MANIPULATING CENTRAL OKLAHOMA RANGELAND VEGETATION FOR BOBWHITE QUAIL

By

CLARK HECTOR DERDEYN

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

John A. Morrison
Thesis Adviser

John J. Barclay

J. Powell

D. D. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Bobwhite quail (Colinus virginianus) is the most popular upland game species in Oklahoma. Clean-farming methods destroy quail habitat, therefore most of the potentiality for improving quail habitat in Oklahoma exists in rangeland. Tallgrass prairie is the largest rangeland habitat in Oklahoma (Duck and Fletcher 1945). The effect of habitat manipulation on production of bobwhite quail foods in tallgrass prairie has not been determined.

Oklahoma rangeland has been considered deficient in quail foods (Davison 1949). Tobler (1973:30) found an average of 1.5 gm of seeds per square meter of land surface used as feeding areas by quail in stabilized dune habitat (Duck and Fletcher 1945) in Dewey Co., Oklahoma. Assuming that 15 g of seed per day is the consumption rate of food among bobwhite quail (as determined by Nice 1910), and assuming that all seeds found were available for use by quail, 10 square meters of this rangeland would feed one quail for one day. Knowledge of comparative productiveness of different kinds of rangeland would enhance quail management in Oklahoma because it would allow managers to predict results of habitat manipulation.

Numerous studies in other portions of the bobwhite's range have documented quail habitat improvements caused by burning (Speake 1966, Stoddard 1931, Rosene 1969, and Hurst 1970). Hines (1967) studied quail habitat changes caused by burning, discing, fertilizing, and planting in Louisiana. No comparisons of the quantity of bobwhite foods produced by burning, discing, or fertilizing have been made in Oklahoma.

Many studies have documented the effects of mowing (Crockett 1966, Mueller 1964), soil disturbance (Penfound 1957, 1964; Penfound and Rice 1957; Rice and Penfound 1954) fire (Aldous 1934; Anderson 1961, 1964, 1965; Gay 1964; Graves 1968; Hanks and Anderson 1947; Kelting 1957; McMurphy and Anderson 1965; Owensby and Anderson 1967; Penfound and Kelting 1950), secondary succession (Hutchinson 1969, Rice et al. 1960, Tomanek et al. 1955, Booth 1941), allelopathy (Floyd and Rice 1967; Olmsted and Rice 1970; Parenti and Rice 1969; Parks and Rice 1969; Rice 1964, 1965a, 1965b, 1968, 1969, 1971; Wilson and Rice 1968), and fertilization (Graves 1968, Gay 1964) on rangelands of this region. Of these studies only those of Gay (1964) and Graves (1968) involve combinations of treatments. They studied combinations of burning and fertilizing.

These studies emphasized mainly the responses of dominant prairie grasses to these treatments and the amount of livestock forage produced. The economics of a management practice are very important to the landowner; but if multiple use of rangeland is desired, uses other than livestock production must also be considered. In the studies reviewed, responses of legumes and other forbs, important plants for quail, were studied very little.

The objectives of this study were to determine the quantity of bobwhite quail foods and the general vegetative changes produced by combinations of burning, discing, and fertilizing of tallgrass prairie in central Oklahoma during early spring and late spring. Species composition, species density, herbage production, seed production, and amount of ground litter were the vegetative parameters of the habitat examined. Special emphasis was given to plants producing seeds used as food by quail and to plants serving best to illustrate the effects of habitat treatments.

CHAPTER II

STUDY AREA

The legal description of the study area is the SW ¼ of the NW ¼ of Section 12, T-28-N, R-10-E, Osage County, Oklahoma. It is 8 km west of Hulah Reservoir on the Hulah Public Hunting Area managed by the Oklahoma Department of Wildlife Conservation. A study location high enough above normal lake elevation to avoid flooding was selected.

The past history of this area is vague. It was grazed until the early 1960's. It was then used as a prairie hay meadow until approximately 1965. Since 1966 the area has been neither grazed nor mowed. It has been burned, unintentionally, at irregular intervals. The most recent fire occurred in the early fall of 1971.

The area lies on a southfacing slope. The upper part has a slope of 1 to 2 degrees and the lower part is near level to 1 degree.

Area vegetation consists mainly of tall grasses. Big bluestem (*Andropogon Gerardi*), little bluestem (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*) are the dominant species (Figure 1).

The soil of the area is part of the Bates-Collinsville complex (Polone 1968). The Collinsville series is the dominant soil of the complex at this site and is a member of the "loamy siliceous, thermic family of Lithic Hapludolls" (U.S. Department of Agriculture 1973). This soil develops from a yellow noncalcareous sandstone under tallgrass prairie vegetation. Bedrock usually occurs at 10 to 80 cm below the soil surface, but some surface outcropping occurs. The stony nature of the study area soil is shown in Figure 2. The Bates series is a member of the "fine-loamy, siliceous, thermic family of typic Argiudolls" (U.S. Department of Agriculture 1969). The depth to bedrock under the Bates series ranges from 50 to 100 cm. Both of these series are slightly acid in reaction. In years of favorable moisture, the Collinsville series will produce 3120 kg/ha of dry herbage and the Bates series will produce 6250 kg/ha of dry herbage (U.S. Department of Agriculture 1969, 1973).

Hulah Dam, 8 km east of the study area, is the nearest weather recording station. Mean annual rainfall for Hulah Dam is 927 mm. May (132 mm), June (117 mm), and September (106 mm) are the wettest months, and January (40 mm) and February (40mm) are the driest. The first freeze of the fall usually occurs in late October. Rainfall from April through September generally provides the growing-season moisture (mean = 655 mm). During the 1973 growing season the area received above-normal rainfall (725 mm), but from 1 May through 31 July the total was 69 mm below normal. Annual mean temperature is 32 C. The mean temperature for July is 44 C and for January is - 1 C. The average total

Figure 1. General view of the study area.

Figure 2. Stony nature of the study area soil is shown in this disced fireguard.

annual evaporation is 1370 mm (U.S. Department of Commerce 1973).

CHAPTER III

METHODS AND MATERIALS

Plot Arrangement

Five replications each containing eight plots were marked on the study area in the fall of 1972. Individual plots measured 12 m by 24 m each, the maximum size obtainable on this study area. Each plot was bordered on all sides by a fireguard 2 to 3 m wide. Surface rock was more abundant on the east half of the study area; therefore, replications were oriented east and west across the slope.

Existing Plant Community

Nine plots were selected by use of a random number table (Snedecor and Cochran 1967) to test the uniformity of the existing vegetative community. Composition of the vegetative community was analyzed with 50 point-centered-quarter strikes (Dix 1961) in each of the nine test plots. Field data were collected from 11 through 27 November 1972. Big bluestem was the dominant species, averaging 160 stems/m^2 (SE = ± 12). Little bluestem was the second most numerous species; it averaged 55 stems/m^2 (SE - ± 7). The combined stems/m^2 of big bluestem and little bluestem were less variable than were their separate densities ($\bar{x}$ = 215 stems/m^2; SE = ± 11), indicating that some shifting of importance value occurred between the two dominants. The total density of all plants averaged 432 stems/m^2 (SE = ± 30).

Soil Fertility

Soil samples from the nine plots and from five additional plots, selected by using a random-number table, were collected. Ten cores from the upper 15 cm of soil were taken from each plot and analysed by the Soil Testing Laboratory at Oklahoma State University. Soil pH averaged 6.3. Mean weights of the available nutrients were 6.4 kg of phosphorus/ha, 270 kg of potassium/ha, 4340 kg of calcium/ha and less than 11.4 kg of nitrogen/ha.

Experimental Design

The pretreatment tests described previously indicated that some variability occurred between the plots. It was felt, however, that five replications in a randomized block design would give adequate degrees of freedom for detecting biologically significant responses caused by the experimental treatments.

Experimental treatments for two seasons of the year (early spring and late spring) and for four treatments per season (control, discing, burning, and burning/discing) were assigned to the eight plots in each of the five blocks by using a table of random numbers. Each of the forty plots was then randomly divided for fertilization (control, phosphorus, and nitrogen/phosphorus) (Table 1).

Plot Protection

Fireguards around the study area and between the plots were mowed leaving a stubble height of 15 cm. Attempts to plow the fireguards with a moldboard-type plow proved unsuccessful because the plow caught on large rocks. A disc-type plow was not available, so large rocks were placed on a 2.44-m tandom disc to accomplish the discing work.

Humphrey (1962:124) stated that rodents can significantly damage plants. Protecting these plots from rodents by use of an electric fence (Prequegnat and Thompson 1949) was not deemed economically feasible. The use of poison bait was ruled out because of the area's status as a public hunting area. Therefore, snaptrapping to reduce rodent damage to the plots was begun on 23 May 1973. Trapping was performed once weekly for 24 weeks. Rat-type traps with enlarged pans were utilized. Trapping was terminated on 19 November 1973.

Other organisms also ate vegetation on the study area, but it was not feasible to try to control them. The most evident uses of vegetation on the study area were those of white-tailed deer (Odocoileus virginianus), which almost totally consumed developing flowers on ashy sunflowers

Table 1. Arrangement of treatments in the study area.

Replication	Plot Number							
No.	1	2	3	4	5	6	7	8
1	LS-BD c p n	ES-BD p n c	ES-BR n c p	LS-DS p c n	ES-TC c p n	LS-TC n p c	ES-DS c n p	LS-BR c p n
2	LS-BR p n c	LS-DS n c p	LS-TC c n p	ES-TC n p c	LS-BD c n p	ES-DS n c p	ES-BD n p c	ES-BR p c n
3	ES-BR n p c	ES-BD p n c	LS-BR n c p	LS-TC n p c	ES-TC n c p	LS-DS n c p	LS-BD n c p	ES-DS c n p
4	LS-DS n p c	ES-BR p c n	ES-BD n p c	ES-DS p c n	LS-BR n c p	LS-TC n c p	LS-BD p n c	ES-TC c n p
5	LS-DS p c n	LS-BD p n c	ES-BR n p c	LS-TC p n c	ES-DS c p n	ES-BD c p n	LS-BR n c p	ES-TC n c p

ES = early-spring season
LS = late-spring season

TC = treatment control
DS = disc treatment
BR = burn treatment
BD = burn/disc treatment

c = control for fertilization
p = phosphorous fertilization
n = nitrogen/phosphorus fertilization

(Helianthus mollis), and insects that damaged forbs.

Habitat Manipulations

Early-spring treatments were initiated by burning ten plots on 16 March 1973. Plots were backfired when the wind was from the northwest at 24 km/h, with gusts to 40 km/h. Rain began falling 20 min after the last plot was burned, so discing was delayed.

Early-spring plots were fertilized on 21 March 1973 by using a hand-operated broadcaster set to deliver 50.5 kg of N/ha and 56 kg of P/ha. The accuracy of the broadcaster's settings was determined by measuring the area covered by a known weight of each fertilizer nutrient. Lanes were marked 2.44 m apart, extending across the subplots, to help insure uniform distribution of the fertilizer. Twenty subplots were fertilized first with 50.5 kg of N/ha then with 56 kg of P/ha. Twenty other subplots were fertilized only with 56 kg of P/ha.

Discing to complete the early-spring treatments was delayed by rainfall and/or wet soil conditions until 5 April 1973. At that time the five unburned plots and five burned plots scheduled for early-spring discing were treated. Even with the additional weight on the disc penetration of the heavy sod was shallow, so the plots were disced twice. First they were disced north and south then east and west.

Late-spring burning was conducted on 30 April 1973.

Late-spring discing was conducted on 5 May 1973. Late-spring fertilizing was completed on 11 May 1973. Methods and amounts of fertilizing were identical to those used in the early-spring applications.

Plant and Seed Identification

Unknown plants were collected and identified near the study area during the summer and fall of 1973. Collected plants were placed in the Oklahoma State University Herbarium.

The primary reference for identifying plant species was Waterfall (1969). Copple and Aldous (1932) and Harrington and Durrell (1944) were used to identify grasses in vegetative condition. Other sources (Fernald 1950, Gates 1941, Hitchcock 1935, Leithead et al. 1971, Steyermark 1963) were used to confirm identification. Common plant names in this report follow Featherly (1946) for the Gramineae and Wolff (1948) for all other species. Correll and Johnston (1970) is the authority for the scientific plant names. Cattle grazing is the primary use of tallgrass prairie, therefore grasses providing economic amounts of livestock forage were assigned to a category entitled desirable grasses (Table 2). Weaver and Fitzpatrick (1932) and Leithead et al. (1971) were the authorities used in assigning grass species to the desirable-grasses category. Other grasses and rushes were placed in a category entitled less-desirable grasses

Table 2. Plants assigned to desirable grasses and less-desirable grasses.

Desirable grasses	Less-desirable grasses
big bluestem (_Andropogon Gerardi_)	common witchgrass (_Panicum capillare_)
little bluestem (_Schizachyrium scoparium_)	Scribner panicum [1/] (_Panicum oligosanthes_)
switchgrass (_Panicum virgatum_)	yellow foxtail [1/] (_Setaria glauca_)
indiangrass (_Sorghastrum avenaceum_)	poverty rush (_Juncus tenuis_)
tall dropseed [1/] (_Sporobolus asper_)	buffalograss (_Buchloe dactyloides_)
prairie dropseed [1/] (_Sporobolus heterolepis_)	fall panicum [1/] (_Panicum dichotomiflorum_)
sideoats grama (_Bouteloua curtipendula_)	windmillgrass (_Chloris verticillata_)
blue grama (_Bouteloua gracilis_)	crabgrass (_Digitaria sanguinalis_)
purpletop (_Tridens flavus_)	

[1/] Plants whose seed are utilized by quail for food.

(Table 2).

The plant family Leguminosae contains many quail-food producing species (Lee 1948), therefore both shrubby species and herbaceous species of this family were assigned to a category entitled legumes (Table 3). Remaining forbs were categorized as other forbs (Table 3). Lee (1948) and Baumgartner *et al*. (1948) were the authorities used to indicate plant species whose seeds are utilized by quail for food.

As seeds became ripe they were collected from plants near the study area and placed in the Oklahoma Cooperative Wildlife Research Unit's reference collection. Delovit (1970), Martin and Barkley (1961), and Musil (1963) were used to identify seed species.

Vegetative Species Sampling

Point-centered-quarter samples (Dix 1961) were taken in September and October of 1973 and in October of 1974. To avoid edge effect between subplots or between subplots and fireguards, only the central portion of the subplots were sampled. Five randomly located sampling points were used in each of the 120 subplots. The distance (to the nearest centimeter) from the point to the nearest plant and the species of the plant were recorded for each of the four quarters around each sampling point. Plant species encountered on the study area are listed in Table 28.

Table 3. Plants assigned to legumes and other forbs.

Legumes	Other forbs
leadplant (*Amorpha canescens*)	western ragweed 1/ (*Ambrosia psilostachya*)
slender lespedeza 1/ (*Lespedeza virginica*)	Missouri goldenrod (*Solidago missouriensis*)
wild-alfalfa 1/ (*Psoralea tenuiflora*)	common eveningprimrose (*Oenothera biennis*)
catclaw sensitivebrier 1/ (*Schrankia uncinata*)	heath aster (*Aster ericoides*)
slickseed wildbean (*Strophostyles leiosperma*)	azure sage (*Salvia azurea*)
roundhead lespedeza 1/ (*Lespedeza capitata*)	floweringspurge 1/ (*Euphorbia corollata*)
showy partridgepea 1/ (*Cassia fasciculata*)	blacksamson (*Echinacea angustifolia*)
plains wildindigo (*Baptisia leucophaea*)	bushy knotweed 1/ (*Polygonum ramosissimum*)
purple prairieclover (*Petalostemum purpureum*)	fourteen other species 2/

1/ Plants whose seed are utilized by quail for food.

2/ Names are given in the Appendix.

Herbage and Seed Sampling

After testing various sampling techniques, I found the largest sampling area of soil (to 1.5 cm depth) and seeds that could be collected with any degree of uniformity was a rectangle 16.7 cm by 25 cm in size (1/24 m^2). Because of the rocky soil, heavy ground litter, and extensive root material, cylinders driven into the soil (Ripley and Perkins 1965) would not lift an even core. Because of the uneven soil surface, larger circular samples (Sackett 1971) lacked uniformity.

The sampling device used was constructed of angle iron 7.6 cm wide. The angle iron was welded into a rectangle of 16.7 cm by 25 cm interior size with one long side left open. The open side was closed by a removable piece of angle iron after the open portion of the device was positioned in the vegetation and driven to a depth of 4 cm. The lower edges of the vertical angles of iron on each side the device were beveled toward the interior to aid in penetrating the soil and roots. The horizontal angle of the iron on each side was directed outward to deflect vegetation not contained within the sample. A forged-steel garden hoe head was driven from the open to the closed side of the sampling device at a depth of 1.5 cm to sever the soil and seed portion of the sample.

The procedure used in collecting the herbage and seed samples was: a random point was located, the sampling device was positioned with the center of the closed long side on the random point and hammered down; within the sampling frame, herbage was cut off at ground level with pruning shears and sacked, ground litter was collected and sacked, after lifting the movable side of the device seeds on the soil surface were brushed into a small dust pan with a whisk broom and sacked, and the soil portion to 1.5 cm deep was severed and sacked. Samples were collected between 5 and 19 November 1973. Herbage and seed sampling was not conducted during 1974.

Herbage Separation

To obtain uniform weights of dry plant materials, the sample sacks were held in an oven at 102 C for 2 h before sorting. Ground litter was weighed to the nearest 0.1 g. Herbage was sorted into four groups (desirable grasses, less-desirable grasses, legumes, and other forbs) and weighed to the nearest 0.1 g.

Seed Separation

Separation of seeds and soil-plant material from soil samples was the most difficult and time-consuming portion of the separation process. Normal sieving was not possible because the soil was either moist enough to plug the screens or dry enough to form clods around the plant roots and would not break down even after 2 h of mechanical shaking. Roots, stems, and seeds were separated from the soil by washing the material over a 1-mm mesh screen with a garden hose. This was similar to the method employed by Weaver (1968:64) in his investigations of plant material in soil. Because common witchgrass (Panicum capillare) seed passed through 1-mm mesh, a smaller size (0.5-mm) was tried; but it plugged with silt grains. Rubber gloves were worn to aid separation of seeds because seed materials could be removed from the gloves much easier than from a naked hand. The separated seeds and soil plant material were held at 102 C until dry.

Seeds from soil-plant material, herbage, ground litter, and surface material were separated by manual sieving and then sorting under a magnifying glass. All materials under 1 mm in size were discarded.

Only seven species of quail-food-producing plants provided sufficient weight of seeds to enable analysis of each species. The species for which data were kept for individual analysis were bushy knotweed, slickseed wild-bean, slender lespedeza, prairie dropseed, western ragweed, catclaw sensitivebrier, and Scribner panicum. The remaining seeds were grouped into a single category entitled: "miscellaneous seeds." The majority of the miscellaneous-seeds category was composed of seed from the dominant grasses (big bluestem, little bluestem, switchgrass, and indiangrass). The number of seeds and the total seed weight for each of the seven plant species and the weight of the miscellaneous-seed category were recorded for each subplot.

Data Analysis

Seed weights were analysed as in-soil seeds, available seeds (obtained by combining the on-plant seeds and the on-soil seeds), and total seeds. The mean weight per seed of the seven species analyzed was calculated from the available-seeds data and analysed.

Species density per unit area was expressed as number of stems per square meter (derived from the point-centered-quarter data). Big bluestem, little bluestem, switchgrass, common witchgrass, Scribner panicum, catclaw sensitivebrier, prairie dropseed, bushy knotweed, slender lespedeza, western ragweed, and slickseed wildbean were analysed individually. The remaining plant species were grouped for analysis into categories entitled: miscellaneous grasses, miscellaneous legumes, and miscellaneous forbs. Samples taken in October of 1974 were recorded in these categories in the field.

Completed data were keypunched onto data cards and computer programs were devised and keypunched. All data were analyzed using the Oklahoma State University Computer Center's IBM 360/65 computer and the SAS 2 software system (Barr and Goodnight 1972). Means were differentiated by Least-Significant-Difference (LSD) multiple-range tests when significant F values were found.

CHAPTER IV

RESULTS AND DISCUSSION

Study Area Variability

Initial computer analysis showed a pronounced difference between replications for many variables (Table 4). The first three replications often had similar means and the last two replications had means more similar to each other than to the other replications. Testing the first three replications against each other for some of the variables removed this difference between replications.

An initial survey of soil characteristics in 1972 showed that soil pH was the most variable characteristic, and pH appeared to increase downslope. The simple correlation coefficient between soil pH and total shoots per square meter equaled 0.61 ($P < 0.05$) and between soil pH and combined shoots per square of big bluestem and little bluestem equaled 0.76 ($P < 0.05$) and between soil pH and combined shoots per square of big bluestem and little bluestem equaled 0.76 ($P < 0.01$).

To test the hypothesis that soil pH was involved in the replication effect, soil tests were conducted on samples taken from all 120 subplots in the fall of 1974

Table 4. Comparison of fall species densities, herbage weights, and seed weights differing significantly between two or more replications, 1973 and 1974.

	Replication				
Types of vegetation	1	2	3	4	5
Densities (stems/m^2) in 1973					
Big bluestem	74a[1]	72a	76ab	93bc	104c
Little bluestem	32a	27a	33ab	50c	43bc
Desirable grasses	126a	121a	128a	156b	163b
Scribner panicum	30b	25b	11a	9a	6a
Less-desirable grasses	54c	43bc	23a	35ab	22a
Western ragweed	12bc	17c	10b	3a	4a
Densities (stem/m^2) in 1974					
Big bluestem	105a	110a	106a	134a	178b
Desirable grasses	107a	172a	167a	228b	255b
Scribner panicum	29c	21bc	14b	12ab	4a
Herbage production (g/m^2) in 1973					
Desirable grasses	330a	330a	440b	490b	500b
Less-desirable grasses	33b	30b	10a	15a	7a
Other forbs	55b	60b	25a	30a	30a
In-soil seed weight (cg/m^2) in 1973					
Western ragweed	44b	73c	30ab	10a	18a
Slickseed wildbean	6b	0a	2ab	7bc	12c
Available-seed weight (cg/m^2) in 1973					
Western ragweed	18b	19b	5a	3a	4a
Mean weight (mg) per seed in 1973					
Western ragweed	2.7d	2.1bc	1.8ab	2.2c	1.7a

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[1] Individual variable means followed by the same letter are not significantly different ($P < 0.05$).

(Table 5). Replications were significantly different ($P < 0.01$) and pH did increase downslope. Grouping the upper-slope replications (1, 2, and 3) together produced a mean pH value of 5.7. Grouping the lower two replications together produced a mean pH value of 6.2. The means of these two groups of replications were significantly different ($P < 0.05$). Since the change in replication results occurs at the change in study area slope, results from the upper replications (1, 2, and 3) will hereafter be referred to as upper-slope position results and results from the lower replications (4 and 5) will hereafter be referred to as lower-slope position results.

Data analysis revealed increases by desirable grasses on the lower-slope position (Table 6). Desirable-grass herbage production is the most important effect of slope-position. Overall slope-position effects are produced by the season x disturbance x fertilization interaction, therefore control (untreated) effects are included for comparison. Control effects also indicated larger production of desirable-grass herbage on the lower-slope position.

The above results indicate that a slope-position effect exists on the study area. Since the lower two replications were the only replications that had mean pH levels exceeding 6.0, the data suggest that soil pH was the factor causing increased herbage production of desirable grasses. However, there are several reasons why this assumption cannot be accepted. Funds to completely check

Table 5. Results of soil pH tests, 1974.

Prameters	Mean pH	Standard error
Replication 1	5.7a[1]	± 0.025
Replication 2	5.7a	± 0.022
Replication 3	5.8b	± 0.020
Replication 4	6.1c	± 0.047
Replication 5	6.3d	± 0.066
Slope Position		
Upper (Replications 1, 2, and 3)	5.7ab	± 0.016
Lower (Replications 4 and 5)	6.2cd	± 0.047

[1] Means followed by the same letter are not significantly different ($P < 0.05$).

Table 6. Comparison of fall species densities and herbage weights on overall (experimental plus control) replicates and control only plots according to slope position.

	Entire replicates			Controls only		
	Slope position			Slope position		
Types of vegetation	Upper	Lower	Average	Upper	Lower	Average
Densities (stem/m^2) in 1973						
Big bluestem	74a[1]	98b	84ab	49a	113b	75a
Little bluestem	31a	46b	37ab	31a	31a	31a
Prairie dropseed	3b	ta[2]	2ab	8b	0a	5b
Desirable grasses	125a	159b	139ab	100a	160b	124a
Less-desirable grasses	40b	29a	36ab	34b	20a	28ab
Western ragweed	13b	3a	9b	14c	0a	8b
Densities (stem/m^2) in 1974						
Big bluestem	107a	156b	127ab	92a	124b	150ab
Desirable grasses	170a	242b	199ab	140a	180a	156a
Miscellaneous grasses	55a	73b	62ab	52a	69b	59ab
Herbage production (g/m^2) in 1973						
Desirable grasses	366a	492b	416ab	394a	553b	458a
Less-desirable grasses	24b	11a	19ab	13b	1a	8ab
Total herbage	447a	540b	484ab	469a	574b	511ab

[1] Variable means within an outcome type followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 stem/m^2.

all soil factors were not available. The study-area soil is a complex, and the lower two blocks may possibly contain a higher proportion of Bates soil, which is naturally more productive (U.S. Department of Agriculture 1969) than Collinsville soil (U.S. Department of Agriculture 1973). The change of the study-area slope to near level on the lower two blocks might cause more moisture to be available there. If the moisture-retaining capacity of lower-slope-position soil is larger, vegetation production would increase. Since fireguard discing turned up less rock material on the lower replications, depth to bedrock may be greater. If depth to bedrock is greater, a greater volume of usable soil per unit area would be available for utilization by the deep-rooted desirable grasses. Therefore, soil pH may just be an indicator of some other factor in the study area that causes this increased herbage production of desirable grasses on sites where the soil pH level is above 6.0.

Effects of Treatments on Species Composition and Plant Density

Natural Conditions

Big bluestem was the dominant plant on the study area both in 1973 and in 1974 (Table 7). Little bluestem was the second most abundant species during both years. Both big and little bluestem increased in density during 1974.

Table 7. Fall species densities (stems/m^2) of plants in different slope positions, 1973 and 1974.

	1973			1974		
	Slope position			Slope position		
Species	Upper	Lower	Average	Upper	Lower	Average
Desirable grasses						
Big bluestem	49a[1]	113b	75a	92a	124b	105ab
Little bluestem	31	31	31	42	40	41
Switchgrass	11	16	13	6	16	10
Prairie dropseed	8b	0a	5b	0	0	0
Sub-total	100a	160b	124a	140	180	156
Less-desirable grasses						
Scribner panicum	26	13	20	28	27	27
Common witchgrass	2	0	1	0	0	0
Miscellaneous grasses	7	7	7	52	69	59
Sub-total	35b	20a	28ab	80	96	86
Legumes						
Catclaw sensitivebrier	0	0	0	0	0	0
Slender lespedeza	0	0	0	0	0	0
Slickseed wildbean	0	0	0	0	0	0
Miscellaneous legumes	4	2	3	5	0	3
Sub-total	4	2	3	5	0	3
Other forbs						
Western ragweed	14c	0a	8b	0	0	0
Bushy knotweed	2	0	1	0	0	0
Miscellaneous forbs	3	7	4	39	29	35
Sub-total	19	7	13	39	29	35
Total	157	189	168	264	305	280

[1] Means for a species within the same year followed by a common letter are not significantly different ($P < 0.05$).

However, their relative densities decreased during 1974 (Table 8).

Slope-position differences occurred in both the stem density and species-composition data. Big bluestem and desirable-grasses stem densities were enhanced in the lower-slope position. Stems/m^2 of big bluestem in the lower-slope position were significantly more numerous both in 1973 ($P < 0.10$) and in 1974 ($P < 0.05$). Stems/m^2 of desirable grasses were significantly ($P < 0.05$) more numerous in the lower-slope position in 1973.

The stem density of prairie dropseed was increased only in the upper-slope position ($P < 0.05$). This implies that prairie dropseed benefitted by reduced competition from the other desirable grasses on this site. Weaver (1950:261) found that prairie dropseed was a better competitor on drier upland sites. Therefore, part of its increase on the upper-slope position may be due to lesser availability of moisture.

Western ragweed and less-desirable grasses significantly increased ($P > 0.05$) in stem density on the upper-slope position indicating that they grew best on locations that favored desirable grasses least.

Disturbance

Big bluestem, desirable grasses, and total-stem density were the only species-density results in 1973 that were significantly different ($P < 0.10$) between disturbances

Table 8. Fall species composition (percent) on different slope positions, 1973 and 1974.

Species	1973			1974		
	Slope position			Slope position		
	Upper	Lower	Average	Upper	Lower	Average
Desirable grasses						
Big bluestem	32	60	45	35	41	37
Little bluestem	20	16	18	16	13	15
Switchgrass	7	9	8	2	5	4
Prairie dropseed	5	0	3	0	0	0
Sub-total	64	85	74	53	59	56
Less-desirable grasses						
Scribner panicum	17	7	12	10	9	10
Common witchgrass	1	0	t[1/]	0	0	0
Miscellaneous grasses	4	4	4	20	23	21
Sub-total	22	11	16	30	32	31
Legumes						
Catclaw sensitivebrier	0	0	0	0	0	0
Slender lespedeza	0	0	0	0	0	0
Slickseed wildbean	0	0	0	0	0	0
Miscellaneous legumes	2	1	2	2	0	1
Sub-total	2	1	2	2	0	1
Other forbs						
Western ragweed	9	0	5	0	0	0
Bushy knotweed	1	0	t	0	0	0
Miscellaneous forbs	2	3	2	15	9	12
Sub-total	12	3	8	15	9	12
Total	100	100	100	100	100	100

[1/] Less than 1%.

(Table 9). None of the 1974 species-density results were significantly different at the 10 percent level.

Big bluestem density was increased on the upper-slope position by early-spring burning, early-spring burning/discing, and late-spring discing. Increased stem density of big bluestem caused by burning occurred also in a study reported by McMurphy and Anderson (1965). Early-spring burning/discing treatments on the upper-slope position enhanced tillering response of big bluestem by removing ground litter and reducing competition from other species. Late-spring discing treatments on the upper-slope position increased big bluestem tillering. It is assumed that reducing standing-dead herbage by shallow late-spring discing, on the upper-slope position, increased availability of sunlight to emerging big bluestem tillers. Density of big bluestem was decreased on the lower-slope position by late-spring discing. The lower slope-position, in an untreated condition, possessed 150 g/m^2 more desirable-grass herbage than did the upper-slope position (Table 6). Big bluestem tillers were apparently decreased because compacting this additional herbage with existing ground-litter mulch, by shallow late-spring discing on the lower-slope position, reduced sunlight penetration.

Large accumulations of grass-material fuel at the time of burning have been noted to reduce ground cover and yield (Hopkins, _et_ _al_. 1948). Big bluestem normally begins vegetative growth, in Oklahoma, in late April (Ahshapanek 1962;

Table 9. Responses of big bluestem, desirable grasses, and total stem density to disturbance in fall, 1973.

Slope position	Habitat disturbance	Big bluestem		Desirable grasses		Total stem density/m^2
		Stems/m^2	Relative density (%)	Stems/m^2	Relative density (%)	
Upper slope	None (control)	49a[1]	32	100ab	65	155ab
	Early spring					
	Discing	55a	40	93ab	67	139a
	Burning	81b	38	138cd	64	215de
	Burning/discing	117cde	44	159de	60	266gh
	Late spring					
	Discing	139e	54	199f	78	255fg
	Burning	52a	29	110bc	61	179bc
	Burning/discing	36a	23	73a	46	158ab
Lower slope	None (control)	113cd	60	160de	85	188bcd
	Early spring					
	Discing	98bc	46	148d	70	211cde
	Burning	96bc	32	254g	86	297h
	Burning/discing	124de	55	158de	70	226ef
	Late spring					
	Discing	50a	36	70a	50	140a
	Burning	170cd	42	190ef	75	252fg
	Burning/discing	54a	29	108bc	58	186bcd

[1] Means for big bluestem, desirable grasses, and total stem density followed by the same letter are not significantly different ($P < 0.05$).

136). Late-spring burning of the increased fuel on the lower-slope position reduced relative density of big bluestem. Late-spring discing, conducted to complete the late-spring burning/discing treatment, further reduced tillering of big bluestem on the lower-slope position.

The largest increase in stem density of desirable grasses occurred on early-spring burning treatments conducted on the lower-slope position. Big bluestem was not increased by this treatment; however, the largest response of little bluestem (148 stems/m^2) occurred from this treatment. Ahshapanek (1962:136) noted that perennating sprouts of little bluestem were above soil level in late February and that seedlings were germinating in March. Therefore, little bluestem responded by increased tillering to the reduction in ground litter caused by early-spring burning. Remaining desirable-grasses treatment responses were parallel to response of big bluestem on the same treatment.

Increased total-stem densities for early-spring burning/discing and late-spring burning treatments conducted on the lower-slope position were caused by increased densities of less-desirable grasses, legumes, and other forbs, (Table 10). Density increases of less-desirable grasses and other forbs brought the total stem density of late-spring burning/discing treatments conducted on the lower-slope position up to the lower-slope-position control-density level. The remaining total stem-density results were parallel to desirable-grasses density results to the same treatments.

Table 10. Responses (density of stems/m^2) of plants, according to species groups, to early-spring burning/discing, late-spring burning, and late-spring burning/discing on lower-slope positions, fall 1973.

	Lower-slope position treatments			
Species groups	None (control)	Early-spring burning/discing	Late-spring burning	Late-spring burning/discing
Desirable grasses	160bc[1]	158b	190c	108a
Less-desirable grasses	19	34	28	48
Other forbs	7	28	20	26
Legumes	2	6	14	4
Total	188a	226b	252b	186a

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[1] Means within a species group followed by the same letter are not significantly different ($P < 0.05$).

The conclusion is that treatments conducted in early spring increased the species diversity of the plant community more than did late-spring treatments. This conclusion is similar to results obtained by McMurphy and Anderson (1965:268) in their 12 years of experimenting with burning. It should be noted that Aldous (1934) found that the most diverse plant communities occurred on plots burned in late fall. The increases in stems/m^2 of desirable grasses on burning disturbances caused the increased total stem density in this treatment. This result also resembles the results of McMurphy and Anderson (op. cit.).

Fertilization

Big bluestem, desirable-grasses, and total-stem density were the only 1973 species-density results that were significantly different ($P < 0.10$) for fertilization (Table 11). None of the 1974 species-density results reached the 10 percent level of significance.

Early-spring fertilizing with nitrogen/phosphorus conducted on the upper-slope position increased stem density and relative density of big bluestem. Since stem-density and relative density of desirable grasses were not affected by this fertilization, the increase of big bluestem caused a decrease in the remaining desirable-grass species. Gay (1964:31) found that big bluestem was the most efficient utilizer of nitrogen fertilizer among the grasses he studied.

Table 11. Responses of big bluestem, desirable grasses, and total stem density to fertilizing, fall 1973.

Slope position	Fertilization	Big bluestem Stems/m^2	Big bluestem Relative density (%)	Desirable grasses Stems/m^2	Desirable grasses Relative density (%)	Total stem density/m^2
Upper slope	None (control)	49ab[1]	32	100ab	64	155abc
	Early spring					
	Phosphorus	64bc	44	104abc	71	146ab
	Nitrogen/ phosphorus	83cd	51	111bc	68	164bc
	Late spring					
	Phosphorus	110e	51	145d	67	215d
	Nitrogen/ phosphorus	50ab	30	103abc	61	169bc
Lower slope	None (control)	113e	60	160d	85	188cd
	Early spring					
	Phosphorus	104de	63	144d	87	165bc
	Nitrogen/ phosphorus	60bc	37	108abc	67	161bc
	Late spring					
	Phosphorus	34a	28	78a	65	120a
	Nitrogen/ phosphorus	105de	60	133cd	76	174bc

[1] Mean stems/m^2 for big bluestem, desirable grasses, and total stem density followed by the same letter are not significantly different ($P < 0.05$).

Early-spring fertilizing with nitrogen/phosphorus on the lower-slope position decreased both species density and relative density of big bluestem and desirable grasses. Less-desirable grasses were also decreased by this fertilization, therefore all Gramineae tested were affected (Table 12). Increases of species density of legumes and other forbs indicate that they were favored by this fertilization. This increase in forbs is similar to the results of Graves (1968:28), who stated: "A future study of this type, using fire, fertilizer, and 2,4-D for the control of broadleaf weeds, deserves consideration."

It should be noted at this point that desirable-grasses stem density and total stem density are not strongly correlated to desirable-grass herbage production. The simple correlation coefficient between desirable-grass herbage production and desirable-grass stem density is 0.03 and between desirable-grass herbage production and total stem density is -0.09. These correlations are not significantly different at the 5 percent level; therefore, density data in this study cannot be used to indicate species-herbage production.

Late-spring fertilizing with phosphorus on the upper-slope position increased stem density and relative density of big bluestem. Stem density of desirable-grasses was also increased by this fertilization, however relative density of desirable grasses was increased only 3 percent. These results indicate that big bluestem increased in den-

Table 12. Responses (density of stems/m^2) of plants, according to species groups, to late-spring fertilizing with phosphorus on the upper-slope position, early-spring fertilizing with nitrogen/phosphorus on the lower-slope position, and late-spring fertilizing with phosphorus on the lower-slope position, fall 1973.

	Slope position and type of fertilization				
	Upper		Lower		
Species group	None (control)	Late-spring phosphorus	None (control)	Early-spring nitrogen/ phosphorus	Late-spring phosphorus
Desirable grasses	100a	145b	160b	108a	78a
Less-desirable grasses	33	24	19	8	28
Legumes	4	12	2	17	6
Other forbs	18	34	7	28	8
Total	155b	215c	188bc	161b	120a

1/ Means within a species group followed by the same letter are not significantly different ($P < 0.05$).

sity at the expense of other desirable grasses. Total stem density was also increased by late-spring application of phosphorus on the upper-slope position, indicating that other-species stem densities were increased. Legumes and other forbs were increased and less-desirable grasses were decreased (Table 12). This result resembles the findings of Speake (1966), who advocated using fertilizer without nitrogen to increase legumes.

Late-spring fertilizing with phosphorus on the lower-slope position decreased both relative density and stem density of big bluestem and the total stem density.

Experiments on fertilizing with phosphorus have produced contradictory results. Byran (1966) found no increase or decrease by phosphorus fertilization. Reardon and Huss (1965) reported increases of little bluestem by phosphorus fertilization. Powell and Box (1967) reported significant decreases caused by phosphorus fertilization. Late-spring-phosphorus fertilization in this study significantly ($P < 0.05$) increased stem density of both big bluestem and desirable grasses on the upper-slope position and significantly ($P < 0.05$) decreased stem density of both big bluestem and desirable grasses on the lower-slope position (Table 11).

Data on fertilizing with phosphorus from this study indicate that additional knowledge of site factors is needed to interpret phosphorus fertilization experiments.

Discing and Fertilizing

Early-spring discing and phosphorus fertilizing increased big bluestem and all species groups on the upper-slope position and decreased big bluestem and desirable grasses on the lower-slope position (Table 13). Late-spring discing and phosphorus fertilizing decreased stem density of desirable grasses and total stem density on the upper-slope position and increased big bluestem and desirable grasses on the lower-slope position.

Early-spring discing and nitrogen/phosphorus fertilizing increased big bluestem and stem density of all species groups on the upper-slope position and reduced big bluestem on the lower slope position. Late-spring discing and nitrogen/phosphorus fertilizing produced no significant differences on the upper slope-position and reduced big bluestem, desirable grasses, and total stem density on the lower-slope position.

Differences caused by slope position in results of discing and fertilizing preclude selecting any single discing treatment for quail management. The three most promising discing treatments, for quail management, would be early-spring discing and phosphorus fertilizing, early-spring discing and nitrogen/phosphorus fertilizing, and late-spring discing without fertilizing on the lower-slope position. The primary reason for these selections was increased densities of legumes and other forbs.

Table 13. Changes in densities of big bluestem and various groups of species in response to discing and fertilizing, fall 1973.

				Big bluestem		Desirable grasses		L-d-g	Legumes	Other forbs	Total
S-P	T	S	F	s/m^2	Rd (%)	s/m^2	Rd (%)	s/m^2	s/m^2	s/m^2	stems/m^2
U-s-p	C	M	0	49ab[1/]	32	100bc	64	33	4	18	155bc
	D	ES	0	55ab	40	93ab	67	12	8	26	139ab
			P	80cd	29	186fgh	67	48	8	37	279g
			N	87cd	34	146de	56	52	40	21	259fg
		LS	0	139f	55	199gh	78	37	4	15	255fg
			P	55ab	45	67a	55	24	10	21	122a
			N	68abc	42	82ab	51	48	5	26	161bc
L-s-p	C	M	0	113e	60	160ef	85	19	2	7	188cd
	D	ES	0	98e	46	148de	70	56	0	7	211de
			P	47a	20	129cd	56	89	0	16	234ef
			N	72bc	32	161ef	71	28	0	38	227ef
		LS	0	50ab	36	70a	50	21	10	39	140ab
			P	161f	65	214h	87	21	7	5	247fg
			N	87cd	48	128cd	70	28	4	22	182cd

L-d-g = Less-desirable grasses
S-p = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
T = Treatment
C = None (Control)
D = Discing
S = Season
M = Slope-position mean
ES = Early spring
LS = Late spring
F = Fertilization
0 = None
P = Phosphorus
N = Nitrogen phosphorus
s = stems
Rd = Relative density

[1/] Mean stems/m^2 for big bluestem, desirable grasses, and total stem density followed by the same letter are not significantly different ($P < 0.05$).

Burning and Fertilizing

Early-spring burning and phosphorus fertilizing increased total-stem density on the upper-slope position, increased big bluestem, desirable grasses, and total stem density on the lower-slope position, and increased the relative density of legumes on both slope positions (Table 14). Early-spring burning and nitrogen/phosphorus fertilizing increased big bluestem, desirable grasses, and total stem density on both slope positions and the relative density of legumes on the lower-slope position.

Results of late-spring burning and phosphorus fertilizing increased the relative density of legumes on the upper slope position and increased big bluestem, desirable grasses, and total-stem density on the lower-slope position. Late-spring burning and nitrogen/phosphorus fertilizing increased big bluestem, desirable grasses, and total-stem density on both slope positions; less-desirable grasses and other forbs, however, were greatly reduced on the lower-slope position.

The most promising of the burning and fertilizing treatments for quail management is early-spring burning with phosphorus fertilizing, since stem density of other forbs and relative density of legumes increased on both slope positions. Hines (1967) found that February burns increased partridgepea (Cassia) in Louisiana. Hutchinson (1969) found forbs to be stimulated by early spring burns.

Table 14. Changes in densities of big bluestem and various groups of species in response to burning and fertilizing, fall 1973.

				Big bluestem		Desirable grasses		L-d-g	Legumes		Other forbs	Total
S-P	T	S	F	s/m^2	Rd (%)	s/m^2	Rd (%)	s/m^2	s/m^2	Rd (%)	s/m^2	$stems/m^2$
U-s-p	C	M	0	49ab[1]	32	100ab	64	33	4	2.3a	18	155ab
	B	ES	0	81cd	38	138cd	64	29	16	7.7f	32	215de
			P	61bc	31	119bc	60	34	9	4.6cde	35	197cd
			N	119e	34	234gh	68	91	3	.9a	20	348h
		LS	0	52ab	29	110abc	61	38	8	4.7cde	23	179bc
			P	31a	24	84a	65	20	7	5.5def	19	130a
			N	105de	48	152d	69	41	4	1.9a	23	220def
L-s-p	C	M	0	113e	60	160de	85	19	2	.9a	7	188bcd
	B	ES	0	96de	32	254hi	86	19	15	5.0de	9	297g
			P	176f	54	238gh	74	19	20	6.2ef	47	324gh
			N	158f	41	281i	73	37	19	5.2def	48	385i
		LS	0	107e	42	190ef	75	28	13	5.0de	21	252f
			P	163f	67	196f	81	0	0	0.0a	46	242ef
			N	159f	63	221fg	94	7	8	3.5bcd	0	236ef

L-d-g = Less-desirable grasses
S-P = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
T = Treatment
C = None (Control)

B = Burning
S = Season
M = Slope-position mean
ES = Early spring
LS = Late spring
F = Fertilization

0 = None
P = Phosphorus
N = Nitrogen/phosphorus
s = stems
Rd = Relative density

[1] Means for big bluestem (s/m^2), desirable grasses, (s/m^2), legumes (Rd), and total stem density followed by the same letter are not significantly different ($P < 0.05$).

Burning/Discing and Fertilizing

Early-spring burning/discing and phosphorus fertilizing increased big bluestem, desirable grasses, and total stem density on the upper-slope position and increased desirable grasses and total-stem density on the lower-slope position (Table 15). Early-spring burning/discing and nitrogen/phosphorus fertilizing increased big bluestem, desirable grasses, and total-stem density on the upper-slope position and decreased big bluestem and desirable grasses on the lower-slope position.

Late-spring burning/discing and phosphorus fertilizing decreased big bluestem and total-stem density on the lower-slope position. Late-spring burning/discing and nitrogen/phosphorus fertilizing reduced big bluestem and desirable grasses and increased total-stem density on the lower-slope position. Common witchgrass stem density was increased by late-spring burning/discing without fertilizer (27 stems/m^2) and late-spring burning/discing with nitrogen/phosphorus fertilizer (55 stems/m^2).

The best burning/discing and fertilizing treatment for quail management would be early-spring burning/discing without fertilizing. The primary reason for this selection is the improved response of legumes and other forbs to this treatment. Late-spring burning/discing treatments did produce a lower stem density that would enhance utilization by quail, however the reduction in desirable-grasses would

Table 15. Changes in densities of big bluestem and various groups of species in response to burning/discing and fertilizing, fall 1973.

				Big bluestem		Desirable grasses		L-d-g	Legumes	Other forbs	Total
S-P	T	S	F	s/m^2	Rd (%)	s/m^2	Rd (%)	s/m^2	s/m^2	s/m^2	stems/m^2
U-s-p	C	M	0	49abc	32	100abcd	64	33	4	18	155ab
	BD	ES	0	117g	44	159fg	60	38	19	50	266de
			P	86de	36	138ef	57	28	17	59	242ef
			N	92def	27	176gh	52	98	17	45	336g
		LS	0	36a	23	73a	46	55	9	21	158ab
			P	71bcd	40	98abc	55	51	10	20	179abc
			N	47ab	31	80ab	53	37	10	23	150a
L-s-p	C	M	0	113fg	60	160fg	85	19	2	7	188bc
	BD	ES	0	124g	55	158fg	70	34	6	28	226de
			P	108efg	48	201h	90	11	5	6	223de
			N	53abc	27	96abc	50	58	5	34	193cd
		LS	0	54abc	29	108bcde	58	48	4	26	186bc
			P	73cd	48	131def	86	20	0	1	152a
			N	44a	19	118cde	52	71	19	19	227e

L-d-g = Less-desirable grasses
S-p = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
T = Treatment
C = None (Control)

BD = Burning/discing
S = Season
M = Slope-position mean
ES = Early spring
LS = Late spring
F = Fertilization

0 = None
P = Phosphorus
N = Nitrogen/phosphorus
s = Stems
Rd = Relative density

1/ Mean stems/m^2 for big bluestem, desirable grasses, or total stem density followed by the same letter are not significantly different ($P < 0.05$).

reduce the treated area's ability to support economic uses (livestock grazing).

Effects of Treatments on Herbage Production

Natural Conditions

Herbage production was affected by slope position (Table 16). Desirable-grass herbage and total herbage were significantly larger ($P < 0.05$) on the lower-slope position. Less-desirable-grass herbage and other-forb herbage were significantly smaller ($P < 0.05$) on the lower-slope position. Legume and other-forb herbage are underestimated, since most of their leaves had fallen by the November sampling date.

Disturbances

Desirable-grass herbage, total herbage, and ground-litter accumulation were significantly different ($P < 0.10$) between disturbances (Table 17).

Accumulation of ground litter was reduced only by the burning and the burning/discing treatments. Stoddard (1931:406) observed that quail would not utilize any habitat that was not open enough at ground level for them to run through. The amount of ground litter present on the control and discing plots during 1973 would prevent quail from utilizing these areas.

Table 16. Natural yields in kg/ha of desirable-grass herbage, less-desirable-grass herbage, legume herbage, other-forb herbage, total herbage, and ground-litter accumulation in 1973 on the upper-slope and lower-slope positions.

	Slope position		
Type of plant material	Upper	Lower	Average
Desirable-grass herbage	3940a[1]	5530b	4580a
Less-desirable-grass herbage	130b	ta	80a
Legume herbage	30a	5a[2]	20a
Other-forb herbage	580b	210a	430b
Total herbage	4680a	5745b	5110ab
Ground-litter accumulation	2730a	2700a	2720a

[1] Means of plant-material types followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 kg/ha.

Table 17. Changes in production of herbage and accumulation of ground litter (kg/ha) in response to disturbance, fall 1973.

S-P	Season	Treatment	Herbage groups: Desirable grasses	L-d-g	Legumes	Other forbs	Total herbage	Ground-litter accumulation
U-s-p	None	Control	3940ef[1]	130	30	580	4680de	2730d
	ES	Discing	2780bcd	80	0	230	3090a	2480d
		Burning	4760fg	40	210	180	5190ef	760b
		Burning/ discing	2540abc	70	180	380	3170ab	390a
	LS	Discing	3450de	460	0	390	4300cd	2630d
		Burning	3240cde	90	80	440	3850bc	490a
		Burning/ discing	3460de	500	0	160	4120cd	360a
L-s-p	None	Control	5530g	t[2]	5	210	5745fg	2700d
	ES	Discing	5610gh	70	0	370	6050gh	2670d
		Burning	2010ab	220	550	140	2920a	640ab
		Burning/ discing	4870fg	70	310	260	5510fg	640ab
	LS	Discing	1890a	320	50	430	2690a	2160c
		Burning	6670h	30	0	0	6700h	820b
		Burning/ discing	4060ef	210	80	190	4540cde	470a

S-P = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
ES = Early spring
LS = Late spring
L-d-g = Less-desirable grasses

[1] Means of plant-material types followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 kg/ha.

The amount of ground litter occurring on the plots during 1974 was not weighed. However, its accumulation on the burning and burning/discing plots was sufficient to make doubtful utilization of these plots by quail.

Desirable-grass herbage and total herbage were increased by late-spring burning conducted on the lower-slope position. Late spring is the most productive time for rangeland burning, however burning by itself is not expected to increase herbage production (McMurphy and Anderson 1965:268). Weaver and Rowland (1952:19) found that the herbage yield of big bluestem increased by 26 to 53 percent when the ground-litter accumulation was removed. Ground-litter accumulation on the study area was heavy; therefore, its removal could account for this increased production.

Desirable-grass herbage production on the upper-slope position was reduced by early-spring discing and early-spring burning/discing. Desirable-grass herbage production on the lower-slope position was reduced by early-spring burning, late-spring discing, and late-spring burning/discing.

Outcomes of total herbage production are nearly parallel to the results discussed for production of herbage in desirable-grasses. Since 86 percent of the total herbage production was composed of desirable-grass herbage, these near-parallel results are to be expected. Therefore, it follows that the total herbage production was controlled by the growth responses of the desirable-grasses.

Fertilization

Desirable-grass herbage production on the lower-slope position was increased by early-spring nitrogen/phosphorus fertilizing and also by late-spring nitrogen/phosphorus fertilizing (Table 18). Production of the largest yield of desirable-grass herbage by nitrogen/phosphorus fertilizing treatments is an expected result. Big bluestem was the dominant plant on the study area. Gay (1964:31) found that big bluestem was the most efficient utilizer of nitrogen fertilizer among grasses he studied. Therefore, most of this increase in production of desirable-grass herbage caused by nitrogen/phosphorus fertilizing can be assigned to big bluestem's response to the nitrogen fertilizer.

Phosphorus fertilizing conducted in late-spring reduced desirable-grass herbage on the lower-slope position. The reduction in desirable herbage caused by late-spring phosphorus fertilizing on the lower-slope position indicate that either the rate of vegetative growth was reduced or that the desirable grasses reached maturity before the end of the growing season. Since seed production was not significantly affected by fertilization it can be assumed that desirable grasses reached maturity. Reardon and Huss (1965) found that production of little bluestem herbage was increased by 90 kg of phosphorus/ha and was neither increased nor decreased by 45 kg of phosphorus/ha. Powell

Table 18. Changes in production of herbage and accumulation of ground litter (kg/ha) in response to fertilizing, fall 1973.

			Herbage groups					
S-P	Season	Fertilization	Desirable grasses	L-d-g	Legumes	Other forbs	Total herbage	Ground-litter accumulation
U-s-p	None	Control	3940ab[1]	130	30	580	4680b	2630
	ES	Phosphorus	3960ab	140	0	530	4630b	3180
		Nitrogen/ phosphorus	4640b	90	0	320	5050b	4030
	LS	Phosphorus	4150ab	30	20	720	4920b	2300
		Nitrogen/ phosphorus	4080ab	300	0	690	5070b	2590
L-s-p	None	Control	5530c	t[2]	5	210	5745cd	2700
	ES	Phosphorus	6100c	10	0	50	6160d	2600
		Nitrogen/ phosphorus	10210d	10	360	310	10890e	2300
	LS	Phosphorus	3520a	100	0	70	3690a	3610
		Nitrogen/ phosphorus	9960d	0	0	150	10110e	2770

S-P = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
ES = Early Spring
LS = Late Spring
L-d-g = Less-desirable grasses

[1] Desirable-grass means and total herbage means followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 kg/ha.

and Box (1967:235) noted a reduction in grass production caused by phosphorus fertilization. Big bluestem was the dominant plant species on the study area and it was the major contributor to desirable-grass herbage. Therefore, its growth must have been depressed by the 56 kg of phosphorus/ha utilized in this study. Onken (1936:47) found that, "Superphosphate added to a moist soil produces a large decrease in pH with subsequent solution of iron, aluminum and calcium compounds. After a period of time the soil buffering system brings the pH back to its original level." Since the soil was moist when fertilizer was applied, the reduction in soil pH described above probably took place. Therefore, the reduction in desirable-grass herbage could have been caused by a slowing of growth during a period of reduced availability of nutrients. This supposition gains some support from big bluestem's reduced stem density by late-spring phosphorus fertilizing in the lower-slope position (Table 11). However, since this result was not produced by late-spring phosphorus fertilizing on the upper-slope position, it might be attributed to variability in the study area.

Disturbance and Fertilization

Both phosphorus fertilizing and nitrogen/phosphorus fertilizing applied to early-spring discing plots reduced desirable-grass herbage on the lower-slope position (Table 19). Other forbs increased on these plots, therefore desir-

Table 19. Changes in production of herbage (kg/ha) in response to discing and fertilizing, fall 1973.

				Herbage groups				
S-P	Treatment	Season	Fertilization	Desirable grasses	L-d-g	Legumes	Other forbs	Total herbage
U-s-p	Control	None	None	3940e	130	30	580	4680
	Discing	ES	None	2780cd	80	0	230	3090
			Phosphorus	2210bc	320	410	680	3620
			Nitrogen/ phosphorus	2790cd	300	220	760	4070
		LS	None	3450de	460	0	390	4300
			Phosphorus	4360e	90	20	270	4740
			Nitrogen/ phosphorus	4260e	400	0	450	5110
L-s-p	Control	None	None	5530f	t[2]	5	210	5745
	Discing	ES	None	5610f	70	0	370	6050
			Phosphorus	3740e	40	0	550	4330
			Nitrogen/ phosphorus	1700a	360	80	1270	3410
		LS	None	1890b	320	50	430	2690
			Phosphorus	2070bc	100	50	350	2570
			Nitrogen/ phosphorus	2350bc	40	0	220	2610

S-P = Slope position
ES = Early spring
U-s-p = Upper-slope position
LS = Late spring
L-s-p = Lower-slope position
L-d-g = Less-desirable grasses

[1] Means followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 kg/ha.

able-grass herbage probably decreased because of increased competition.

Nitrogen/phosphorus fertilizing of late-spring burning plots increased desirable-grass herbage production on both the upper-slope position and the lower-slope position (Table 20). Nitrogen/phosphorus fertilizing of early spring burning plots increased desirable-grass herbage on the lower-slope position and decreased desirable-grass herbage on the upper-slope position. Phosphorus fertilizing of late-spring burning plots decreased desirable-grass herbage production on the lower-slope position. Phosphorus fertilizing of early-spring burning plots increased desirable-grass herbage on the lower-slope position and decreased desirable-grass herbage on the upper-slope position.

Nitrogen/phosphorus fertilizing of late spring burning/discing plots increased desirable-grass herbage production on the lower-slope position (Table 21). Phosphorus fertilizing of late-spring burning/discing plots increased desirable-grass-herbage production on the upper-slope position. Phosphorus fertilizing of early-spring burning/discing plots decreased desirable-grass herbage production on the lower-slope position.

Early-spring burning and fertilizing with phosphorus presents the best option for quail management because legumes and other forbs increased on both the upper-slope position and the lower-slope position. In addition ground

Table 20. Changes in production of herbage (kg/ha) in response to burning and fertilizing, fall 1973.

				Herbage groups				
S-P	Treatment	Season	Fertilization	Desirable grasses	L-d-g	Legumes	Other forbs	Total herbage
U-s-p	Control	None	None	3940c	130	30	580	4680
	Burning	ES	None	4760cd	40	210	180	5190
			Phosphorus	1630a	100	1130	1060	3920
			Nitrogen/ phosphorus	3400b	140	20	360	3920
		LS	None	3240b	90	80	440	3850
			Phosphorus	3600b	150	40	220	4010
			Nitrogen/ phosphorus	6470e	30	40	390	6930
L-s-p	Control	None	None	5530d	t [2/]	5	210	5745
	Burning	ES	None	2010a	220	550	140	2920
			Phosphorus	4790d	20	330	350	5490
			Nitrogen/ phosphorus	5280d	30	0	310	5620
		LS	None	6670e	30	0	0	6700
			Phosphorus	3690b	20	150	120	3980
			Nitrogen/ phosphorus	9640f	10	0	200	9850

S-P = Slope position
U-s-p = Upper-slope position
L-s-p = Lower-slope position
ES = Early spring
LS = Late spring
L-d-g = Less-desirable grass

[1/] Means followed by the same letter are not significantly different ($P < 0.05$).

[2/] Less than 1 kg/ha.

Table 21. Changes in production of herbage (kg/ha) in response to burning/discing and fertilizing, fall 1973.

S-P	Treatment	Season	Fertilization	Herbage groups Desirable grasses	L-d-g	Legumes	Other forbs	Total herbage
U-s-p	Control	None	None	3940cde[1]	130	30	580	4680
	Burning/ discing	ES	None	2540a	70	180	380	3170
			Phosphorus	3040ab	140	0	510	3690
			Nitrogen/ phosphorus	2460a	60	160	530	3210
		LS	None	3460bcd	500	0	160	4120
			Phosphorus	4590ef	700	140	370	5800
			Nitrogen/ phosphorus	3810bcde	1320	10	240	5380
L-s-p	Control	None	None	5530gh	t[2]	5	210	5745
	Burning/ discing	ES	None	4870fg	70	310	260	5510
			Phosphorus	3180abc	140	0	50	3370
			Nitrogen/ phosphorus	5990h	370	0	560	6920
		LS	None	4060def	210	80	190	4540
			Phosphorus	3920cde	290	0	470	4680
			Nitrogen/ phosphorus	5800h	190	0	0	5990

S-P = Slope position
U-s-p = Upper slope position
L-s-p = Lower-slope position
ES = Early spring
L-d-g = Less-desirable grasses
LS = Late spring

[1] Means followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 kg/ha.

litter accumulation was reduced to an acceptable level.

Effects of Treatments on Seed Production

Total Seed Production

Total seed production consisted of the combined total seed weights of the seven quail food species plus the total weight of miscellaneous seeds (Table 22).

The combined weight of the seven quail food species was largest on the upper-slope position. Miscellaneous seeds were more numerous on the lower-slope position. Weights for the combined seven quail-food species, the miscellaneous seeds, and the total seed production were not significantly different at the 10 percent level.

Treatments similar to those performed in this study have been recommended in other geographic areas to increase the production of seeds utilized by quail for food.

As a group, legumes are one of the most important producers of quail food. The relative density of legumes was significantly increased 200 to 400 percent by several of the burning and fertilizing treatments; however, production of quail food was not increased.

Late-spring burning/discing and fertilizing with nitrogen/phosphorus on the lower-slope position increased the number of plants that normally provide quail food by 400 percent; however, total production of seed utilized by quail for food was not increased and production of herbage

Table 22. Weights (cg of seeds/m^2) of combined quail-food-seed species, miscellaneous seed species, and total seed production on control plots, fall 1973.

	Slope position		
Seed group	Upper	Lower	Average
Quail-food species	86	14	57
Miscellaneous-seeds group	100	119	108
Total seed production	186	133	165

Table 23. In-soil-seed weights and available-seed weights (cg of seeds/m^2) of western ragweed, catclaw sensitivebrier, prairie dropseed, slender lespedeza, Scribner panicum, slickseed wildbean, and bushy knotweed on control plots, fall 1973.

		Slope position		
Seed species	Location	Upper	Lower	Average
Western ragweed	in-soil	57	5	36
	available	6	0	4
Catclaw sensitivebrier	in-soil	10	0	6
	available	0	0	0
Prairie dropseed	in-soil	0	0	0
	available	0	0	0
Slender lespedeza	in-soil	0	4	1
	available	0	0	0
Scribner panicum	in-soil	6	1	4
	available	2	0	1
Slickseed wildbean	in-soil	0	4	1
	available	0	0	0
Bushy knotweed	in-soil	4	2	3
	available	t[1/]	4	2

[1/] Less than 1 cg/m^2.

by desirable grasses was increased 180 percent.

The benefit of reduced competition by desirable-grasses to production of quail-food seeds is shown by the simple correlation coeffiecient between herbage production of desirable grasses and total production of available quail food seeds equaling -0.22 ($P < 0.05$). This effect is also illustrated by the production of desirable-grass herbage in the replications and its inverse relationship to production of other-forb herbage and weight of available western ragweed seed (Figure 3).

Seed Production by Quail-Food Species

Seeds of plant species that were analyzed separately were western ragweed, catclaw sensitivebrier, prairie dropseed, slender lespedeza, Scribner panicum, slickseed wildbean and bushy knotweed. The in-soil seed weight and available-seed weight, on untreated plots, of these seven species are presented in Table 23. Available-seed weight is composed of the combined weight of on-plant seed and seed found on the soil surface. Western ragweed was the most abundant of the seven quail-food-seed species. Prairie dropseed was the only species not represented on untreated plots.

In-soil Scribner panicum seeds and in-soil slickseed wildbean seeds were the only seed species results significantly increased ($P < 0.10$) by treatments.

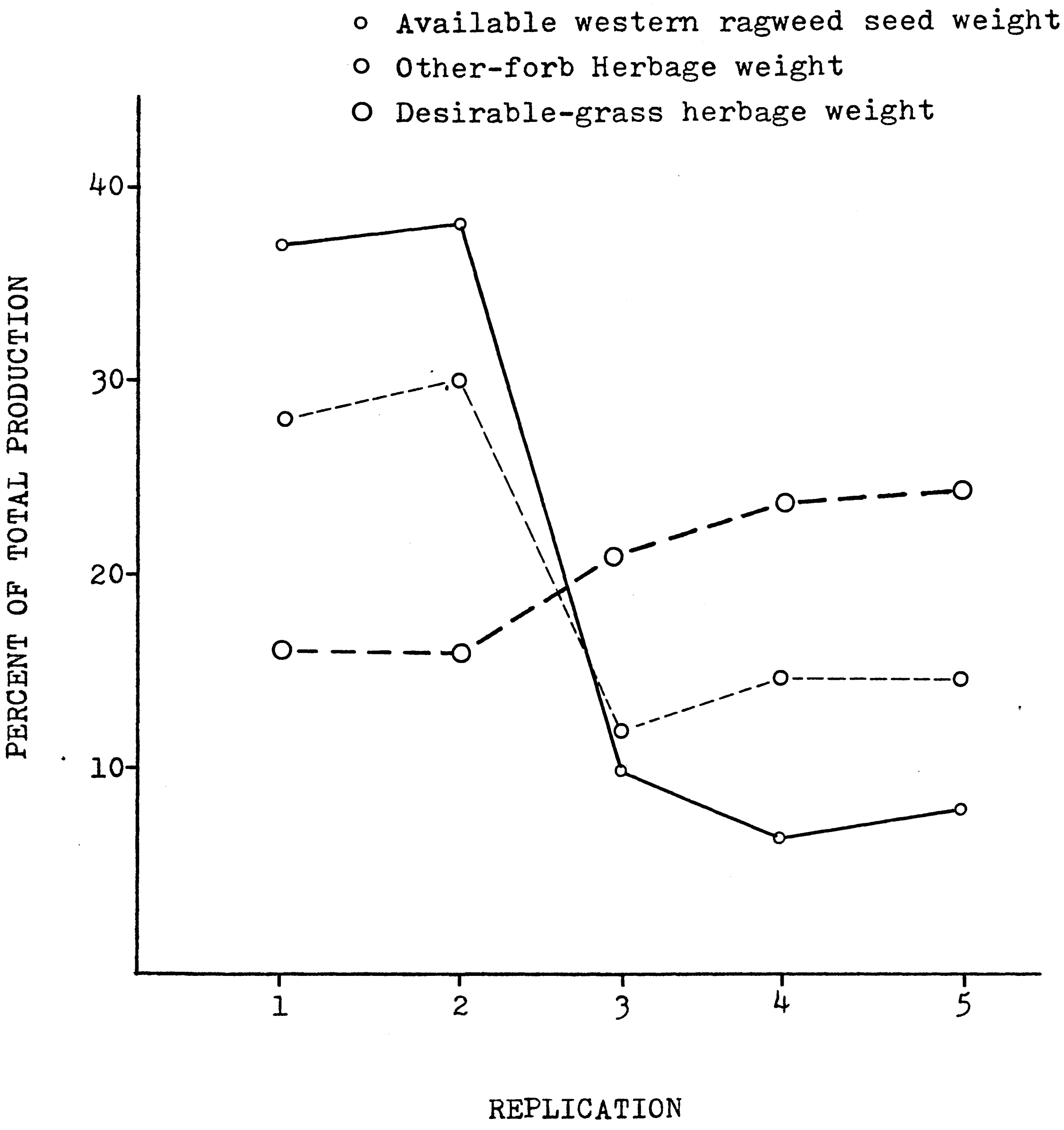

Figure 3. Desirable-grass herbage, forb herbage, and available western ragweed seed production by replications.

In-soil seeds of Scribner panicum were increased on the lower-slope position by early-spring discing and late-spring discing. The only upper-slope-position disturbance that did not decrease in-soil seeds of Scribner panicum was late-spring discing (Table 24). In-soil seeds of Scribner panicum were increased on the upper-slope position by both early-spring phosphorus fertilizing and early-spring nitrogen/phosphorus fertilizing. On the lower-slope position Scribner panicum in-soil seeds were increased by early-spring phosphorus, early-spring nitrogen/phosphorus, and late-spring phosphorus fertilizings (Table 25); and by early-spring discing and fertilizing with nitrogen/phosphorus on the lower-slope position (Table 26).

Slickseed wildbean in-soil seeds were increased on both the upper-slope position and the lower-slope position by early-spring discing (Table 24); by early-spring phosphorus, early-spring nitrogen/phosphorus, and late-spring phosphorus fertilizings (Table 25); and by late-spring discing and fertilizing with nitrogen/phosphorus (Table 26).

Increased production of slickseed wildbean and Scribner panicum seeds on disced plots indicates that their seed production is improved by soil disturbance and/or reduction in spring-season competition from desirable-grasses. However, the heavy accumulation of ground-litter on disced areas makes these seeds unavailable to quail.

Table 24. Weight changes (cg of seeds/m^2) in amounts of quail-food-seed species in response to disturbances, fall 1973.

		Upper slope position							Lower slope position						
			Early spring			Late spring				Early spring			Late spring		
Ss	Sl	Uc	D	B	Bd	D	B	Bd	Lc	D	B	Bd	D	B	Bd
Amps	Is	57	44	16	47	10	137	6	5	42	1	6	79	0	2
	Av	6	15	18	38	10	10	0	0	6	0	0	41	0	0
Scun	Is	10	2	0	0	0	15	0	0	6	24	132	19	0	30
	Av	0	0	3	0	0	0	0	0	0	0	0	24	0	5
Sphe	Is	0	0	1	1	0	2	0	0	0	0	0	0	1	0
	Av	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Levi	Is	0	2	0	0	1	0	1	4	0	0	12	12	0	1
	Av	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Paol	Is	6b[1]	1a	0a	1a	5b	0a	1a	1a	7b	1a	0a	12c	0a	0a
	Av	2	0	0	0	7	1	1	0	0	0	1	5	0	0
Stle	Is	0a	12b	0a	0a	3a	0a	5a	4a	42c	0a	0a	5a	0a	0a
	Av	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pora	Is	4	3	2	2	2	6	5	2	6	0	2	1	2	2
	Av	t[2]	0	0	1	0	2	0	4	0	0	0	0	0	0

Ss = Seed species
Amps = Western ragweed
Scun = Catclaw sensitivebrier
Sphe = Prairie dropseed
Levi = Slender lespedeza

Paol = Scribner panicum
Stle = Slickseed wildbean
Pora = Bushy knotweed
Sl = Seed location
Is = In soil; Av = Available

Uc = Upper-slope control
Lc = Lower-slope control
D = Discing
B = Burning
Bd = Burning/discing

[1] Seed location means for a species followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 cg/m^2.

Table 25. Weight changes (cg of seeds/m^2) in amounts of quail-food-seed species in response to fertilization, fall 1973.

			Upper slope position					Lower slope position			
			Early spring		Late spring			Early spring		Late spring	
Seed species	Sl	Uc	P	N	P	N	Lc	P	N	P	N
Western ragweed	Is	57	78	53	44	69	5	14	6	5	0
	Av	6	16	30	14	10	0	0	0	0	0
Catclaw sensitivebrier	Is	10	3	2	0	0	0	0	0	5	23
	Av	0	0	0	3	0	0	0	0	0	6
Prairie dropseed	Is	0	0	0	0	0	0	0	0	0	0
	Av	0	0	0	0	0	0	0	0	0	0
Slender lespedeza	Is	0	0	4	0	0	4	1	6	2	0
	Av	0	0	1	0	0	0	0	0	0	0
Scribner panicum	Is	6b[1]	11c	19d	7b	6b	1a	8bc	5b	5b	1a
	Av	2	0	2	2	6	0	0	0	1	0
Slickseed wildbean	Is	0a	0a	0a	0a	0a	4a	11b	30d	18c	0a
	Av	0	0	0	0	0	0	12	0	0	0
Bushy knotweed	Is	4	1	2	1	0	2	0	6	1	1
	Av	t[2]	0	0	0	0	4	0	0	0	0

Sl = Seed location
Is = In soil
Av = Available

Uc = Upper-slope control
Lc = Lower-slope control

P = Phosphorus
N = Nitrogen/phosphorus

[1] Seed location means for a species followed by the same letter are not significantly different ($P < 0.05$).

[2] Less than 1 cg/m^2.

Table 26. Weight changes (cg of seeds/m^2) in amounts of in-soil seeds of Scribner panicum and slickseed wildbean in response to discing and fertilizing, fall 1973.

				Seed species	
S-P	Treatment	Season	Fertilization	Scribner panicum	Slickseed wildbean
Upper	None	Control	None	6cd[1/]	0a
	Discing	Early spring	None	1a	12b
			Phosphorus	1a	3a
			Nitrogen/ phosphorus	3abc	5a
		Late spring	None	5bcd	3a
			Phosphorus	2ab	0a
			Nitrogen/ phosphorus	4bcd	24c
Lower	None	Control	None	1a	4a
	Discing	Early spring	None	7d	42d
			Phosphorus	6cd	0a
			Nitrogen/ phosphorus	18f	12c
		Late spring	None	12e	5a
			Phosphorus	1a	0a
			Nitrogen/ phosphorus	2ab	48e

S-P = Slope position

[1/] Seed species means followed by the same letter are not significantly different ($P < 0.05$).

Mean Weight per Seed

The mean weight per seed for western ragweed, catclaw sensitivebrier, prairie dropseed, slender lespedeza, Scribner panicum, slickseed wildbean, and bushy knotweed was calculated from available-seed data from untreated plots (Table 27). None of the mean-weight-per-seed results were significantly different at the 10 percent level.

Table 27. Mean weight per seed (mg/seed) of western ragweed, catclaw sensitivebrier, prairie dropseed, slender lespedeza, Scribner panicum, slickseed wildbean, and bushy knotweed.

Seed species	Slope position		
	Upper	Lower	Average
Western ragweed	2.2	1.9	2.1
Catclaw sensitivebrier	7.3	7.2	7.3
Prairie dropseed	2.1	2.0	2.1
Slender lespedeza	2.1	2.1	2.1
Scribner panicum	1.6	1.5	1.6
Slickseed wildbean	20.0	20.3	20.0
Bushy knotweed	1.4	1.3	1.3

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Implication of Site Variability

Initial examination of the study area indicated that site variability was probably greatest across the south-facing slope; however, sampling to evaluate the experimental results revealed greatly increased production of desirable grasses on the lower portion of the study area. Therefore, this study actually tested treatments on two significantly different sites.

The implication of this result is that natural variations in a study area must be accurately delineated prior to selecting an experimental design and performing the treatments. This evaluation of original vegetative conditions should be performed by the same techniques that will be used later to analyze effects of treatments. If significant variations in natural site conditions are encountered, reasons for the variations must be identified and quantified before any experimental treatments are applied so that their effects may be distinguished from experimental results.

Study Limitations

The primary use of tallgrass prairie habitat is cattle grazing; however, preferential grazing of small experimental plots by cattle would prevent accurate determination of plant responses to treatments. Therefore, the study area was protected from cattle grazing.

Recommendations based on results of this study and other published findings are presented; however, actual management of tallgrass prairie habitat for quail would have to be conducted in conjunction with the primary land use (cattle grazing). Therefore, recommendations and conclusions presented should not be considered as management techniques, but rather as management possibilities deserving additional research effort.

Land Management Considerations

The basis of land management usually should be renewable natural resources. Land management practices that do not maintain their resource base are morally and environmentally as well as economically wrong. Conversely, failure to utilize renewable resources is wasteful.

Discing and burning/discing treatments did improve the habitat for quail, however their use is not recommended. The reduction in herbage production caused by discing would reduce grazing revenue from the land, and discing is a much more expensive treatment than burning alone. In addition, increased density and herbage production by less-desirable grasses and reduced herbage production by desirable-grasses indicate that earlier-successional types of plants are encouraged by discing and burning/discing treatments. Returning an area of existing tallgrass prairie to an earlier stage of plant succession cannot be considered economically or environmentally sound.

Quail Habitat Considerations

The low level of seed production by the quail-food producing plants was not the major factor limiting quail use of habitat on the study area. The excessive ground-litter mulch existing on all but the burning and the burning/discing plots would make quail utilization of the habitat improbable. Accumulation of ground litter on the burning and the burning/discing plots became thick enough during 1974 to make these plots again unacceptable as quail habitat.

Additional research is needed to determine the point at which accumulation of tallgrass prairie ground litter begins to suppress utilization by quail. A study using radio telemetry, similar to the research of Yoho (1970), would be the best technique to use in such a study.

Recommendations for Quail Management

The reduction of ground litter coupled with the increased relative density of legumes on both slope positions indicate that early-spring burning and fertilizing with phosphorus is the most valuable technique for use in managing tallgrass prairie habitat for quail on this area. Phosphorus fertilization is included in the above recommendation since its application often increased the herbage production and species density of legumes and other forbs. In addition, spring burning increases the abundance of insects (Carpenter 1939) and insect abundance is necessary for quail chick survival (Stoddard 1931). Some nesting habitat for quail would have to be protected from burning if quail management is to be successful.

Ecotone (edge effect) is an important part of quail habitat as illustrated by DeArment (1950) who flushed 62 percent of all quail located in his study within 2.3 m of an ecotone. Providing "quail covey headquarters" (Robinson 1957) is one of the most important functions of ecotone. The absence of sufficient numbers of quail covey headquarters is an important limiting factor for quail in tallgrass prairie habitat (Robinson op cit.); therefore, any attempts to increase quail on prairie not containing woody draws would have to include establishment of covey headquarters. I would recommend that individual covey headquarters have a maximum size of 10 m x 20 m and that the maximum density of covey headquarters be one for each 5 ha of land area. Smooth sumac (Rhus glabra) is a good choice, since it is used as a covey headquarter (Davis 1964) and it does furnish food (Lee 1948). Smooth sumac plantings might have to be utilized to establish a suitable distribution of covey headquarters. Thereafter, spring burning will increase stands of smooth sumac (McMurphy and Anderson 1965).

Examination of the response of quail to large-scale burning and fertilizing treatments conducted on tallgrass prairie is needed to test these recommendations. Cattle grazing must occur on the prairie habitat being examined, since total absence of grazing does not represent an actual prairie situation.

Recommendations for Cattle Management

Fertilization rates of 50 kg of N and 55 kg of P/ha (nitrogen/phosphorus) significantly increase production of desirable-grasses herbage. Herbage production of desirable-grass on undisturbed plots occurring on the lower-slope position increased from 5500 kg to 10200 kg/ha by early-spring nitrogen/phosphorus fertilization and from 5500 kg to 10000 kg/ha by late-spring nitrogen/phosphorus fertilization. Late-spring burning and fertilizing with nitrogen-phosphorus increased herbage production of desirable grasses from 3900 kg to 6500 kg/ha on the upper-slope position and from 5500 kg to 9600 kg/ha on the lower-slope position.

The above increases of desirable-grasses herbage should be important for cattle management on tallgrass-prairie habitat, therefore additional range fertilization experiments are needed.

Recommendations for Quail and Cattle Management

The findings below indicate that treatments benefitted cattle habitat or quail habitat, but usually not both simultaneously:

Late-spring burning of tallgrass prairie produces the best weight gains by cattle (McMurphy and Anderson 1965) and increases the species density of big bluestem; however, quail reproductive success would be reduced by late-spring burning.

Early-spring burning of tallgrass prairie produced suitable quail habitat, but reduced the relative density of big bluestem.

Fertilizing of plots burned in the late spring with nitrogen/phosphorus increased production of desirable grass herbage, but competition from desirable grasses suppressed the growth and seed production of legumes and other forbs.

Fertilizing of untreated tallgrass prairie on the lower-slope position increases the production of desirable-grass herbage, but quail chick survival is reduced by ground litter (Hurst 1970).

Phosphorus fertilizing of burning treatments often increaed the relative density of legumes, but desirable-grass herbage was often reduced.

Since competition from desirable grasses, on plots treated by early-spring burning and fertilizing with phosphorus, suppressed the growth and seed production of legume and other forb species, cattle grazing should be included in quail management. Utilization of legumes and other forbs by cattle is greatest in June and July (Dwyer 1961). Big bluestem, switchgrass, indiangrass, and little bluestem are the plant species preferred by cattle in May (Dwyer 1961). Therefore, fairly intensive cattle grazing conducted only in late April and May, on pastures treated by early-spring burning and fertilizing with phosphorus, would reduce desirable-grass competition without allowing severe utilization of the legumes and other forbs by cattle. The late April and May grazing intensity should be adjusted, by experimentation, to increase production of quail food yet not excessively reduce the pastures range-condition class.

Once the quail population reaches an adequate level, the habitat can possibly be maintained by cattle grazing conducted from early winter through May and by early-spring burning conducted every second or third year. Cattle utilization of the desirable-grass roughage beginning in early winter would help reduce ground litter by both ingesting and trampling vegetation. In addition, cattle trails are often utilized by quail in their daily movements.

Incorporating the above quail management system into a rotation grazing management plan for a ranch area or grazing allotment on a pasture by pasture primary-use basis could possibly benefit range condition, cattle production, and quail management.

Pastures chosen primarily for management of quail should contain more woody plant species and be in a lower range-condition class than the pastures chosen primarily for production of cattle. The quail management pastures should be treated by early-spring burning, fertilized with phosphorus, and not grazed during June and July.

Pastures chosen primarily for production of cattle should be treated by late-spring burning, fertilizing with nitrogen/phosphorus and not grazed during late April and May. The late-spring burning and fertilizing with nitrogen/phosphorus should increase the production of desirable-grass herbage and the absence of grazing pressure during late April and May should improve the species density of desirable grasses.

Additional research is needed to determine how to obtain the optimum balance between wildlife and livestock production on tallgrass prairie sites.

CHAPTER VI

SUMMARY

The objectives of this study were to determine the quantity of bobwhite quail foods and the general vegetative changes produced by combinations of burning, discing, and chemically fertilizing tallgrass prairie in central Oklahoma during different seasons of the year. A study area was located in northeastern Osage County, Oklahoma.

A strong slope-position effect occurred on the study area. Desirable-grass herbage, total herbage, big bluestem species density, and desirable-grasses species density were significantly larger ($P < 0.05$) on the lower-slope position. Less-desirable-grass herbage and less-desirable-grass species density were significantly larger ($P < 0.05$) on the upper-slope position.

Habitat treatments increased quail-food-producing plants; however, this increase was not similarly reflected in their production of seed. The combined total seed production by the seven most numerous quail-food-producing plant species was not significantly increased by any of the treatments. The reason for this suppression of seed responses was competition from the desirable grasses. Weight of in-soil seeds for Scribner panicum and for slickseed wildbean were increased by discing and by fertilizing.

Burning and burning/discing treatments were the only treatments that reduced ground litter accumulation enough to allow quail to utilize the habitat.

Early-spring burning followed by phosphorus fertilization treatments of tallgrass prairie showed the best potentiality for improving quail habitat.

Herbage production of desirable grasses was increased by nitrogen/phosphorus fertilizing.

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APPENDIX

Table 28. Scientific and common names of plant species collected on the study area, fall 1973.

Scientific name	Common name	Number of shoots[1]
Ambrosia artemisifolia	common ragweed	2
Ambrosia psilostachya	western ragweed	103
Amorpha canescens	leadplant	31
Andropogon Gerardi	big bluestem	972
Artemisia ludoviciana	Louisiana sagewort	3
Aster ericoides	heath aster	12
Baptisia leucophaea	plains wildindigo	2
Bouteloua curtipendula	sideoats grama	23
Bouteloua gracilis	blue grama	6
Buchloe dactyloides	buffalograss	3
Cassia fasciculata	showy partridgepea	2
Chloris verticillata	windmillgrass	1
Cirsium ochrocentrum	yellowspine thistle	1
Digitaria sanguinalis	crabgrass	1
Echinacea angustifolia	blacksamson	4
Erigeron annuus	daisy fleabane	1
Eupatorium serotinum	late eupatorium	12
Euphorbia corollata	floweringspurge	4
Euphorbia hexagona	sixangle euphorbia	5
Helianthus mollis	ashy sunflower	2

Table 28. (Continued)

Scientific name	Common name	Number of shoots[1/]
Juncus tenuis	poverty rush	53
Lepidium virginicum	Virginia pepperweed	1
Lespedeza capitata	roundhead lespedeza	2
Lespedeza virginica	slender lespedeza	10
Oenothera biennis	common eveningprimrose	2
Oxalis violacea	violet woodsorrel	2
Panicum capillare	common witchgrass	112
Panicum dichotomiflorum	fall panicum	3
Panicum oligosanthes	Scribner panicum	186
Panicum virgatum	switchgrass	173
Petalostemum purpureum	purple prairieclover	6
Plantago spp.	plantago	32
Polygonum ramosissimum	bushy knotweed	43
Psoralea tenuiflora	wild-alfalfa	11
Rosa suffulta	sunshine rose	2
Salvia azurea	azure sage	2
Schizachyrium scoparium	little bluestem	438
Schrankia uncinata	catclaw sensitivebrier	13
Setaria glauca	yellow foxtail	7
Solanum eleagnifolium	silverleaf nightshade	2
Solidago missouriensis	Missouri goldenrod	33

Table 28. (Continued)

Scientific name	Common name	Number of shoots[1/]
Solidago rigida	stiff goldenrod	1
Sorghastrum avenaceum	indiangrass	22
Sporobolus asper	tall dropseed	1
Sporobolus heterolepis	prairie dropseed	18
Strophostyles leiosperma	slickseed wildbean	20
Symphoricarpos orbiculatus	coralberry	3
Tephrosia virginiana	Virginia tephrosia	9
Tridens flavus	purpletop	2

[1/] Numbers of shoots occurring in point-centered-quarter samples.

VITA

Clark Hector Derdeyn

Candidate for the Degree of

Master of Science

Thesis: MANIPULATING CENTRAL OKLAHOMA RANGELAND VEGETATION FOR BOBWHITE QUAIL

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born in Pauls Valley, Oklahoma, January 5, 1935, the son of Marcell H. and Florence Jesse Derdeyn. Married July 12, 1959 to Betty Jean Stabe at Lahoma, Oklahoma. Children are Dana Scott born November 12, 1962 in Enid, Oklahoma and Sheila Dawn born July 23, 1964 in Enid, Oklahoma.

Education: Pawhuska High School, Pawhuska, Oklahoma in 1953; Bachelor of Science in Geology, Oklahoma State University 1961; completed requirements for the Master of Science degree at Oklahoma State University in May 1975.

Professional Experience: Game Ranger for Murray County and Area Manager of Arbuckle Public Hunting Area, Sulphur, Oklahoma from April 1966 to November 1968; Area Manager of Canton Public Hunting Area, Longdale, Oklahoma from November 1968 to January 1972; Upland Game Research Biologist at Wildlife Research Center, Stillwater, Oklahoma from January 1972 to September 1974; Area Manager for Keystone and Heyburn Public Hunting Areas and Area Biologist for seven counties in northcentral Oklahoma from September to present.

Professional Societies: Society for Range Management and The Wildlife Society.