	11.8	6.5
Cda												
Inv	39.9	48.6	37.7	39.8	47.8	31.7	45.6	47.4	54.5	43.6	47.1	50.7

[1] See Appendix Table VI for key to names.

TABLE VIII

SPECIES COMPOSITION OF UNBURNED PLOTS 1964 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age	14.6	7.7	7.9	7.9	11.2	12.2	8.6	12.1	6.5	12.1	10.1	13.6
Asc	1.9	4.7	10.3	4.1	4.5	2.5	6.1	3.4	4.1	4.4	2.8	6.2
Pvi	2.7		.4	1.4	.9			4.8		1.9	1.3	
Snu	.5	.2	1.8	.6			1.5	2.4	1.3	.6	2.2	2.3
Dec	19.7	12.6	20.4	14.0	16.6	14.7	16.1	22.7	11.9	19.0	16.4	22.1
Bcu	22.2	15.2	20.8	18.9	21.3	17.1	25.7	21.3	24.9	17.6	15.8	21.9
Bgr	2.1	4.5	.9	2.4	4.9	10.7	.2	8.1	5.4	2.5	.8	.8
Bhi	1.9	.6	1.8	3.3	4.5	4.4	2.9	5.6	3.5	2.6	4.8	1.9
Sas												
Esp	.2				.2					.2	.2	.4
Lco	.5	1.0	.9	1.0	.9	1.3	.4	2.2	.4	.5	.5	1.0
Pst	8.8	7.3	8.8	7.7	6.3	8.2	10.2	7.9	12.3	8.3	7.3	6.3
Psc	.5			.2	.5				.4		.3	
Csp												
Inc	36.0	28.6	33.0	33.5	38.6	41.7	39.5	45.2	47.0	31.7	29.7	32.8
Sge												
Bda	10.5	21.5	17.1	22.0	15.2	6.9	3.1	3.0	12.6	20.1	31.0	10.5
Asa												
Avi	.8	2.0	1.5	1.6	.5	3.6	.2	1.6		.9	1.0	
Pdi												
Cve	17.2	20.1	17.3	15.2	17.3	18.1	22.3	14.1	17.1	18.7	11.5	24.2
Aol	2.1	1.6		2.8	1.8	1.9	2.7	1.6	1.3	.7	1.0	1.6
Ein	13.8	13.6	10.7	10.8	10.1	13.1	16.1	11.7	10.2	8.9	9.3	8.9
Cda												
Inv	44.4	58.8	46.6	52.4	44.9	43.6	44.4	32.1	41.2	49.3	43.8	45.1

TABLE IX

SPECIES COMPOSITION OF BURNED PLOTS 1966 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age	10.6	11.9	12.0	13.8	10.4	12.9	11.7	13.5	16.3	18.7	20.1	24.0
Asc	19.3	24.7	18.8	16.6	19.1	17.1	21.2	16.4	30.7	27.4	22.7	18.4
Pvi	.4		.2							.2		
Snu	6.7	1.2	18.0	7.0	5.7	4.0	4.5	2.1	4.4	5.0	7.4	3.6
Dec	37.0	37.8	49.0	37.4	35.2	34.0	37.5	32.0	51.4	51.4	50.1	46.0
Bcu	16.1	19.3	27.0	27.8	19.6	24.6	25.8	17.8	12.7	13.2	17.8	23.0
Bgr	5.7	8.7	1.3	3.5	9.4	10.8	2.9	6.6	1.0	9.1	3.4	.7
Bhi	.4		.4	2.4	.2		.2	.2		.5	2.8	.7
Sas	.4	2.0		.4	1.1	3.3	2.1	2.7	1.6	.2	2.3	2.3
Esp	1.0	2.0	.8	3.1	.5	1.9	.2	2.3	1.3	.5		1.0
Lco	2.0	1.8	.4	.7	4.6	2.1	3.6	1.6	2.8	2.3	2.3	.3
Pst	2.2	2.8	.8	.9	1.6	1.2	.5	.2				.3
Psc	1.4	.4	.6	1.3	1.1	.5	1.2	.5	.3	.2	.6	1.0
Csp	4.9	2.6	2.8	6.6	2.3	1.6	2.6	4.1	2.1	2.5	5.1	1.0
Inc	34.1	35.7	34.0	44.4	40.6	45.9	39.1	33.8	21.7	28.5	34.3	30.3
Sge	.4			.2	.2	.7	1.2		.3		.3	
Bda	.2	3.2	1.3	7.2	6.7	.9	7.4	13.9	3.1	1.8	2.8	6.2
Asa		.6				.2	.7			.9	1.1	
Avi					.5	2.1		1.4	1.0	1.4		
Pdi									3.9			
Cve	4.3	2.6	3.2	4.8	1.1	2.8	3.1	5.9	.8	.5	1.1	1.3
Aol	9.4	3.4	3.4	2.2	2.5	.9	.5	2.7	.5	.9	1.1	
Ein	3.1	1.2	4.0	1.8	2.5	1.4	4.8	.9	1.6	4.1	1.7	2.0
Cda	8.5	2.8		.2	7.1	4.7	.7	1.1	11.1	6.4	.3	3.3
Inv	26.0	13.9	11.9	16.4	20.7	13.8	18.4	26.0	22.2	16.0	8.5	12.8
Forbs	2.9	2.6	5.1	1.8	3.5	6.3	5.0	8.2	4.7	4.1	7.1	10.9

TABLE X

SPECIES COMPOSITION OF UNBURNED PLOTS 1966 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age	12.2	8.0	7.5	6.8	8.4	12.0	7.8	13.2	4.4	8.7	16.8	12.7
Asc	7.7	21.1	16.0	21.4	15.7	16.0	18.4	16.5	11.1	19.5	11.9	20.8
Pvi	1.8		.7	.2	.4	.4	1.0	.6	.2	1.4	2.2	.9
Snu	1.8	4.3	2.9	1.2	1.0	.8	4.0	2.7	.3	1.7	.4	2.1
Dec	23.5	37.5	27.1	29.5	25.4	29.2	31.2	33.0	15.9	31.3	31.3	36.4
Bcu	23.5	13.1	20.3	17.0	21.0	12.4	22.2	21.0	9.4	15.9	28.0	23.2
Bgr	.2	2.0	.9	3.8	2.1	4.5	.9	.9	1.0	.5	1.1	.3
Bhi	3.2	2.7	.9	1.2	1.1	1.8		2.1		.5	.4	.3
Sas		.6	.9	.2	2.9	2.6	1.7	4.5	2.2	3.4	3.0	3.3
Esp	1.6	1.8	.7	1.7	2.9	.2	.5	3.0	1.5	1.9	.4	.3
Lco	4.1	3.5	.9	1.2	2.5	3.4	2.1	.6	.7	4.1	3.4	1.5
Pst	1.2	2.7	.7	.7	.6	.2	.5	.6	.3	.5	.4	
Psc	.5	.4	.5	.2	.4	.6	.2	1.5	.3	.7		.3
Csp	1.8	2.0	1.8	2.8	.6	.2	1.9		.3		2.2	3.6
Inc	36.1	28.9	27.6	28.8	34.1	26.0	30.0	34.2	15.8	27.4	38.8	32.8
Sge								.3	.2			
Bda	3.9	3.5	9.6	7.8	2.3	.8	1.7	1.8	.3	4.8	9.3	5.1
Asa					.4	.4		.6		.5		
Avi						.6						
Pdi							.2					
Cve	9.9	8.2	4.6	6.9	2.5	2.0	5.4	5.1	1.5	2.2	1.5	2.1
Aol	16.4	17.2	24.1	18.2	27.0	33.9	22.9	13.2	59.1	21.9	5.6	7.8
Ein	4.1	3.3	.4	3.0	1.3	1.2	1.4	2.4	.5	3.1	2.2	1.8
Cda	.8			.2	2.9	3.7	.5	.6	4.4	3.8	1.1	3.3
Inv	35.1	28.7	38.7	36.1	36.3	42.6	32.2	24.0	65.9	36.3	19.8	20.2
Forbs	5.3	4.9	6.6	5.6	4.2	2.2	6.6	8.8	2.3	5.0	10.1	10.6

TABLE XI

SPECIES COMPOSITION OF BURNED PLOTS 1967 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age	6.8	15.2	9.7	12.8	9.6	11.3	18.3	25.2	23.5	19.2	23.7	29.0
Asc	27.9	14.3	24.6	20.0	20.1	24.1	26.4	10.0	27.7	33.8	21.0	29.8
Pvi	1.1				.2	2.6			.5	1.2	.6	.9
Snu	8.7	.8	16.2	7.2	3.5	1.8	3.3	1.9	1.9		12.5	1.4
Dec	44.6	30.3	50.5	40.0	33.3	39.8	47.9	37.1	53.6	54.2	57.8	61.1
Ate			.4				.4				.3	
Bcu	25.1	25.2	27.5	30.3	16.2	26.8	19.9	19.6	17.1	13.4	16.7	19.9
Bgr	5.1	10.7	.2	5.6	10.1	10.1	2.1	17.5	2.7	4.5	2.4	.3
Bhi	.8	4.1	1.0	2.7	1.0	1.2	2.3	1.5		.9	.6	.3
Sas	.6	.4	.2	.9	1.0	.6	1.0	.4	1.3	1.2	2.1	.3
Esp	.8	2.9	.8	.9	.4	.4		1.7	.5	.5	1.5	1.1
Lco	2.8	1.8	1.9	1.3	5.1	2.4	2.7	.6	5.9	5.6	.9	.6
Pst	3.2	1.0	1.0	1.1	1.0	2.4	.6	.4	1.3	1.2	.6	
Psc	.4	1.4	1.2	.7	1.4	1.2	.4	1.5	1.3	.5	1.8	
Csp	5.5	6.6	4.3	5.9	2.6	4.0	2.9	5.2	1.9	1.4	4.0	2.6
Inc	44.2	54.1	38.7	49.4	38.6	49.1	32.4	48.3	32.0	29.1	31.0	25.0
Sge			.2		.6	.2						.9
Bda	.4	4.9		2.5	7.0	1.4	7.7	4.2	1.6	2.6		.6
Asa		.8		.2			4.2		.5	.2		
Avi	.6	1.2	.2	.9		.4		.6				
Pdi												
Cve	2.5	2.9	2.3	2.9	1.2	.6	.8	1.0	.3	.2		.6
Aol	.4		.6	.2	.4	.4		.2	.3			.3
Ein	2.3	2.0	1.0	1.3	2.3	1.6	1.7	1.5	.5	.2		.6
Cda	1.1		1.6		7.8	.8	2.5	1.9	7.2	11.3	2.4	4.5
Inv	7.2	13.5	4.4	7.9	19.3	5.4	16.8	9.4	10.4	15.6	2.4	7.4
Forbs	4.0	2.1	6.4	2.7	8.8	5.7	2.9	5.2	4.0	2.1	8.8	6.5

TABLE XII

SPECIES COMPOSITION OF UNBURNED PLOTS 1967 AS PERCENT OF TOTAL NUMBER OF PLANTS ON THE ONE METER TRANSECTS

	Treatments											
N	0	0	0	0	40	40	40	40	80	80	80	80
P	0	0	18	18	0	0	18	18	0	0	18	18
K	0	33	0	33	0	33	0	33	0	33	0	33
Age	14.5	14.6	13.4	12.6	10.7	22.1	9.3	14.1	11.4	18.1	19.6	20.3
Asc	17.0	35.7	33.7	36.0	28.5	18.5	29.5	26.0	26.8	26.8	27.4	19.9
Pvi	1.5		1.2	1.2	2.4			2.6	.2	5.0	4.1	.4
Snu	2.7	3.5	5.5	.6	1.9	.5	4.9	4.0	1.4	1.8	7.5	6.4
Dec	35.7	53.8	53.8	50.4	43.5	41.1	43.8	47.1	39.8	51.7	58.6	47.0
Ate	.2		.7		.5						.4	.8
Bcu	20.9	17.4	15.9	11.5	14.1	10.7	16.6	16.7	11.1	10.8	14.3	11.7
Bgr	1.2	2.0	.2	3.5	1.4	3.3		1.1		1.0		2.6
Bhi	10.1	2.6	1.5	2.1	2.9	.5	1.3	2.9				1.1
Sas	.7		.2	.8	.7	5.6	2.3	1.1	1.1	1.6	1.9	.4
Esp	1.0	1.7	2.7	1.2	.7	.3	2.1	2.6	.5	2.1	1.1	2.3
Lco	2.7	2.0	1.2	1.0	3.8	3.3	3.6	4.0	5.5	5.8	5.3	4.9
Pst	1.0	.9	.5				.3				.4	
Psc	.5	.7			1.0	.3	.5		.7	1.0	.4	
Csp	.7	1.5	1.7	2.9	2.4	2.3	4.9	1.7	.7	.5	2.3	2.6
Inc	39.2	27.7	24.8	23.0	27.5	26.1	31.6	30.2	19.6	22.8	26.0	26.3
Sge		.2	.2					1.7			.4	
Bda	1.5	1.7	1.2	6.2	.7	1.0	.5			1.6	1.5	
Asa				.2						.3		
Avi	.7	.2		.2	1.0			.6			1.5	4.1
Pdi												
Cve	4.7	1.7	2.2	1.9	1.2	1.3	2.3	2.0	.7	.3	.4	.4
Aol	14.8	11.5	11.2	14.0	21.3	17.0	12.4	9.5	29.5	13.4	2.3	4.5
Ein	.2	.7	1.0	.4		1.0	.8	1.4	.5	.3	.4	.8
Cda	.7				1.4	1.5	1.6	.6	5.2	5.5	1.9	3.8
Inv	22.7	16.1	15.9	23.0	25.6	21.8	17.6	15.8	35.9	21.3	8.3	13.5
Forbs	2.4	2.4	5.5	3.6	3.4	10.9	7.0	6.9	4.7	4.2	7.1	13.2

TABLE XIII

DRY MATTER PRODUCTION IN POUNDS PER ACRE, OVEN DRY WEIGHT

Treatment	1964	1965	1966	1967	Total
			Burned		
0-0-0	2138	1936	2630	2374	9,078
0-0-33	2047	2188	2913	2784	9,932
0-18-0	1774	2689	3879	3356	11,698
0-18-33	2239	2898	3516	3622	12,275
40-0-0	2298	3794	4156	5186	15,434
40-0-33	3547	3760	4785	4946	17,038
40-18-0	3297	4338	5858	6279	19,772
40-18-33	2848	3510	5399	5431	17,188
80-0-0	3580	5116	6764	7272	22,732
80-0-33	3125	4310	6812	6445	20,692
80-18-0	3084	5063	5138	6813	20,098
80-18-33	3705	5149	5724	6781	21,359
Total	33,682	44,751	57,574	61,289	197,296
			Unburned		
0-0-0	2572	2769	3297	3783	12,421
0-0-33	1938	3330	3718	4193	13,179
0-18-0	2917	2840	3265	3996	13,018
0-18-33	2113	2966	3809	3516	12,404
40-0-0	3294	4060	5516	5628	18,498
40-0-33	2983	4839	6252	5340	19,414
40-18-0	3225	3848	4919	6258	18,250
40-18-33	3466	4236	5436	5794	18,932
80-0-0	3428	4366	5836	6626	20,256
80-0-33	3521	4258	5399	6519	19,697
80-18-0	3678	5106	4381	6487	19,652
80-18-33	3893	4540	5597	6445	20,475
Total	37,028	47,158	57,425	64,585	206,196

TABLE XIV

FORAGE YIELD ANALYSIS OF VARIANCE FOR BURNED PLOTS ONLY

		1966		1967	
Source	df	MS	F	MS	F
Total	47				
Replication	3	8,186.3	3.160*	14,185.2	4.812*
Fertility	11	18,283.8	7.058**	24,625.8	8.354**
N	2	74,586.9	28.793**	122,005.2	41.387**
P	1	2,028.0	.783N.S.	11,750.0	3.986N.S.
K	1	280.4	.108N.S.	4,051.7	1.374N.S.
NP	2	17,258.1	6.662**	286.2	.097N.S.
NK	2	287.0	.112N.S.	3,418.2	1.159N.S.
PK	1	705.3	2.634N.S.	1,312.5	.445N.S.
NPK	2	6,822.2		1,175.4	.399N.S.
Error	33	2,590.4		2,947.9	

* Significant at the .05 level.

** Significant at the .01 level.

TABLE XV

PRECIPITATION DATA[1] FOR STILLWATER[2] OKLAHOMA
1964, 1965, 1966 AND 1967

Month	Inches of Precipitation					
	1964	1965	1966	1967	4 Yr. Mean	Mean Departure From Normal
January	.54	.99	.18	2.32	1.01	+ .02
February	1.61	.71	1.48	.33	1.03	- .33
March	1.02	1.38	.17	1.46	1.01	- .78
April	1.71	1.92	2.39	2.74	2.19	- .68
May	4.04	3.78	3.48	6.22	4.38	- .49
June	1.17	5.28	3.75	3.93	3.53	- .75
July	.28	1.73	7.34	4.59	3.48	- .21
August	7.30	2.67	3.32	1.28	3.64	+ .55
September	2.43	6.50	1.34	4.60	3.72	0.00
October	.54	.52	.40	2.58	1.01	-1.63
November	5.28	.04	.13	.72	1.54	- .11
December	.64	2.26	1.41	.71	1.26	+ .08
Total	26.56	27.78	25.39	31.48	27.80	-4.40

1/ Climatological Summary 1938-1967, Stillwater, Oklahoma (Feb. 1968) No. 20-34.

2/ Experimental plots were located about 4 miles northeast of the weather station.

VITA

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