FORAGE PRODUCTION, VEGETATIVE COMPOSITION AND PLANT VIGOR IN RELATION TO RANGE CONDITION

By

DON B. HAZELL

Bachelor of Science
Fort Hays Kansas State College
Hays, Kansas
1956

Master of Science
Fort Hays Kansas State College
Hays, Kansas
1960

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
May, 1964

OKLAHOMA
STATE UNIVERSITY
LIBRARY

JAN 5 19..

FORAGE PRODUCTION, VEGETATIVE COMPOSITION

AND PLANT VIGOR IN RELATION TO

RANGE CONDITION

Thesis Approved:

Wallace W. Hanson
Thesis Adviser

Don D. Dwyer

U. T. Waterfall

Jack R. Harlan

L. L. Pope

J. H. Boggs
Dean of the Graduate School

569592

ACKNOWLEDGMENTS

Appreciation is extended to Phillips Petroleum Company, Bartlesville, Oklahoma, for providing financial assistance during the course of this project.

Acknowledgement is granted Mr. K. S. Adams, owner of Adams' Ranch, for permission to conduct this study on his ranch.

I am deeply indebted to Dr. Don D. Dwyer, under whose supervision this study was conducted. For helpful suggestions in the plan of study and manuscript, Drs. W. W. Hansen, U. T. Waterfall, L. S. Pope and J. R. Harlan, all of Oklahoma State University, are gratefully acknowledged.

I am very grateful to my wife Koula, who was highly instrumental in making this study a success.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

Figure | Page

CHAPTER I

INTRODUCTION

The Soil Conservation Service uses species composition as an index to range condition. This system involves ecological analysis of the climax and successions leading to and away from the climax. By listing the theoretical or expected percentage of the climax composition on a given site and comparing to actual composition, it is possible to determine what per cent of the present composition on the site can be called climax. This system presupposes knowledge of climax, and it is not always possible to determine climax with reasonable assurance, but it is still one of the most widespread systems used today. At present, the practice is to designate ranges from 75 to 100 per cent of climax as excellent condition, 50 to 75 per cent as good condition, 25 to 50 per cent as fair condition and 0 to 25 per cent as poor condition (Stoddart and Smith, 1955).

Species composition is an important index to range condition, but it is just one tool that might be considered. Forage production is considered by Humphrey (1949) to be an important index to condition. This can be associated with species composition in that two similar areas may produce the same amount of total forage, but the species of plants contributing to the production may be entirely different. If no other factors such as soil, climate or topography are limiting, this is probably due to the way the area is being used, or has been used in the past.

The rate of growth or vigor of the plants may be associated with range condition, although the determination of vigor is largely subjective. Since a decline in plant vigor usually precedes a change in composition, it may serve as a helpful tool for determining the state of health of the range, and this in reality is range condition.

The purpose of this study was to determine how forage production, vegetative composition and plant vigor may be related to range condition. Six different areas representing the loamy prairie site, and an area representing the claypan site, were selected for study. Following the Soil Conservation Service system, an effort was made to obtain a representation of one of each range condition classification: excellent, good, fair and poor. The rate of growth of the dominant species, relative composition and forage production of both grasses and forbs, basal cover and plant vigor were determined in each area.

It is hoped that this study will provide some further knowledge for establishing a management plan for both cattle and range. Only ecological knowledge plus managing experience can determine a standard of utilization.

CHAPTER II

REVIEW OF LITERATURE

Plant vigor

It has been shown by many investigators that forage production varies directly with vegetative composition and the rate of growth of the plants on a given range site, and that these criteria are essential for determining range condition. Humphrey (1949) states that one cannot be used without the other, because one by itself can be misleading. Vegetative composition will gradually change on a range continuously overgrazed by sheep, and a plant that is not preferred by sheep and therefore not grazed will show excellent vigor even though the range may only be in fair condition. Plant vigor can also be misleading on poor ranges protected from grazing for a period of years. After one or two years the previously established grasses may exhibit excellent vigor, but the basal density may be very low. Short and Woolfolk (1956) listed this fact as one of the common objections to the use of plant vigor as a criterion of range welfare. Other objections listed were that vigor is difficult to describe and measure, and it is obscured by the effects of current weather.

A search in the literature failed to reveal clear-cut information on procedures for sampling plant vigor or for measuring the vigor of plants of different growth forms. Weaver and Darland (1947) measured vigor according to root development, foliage height, dry weight of tops and roots, length and width of leaves, size of clumps, number of stems, absence or presence of dead centers and partial or complete death of tufts or bunches. In their study, vigor of range grasses on overgrazed, moderately grazed and nongrazed pastures was measured by digging up sods and planting them in a greenhouse, and then clipping them at different intervals. Weaver (1954) states an excellent test of vigor is the measurement of growth in the spring, after grazing or after transplanting. The National Research Council (1962) lists size, character and condition of the plants as the most visible and easily recognized indicators of plant vigor. Different studies show that all possible clues to plant vigor must be considered before a final evaluation is made. The greater the number of valid factors considered and measured, the greater the confidence in the results.

Although plant height has been used by many investigators as an estimation of vigor in one way or another, Blaisdell and Pechanec (1949) found that leaf height was not a reliable indicator. According to Heady (1957) there are many factors which make the measurement of height difficult, and these are as follows:

1. When plants are trailing or drooping
2. If the highest part is not perpendicular from the base of the plant
3. Configuration and slope of the ground surface
4. Wind
5. Temporary wilting

This study by Heady employs the concept of height, mentions some of the difficulties in the accurate measurement of height, discusses the usefulness of height measurements and describes a new method whereby the point-plot system may be employed to obtain an objective sample of height of plant materials.

Forage production

Evans and Jones (1958) studied two methods of determining forage production. One method was clipping the forage, the other was multiplying the average plant height by the average ground cover percentage. High variability was encountered with both methods. Short and Woolfolk (1956) showed that plant vigor varied from the effects of weather, of protection from grazing and of cumulative range condition.

Other studies concerning plant vigor have shown that whenever a change is made in the intensity of grazing use, it is first reflected in vigor, later followed by changes in density, composition and soil stability. Vigor is thus indicative of short-time trends.

From exclosures ungrazed since 1930, Johnson (1956) determined the effect of grazing intensity on plant composition, vigor and growth of pine-bunchgrass ranges in central Colorado. Results showed that height of leaf growth was the most consistent plant response to the different grazing intensities. A similar study to determine cover, composition, forage yield and root development of native vegetation and the effects of grazing on these factors was conducted by Tomanek and Albertson (1953). Results showed that heavily utilized pastures often produced less than half as much forage as nongrazed prairies. Reduction of yield under moderate use was very small, and some sites on moderately grazed pastures outyielded those under nongrazing. A later study by Tomanek and Albertson (1957) showed that grazing in the mixed prairie causes a decrease in mid- and tall-grasses and a proportionate increase in short-grasses.

Changes in plant vigor are expressed in several ways. Physical changes in herbage cover per plant, height, number of inflorescences and width and length of leaves are among the best indicators according to Cook and Goebel, 1962. In this study conducted in southwestern Utah, plants of apparent high vigor covered more ground surface, had longer leaves, fruiting culms, and annual growth, and had more inflorescences per plant than did plants of apparent poor vigor. Also, all species of high vigor were generally higher in ether-extract material, lignin, and gross energy than plants of low vigor. An earlier study by Goebel and Cook (1960) was conducted to determine the effect of range condition on plant vigor, production and nutritive value of forage. Since change of vigor is one of the first indicators of grazing intensity, it has often been used as an indication of range condition. The effects of litter accumulation or mulch on yield, cover and soil conditions are described in the mixed prairie of west-central Kansas by Hopkins (1956), and could be applied to most grassland regions.

The value of range condition surveys in analyzing range problems was recognized early by the Soil Conservation Service in the Pacific Northwest, and it is from this region that the technique has received its greatest impetus. Range management specialists use the phrase "range condition" to mean the present vegetative composition of the range in terms of idealized composition for the site. According to Dyksterhuis (1949), differences in range condition are recognized by comparing present vegetation with climax vegetation. The criteria most frequently used in describing condition of the range include botanical composition, plant density, comparative vigor of forage species, total forage production, litter accumulation and soil stability. Parker (1954) lists vigor of the desired species, density and composition as three factors which may be used in delineating range condition. Vigor is important in that it is usually a reflection of the degree and intensity of past grazing use and competition for moisture from other plants. Voight and Weaver (1951) list percentage composition of the vegetation as the most satisfactory basis for classifying ranges in the midwestern United States.

The effect of different clipping treatments has been used by numerous investigators as a tool for determining the development of prairie grass vegetation. In nearly all cases, there is considerable decrease in ground cover as the weakened grasses become defoliated (Biswell and Weaver, 1933). In general, clipping also reduces growth of roots. Robertson (1933) found that clipping reduced growth of roots, based on dry weight, about twice as much as that of tops. This study by Robertson showed that growth of tops, number and width of leaves, and number of tillers were also reduced by clipping. Aldous (1930) found that while the lowest yields were obtained from plots clipped most frequently, the vegetation on these plots had the highest nutritive value. However, this nutritive value could not compensate for the decrease in density and yield of the vegetation.

A study in south-central Texas by Jameson and Huss (1959), in which the effect of removing leaves could be evaluated independently from the effect of removing stems, showed that clipping before fruiting culm production reduced production, and that clipping the entire plant after fruiting culm production increased production.

CHAPTER III

THE STUDY REGION

Climate

The general climate of the region is one of dry, hot summers and wet springs and falls. Rains with a duration of several days are common, and long continued droughts are infrequent. During the winter little precipitation occurs.

Records from the United States Weather Bureau for the years 1944-1961 inclusive for Foraker, Oklahoma, a small town 5 miles south of the ranch headquarters, showed a mean annual precipitation of 32.81 inches with about three-fourths of it falling during the growing season, April to September inclusive. This average includes the drought years of 1953-1956, when the annual average for this period was 24.16 inches. During the period of this study, which included the summer months of June, July, August of 1961 and 1962, the growing conditions were ideal. Records obtained from a rain gauge located in the study region showed that total precipitation amounted to 17.03 inches during these months of 1961, and 12.27 inches for the same period of 1962. Of this total for 1961, 2.33 inches of rainfall came during June, 6.00 inches during July and 8.70 inches during August. For 1962, 4.82 inches came during June, 3.75 inches during July and 3.70 inches during August.

Summer temperatures are usually high with frequent extremes of 100°F., and the temperature relations are favorable for plant development. The average date of the last killing frost is April 1, and the average date of the first killing frost is November 1. Thus, there is a growing season of around 215 days. The hot, relatively dry summers are preceded by a long, balmy spring season and followed by many weeks of cool autumn weather. During winter, zero temperatures occur only infrequently, and temperatures below the freezing point are of short duration.

Temperatures were measured continuously during the two summers by a hygrothermograph. The average maximum and minimum temperatures were determined to show the range of temperature fluctuation. They are important since plant distribution may be controlled by temperature extremes. The average day and night temperatures were also determined (Table I). Average day temperatures were calculated between the hours of 6:00 A.M. and 6:00 P.M., while an average night was calculated between the hours of 6:00 P.M. and 6:00 A.M. These temperatures were determined by adding the readings of the even hours and dividing by the total number of readings for the seven days of the week (Bruner, 1931).

TABLE I

TEMPERATURE RELATIONS FOR THE SUMMER MONTHS OF JUNE, JULY AND AUGUST, 1961 AND 1962

	Je '61	Je '62	Jul '61	Jul '62	Aug '61	Aug '62
Avg. daily max. temp.	85.7	85.3	85.0	91.7	85.6	93.3
Avg. daily min. temp.	63.8	62.0	62.1	68.2	62.7	66.5
Avg. day temp.	77.6	78.6	78.3	83.4	78.5	85.0
Avg. night temp.	63.8	68.7	67.8	75.0	67.7	74.2

Humidity was also measured continuously during the two summers by the hygrothermograph. The average high, average low and average daily humidities were determined, and they were found to vary directly with precipitation. The average daily humidities are shown in Table II.

TABLE II

COMPARISON OF HUMIDITY FOR THE SUMMER MONTHS OF JUNE, JULY AND AUGUST, 1961 AND 1962 (FIGURES ARE BASED ON 24-HOUR PERIOD)

	Je '61	Je '62	Jul '61	Jul '62	Aug '61	Aug '62
Average daily high	99.4	100.0	99.9	98.7	99.9	96.3
Average daily low	66.1	66.4	59.2	59.0	57.3	42.4
Average	82.8	82.2	79.6	78.9	78.6	69.4

Soil temperatures, taken each day at 2:00 P.M., were also measured during the two summers at depths of 1 and 6 inches. Soil temperature fluctuations at both depths closely followed the daily fluctuations in air temperature. A general upward trend in soil temperatures throughout the summer was characteristic for 1962; however, the opposite trend was noted for 1961 (Table III). This was due to more cloudy days in July and August of 1961 and nearly twice as much rainfall during these months than in 1962.

TABLE III

SOIL TEMPERATURES FOR THE SUMMER MONTHS OF JUNE, JULY AND AUGUST FOR THE YEARS 1961 AND 1962

Depth	Je '61	Je '62	Jul '61	Jul '62	Aug '61	Aug '62
1 inch	86.9	79.3	85.1	81.9	83.8	86.3
6 inches	78.4	76.6	77.5	78.7	78.6	78.8

Location and Description of the Region

The study was conducted on Adams' Ranch, a 33,000 acre tract of land located in the northern part of Osage County, Oklahoma, and the southern extremities of Chautauqua and Cowley Counties, Kansas. Only a small portion of the ranch, 1,120 acres, lies in Kansas. The ranch is situated in the heart of the Osage Hills, an area world renowned for its bluestem fattened cattle. According to Anderson (1953), "the Flint Hills of Kansas are joined on their southern end by the Osage range lands of Oklahoma, a region of similar grasslands." This constitutes one of the last large segments of true prairie in the United States.

Topography

As the name Osage Hills implies, this is a hilly region with gently rolling topography characteristic of much of the study area. A much smaller portion of the ranch is typified by steeply rolling sites, with trees and shrubs being found only in the canyons and along the steeper slopes. The ranch elevation varies from about 800 feet in the lower portions to 1,339 feet on the airfield.

Vegetation

Native grass is the most practical vegetation that these rough lands are capable of supporting. Dwyer (1958) reported more than 300 species of forbs, grasses and grass-like plants present on Adams' Ranch. Four important grass species, Andropogon scoparius Michx.,[1] A. Gerardi Vitman, var. Gerardi, Panicum virgatum L. and Sorghastrum nutans (L.) Nash dominate the region. It is not uncommon for these species to represent 70-90 per cent of the total vegetative composition on a well-managed loamy prairie site. Throughout this paper, these species will be referred to as the "major four." Bouteloua curtipendula (Michx.) Torr., Panicum oligosanthes Schultes, var. Scribnerianum (Nash) Fern. and Sporobolus asper (Michx.) Kunth, var. macer (Trin.) Shinners are principle increasers on the loamy prairie site, while Bothriochloa saccharoides (Swartz) Rydb.,[2] (Brittonia 1:81. 1931) is an early invader. Woody vegetation grows on the slopes and in the ravines of the breaks sites, and perennial legumes occur abundantly throughout the region.

Soils

The soils are sometimes rocky with cherty materials at the surface, and have developed from limestones and clay shales of the Lower Permian and Upper Pennsylvanian Age. The range sites of concern in this study were the loamy prairie site and claypan site. The loamy prairie site represents all the study areas except the claypan site, and soil surveys have shown this site to be characterized by a fertile, deep upland soil

---

[1]Scientific names follow Keys to the Flora of Oklahoma (Waterfall, 1962).

[2]F. W. Gould, 1959, Transfers from Andropogon to Bothriochloa (Gramineae), The Southwestern Naturalist 3:212.

(greater than 36 inches) made up of the Labette and Summit clay loam series. These soils are nearly black, highly granular, and permit good root penetration. The Osage County Soil Conservation Service has estimated air dry forage production on this site at 5,500 to 6,000 pounds per acre during favorable rainfall years (Figure 1).

The claypan site occurs over much of the region and belongs to the Parsons silt loam soil series. Claypan soils, which have 5 to 16 inches of medium acid and rather floury silt loam over a compact clay layer, have developed from mottled olive, yellow and dark brown clayey shales (Gray and Galloway, 1959). They exhibit very slow permeability, seasonal wetness and low fertility. According to Weaver and Crist (1922) claypans appear in some localities to be due largely to the calcareous nature of the soil, and in others to the concentration and cementing effect of colloidal clay aided in part by the carbonates. Because of the slow water penetration, the soil is poorly adapted for the deeply rooted tall grasses. Thus, the vegetation is primarily made up of the short-rooted grasses, Buchloë dactyloides (Nutt.) Engelm, and Bouteloua gracilis (Willd. ex HBK.) Lag. ex Griffiths. On the well-managed claypan site used in this study, these two species made up 80.2 per cent of the total vegetative composition. Ambrosia psilostachya DC., var. coronopifolia (T. & G.) Farw., Liatris punctata Hook., var. nebraskensis Gaiser and Aster ericoides L. are the principle forbs growing on this site (Figure 2). During times of drought, when water relationships are poor, root penetration on these claypan soils is greatly restricted, and forage production is greatly reduced.

Figure 1. General view of the loamy prairie range site in early June, 1962, showing the structure of the vegetation. Fruiting culms of Andropogon Gerardi and A. scoparius from the preceding year are apparent.

Figure 2. Claypan soils occur throughout the region. Note the distinct boundary of tall grasses on the upper right.

CHAPTER IV

DESCRIPTION OF THE STUDY AREAS

Six of the study areas were similar in that climate and topography were comparable. Vegetative composition was different on each area due to variations in past use. The seventh site was a claypan site and was studied separately. The following areas were selected for study:

Study area 1. Loamy prairie in excellent condition

This site, which will be referred to as a native grass meadow, has been mowed once annually for the past three years. During the summer of 1961 the meadow was mowed on June 12, and in 1962 it was mowed on July 5. This site was dominated by the "major four," *Andropogon scoparius* being the most abundant species. Other grasses encountered with the point quadrat were *Buchloë dactyloides*, *Bouteloua curtipendula* and *Sporobolus asper*. The five predominant forbs were *Ambrosia psilostachya*, *Psoralea tenuiflora* Pursh, *Salvia azurea* Lam., var. *grandiflora* Benth., *Vernonia Baldwinii* Torr., var. *Baldwinii* and *Erigeron strigosus* Muhl. ex Willd.

Study area 2. Loamy prairie in excellent condition

Cattle are in this pasture only during calving periods, generally in the fall between October 15 and December 1, and in the spring between February 15 and May 1. The "major four" were also the dominant grass species in this study area. Other predominant grasses were *Bouteloua curtipendula*, *Buchloë dactyloides*, *Panicum oligosanthes*, *Paspalum ciliatifolium* Michx. and *Eragrostis spectabilis* (Pursh) Steud. The five predominant forbs were Ambrosia psilostachya, Aster ericoides, Salvia azurea, Ruellia humilis Nutt. (R. ciliosa of manuals, in part) and Kuhnia eupatorioides L., var. corymbulosa T. & G.

Study area 3. Loamy prairie in excellent condition

This study area represents an annually mowed cemetery on the loamy prairie site. Over 90 per cent of the total composition on this site was made up by members of the "major four." Other grasses were Panicum oligosanthes, Bouteloua gracilis, Koeleria macrantha (Lebed.) Spreng. (K. cristata), Eragrostis spectabilis and Sporobolus asper. The five predominant forbs were Solidago missouriensis Nutt., var. fasciculata Holz., Coreopsis grandiflora Hogg, var. grandiflora, Aster ericoides, Euphorbia corollata L., var. corollata and Achillea lanulosa Nutt., forma lanulosa. This site is mowed in late August and provides a good comparison to the native grass meadow.

Study area 4. Loamy prairie in high good condition

This study area is grazed the year around, and the composition of the "major four" is somewhat lower in this area than in the areas mentioned above. Other grasses were Buchloë dactyloides, Panicum oligosanthes, Sporobolus asper, Bouteloua curtipendula, Leptoloma cognatum (Schultes) Chase and Chloris verticillata Nutt. The five predominant forbs were Ambrosia psilostachya, Ruellia humilis, Vernonia Baldwinii, Aster ericoides and Gutierrezia dracunculoides (DC.) Blake.

Study area 5. Loamy prairie in low good condition

This study area is also grazed the year around, and the "major four" on this site made up 61.7 per cent of the total vegetative composition. Other grasses were Sporobolus asper, Buchloë dactyloides, Chloris verticillata, Panicum oligosanthes, Bouteloua gracilis and Paspalum ciliatifolium. The five predominant forbs were Ambrosia psilostachya, Vernonia Baldwinii, Artemisia ludoviciana Nutt., var. ludoviciana, Salvia azurea and Psoralea tenuiflora.

Study area 6. Loamy prairie in poor condition

This study area is heavily grazed the year around; it is located two miles south of Foraker, Oklahoma. The "major four" on this site contributed only a small portion to the total composition. Other important grasses were Sporobolus asper, Bothriochloa saccharoides, Bouteloua gracilis, Buchloë dactyloides, Chloris verticillata, Bouteloua curtipendula, Panicum oligosanthes, Paspalum ciliatifolium and Schedonnardus paniculatus (Nutt.) Trel. The six predominant forbs on this site were Ambrosia psilostachya, Aster ericoides, Kuhnia eupatorioides, Artemisia ludoviciana, Vernonia Baldwinii and Salvia azurea.

Study area 7. Claypan

The claypan site used in this study was in excellent range condition. Buchloë dactyloides and Bouteloua gracilis were by far the most abundant species on this site. Other grasses were Chloris verticillata, Sporobolus asper, Bothriochloa saccharoides, Schedonnardus paniculatus, Eragrostis spectabilis, Bouteloua curtipendula, Bouteloua hirsuta and Agropyron Smithii Rydb. var. Smithii. The five predominant forbs were Ambrosia psilostachya, Liatris punctata, Achillea lanulosa, Aster ericoides and Gutierrezia dracunculoides.

CHAPTER V

MATERIAL AND METHODS

Vegetative composition and basal density

The point quadrat method of vegetation analysis (Levy and Madden, 1933) was used in this study to determine the basal density and per cent composition of the vegetation on each site. The apparatus used consisted of a frame three feet long containing ten steel pins spaced three inches apart (Figure 3). The pins were sharpened as finely as practicable since the pin diameter has been found to affect the results markedly (Goodall, 1952).

The system for recording hits depends upon the type of vegetation sampled and the purpose of the sample. In this study a "hit" was recorded only if the pin contacted the base (crown) of the plant. There is no standard practice regarding the distribution of points or the number of points required. The number of points does not depend to any extent on the size of the field, but rather on the nature of the vegetation, the closeness or sparseness of the cover, and also on the part of the plant on which hits are to be recorded (Brown, 1954). In this study 200 sets, or 2000 points, were taken along pace transects in each area. The equation which was used for determining total basal area is as follows:

$$\frac{\text{No. hits all species}}{\text{Total no. of points}} \times 100$$

If the total number of hits for all species is 200, and the total number

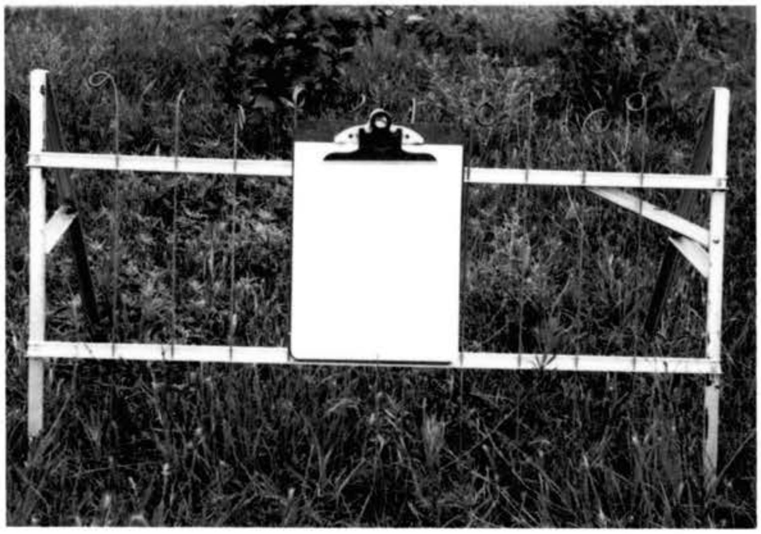

Figure 3. Apparatus for analyzing vegetation by the point quadrat method. Composition and density of the plant cover can be obtained from the number of hits and expressed in percentage.

Figure 4. The movable cage. The cage method permits a measurement of herbage production on an area while the surrounding vegetation is currently being grazed. The cages are somewhat larger than the area to be clipped to reduce border effect.

of points taken is 2000, then the basal density is 10%. The relative composition formula used is as follows:

$$\frac{\text{No. hits for a species}}{\text{Total no. of hits}} \times 100$$

If the number of hits for all species is 200, and the number of hits for *Andropogon Gerardi* is 20, then *A. Gerardi* contributes 10% to the total vegetative composition.

Forb count

The total number of forbs per square foot and per acre and the five dominant forbs on each study area were determined by the square-foot method. One hundred randomly located square-foot plots were used and the number of species in each plot was counted. The average for each plot represents the number per square foot, and the average per square foot times 43,560 results in the number of forbs per acre.

Forage production

Twenty movable exclosures (Figure 4) were placed at random in each study area from May 26 to August 25 of each year. The cages were used to prevent grazing of the vegetation on areas where the herbage was to be measured at a later date. According to Weaver and Clements (1938), exclosures should rarely be located at random except in pure stands of a single species, or where large numbers are employed.

Near the close of the growing season, plots 11½ x 24" were hand clipped at ground level in each exclosure to determine forage production. At the time of clipping, the forage in each plot was separated into *Andropogon Gerardi*, *A. scoparius*, *Sorghastrum nutans*, *Panicum virgatum*, other grasses and forbs. On the claypan site and the poor condition site, the forage was separated into the predominant species for that area. The clipped samples were then weighed, dried, and reweighed. The samples were air-dried the first summer, but oven-dried (100-105°C. for 24 hours) the second summer. The average dry weight of forage in grams multiplied by the factor 50 was used to determine pounds of forage produced per acre. Forage production of the annual species *Bromus japonicus* Thunb. and *Hordeum pusillum* Nutt. was determined for each area by the above procedure. This was done during the latter part of May before the annuals had shed their fruits.

Exclosures and seed production

Since the number of fruiting culms and the number of inflorescences have been found to correlate with plant vigor, they were collected in this study. In the five study areas grazed the year around, exclosures were built for this purpose. The exclosures were 6' x 12' and consisted of four strands of barbed wire placed 2' apart. The exclosures were not placed at random, but instead, a representative plot was selected whereby a few samples from each of the "major four" grasses could be counted and collected.

Farmers and ranchers frequently assert that bluestem grasses will only produce seed every seventh year (Cornelius, 1950). Seed crops are dependent upon the prevalence of climatic conditions favorable to the growth of native grass, and such conditions are extremely erratic. Since the amount and distribution of rainfall are the most important factors limiting production (Harlan, 1960), and since distribution of rainfall is an important factor influencing seed production, small exclosures were also placed in each study area, and a rain gauge was then placed in the exclosure.

The small exclosures, fenced against domestic stock, were attractive to the cattle in the pasture. Excess grazing, trampling, and rubbing occurred around the plots, but the plots were large enough to afford a suitable index to normal conditions.

Plant vigor

Vigor of the important species was determined for each of the study areas by the following measurements:

1. Maximum height
2. Average height
3. Leaf length
4. Leaf width
5. Number of leaves per plant

On all the areas except the claypan site, the "major four" grasses and the four or five predominant forbs were measured. On the poor condition site, the "major four" grasses and predominant forbs were measured, as well as the species of grasses that were dominant for the area. To obtain the measurements of leaf length and leaf width of forbs, ten randomly located leaves from each plant were measured from petiole to tip. On grasses, the third leaf from the base of the culm was measured on ten random plants.

The measurements were made the middle part of each month during as short an interval as possible, usually around six days. The sequence of sampling the study areas was rotated each month.

At the end of the growing season, when inflorescences were developed, the following measurements were used as further criteria for plant vigor:

1. Maximum height of fruiting culms
2. Average height of fruiting culms
3. Fruiting culms per plant

4. Inflorescences per fruiting culm

Ten randomly located plants for each species were used to determine these measurements.

Soil moisture

Water content of the soil is one of the most important habitat factors regulating plant distribution and behavior. Sampling for soil moisture was done at two-week intervals with a soil tube or geotome. This instrument has a sharp cutting edge on one end and a reinforcement on the other end to allow forcing it into the soil.

Duplicate samples were taken at depths of 6, 12, 24, and 36 inches, the second lot being taken a few feet from the first. The samples were each placed in a numbered metal can containing a closely fitting lid. The soil cans were weighed to the nearest tenth-gram soon after the sample was taken; then the lids were removed and placed with the cans in an oven at 110°C. for a minimum of 48 hours. The per cent water in the sample was then calculated (Weaver and Clements, 1938).

CHAPTER VI

RESULTS

Composition and Basal Density

Grasses

Study areas 1, 2, and 3:

Eighteen grass species were recorded in sampling these study areas (Table IV). Study area 1 (native grass meadow), study area 2, and study area 3 (cemetery) were in excellent range condition, with *Andropogon scoparius* being the most abundant grass species on these sites. *Andropogon Gerardi* was second in abundance in study areas 1 and 2. In area 3, *Sorghastrum nutans* was second in abundance while *Andropogon Gerardi* rated third. *Sorghastrum nutans* was third in abundance in both areas 1 and 2. *Panicum virgatum* rated fourth in abundance on each of the three areas. These four grass species made up 93.5, 92.5 and 94.0 per cent of the composition on study areas 1, 2 and 3 respectively, indicating their importance on the loamy prairie site. Other grasses making significant contributions to the composition in these areas were *Bouteloua curtipendula*, *Buchloë dactyloides* and *Sporobolus asper*. The per cent basal density on study areas 1, 2 and 3 was 10.5, 12.4 and 9.7 respectively. Basal density refers to the per cent of the soil covered by stems of the vegetation at the ground level.

TABLE

COMPOSITION OF GRASSES ON THE SEVEN STUDY AREAS FOR THE

Scientific Name	1-Native Meadow Per cent 1961	1962	Avg.	2-Excellent Per cent 1961	1962	Avg.	3-Cemetery Per cent 1961	1962	Avg.
Asc	58.5	66.3	62.4	69.1	74.1	71.6	64.0	68.5	66.3
Age	27.0	20.0	23.5	12.5	13.5	13.0	9.1	12.7	10.9
Snu	6.3	4.6	5.5	7.3	4.8	6.1	20.0	10.0	15.0
Pvi	1.8	2.5	2.2	2.0	1.6	1.8	2.0	1.6	1.8
Bcu	0.9	1.5	1.2	2.0	1.6	1.8	1.0	---	0.5
Pol	---	---	---	1.4	0.4	0.9	1.9	1.6	1.8
Bda	1.9	2.5	2.2	3.0	1.6	2.3	---	---	---
Sas	0.9	1.5	1.2	1.1	0.4	0.7	---	0.6	0.3
Carex	---	1.1	0.5	---	0.4	0.2	1.0	2.2	1.6
Bgr	---	---	---	---	0.4	0.2	---	1.1	0.5
Scr	2.7	---	1.4	---	0.4	0.2	---	---	---
Esp	---	---	---	---	0.4	0.2	---	0.6	0.3
Pci	---	---	---	0.4	0.4	0.4	---	---	---
Lco	---	---	---	---	---	---	1.0	---	0.5
Cve	---	---	---	0.8	---	0.4	---	---	---
Bsa	---	---	---	0.4	---	0.2	---	---	---
Bhi	---	---	---	---	---	---	---	---	---
Spa	---	---	---	---	---	---	---	---	---
Kma	---	---	---	---	---	---	---	1.1	0.6
Total	100.0	100.0	100.1	100.0	100.0	100.0	100.0	100.0	100.1
Per cent Basal Cover	11.1	9.8	10.5	12.4	12.4	12.4	10.2	9.1	9.7
Per cent Climax	94.5	94.9	94.7	92.9	95.6	94.3	96.1	92.8	94.5
Range Condition		Excellent			Excellent			Excellent	

Asc - Andropogon scoparius
Age - Andropogon Gerardi
Snu - Sorghastrum nutans
Pvi - Panicum virgatum
Bcu - Bouteloua curtipendula
Pol - Panicum oligosanthes
Bda - Buchloë dactyloides
Sas - Sporobolus asper
Bgr - Bouteloua gracilis

IV

SUMMERS OF 1961, 1962, AND AVERAGE FOR THE TWO SUMMERS

4-High Good			5-Low Good			6-Poor			7-Claypan		
Per cent			Per cent			Per cent			Per cent		
1961	1962	Avg.	1961	1962	Avg.	1961	1962	Avg.	1961	1962	Avg.
38.3	45.2	41.8	4.0	22.3	13.2	4.7	6.1	5.4	---	---	---
17.5	28.4	23.0	43.2	39.5	41.4	4.7	6.1	5.4	---	---	---
6.6	2.9	4.8	---	1.3	0.7	---	---	---	---	---	---
2.5	0.7	1.6	4.0	5.7	4.9	1.1	---	0.6	---	---	---
5.0	0.8	2.9	1.1	---	0.6	3.9	4.0	4.0	---	0.5	0.3
0.9	2.9	1.9	1.1	1.9	1.5	3.4	3.1	3.2	---	---	---
23.3	8.0	15.7	2.3	3.8	3.1	40.0	8.1	24.1	37.5	23.5	30.5
2.6	2.9	2.7	35.2	15.3	25.3	11.6	33.7	22.7	2.7	2.3	2.5
---	1.4	0.7	1.1	6.4	3.7	---	3.0	1.5	---	0.9	0.5
---	---	---	---	0.6	0.3	14.1	9.2	11.7	40.4	59.0	49.7
---	---	---	---	---	---	---	---	---	0.6	1.4	1.0
---	---	---	---	---	---	---	---	---	---	0.5	0.3
---	---	---	2.3	0.6	1.4	---	2.0	1.0	---	---	---
---	0.8	0.4	---	---	---	---	---	---	---	---	---
2.5	5.8	4.2	1.1	2.5	1.8	5.8	6.1	6.0	12.0	8.8	10.4
---	---	---	4.6	---	2.3	7.1	17.4	12.4	2.0	1.4	1.7
---	---	---	---	---	---	---	---	---	---	0.5	0.2
0.9	---	0.5	---	---	---	3.5	1.0	2.2	4.8	1.4	3.1
---	---	---	---	---	---	---	---	---	---	---	---
100.1	99.8	100.1	100.0	99.9	100.2	100.0	99.8	100.2	100.0	100.2	100.2
12.0	7.0	9.5	8.8	8.0	8.4	8.5	10.2	9.4	19.7	10.9	15.3
69.9	78.0	74.0	52.3	68.8	60.5	14.4	16.2	15.3	80.6	85.3	83.0
High Good			Low Good			Poor			Excellent		

Scr - *Sporobolus cryptandrus*
Esp - *Eragrostis spectabilis*
Pci - *Paspalum ciliatifolium*
Lco - *Leptoloma cognatum*
Cve - *Chloris verticillata*
Bsa - *Bothriochloa saccharoides*
Bhi - *Bouteloua hirsuta*
Spa - *Schedonnardus paniculatus*
Kma - *Koeleria macrantha*

Study areas 4 and 5:

Study area 4 was in high good range condition with Andropogon scoparius contributing 41.8 per cent to the total composition (Table IV). Study area 5 was in low good range condition and Andropogon scoparius contributed 13.2 per cent to the total composition. Andropogon Gerardi was second in abundance in area 4 with 23.0 per cent, but Sporobolus asper was second in abundance in area 5 with 25.3 per cent. Thus, the two most abundant grasses in study area 4 made up 64.8 per cent of the composition, and the two most abundant grasses in study area 5 made up 66.7 per cent of the composition. Although these two figures are approximately the same, the two areas differ since the 25.3 per cent of Sporobolus asper in area 5 is not allowable when determining range condition on the loamy prairie site. Sporobolus asper made up only 2.7 per cent of the composition on area 4. Sorghastrum nutans and Panicum virgatum together made up approximately the same per cent on both areas, while Andropogon Gerardi was the most abundant grass on study area 5. The "major four" made up 71.1 per cent of the composition on area 4 and 59.9 per cent on area 5. Other grasses making significant contributions to the composition on these two areas were Bouteloua curtipendula, Panicum oligosanthes, Buchloë dactyloides (particularly in study area 4), and Chloris verticillata.

The per cent basal density on study areas 4 and 5 was 9.5 and 8.4 respectively.

Study area 6:

Study area 6 was in poor range condition as the "major four" contributed only 11.4 per cent to the total composition (Table IV). Although present, Sorghastrum nutans was not sampled either year with the point quadrat. The four most abundant grasses in this study area were Buchloë dactyloides (24.1 per cent), Sporobolus asper (22.7 per cent), Bothriochloa saccharoides (12.4 per cent) and Bouteloua gracilis (11.7 per cent). Since this area represented a loamy prairie site, none of these grasses were allowable when using Soil Conservation Service guide for determining range condition. Bouteloua curtipendula, Panicum oligosanthes, Chloris verticillata and Schedonnardus paniculatus were other grasses of importance on the site.

Additional samples (2000 points) were taken on this area in which annuals were recorded, and it was found that Bromus japonicus contributed 13.2 per cent to the composition during its period of growth. The basal density was 9.4 per cent for this study area.

Study area 7:

Due to the restriction of root development and poor soil-water-root relationships on this site, tall grasses were excluded and short grasses provided the dominant vegetation. Bouteloua gracilis and Buchloë dactyloides predominated, composing 49.7 and 30.5 per cent respectively of the vegetation (Table IV). Panicum virgatum was the only tall grass present on this study area, but it was very sparse and was not sampled either year with the point quadrat. This claypan was in excellent range condition since the most abundant grasses represented the highest unit of vegetation that this site is capable of producing. Buchloë dactyloides, Bouteloua gracilis, Sporobolus asper and Bouteloua curtipendula made up 80.3 per cent of the total composition, and each of these four grasses is allowable in determining range condition. Chloris verticillata and Schedonnardus paniculatus were other grasses contributing to the composition.

Because of the abundance of the low-growing, sod-forming short grasses the per cent basal density was greater on the claypan site, and in this particular study area the basal density was 15.3 per cent.

Forb Number

There are many species of prairie plants other than grasses. Since it has been shown by Weaver and Albertson (1943) that forbs often contribute 10-16 per cent of the total prairie yield, they surely deserve much more consideration than they often receive. Practically all the forbs observed in this study were perennials; the annuals and biennials constituted only a very small percentage.

Study areas 1, 2, and 3:

Ambrosia psilostachya was the most abundant forb on study areas 1 (native grass meadow) and 2 (Table V). It is a potential menace not only because it is not grazed, but also because it sometimes spreads rapidly by underground stems and forms dense societies. This species represented 31 per cent of the total forb numbers in study area 1, and 22 per cent in study area 2.

A large decrease in forb numbers occurred in both study areas 1 and 2 between 1961 and 1962. The number decreased 29 per cent in study area 1 and 51 per cent in study area 2. The average number of forbs per square foot for both years was 2.1 in area 1 and 2.4 in area 2. As a whole, these two areas were remarkably free of forbs.

In study area 3 (annually mowed cemetery), the most abundant forb was *Solidago missouriensis*, which represented 23 per cent of the total forb population. It was followed in abundance by *Coreopsis grandiflora* and *Aster ericoides*, as these two species represented 17 and 10 per cent respectively of the total forbs present. In study area 3, the forb population increased between 1961 and 1962 from 4.39 to 6.67 per square foot.

TABLE V

NUMBER OF FORBS PER SQUARE FOOT AND PER ACRE ON EACH STUDY AREA. FIGURES REPRESENT THE SUMMERS OF 1961, 1962, AND AN AVERAGE OF THE TWO SUMMERS

Species	No. Per Sq. Foot 1961	1962	Avg.	No. Per Acre 1961	1962	Avg.
Study Area 1 - Native Meadow						
Ambrosia psilostachya	1.03	0.17	0.60	47,916	7,405	27,661
Psoralea tenuiflora	0.21	0.50	0.36	9,147	21,760	15,454
Salvia azurea	0.08	0.36	0.22	3,484	15,682	9,583
Vernonia Baldwinii	0.20	0.06	0.13	8,712	2,614	5,663
Erigeron strigosus	0.04	0.24	0.14	1,742	10,454	6,098
Others	0.85	0.38	0.62	33,553	16,573	25,063
Total	2.41	1.71	2.07	104,554	74,488	89,522
Study Area 2 - Excellent						
Ambrosia psilostachya	0.36	0.41	0.38	16,988	17,860	17,424
Salvia azurea	0.12	0.10	0.11	5,227	4,356	4,792
Aster ericoides	0.31	0.36	0.33	13,504	15,682	14,593
Kuhnia eupatorioides	0.35	0.06	0.21	15,246	2,614	8,930
Gutierrezia dracunculoides	0.23	0.19	0.21	10,019	8,276	9,148
Others	2.24	0.09	1.16	47,916	3,920	25,918
Total	3.61	1.21	2.40	108,900	52,708	80,805
Study Area 3 - Cemetery						
Aster ericoides	0.42	0.72	0.57	17,424	31,363	24,394
Solidago missouriensis	1.12	1.45	1.29	47,916	63,162	55,539
Coreopsis grandiflora	1.00	0.82	0.91	43,560	35,719	39,640
Euphorbia corollata	0.68	0.21	0.50	30,492	9,148	19,820
Achillea lanulosa	0.23	0.17	0.20	10,019	7,405	8,712
Others	0.94	3.30	2.12	41,817	143,748	92,782
Total	4.39	6.67	5.53	191,228	290,545	240,887
Study Area 4 - High Good						
Ambrosia psilostachya	3.40	6.22	4.81	148,104	270,943	209,523
Ruellia humilis	0.93	1.11	1.02	39,204	48,352	43,778
Vernonia Baldwinii	0.70	0.71	0.70	30,492	30,928	30,710
Aster ericoides	0.36	0.45	0.41	15,682	19,602	17,642
Gutierrezia dracunculoides	0.15	0.53	0.34	6,534	23,087	14,811
Others	0.86	1.17	1.02	34,412	50,964	42,688
Total	6.40	10.19	8.30	274,428	443,876	359,152

TABLE V (Continued)

Species	No. Per Sq. Foot 1961	1962	Avg.	No. Per Acre 1961	1962	Avg.
			Study Area 5 - Low Good			
Ambrosia psilostachya	2.96	5.79	4.37	130,680	252,212	191,446
Vernonia Baldwinii	0.76	1.91	1.33	33,106	83,200	58,153
Artemisia ludoviciana	0.42	0.50	0.46	18,295	21,780	20,037
Salvia azurea	0.52	0.26	0.39	22,651	11,326	16,988
Psoralea tenuiflora	0.20	0.15	0.17	8,712	6,534	7,623
Others	0.80	2.19	1.50	47,916	95,396	71,656
Total	5.66	10.80	8.22	261,360	470,448	365,903
			Study Area 6 - Poor			
Ambrosia psilostachya	9.02	2.73	5.87	392,040	118,919	255,480
Aster ericoides	0.26	1.84	1.05	13,068	80,150	46,609
Kuhnia eupatorioides	0.23	1.11	0.67	10,019	48,352	29,185
Artemisia ludoviciana	1.10	1.00	1.05	47,816	43,560	45,688
Vernonia Baldwinii	0.82	0.28	0.55	34,848	12,197	23,522
Salvia azurea	0.40	0.29	0.34	17,424	12,632	15,028
Others	0.31	2.19	1.25	7,505	95,396	51,451
Total	12.14	9.44	10.78	522,720	411,206	466,963
			Study Area 7 - Claypan			
Ambrosia psilostachya	3.20	10.71	6.95	139,392	466,528	302,960
Aster ericoides	0.46	1.60	1.03	20,038	69,696	49,867
Liatris punctata	1.72	3.33	2.52	74,052	145,055	109,553
Achillea lanulosa	0.62	0.55	0.58	26,136	23,958	25,047
Gutierrezia dracunculoides	0.44	0.93	0.68	19,166	40,511	29,838
Others	0.24	0.64	0.44	12,197	27,878	20,037
Total	6.68	17.76	12.20	290,981	773,626	532,303

Numerous desirable forbs such as Amorpha canescens Pursh, forma canescens, Silphium laciniatum Torr., var. laciniatum and Dalea purpurea Vent. were found in this study area since this site is not grazed. The average number of forbs per square foot for both years in study area 3 was 5.5 (Figure 5).

Study areas 4 and 5:

Ambrosia psilostachya was by far the most abundant forb in each of these two areas, totaling 209,523 per acre, or 58 per cent of the total population in study area 4 (high good), and 191,446 per acre, or 52 per cent in study area 5 (low good) (Table V). Vernonia Baldwinii was also abundant in both areas.

The forb population increased 38 per cent in study area 4 and 44 per cent in study area 5 between 1961 and 1962.

Study area 6:

A host of forbs headed by Ambrosia psilostachya (Figure 6) was present on this heavily grazed pasture in poor range condition. An average of 10.8 forbs per square foot was representative of this pasture and they were either uneaten by stock or grazed only sparingly. Ambrosia psilostachya numbered 5.9 per square foot, or 255,480 per acre (Table V), representing 55 per cent of the total forb population. Aster ericoides and Artemisia ludoviciana were second in number, each with 1.1 plants per square foot. The average number of forbs per acre in this study area was 466,963 and between 1961 and 1962 the number decreased 21 per cent.

Study area 7:

The number of forbs more than doubled on this claypan site between 1961 and 1962. This was due mostly to the 70 per cent increase of Ambrosia psilostachya and the 49 per cent increase of Liatris punctata

Figure 5. Study area 3 (cemetery) June, 1962, showing abundance of forbs. The conspicuous forbs are Echinacea pallida Nutt., Euphorbia corollata, and Silphium laciniatum.

Figure 6. Ambrosia psilostachya was the most abundant forb in the heavily grazed pasture in poor range condition. A pure stand was typical throughout most of the study area. August, 1961.

(Table V). The increase of total forbs per acre was 62 per cent from 1961 to 1962. The only forb that did not increase was *Achillea lanulosa*.

Forage Production

Forage production is strongly influenced by range condition. Humphrey (1949) has even defined range condition in terms of forage production. By determining the amount of forage being produced, and analyzing the results with the combined effects of all the factors involved, a truer measure of range condition could probably be obtained.

All study areas except the heavily grazed pasture in poor range condition (study area 6) showed a marked decrease in forage production from 1961 to 1962. Variation in yield was probably due chiefly to variations in the amount of rainfall during the growing season. There was relatively little rainfall during May, 1962.

Study areas 1 and 3:

Most species of the "major four" showed a decrease in dry forage per acre in 1962 (Table VI). The only exception was *Andropogon Gerardi* in study area 1 (native grass meadow). The decrease was 16 per cent in study area 1 and 27 per cent in study area 3 (annually mowed cemetery).

In comparing the native grass meadow, usually mowed in late June or early July, with the annually mowed cemetery, usually mowed the last of August or early September, it was found that the forage yield in the cemetery was only 59 per cent of that in the native grass meadow in the summer of 1961 and 49 per cent in 1962.

The differences in forage production between the two study areas for both years are presented in Table VII. Forage produced by *Andropogon Gerardi* and *Panicum virgatum* was significantly greater in the native grass meadow than in the cemetery. The results were significant at the .01

TABLE VI

FORAGE PRODUCTION, PER CENT FORAGE AND PER CENT COMPOSITION ON STUDY AREAS 1, 2 AND 3

Species	Dry Weight 1961	Dry Weight 1962	% Forage 1961	% Forage 1962	% Comp. 1961	% Comp. 1962
		1-Native Meadow				
Andropogon scoparius	1109	970	25.7	26.8	58.5	66.3
Andropogon Gerardi	1780	1804	41.3	49.8	27.0	20.0
Sorghastrum nutans	639	444	14.8	12.2	6.3	4.6
Panicum virgatum	315	230	7.4	6.3	1.8	2.5
Forbs	313	18	7.3	0.5	---	---
Others	152	158	3.5	4.4	---	---
Total Production	4308	3623	---	---	---	---
		2-Excellent				
Andropogon scoparius	1970	1813	44.5	58.2	69.1	74.1
Andropogon Gerardi	1426	484	32.3	15.6	12.5	13.5
Sorghastrum nutans	457	347	10.3	11.1	7.3	4.8
Panicum virgatum	309	156	7.1	5.0	2.0	1.6
Forbs	43	50	1.0	1.6	---	---
Others	213	265	4.8	8.5	---	---
Total Production	4418	3116	---	---	---	---
		3-Cemetery				
Andropogon scoparius	1037	769	42.8	43.4	64.0	68.5
Andropogon Gerardi	383	302	15.8	17.0	9.1	12.7
Sorghastrum nutans	570	293	23.6	16.5	20.0	10.0
Panicum virgatum	31	40	1.3	2.3	2.0	2.2
Forbs	269	132	11.1	7.5	---	---
Others	130	237	5.4	13.3	---	---
Total Production	2420	1772	---	---	---	---

TABLE VII

DIFFERENCES IN PRODUCTION OF GRASSES ON THE NATIVE GRASS MEADOW (STUDY AREA 1) AND THE ANNUALLY MOWED CEMETERY (STUDY AREA 3). FIGURES REPRESENT PRODUCTION OF THE CEMETERY SUBTRACTED FROM THE NATIVE GRASS MEADOW

Species	Pounds	
	1961	1962
Andropogon scoparius	72	201*
Andropogon Gerardi	1397**	1502**
Sorghastrum nutans	69	151
Panicum virgatum	284**	190**

* Significant at .05 level

** Significant at .01 level

level for both years. Forage production of Andropogon scoparius was not significantly different between the two areas in 1961, but in 1962 the native grass meadow produced a greater total amount of dry forage than the cemetery. This difference was significant at the .05 level. The difference in forage produced by Sorghastrum nutans on the two study areas was not significant either year. The difference in forage production is due to the difference in vigorous top growth shown in Figures 7 and 8.

Late mowing may have been less detrimental to Sorghastrum nutans than other members of the "major four." The per cent composition of Sorghastrum nutans was higher in the cemetery than in the native grass meadow.

Even though Andropogon scoparius exhibited a higher per cent composition in study area 1 than A. Gerardi, the former still provided less dry forage per acre than the latter. This was true for both years. Andropogon Gerardi is a tall grass that grows in large clumps and becomes extremely leafy, while A. scoparius is a bunch grass which normally grows only about half as tall as A. Gerardi. Generally speaking, Andropogon Gerardi will produce more forage per acre than A. scoparius even though the per cent composition is somewhat less. If, however, the composition of Andropogon scoparius is extremely greater than that of A. Gerardi, the latter will be outyielded. This was the case in study area 3.

Study areas 2 and 6:

The loamy prairie pasture in excellent range condition (study area 2) and the loamy prairie pasture in poor range condition (study area 6) are discussed together since these sites were similar in topography and climate, but the plant composition and forage production were different due

Figure 7. Closeup of study area 1 (native grass meadow) in July, 1962. This is the date the meadow was mowed. Note the vigorous growth of Sorghastrum nutans in the center of the photo.

Figure 8. Closeup of study area 3 (cemetery) in August, 1962. This is the date the cemetery was mowed. Note the less vigorous growth of the forage in contrast to the above photo.

to degree of grazing. As discussed previously, study area 2 was grazed only during calving periods, which amounted to about four months per year, while study area 6 was grazed heavily the year around. As a result, composition and forage production were markedly different. The forage produced by each member of the "major four" was significantly greater on study area 2 than on study area 6. These differences were significant at the .01 level, and are presented in Table VIII.

TABLE VIII

DIFFERENCES IN PRODUCTION OF GRASSES ON THE LOAMY PRAIRIE PASTURE IN EXCELLENT RANGE CONDITION (STUDY AREA 2) AND THE LOAMY PRAIRIE PASTURE IN POOR RANGE CONDITION (STUDY AREA 6). FIGURES REPRESENT PRODUCTION OF THE POOR CONDITION PASTURE SUBTRACTED FROM THE EXCELLENT CONDITION PASTURE

Species	Pounds 1961	Pounds 1962
Andropogon scoparius	1759**	1666**
Andropogon Gerardi	1213**	479**
Sorghastrum nutans	255**	304**
Panicum virgatum	296**	111**

**Significant at .01 level

In study area 2, forage produced by the "major four" decreased 30 per cent from 1961 to 1962. The largest decrease was by Andropogon Gerardi (Table VI), while other members decreased only slightly. Andropogon scoparius was so much more abundant in study area 2 than A. Gerardi that the latter was outyielded. Forage produced by forbs and "other grasses" was approximately the same for both years.

In 1961 the "major four" produced only 639 pounds of dry forage per acre, or 20.3 per cent of the total forage in study area 6. In 1962, the production by these important grasses was only 240 pounds, or 7.5 per cent of the total forage. *Sorghastrum nutans*, in particular, was very sparse and was not sampled either year by the point quadrat. *Andropogon Gerardi* exhibited the highest per cent composition of the "major four," but still produced only an average of 109 pounds per acre for the two years. Members of the "major four" that were present, however, exhibited very vigorous growth, and this will be discussed later.

Sporobolus asper, *Bouteloua gracilis* and *Bothriochloa saccharoides* were three of the main forage producers in study area 6, producing an average of 377, 256 and 247 pounds per acre, respectively, for the two years. *Buchloë dactyloides* and *Chloris verticillata* were also significant forage producers.

Other species of grasses and forbs were the main forage producers in this study area. These two categories together produced 55 per cent of the total forage in 1961 and 51 per cent of the total forage in 1962. In the category of "other grasses" were such species as *Bouteloua curtipendula*, *Aristida purpurea* Nutt., (Figure 9), *Paspalum ciliatifolium* and *Panicum oligosanthes*. This category produced an average of 622 pounds, or 19.6 per cent, of the total forage per acre.

The abundance of forbs accounted for the highest per cent of the total forage production with an average of over 1000 pounds of dry forbs produced per acre for the two years, an average of 33.2 per cent of the total forage for the two years.

Study areas 4 and 5:

The total dry forage produced per acre in these two areas was nearly the same for both years. In 1961 area 4 produced 3,736 pounds per acre, and area 5 produced 3,961 pounds per acre (Table IX). In 1962, area 4 produced 3,110 pounds per acre while area 5 produced 3,227 pounds.

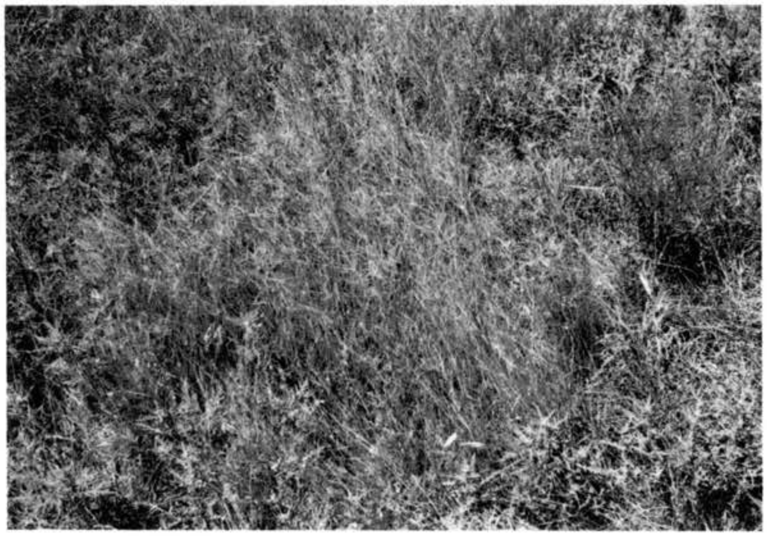

Figure 9. Pure stands of Aristida purpurea were typical in the study area in poor range condition. The category of "other grasses," in which this species was placed, produced an average of 622 pounds of dry forage per acre.

Figure 10. Sporobolus asper made up 25.3 per cent of the total vegetative composition in study area 5. This photo shows abundant patches of this grass typical for the area. August, 1962.

TABLE IX

FORAGE PRODUCTION, PER CENT FORAGE AND PER CENT COMPOSITION ON STUDY AREAS 4, 5, 6 AND 7

	Dry Weight		% Forage		% Comp.		Dry Weight		% Forage		% Comp.	
	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962
			4-High Good						5-Low Good			
Andropogon scoparius	1214	972	32.5	31.3	38.3	45.2	584	323	14.7	10.0	4.0	22.3
Andropogon Gerardi	1310	836	35.1	26.9	17.5	28.4	1059	810	26.7	25.1	43.2	39.5
Sorghastrum nutans	205	222	5.5	7.1	6.6	2.9	534	220	13.5	6.8	0.0	1.3
Panicum virgatum	71	113	1.9	3.6	2.5	0.7	313	112	8.0	3.4	4.0	5.7
Forbs	526	423	14.0	13.6	---	---	810	711	20.4	22.3	---	---
Others	410	545	11.0	17.5	---	---	661	1051	16.7	32.5	---	---
Total Production	3736	3110	---	---	---	---	3961	3227	---	---	---	---
			6-Poor						7-Claypan			
Andropogon scoparius	211	147	6.7	4.6	4.7	1.4	---	---	---	---	---	---
Andropogon Gerardi	213	5	6.8	0.2	4.7	3.0	---	---	---	---	---	---
Sorghastrum nutans	202	43	6.4	1.3	0.0	0.0	---	---	---	---	---	---
Panicum virgatum	13	45	0.4	1.4	1.1	0.5	---	---	---	---	---	---
Buchloë dactyloides	201	103	6.4	3.2	40.0	17.6	203	67	9.4	3.7	37.5	23.5
Bouteloua gracilis	207	305	6.6	9.6	14.1	11.7	721	627	33.5	34.3	40.4	59.0
Bothriochloa saccharoides	31	463	1.0	14.5	7.1	13.2	---	---	---	---	---	---
Chloris verticillata	29	20	0.9	0.6	5.8	5.4	---	---	---	---	---	---
Sporobolus asper	317	438	10.1	13.8	11.6	20.1	---	---	---	---	---	---
Forbs	1448	659	45.8	20.6	---	---	699	676	32.5	37.1	---	---
Others	281	964	8.9	30.2	---	---	529	454	24.6	24.9	---	---
Total Production	3153	3192	---	---	---	---	2152	1824	---	---	---	---

Although total production was nearly the same in both areas, the "major four" in study area 4 produced 2,800 and 2,143 pounds per acre in 1961 and 1962, respectively, while the same species in study area 5 produced 2,490 and 1,465 pounds per acre, respectively, in 1961 and 1962. One of the reasons total production was approximately the same in both areas was due to the higher percentage of forbs in study area 5. Another factor accounting for the total production being similar in the two areas was the abundance of Sporobolus asper in study area 5. At the time of clipping, Sporobolus asper was placed in the category of "other grasses" (Table IX), and this grass made up 25.3 per cent of the vegetative composition in this area. The two-year average per cent forage of other grasses in study area 4 was 14.2, while the average was 24.6 per cent in study area 5. Abundant patches of Sporobolus asper in study area 5 can be seen in Figure 10. The per cent of the total forage produced by forbs in study area 4 averaged 13.8 for the two years, while in study area 5, 21.4 per cent of the total production consisted of forbs. The abundance of forbs in the two areas can be seen in Figures 11 and 12.

A note of interest in study area 5 was the high composition of Andropogon Gerardi. This high percentage kept the pasture from being placed in a lower range condition class, as the per cent composition of the other members of the "major four" was relatively low.

Forage produced by annual grasses decreased on most of the study areas from 1961 to 1962. A slight increase was noted on the claypan site, while a 41 per cent increase occurred on the pasture in low good range condition.

The largest amount of forage produced by annual grasses was on the poor condition pasture, as 820 pounds were produced in 1961, and 260

Figure 11. Study area 4, August, 1962, showing the abundance of forbs. The conspicuous tall growing forb is Vernonia Baldwinii.

Figure 12. Study area 5 in low good range condition produced a higher percentage of forbs than the study area in high good range condition shown above. August, 1962.

pounds in 1962. Forage production by annuals on all areas is presented in Table X.

Study area 7:

Bouteloua gracilis and *Buchloë dactyloides*, the most abundant grasses on the claypan site, produced the major portion of the forage. Total forage production in this study area was 2152 pounds per acre in 1961, and 1824 pounds per acre in 1962 (Table IX). Of this total production, *Bouteloua gracilis* averaged 674 pounds production for the two years, or 33.9 per cent of the total production. *Buchloë dactyloides* produced an average of 135 pounds of dry forage per acre, or 6.6 per cent of the total production.

Other grasses, including *Chloris verticillata*, *Schedonnardus paniculatus*, *Eragrostis spectabilis*, *Bothriochloa saccharoides* and *Sporobolus asper* produced an average of 491 pounds of dry forage per acre, accounting for 24.8 per cent of the total forage produced. The claypan site also exhibited numerous forbs which produced an average of 687 pounds per acre for the two years, or 34.8 per cent of the total forage production.

Plant Vigor

Grasses

Although herbage yield is undoubtedly a more accurate measure of plant vigor than any single character, the measurements used in this study should serve as valuable criteria for evaluating plant vigor. Together, these can be used to classify range condition and serve as criteria for evaluating range improvement or deterioration.

Data showing differences in vigor of the same species on the native grass meadow (study area 1) and the cemetery (study area 3) are presented

TABLE X

FORAGE PRODUCTION BY ANNUAL GRASSES (*BROMUS JAPONICUS* AND *HORDEUM PUSILLUM*) ON EACH AREA FOR THE TWO SUMMERS

	lbs./acre 1961	lbs./acre 1962
Area 1 - Native Meadow	135	12
Area 2 - Excellent	235	105
Area 3 - Cemetery	25	10
Area 4 - High Good	145	76
Area 5 - Low Good	85	145
Area 6 - Poor	820	260
Area 7 - Claypan	75	77

in Table XI. Generally, the grass species on the native grass meadow produced a significantly greater maximum height, average height, and leaf length than the same species on the cemetery. As can be seen in Table XI, the figures were mostly significant at the .01 level. Differences in leaf width and number of leaves were not great enough to show statistical significance.

Results of these measurements show that the date of mowing must be an important factor influencing the vigor of the desirable forage species. The cemetery is usually mowed in late August and the native grass meadow is mowed in late June or early July, thus giving the plants time to recover from mowing. The differences in growth of grasses can clearly be seen in Figures 13 and 14. A decline in plant vigor was not accompanied by a decrease in range condition in the cemetery.

It can safely be said that an earlier mowing date for the cemetery would restore the vigor of the grasses. According to Humphrey (1949), grasses in low vigor will usually show good to excellent vigor within a period of only one or two years, if the cause is corrected.

Actual measurements of the grasses on the two study areas can be seen in Appendix A.

Measurement data to determine differences in vigor of the same species on the loamy prairie site in excellent range condition (study area 2) and the loamy prairie site in poor range condition (study area 6) are presented in Table XII. Study area 2 is grazed twice yearly during calving periods for about four months while study area 6 is grazed heavily the year around.

Andropogon scoparius and *A. Gerardi* showed greater maximum height and average height on the poor condition pasture in June, 1961, than on

TABLE XI

AVERAGE DIFFERENCES IN MEASUREMENTS FOR VIGOR OF GRASSES FOUND ON NATIVE GRASS MEADOW AND CEMETERY
FIGURES REPRESENT MEASUREMENTS OF CEMETERY SUBTRACTED FROM NATIVE GRASS MEADOW

	Max. Ht. (cm)		Avg. Ht. (cm)		Leaf Length (cm)		Leaf Width (mm)		No. Leaves	
Species	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62
Asc	12.5**	17.0**	4.3**	17.2**	4.0**	10.8*	0.3	0.0	0	0
Age	15.3**	30.1**	6.5**	32.0**	9.0**	10.8**	1.4	0.0	0	1
Snu	18.2**	22.2**	13.7**	20.3**	8.4**	17.1**	-0.6	0.7	0	1
Pvi	23.0**	40.2**	7.0**	28.8**	10.0**	20.6**	0.5	0.5	0	0
	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62
Asc	27.2**	14.3**	17.8**	12.5**	18.0**	11.5**	2.0	-0.4	1	0
Age	29.4**	30.1**	25.1**	32.7**	11.4**	20.5**	0.8	0.4	1	-1
Snu	15.5**	16.7**	7.0**	16.1**	2.0	8.6*	2.2	0.5	0	0
Pvi	34.0**	27.6**	23.4**	22.5**	12.1**	14.7**	1.0	0.9	0	0
	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62
Asc	-0.8	14.8**	11.6**	12.0**	9.0**	10.7**	0.1	-0.1	3	0
Age	10.0†	19.1**	24.8**	31.9**	12.6**	15.7**	1.4	1.0	4	0
Snu	1.9	14.2**	14.5**	13.3**	16.4**	10.4**	1.2	-0.2	0	0
Pvi	35.2**	13.3**	28.6**	27.1**	11.4**	10.4**	-1.1	2.1	-1	-2

Asc - *Andropogon scoparius*
Age - *Andropogon Gerardi*
Snu - *Sorghastrum nutans*
Pvi - *Panicum virgatum*

* Significant at the .05 level
** Significant at the .01 level
† Significant at the .1 level

Figure 13. Photo of native grass meadow on June 1, 1962, showing the vigorous growth of grasses. The meadow is usually mowed in late June or early July.

Figure 14. Photo of the annually mowed cemetery on June 1, 1962. The cemetery is usually mowed in late August. The grasses exhibit low vigor compared to the native grass meadow.

TABLE XII

AVERAGE DIFFERENCES IN MEASUREMENTS FOR VIGOR OF GRASSES FOUND ON THE LOAMY PRAIRIE PASTURE IN EXCELLENT CONDITION (STUDY AREA 2) AND THE LOAMY PRAIRIE PASTURE IN POOR CONDITION (STUDY AREA 6). FIGURES REPRESENT MEASUREMENTS OF POOR CONDITION PASTURE SUBTRACTED FROM EXCELLENT CONDITION PASTURE

	Max. Height (cm)		Avg. Height (cm)		Leaf Length (cm)		Leaf Width (mm)		No. Leaves	
	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62
Asc	-2.0	16.1**	-12.0**	11.2**	-2.5	1.0	-1.1	-0.6	1	1
Age	-5.8	17.0**	-7.0**	16.1**	-0.6	8.8**	0.7	-0.4	0	-1
Snu	4.9	7.7**	9.5**	14.4**	7.7**	9.0**	0.2	-0.3	0	-1
Pvi	4.3	28.4**	-10.5**	30.7**	9.2**	15.8**	0.3	0.4	0	-1
	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62
Asc	15.0**	9.9*	13.8**	6.7**	1.7	8.3†	-1.0	-0.6	-1	1
Age	11.0**	3.7	12.7**	9.8**	3.0	4.7	1.3	-0.2	-3	-1
Snu	11.0**	14.0**	7.0**	7.5**	7.4	8.9**	0.8	-0.3	2	0
Pvi	14.5**	41.3**	13.3**	30.6**	3.0	5.0**	0.8	-0.3	2	1
	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62
Asc	-2.4	-17.0**	9.0*	5.2†	10.0**	21.6**	0.5	0.1	0	-1
Age	-16.0**	-9.5**	-7.8†	10.6**	-1.8	15.4**	0.5	1.3	1	1
Snu	1.0	13.7**	6.0	2.4	1.5	6.9*	0.1	1.2	1	1
Pvi	0.7	29.6**	-2.8	30.6**	2.4	5.9**	1.4	1.4	0	0

Asc - _Andropogon scoparius_
Age - _Andropogon Gerardi_
Snu - _Sorghastrum nutans_
Pvi - _Panicum virgatum_

* Significant at the .05 level
** Significant at the .01 level
† Significant at the .1 level

the excellent condition pasture (Table XII). But in June, 1962, the maximum and average heights of these species were significantly greater at the .01 level on the excellent condition pasture. These species were significantly greater in both maximum and average heights on the loamy prairie pasture in excellent condition in July of both years, but in August of both years the maximum and average heights were generally greater in the poor condition pasture. Sorghastrum nutans and Panicum virgatum were generally greater in both maximum and average heights on the excellent condition pasture, and in July of both years the heights were significant at the .01 level.

Average measurements of the grasses on the two study areas are in Appendix A, and the differences in growth of the grasses are in Figures 15 and 16.

Measurement data to determine differences in vigor of the same species on the loamy prairie pasture in high good range condition (study area 4) and the loamy prairie pasture in low good range condition (study area 5) are shown in Table XIII. Average measurements of the grasses on the two study areas are in Appendix A.

In general, the grass species in the pasture in low good range condition produced a slightly greater maximum height, average height, and leaf length than the same species on the pasture in high good range condition. Differences in leaf width and number of leaves were about the same on both areas.

The more vigorous growth on the low good condition pasture was again probably due to the density being lower than on the pasture in high good condition. The grass species listed represented 60.2 per cent of the total composition on the low good condition pasture, while the same species made up 71.2 per cent of the composition on the high good pasture.

Figure 15. Loamy prairie pasture in excellent condition on July 5, 1962, showing the vigorous growth of grasses. Note the absence of forbs.

Figure 16. Loamy prairie pasture in poor range condition on August 3, 1962. Forbs were very abundant in this pasture, and the density of desirable grasses was very low.

TABLE XIII

AVERAGE DIFFERENCES IN MEASUREMENTS FOR VIGOR OF GRASSES FOUND ON THE LOAMY PRAIRIE PASTURE IN HIGH GOOD CONDITION (STUDY AREA 4) AND THE LOAMY PRAIRIE PASTURE IN LOW GOOD CONDITION (STUDY AREA 5). FIGURES REPRESENT MEASUREMENTS OF STUDY AREA 4 SUBTRACTED FROM STUDY AREA 5

Species	Max. Height (cm)		Avg. Height (cm)		Leaf Length (cm)		Leaf Width (mm)		No. Leaves	
	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62	June/61	June/62
Asc	1.0	4.9	16.4	4.5	-0.5	4.4	-0.6	-0.2	2	1
Age	2.4	13.5	14.7	7.6	1.3	7.9	-1.5	-0.3	0	-1
Snu	8.5	13.0	14.3	8.2	11.0	10.5	0.0	1.0	1	0
Pvi	9.8	16.4	22.3	10.9	1.8	6.6	-0.8	1.4	2	0
	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62	July/61	July/62
Asc	-8.0	2.7	-5.2	1.4	2.3	3.6	0.0	-0.2	0	0
Age	6.0	7.8	8.3	3.5	2.0	6.2	0.0	0.6	0	-1
Snu	-3.4	-0.8	4.6	2.8	10.4	-0.7	0.6	0.0	0	0
Pvi	24.7	21.1	1.4	7.0	-3.0	8.3	-1.5	0.5	0	0
	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62	Aug./61	Aug./62
Asc	1.1	8.8	0.8	3.3	0.6	-2.2	-0.3	0.0	-5	1
Age	2.5	12.7	4.4	5.6	10.5	9.4	0.7	1.2	-1	0
Snu	1.5	3.3	9.9	0.1	8.3	-0.7	0.4	1.2	0	0
Pvi	18.0	-1.2	15.8	-0.8	-1.8	-2.5	0.0	-0.4	0	0

Asc - *Andropogon scoparius*
Age - *Andropogon Gerardi*
Snu - *Sorghastrum nutans*
Pvi - *Panicum virgatum*

Not Significant

A slight increase in vigor is thus correlated with a slight decrease in density. This result is more evident in the two study areas discussed previously.

Since Sporobolus asper was quite abundant (making up 25.3 per cent of the vegetative composition) in the low good condition pasture, it was measured separately to provide a comparison with the desirable grasses that were measured. Without exception, Sporobolus asper exhibited the greatest average height of any of the grasses, and in general this species showed the greatest maximum height. In July of 1961 and 1962, and in August of 1962, Panicum virgatum grew to a greater maximum height. The leaves of Sporobolus asper were longer than those of the other grasses, and in general this species produced as many or more leaves than did the other species. The leaves of Sporobolus asper were wider than those of Andropogon scoparius.

Photos of the two areas showing the structure of the vegetation are shown in Figures 17 and 18.

Measurements of maximum height, average height, leaf length, leaf width and number of leaves were made on the five most predominant grasses found on the claypan site (Table XIV).

Buchloë dactyloides and Bouteloua gracilis were the most abundant species in this study area, together making up 80.2 per cent of the total composition. According to Weaver and Albertson (1956) these species are of far greater drought resistance than most plains grasses.

The average foliage height of Bouteloua gracilis exceeded that of Buchloë dactyloides throughout the summer months, and the numerous slender fruiting culms reached heights varying from 29.0 cm in July, 1961, to 53.0 cm in August, 1962. On Buchloë dactyloides the fruiting culms varied from 19.5 cm in July, 1961, to 23.8 cm in August, 1961. The leaves of Bouteloua

Figure 17. Loamy prairie pasture in high good range condition on July 5, 1962. The "major four" in this study area represented 71.2 per cent of the composition.

Figure 18. Loamy prairie pasture in low good range condition on July 5, 1962. Note the presence of more forbs than in the above photo, the most conspicuous forb being Vernonia Baldwinii.

TABLE XIV

MEASUREMENTS FOR VIGOR OF GRASSES ON THE CLAYPAN SITE FOR JUNE, JULY AND AUGUST OF 1961 AND 1962

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. of Leaves
		June, 1961			
Bda	16.0	9.0	7.3	1.7	5
Bgr	26.5	12.8	15.0	2.0	4
Cve	16.5	8.0	8.9	3.3	5
Sas	45.0	22.0	21.3	3.0	5
Spa	36.7	11.0	7.3	2.7	6
		July, 1961			
Bda	19.5	12.0	11.6	2.0	5
Bgr	29.0	15.5	17.0	2.7	5
Cve	20.0	12.0	9.5	4.0	8
Sas	52.7	40.5	38.5	4.3	6
Spa	55.0	16.0	8.5	3.0	10
		Aug. 1961			
Bda	23.8	16.2	11.7	2.0	7
Bgr	46.5	29.0	15.2	2.5	7
Cve	24.0	16.0	9.4	3.8	8
Sas	78.4	62.2	43.5	4.7	7
Spa	60.2	17.3	8.4	3.3	7
		June, 1962			
Bda	20.3	8.7	7.9	2.0	5
Bgr	24.3	17.0	12.9	2.1	4
Cve	18.1	12.0	7.2	3.5	6
Sas	57.4	40.2	26.2	3.0	5
Spa	51.0	18.9	6.7	2.7	5
		July, 1962			
Bda	21.3	11.5	8.6	2.0	6
Bgr	35.9	24.9	16.7	2.0	5
Cve	27.0	16.2	9.4	3.3	7
Sas	71.1	58.5	36.6	3.3	7
Spa	68.5	22.5	10.4	2.9	7
		Aug. 1962			
Bda	22.7	17.8	11.3	2.0	7
Bgr	53.0	36.3	17.3	2.0	7
Cve	32.4	19.5	10.2	3.0	10
Sas	89.5	70.7	47.4	4.6	10
Spa	70.4	26.6	8.3	3.2	11

Bda - <u>Buchloë dactyloides</u>
Bgr - <u>Bouteloua gracilis</u>
Cve - <u>Chloris verticillata</u>
Sas - <u>Sporobolus asper</u>
Spa - <u>Schedonnardus paniculatus</u>

gracilis, largely confined to the base of the plant, ranged in length from 12.9 to 17.3 cm and in width from 2.0 to 2.5 mm. The narrow leaves of *Buchloë dactyloides* occur mostly near the soil surface and ranged from 7.3 to 11.7 cm in length and from 1.7 to 2.0 mm in width. The number of leaves produced by these two species was generally the same.

Sporobolus asper was the tallest growing grass species on the claypan site. It reached a maximum height of 89.5 cm and an average height of 70.7 cm in August, 1962. The leaves of this species were longer and wider than any of the other grasses, but the number of leaves produced per plant was generally the same as the others.

Chloris verticillata and *Schedonnardus paniculatus* were other abundant species growing on the claypan site. The growth measurements of *Chloris verticillata* were generally the same as those of *Buchloë dactyloides*, the only significant difference being that the leaves of *C. verticillata* were about twice as wide as those of *B. dactyloides*.

Inflorescence Production

The maximum and average height of fruiting culms of the "major four" were measured in each of the loamy prairie study areas and the number of fruiting culms per plant and inflorescences per fruiting culm were counted. Seed production was not determined, since during both years of this study there were no stands productive enough to warrant counting. This is not unusual in that during a nine-year study throughout Kansas (1937-1945) native bluestem prairies produced seed in only three of these years (Cornelius, 1950). Distribution of rainfall may have been the important factor here since critical periods are from four to six weeks before flowering until two weeks after flowering.

It has been found that the number of fruiting culms was correlated with vigor (Blaisdell and Pechanec, 1949). This factor, as well as maximum and average height of the fruiting culms, should provide pertinent information as to differences between the study areas.

The maximum and average heights of the fruiting culms were less in 1962 than in the previous year (Table XV). This can be correlated with forage production in that a marked decrease in production occurred between 1961 and 1962 (Tables VI and IX). Although the heights of the fruiting culms were less in 1962, the number of fruiting culms per plant and number of inflorescences per fruiting culm were generally greater in 1962 than in the previous year.

Sorghastrum nutans rated number one in maximum and average height of fruiting culms, while Andropogon scoparius produced the most fruiting culms per plant and inflorescences per fruiting culm. Andropogon Gerardi rated second in both of these categories. Sorghastrum nutans and Panicum virgatum produced one fruiting culm per plant and one inflorescence per fruiting culm on all of the study areas.

The native grass meadow (study area 1) exhibited the most vigorous growth of the fruiting culms. It was found in this area that the fruiting culms of Andropogon Gerardi grew an average of 1 5/8 inches per day. Study area 2, in excellent range condition, showed the next most vigorous growth of fruiting culms (Table XV).

Although in excellent range condition, the annually mowed cemetery (study area 3) exhibited very low vigor as determined by fruiting culm growth and also fruiting culms per plant and inflorescences per fruiting culm.

As for study area 4 (high good), study area 5 (low good), and study area 6 (poor), the general trend was toward an increase in fruiting culm height with a decrease in range condition. This was probably due to

TABLE XV

MEASUREMENTS FOR VIGOR SHOWING THE MAXIMUM AND AVERAGE HEIGHTS OF THE PLANTS, FRUITING CULMS PER PLANT, AND INFLORESCENCES PER FRUITING CULM

	Maximum Height cm		Average Height cm		Fruiting Culms Per Plant		Inflores-cences Per Fruit-ing Culm		Maximum Height cm		Average Height cm		Fruiting Culms Per Plant		Inflores-cences Per Fruit-ing Culm	
	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962
	1 - Native Meadow								2 - Excellent							
Asc	87.4	67.6	74.8	55.4	1	2	8	7	91.4	79.6	74.1	62.4	1	1	4	5
Age	164.8	115.5	121.8	93.4	1	1	6	4	128.5	96.4	90.9	78.9	1	1	4	5
Snu	168.3	129.1	120.2	97.9	1	2	1	1	146.9	137.8	115.9	107.8	1	1	1	1
Pvi	128.0	96.1	95.0	84.8	1	1	1	1	122.3	100.0	93.8	70.8	1	1	1	1
	3 - Cemetery								4 - High Good							
Asc	91.7	78.8	77.0	61.8	1	2	3	4	89.6	78.6	66.6	66.0	1	2	4	6
Age	122.0	88.3	93.0	70.5	1	1	5	2	106.0	104.3	83.1	88.6	1	1	4	5
Snu	125.0	111.5	103.9	80.3	1	1	1	1	127.7	120.4	99.3	82.8	1	1	1	1
Pvi	100.0	82.8	73.0	57.7	1	1	1	1	104.9	81.1	86.0	63.0	1	1	1	1
	5 - Low Good								6 - Poor							
Asc	91.5	76.1	75.9	67.4	1	2	4	5	97.3	85.5	78.0	67.3	1	2	4	7
Age	122.1	104.5	84.5	81.3	1	1	2	4	135.4	123.6	105.8	84.8	1	1	4	3
Snu	132.2	121.3	101.4	92.5	1	1	1	1	137.8	113.4	105.8	88.3	1	1	1	1
Pvi	102.0	100.3	81.4	76.0	1	1	1	1	100.0	92.7	81.0	62.2	1	1	1	1

Asc - *Andropogon scoparius*
Age - *Andropogon Gerardi*
Snu - *Sorghastrum nutans*
Pvi - *Panicum virgatum*

competition between plants of the same species being decreased as the stands became less dense.

Vigor of Forbs

The dominant plants of the study areas were grasses, but forbs were quite abundant and formed a conspicuous part of the vegetation. The following list includes the most important forb species which will be discussed somewhat in the order of their common occurrence throughout the study areas. The number in parentheses indicates the number of the study area on which the species occurred as one of the five most abundant forbs:

Ambrosia psilostachya	(6)
Aster ericoides	(5)
Vernonia Baldwinii	(4)
Salvia azurea	(3)
Gutierrezia dracunculoides	(3)

Ambrosia psilostachya was the most abundant forb on all study areas except the annually mowed cemetery (study area 3). It was found commonly, and often abundantly, in the high good and lower condition areas. In June this species was at least 10 inches tall, and in mid-August when the last measurements were taken, it had at least doubled in height. In 1961 this species exhibited the most vigorous growth, as determined by maximum and average height, on study areas 1, 5, 6, 4, 2 and 7, respectively. In 1962 the sequence was 2, 5, 4, 1, 6 and 7. There was no significant difference between the leaf length and leaf width of this species on the various study areas, but the general trend was toward a production of more leaves per plant as the areas decreased in range condition.

Aster ericoides also occurred throughout the study areas. Although this species was present in the native grass meadow (study area 1), and the pasture in low good range condition (study area 5), it did not rate as one of the five most abundant forbs, and thus was not measured on these two areas. In 1961 this species was most vigorous, as determined by maximum and average height, on study areas 4, 2, 7, 6 and 3 respectively. In 1962 the sequence was 2, 7, 4, 6 and 3.

Vernonia Baldwinii was quite abundant on four of the seven study areas and was quite conspicuous by its tall, coarse growth forms. When measurements were first begun in June, this leafy perennial was already at least 2 feet in height, and the mature plants, with great clusters of purple flowers which appeared after mid-summer, were 3 to 4 feet tall when the last measurements were taken in mid-August. This species was in general most vigorous on the study area in low good range condition (study area 5) and the poor condition pasture (study area 6).

Salvia azurea was another important forb throughout the study areas. Since it was one of the dominant forbs in three of the areas, it was measured. In August this species attained an average maximum height in excess of 3 feet on the native grass meadow and poor condition pasture, and about 2 feet on the low good condition pasture. The leaves of this plant doubled in number from June to August.

Gutierrezia dracunculoides is generally no problem on well-managed pastures with vigorous stands of desirable grasses, but this species was important enough to measure growth rate on three of the study areas. It was quite abundant on the claypan site.

In August the tough, woody stems of this annual reached a maximum height of 2½ feet on the high good condition pasture, and 2 feet on the claypan site. The leaves increased in number from about 40 in June to an indefinite number ranging anywhere from 800 to 1300 in August.

The forb composition on the annually mowed cemetery was quite different from those on the other study areas, as only *Aster ericoides* was found commonly on the other areas. The measurements of forbs on the cemetery, as well as other less important forbs found throughout the other study areas, are presented in Appendix B.

Soil Moisture

Water content of the soils in the various study areas apparently played no significant role in this study since there appeared to be practically no moisture stress during either summer. If, however, soil moisture had been determined for the month of May, there would surely have been a significant difference between the two summers. There was practically no rainfall during May, 1962, and this would probably account for the decrease in forage production in 1962.

Moisture at all depths was generally more abundant in 1962 than in 1961 (Table XVI) during the month of June. On the other hand, moisture content of the soils was greater in 1961 than in 1962 during July. In fact, during a few days in July of 1962 the plants appeared to show moisture stress, but this was only apparent for a short while in that two rains of over one inch fell during the last week of July.

The per cent soil moisture during August was somewhat higher than either of the preceding months, and this was true for both summers.

Soil moisture was generally greatest in the third foot of soil. The only exception to this was the pasture in poor range condition (study area 6). Per cent moisture was also quite high in the second foot of soil, and in some cases was more moist than the three foot layer. In the poor condition pasture the three foot layer exhibited the least water content, with the two foot layer being almost as dry. In all study areas,

TABLE XVI

SOIL MOISTURE AT DIFFERENT DEPTHS FOR JUNE, JULY AND AUGUST
FIGURES REPRESENT AVERAGE PER CENT

Area	0-6" 1961	0-6" 1962	6-12" 1961	6-12" 1962	12-24" 1961	12-24" 1962	24-36" 1961	24-36" 1962
				June				
1-Meadow	15.4	25.7	20.1	21.5	23.3	25.6	25.4	26.5
2-Excellent	25.4	23.7	18.6	24.7	19.4	26.2	21.4	22.7
3-Cemetery	20.3	20.8	19.3	22.2	18.7	22.5	23.7	21.8
4-High Good	17.3	19.0	20.0	26.1	24.8	26.2	27.6	23.2
5-Low Good	20.6	23.8	25.4	20.5	30.0	22.8	31.9	23.7
6-Poor	20.8	21.4	17.6	20.3	23.0	18.2	21.2	13.9
7-Claypan	13.2	13.6	14.3	12.0	24.1	17.0	21.2	23.2
				July				
1-Meadow	13.0	24.7	17.0	17.1	23.1	19.6	24.5	21.2
2-Excellent	13.9	18.6	18.6	19.4	27.2	25.4	23.5	19.5
3-Cemetery	14.5	16.6	14.9	13.0	19.8	23.1	27.1	22.5
4-High Good	15.2	15.1	18.4	17.6	24.0	22.0	27.4	24.2
5-Low Good	14.4	15.1	16.3	15.2	24.7	17.5	20.5	22.0
6-Poor	16.8	21.6	20.0	20.8	21.5	16.8	19.8	7.2
7-Claypan	14.2	13.4	17.9	12.9	25.4	19.0	21.6	25.1
				August				
1-Meadow	18.7	19.7	21.0	22.0	25.2	24.1	25.0	23.1
2-Excellent	21.0	22.9	22.0	23.1	26.0	24.0	26.1	25.2
3-Cemetery	23.2	16.0	25.4	16.5	24.4	19.5	29.1	22.0
4-High Good	17.6	18.7	20.9	23.1	24.8	26.0	27.5	23.8
5-Low Good	20.2	16.0	22.2	15.0	24.9	16.3	20.5	21.0
6-Poor	20.2	15.8	26.0	19.3	26.6	21.0	25.2	18.6
7-Claypan	12.5	8.0	23.1	12.6	23.2	18.5	21.0	24.8

the first and second six inches of soil showed approximately the same water content. Only in the native grass meadow did these two layers vary to any degree.

The first foot of soil was driest in the claypan site. The moisture content of the first six inches was generally between 5 and 10 per cent, while the water content of the second six inches tended to fluctuate between 10 and 15 per cent. Once beyond the clay layer, the soil was quite moist.

CHAPTER VII

DISCUSSION AND SUMMARY

This study was conducted on Adams' Ranch, a 33,000 acre tract of land located in the northern part of Osage County, Oklahoma. During normal rainfall years the native vegetation in excellent condition will easily support a cow and her calf year-long on ten acres. The only supplemental feed necessary is protein during winter.

As the name Osage Hills implies, this is a hilly, rolling region, and native grass is the vegetation best suited for these rough lands. *Andropogon scoparius*, *A. Gerardi*, *Sorghastrum nutans* and *Panicum virgatum* are the four most important grass species that dominate the region, often making up 70-90 per cent of the total vegetative composition on a well-managed loamy prairie site.

The soils of the region have developed from limestone and clay shales of the Lower Permian and Upper Pennsylvanian Age. The loamy prairie site is the most important in the area and is characterized by a fertile, deep upland soil. This soil is nearly black, highly granular, permits good root penetration, but moisture penetration is slow. The slow permeability of the soils, as well as the rolling topography with many steep winding ravines, makes difficult the cultivation of forage crops. Claypan soils also exist over much of the region and were of concern in this study.

The study was designed to determine forage production, vegetative composition and plant vigor on seven different areas of bluestem rangeland.

The study areas were selected on basis of range condition. Vegetative composition differed on each area due to variations in past grazing use.

Six of the areas were on the loamy prairie range site and were comparable in climate and topography. The seventh study area, the claypan site, was studied separately. Vegetative composition, basal density, forage production, plant vigor and soil moisture were determined for each study area.

Vegetative composition was used to determine the range condition of the various study areas as outlined by the Soil Conservation Service guide to range condition classification. The vegetation on study areas 1, 2 and 3 was predominantly made up of climax plants, but on areas 4, 5 and 6 the climax grasses were less abundant due to increased grazing, and the areas had regressed to a lower range condition class.

Species composition appeared to be a more important criteria in determining condition than basal density. In some cases basal density was found to increase as regression from high range condition occurred. This was often dependent upon the species involved in the secondary succession. The basal density on the poor condition pasture was as high as the pasture in high good condition and was greater than the pasture in low good condition. This was due to the increase of secondary species such as Buchloë dactyloides and Bouteloua gracilis, which are low-growing, turf-forming grasses usually giving high basal density values.

Yields of 4000 to 5000 pounds of dry matter per acre per season were produced on the excellent range condition areas, and yields near 3000 pounds were common on the other study areas. If forage production is to be used as one of the criteria for determining range condition, the species making up this production must be considered. For example, the poor condition pasture produced just as much total forage per acre in 1962 as did the excellent condition pasture, but the species making up the production were entirely different. The major forage producers in the excellent condition pasture were Andropogon Gerardi, A. Scoparius, Sorghastrum nutans and Panicum virgatum, while the major forage producers in the poor condition pasture were Buchloë dactyloides, Bouteloua gracilis, Bothriochloa saccharoides and Andropogon scoparius. Forbs and annual grasses also contributed greatly to the production in the poor condition pasture.

Species making up the major portion of the composition in an area were found to not necessarily contribute the most to forage production. Due to its larger growth form, Andropogon Gerardi generally produced more forage per acre than A. scoparius even though the per cent composition of A. Gerardi was somewhat less.

Variation in yield between 1961 and 1962 may have been due chiefly to variations in the amount of rainfall which fell during the month of May. There were only 1.86 inches of rainfall during May, 1962, and the forage production for that year was below 1961 when rainfall for May amounted to 5.66 inches.

A trend showing an increase in fruiting culm height with a decrease in range condition indicates that height of fruiting culms is not positively correlated with range condition. The fruiting culms produced by grasses on the poor condition pasture grew to a greater height than those on the excellent condition pastures. This was probably due to competition between plants of the same species being decreased as the stands became less dense. Leaf growth measurements, however, showed that height of leaf growth was one of the most consistent indicators of plant vigor. Statistical analysis showed that maximum and average heights of leaf growth were significantly greater for plants in the excellent condition pasture as compared to the poor condition pasture. Leaf width and number of leaves, however, were shown not to be correlated with vigor.

Results concerning forage production and vigor of plants on the native meadow and the cemetery indicate that date of mowing may have some influence on these factors. The native meadow is usually mowed sometime during the last week of June or the first week of July. The cemetery is usually mowed the last of August or first of September, and this has been the common practice for many years. In both study years the native meadow produced twice as much forage as the cemetery. Removal of top growth late in the growing season appears to be effective in reducing the plant's ability to produce forage the following year. Since *Sorghastrum nutans* is the latest maturing grass of the "major four," late mowing may be less detrimental to this species than the others. The per cent composition of *Sorghastrum nutans* was higher in the cemetery than in the native meadow. Even though the plants in the cemetery exhibited very low vigor, a decline in plant vigor was not accompanied by a decrease in range condition.

Water content of the soils during June, July and August of both summers apparently played no significant role in this study since there appeared to be practically no moisture stress during either summer. If soil moisture had been determined for the month of May, however, there probably would have been a significant difference between the two years.

LITERATURE CITED

Aldous, A. E. 1930. Effect of different clipping treatments on the yield and vigor of prairie grass vegetation. Ecology 11: 752-759.

Anderson, K. L. 1953. Utilization of grasslands in the Flint Hills of Kansas. Jour. Range Mgmt. 6(2): 86-93.

Biswell, H. H. and J. E. Weaver. 1933. Effect of frequent clipping on the development of roots and tops of grasses in prairie sod. Ecology 14: 368-390.

Blaisdell, J. P. and J. F. Pechanec. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsam root. Ecology 30: 298-305.

Brown, Dorothy. 1954. Methods of surveying and measuring vegetation. Commonwealth Agricultural Bureau. Bucks, England. 223 pp.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monog. 1: 99-188.

Cook, C. W. and C. J. Goebel. Summer, 1962. The association of plant vigor with physical stature and chemical content of desert plants. Ecology 43(3): 543-546.

Cornelius, D. R. 1950. Seed production of native grasses. Ecol. Monog. 20: 3-29.

Dwyer, D. D. 1958. An annotated plant list for Adams' Ranch. Unpubl. M. S. thesis. Fort Hays Kansas State College, Hays.

Dyksterhuis, E. J. 1949. Condition and management of range land based on quantitative ecology. Jour. Range Mgmt. 2: 104-115.

Evans, R. A. and M. B. Jones. 1958. Plant height times ground cover versus clipped samples for estimating forage production. Agron. Jour. 50: 504-506.

Goebel, C. J. and C. W. Cook. 1960. Effect of range condition on plant vigor, production, and nutritive value of forage. Jour. Range Mgmt. 13:307.

Goodall, D. W. 1952. Some considerations in the use of point quadrats for analysis of vegetation. Aust. Jour. Sci. Res. 5: 1-41.

Gould, F. W. 1959. Transfers from Andropogon to Bothriochloa. The Southwestern Naturalist 3: 212.

Gray, Fenton and H. M. Galloway. 1959. Soils of Oklahoma, Miscellaneous publication 56. Oklahoma State University, Stillwater, Oklahoma.

Harlan, Jack R. 1960. Native Range. Okla. Expt. Sta. Bull. B-547. 34 pp.

Heady, H. F. 1957. The measurement and value of plant height in the study of herbaceous vegetation. Ecology 38: 313-320.

Hopkins, H. H. 1956. Effects of mulch on yield and cover in mixed prairie. Trans. Kans. Acad. Sci. 59: 71-75.

Humphrey, R. R. 1949. Field comments on the range condition method of forage survey. Jour. Range Mgmt. 2(1): 1-10.

Jameson, D. A. and D. L. Huss. 1959. The effect of clipping leaves and stems on number of tillers, herbage weights, root weights, and food reserves of little bluestem. Jour. Range Mgmt. 12: 122-126.

Johnson, W. M. 1956. The effect of grazing intensity of plant composition, vigor, and growth of pine-bunchgrass ranges in central Colorado. Ecology 37: 790-798.

Levy, E. B. and E. A. Madden. 1933. The point method of pasture analysis. N. Z. Jour. Agric. 46: 267-279.

National Reserach Council. 1962. Basic problems and techniques in range research. National Academy of Sciences.

Parker, K. W. 1954. Application of ecology in the determination of range condition and trends. Jour. Range Mgmt. 7: 14-23.

Robertson, J. H. 1933. Effect of frequent clipping on the development of certain grass seedlings. Plant Phys. 8: 425-447.

Short, L. R. and E. J. Woolfolk. 1956. Plant vigor as a criterion of range condition. Jour. Range Mgmt. 9: 66-69.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of statistics. McGraw-Hill Book Company, Inc., New York.

Stoddart, L. A. and A. D. Smith. 1955. Range Management. McGraw-Hill Book Co., Inc., New York.

Tomanek, G. W. and F. W. Albertson. 1953. Some effects of different intensities of grazing on mixed prairies near Hays, Kansas. Jour. Range Mgmt. 6: 299-306.

__________. 1957. Variations in cover, composition, production, and roots of vegetation on two prairies in western Kansas. Ecol. Monog. 27: 267-281.

Voight, J. W. and J. E. Weaver. 1951. Range condition classes of native midwestern pasture: an ecological analysis. Ecol. Monog. 21: 39-60.

Waterfall, U. T. 1962. Keys to the Flora of Oklahoma. The Research Foundation. Botany and Plant Pathology Department, Oklahoma State University, Stillwater.

Weaver, J. E. 1954. North American Prairie. Johnsen Publ. Co., Lincoln, Nebraska.

Weaver, J. E. and F. W. Albertson. 1943. Resurvey of grasses, forbs, and underground plant parts at the end of the great drought. Ecol. Monog. 13: 63-117.

_________. 1956. Grasslands of the Great Plains. Johnsen Publ. Co., Lincoln, Nebraska.

Weaver, J. E. and F. E. Clements. 1938. Plant Ecology. McGraw-Hill Book Company, Inc., New York.

Weaver, J. E. and J. W. Crist. 1922. Relation of hardpan to root penetration in the great plains. Ecology 3: 237-249.

Weaver, J. E. and R. W. Darland. 1947. A method of measuring vigor of range grasses. Ecology 28: 146-162.

APPENDIX A

MEASUREMENTS OF GRASSES ON STUDY AREAS FOR THE SUMMERS OF 1961 AND 1962

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 1 - Native Meadow			
		June, 1961			
Asc	60.0	35.3	27.3	2.3	5
Age	71.3	43.0	32.0	7.4	6
Snu	78.0	44.0	37.2	7.4	4
Pvi	81.5	46.0	34.0	9.5	5
		July, 1961			
Asc	83.5	62.5	45.0	4.0	6
Age	94.0	74.7	42.0	7.4	8
Snu	85.8	65.0	40.0	6.3	5
Pvi	109.0	79.0	43.4	9.0	6
		August, 1961			
Asc	86.2	65.4	42.0	3.4	10
Age	138.5	82.0	57.6	9.0	11
Snu	100.3	77.5	55.0	10.2	7
Pvi	127.0	95.4	44.2	8.4	7
		June, 1962			
Asc	56.9	47.8	32.6	2.2	5
Age	86.8	70.5	33.8	5.8	6
Snu	74.0	60.0	39.3	6.7	5
Pvi	86.1	61.2	40.5	7.0	5
		July, 1962			
Asc	64.7	57.2	35.6	2.4	6
Age	90.4	78.4	47.8	6.4	7
Snu	76.3	63.3	41.4	7.1	6
Pvi	90.8	69.1	38.6	7.4	6
		August, 1962			
Asc	77.3	58.7	37.3	3.0	7
Age	114.7	83.7	48.5	7.0	9
Snu	89.0	68.2	46.9	7.5	8
Pvi	96.1	84.8	39.1	9.3	6

Asc - _Andropogon scoparius_
Age - _Andropogon Gerardi_
Snu - _Sorghastrum nutans_
Pvi - _Panicum virgatum_

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 2 - Excellent			
		June, 1961			
Asc	45.0	27.0	20.0	2.5	5
Age	45.7	26.0	24.0	7.0	7
Snu	55.7	38.0	32.0	8.5	4
Pvi	63.8	33.0	28.5	9.3	5
		July, 1961			
Asc	59.3	46.7	26.7	2.7	5
Age	76.0	58.7	33.3	8.3	7
Snu	68.0	51.0	35.0	9.3	7
Pvi	83.7	64.3	35.0	10.0	7
		August, 1961			
Asc	83.3	60.7	33.0	4.0	8
Age	123.0	53.6	38.2	7.5	8
Snu	89.0	64.0	35.0	9.4	7
Pvi	100.0	70.8	33.0	9.9	7
		June, 1962			
Asc	57.1	44.3	24.5	2.2	5
Age	59.8	49.6	30.1	5.5	5
Snu	59.8	49.7	34.7	6.8	4
Pvi	79.8	67.1	40.1	7.8	4
		July, 1962			
Asc	66.2	55.6	35.7	2.6	6
Age	74.3	60.0	38.6	6.2	7
Snu	74.7	54.9	42.8	8.0	6
Pvi	103.6	76.7	34.0	7.9	7
		August, 1962			
Asc	76.8	64.8	41.9	3.2	8
Age	103.2	68.0	48.2	7.7	10
Snu	94.3	67.0	43.7	9.2	8
Pvi	122.3	93.8	38.3	10.9	7
		Study Area 3 - Cemetery			
		June, 1961			
Asc	47.5	31.0	23.3	2.0	5
Age	56.0	36.5	23.0	6.0	6
Snu	59.8	30.3	28.8	8.0	4
Pvi	58.5	39.0	24.0	9.0	5
		July, 1961			
Asc	56.3	44.7	27.0	2.0	5
Age	64.6	49.6	30.6	6.6	7
Snu	70.3	58.0	38.0	8.5	5
Pvi	75.0	55.6	31.3	8.0	6

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 3 - Cemetery (Cont.)			
		August, 1961			
Asc	87.0	53.8	33.0	3.3	7
Age	128.5	57.2	45.0	7.6	7
Snu	98.4	63.0	38.6	9.0	7
Pvi	91.8	66.8	32.8	9.3	8
		June, 1962			
Asc	39.9	30.6	21.8	2.2	5
Age	56.7	38.5	23.0	5.8	5
Snu	51.8	39.7	22.2	6.0	4
Pvi	45.9	32.4	19.9	6.5	5
		July, 1962			
Asc	50.4	44.7	24.1	2.8	6
Age	60.3	45.7	27.3	6.0	8
Snu	59.6	47.2	32.8	6.6	6
Pvi	63.2	46.6	23.9	6.5	6
		August, 1962			
Asc	62.5	46.7	26.6	3.1	7
Age	95.6	51.8	32.8	6.0	9
Snu	74.8	54.9	36.5	7.7	8
Pvi	82.8	57.7	28.7	7.2	8
		Study Area 4 - High Good			
		June, 1961			
Asc	60.0	30.3	28.7	3.0	4
Age	60.8	33.3	31.0	7.0	6
Snu	54.7	35.5	29.7	8.7	4
Pvi	63.0	32.3	31.3	8.3	4
		July, 1961			
Asc	77.0	58.9	33.3	3.0	6
Age	61.0	42.7	32.0	7.0	7
Snu	74.0	54.0	38.0	9.0	5
Pvi	68.0	55.0	38.0	10.3	6
		August, 1961			
Asc	85.5	67.0	35.4	3.4	13
Age	97.5	60.8	35.6	6.3	9
Snu	78.5	56.3	40.0	8.2	7
Pvi	84.0	60.7	33.0	8.0	8
		June, 1962			
Asc	50.2	40.1	23.6	2.4	4
Age	50.3	40.2	21.9	5.4	6
Snu	51.8	39.3	25.0	6.2	4
Pvi	57.2	42.5	26.1	5.9	5

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 4 - High Good (Cont.)			
		July, 1962			
Asc	58.3	50.3	31.7	3.1	5
Age	66.6	53.7	33.4	5.7	7
Snu	72.4	49.9	34.4	7.2	5
Pvi	71.5	55.0	26.7	6.9	6
		August, 1962			
Asc	76.9	57.3	34.3	3.1	8
Age	92.4	62.4	40.3	5.8	9
Snu	81.3	59.2	43.7	7.6	7
Pvi	104.9	81.1	35.5	9.0	7
		Study Area 5 - Low Good			
		June, 1961			
Asc	61.0	46.7	28.2	2.4	6
Age	63.2	48.0	32.3	5.5	6
Snu	63.2	49.8	40.7	8.7	5
Pvi	72.8	54.6	33.1	7.5	6
Sas	80.2	56.3	43.4	4.0	5
		July, 1961			
Asc	69.0	53.7	35.6	3.0	6
Age	67.0	51.0	34.0	7.0	7
Snu	70.6	58.6	48.4	9.6	5
Pvi	92.7	56.4	35.0	8.8	6
Sas	89.4	59.8	49.3	4.0	6
		August, 1961			
Asc	86.6	67.8	36.0	3.1	8
Age	100.0	65.2	46.1	7.0	8
Snu	80.0	66.2	48.3	8.6	7
Pvi	102.0	76.5	31.2	8.0	8
Sas	104.0	83.1	60.3	4.1	8
		June, 1962			
Asc	55.1	44.6	28.0	2.2	5
Age	63.8	47.8	29.8	5.1	5
Snu	64.8	47.5	35.5	7.2	4
Pvi	73.6	53.4	32.7	7.3	5
Sas	77.5	57.2	46.8	4.1	6
		July, 1962			
Asc	61.0	51.7	35.3	2.9	5
Age	74.4	57.2	39.6	6.3	6
Snu	71.6	52.7	33.7	7.2	5
Pvi	92.6	62.0	35.0	7.4	6
Sas	91.2	72.0	45.3	4.4	7

Sas - _Sporobolus asper_

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 5 - Low Good (Cont.) August, 1962			
Asc	85.7	60.6	32.1	3.1	9
Age	105.1	68.0	49.7	7.0	9
Snu	84.6	59.3	43.0	8.8	7
Pvi	103.7	80.3	33.0	8.6	7
Sas	100.3	81.4	53.4	4.2	9
		Study Area 6 - Poor June, 1961			
Asc	47.0	39.0	22.5	3.6	4
Age	51.5	33.0	24.6	6.3	7
Snu	50.8	28.5	24.3	8.3	4
Pvi	59.5	43.5	19.3	9.0	5
		July, 1961			
Asc	44.3	32.9	25.0	3.7	6
Age	65.0	46.0	30.3	7.0	10
Snu	57.0	44.0	27.6	8.5	5
Pvi	69.2	51.0	32.0	9.2	5
		August, 1961			
Asc	85.7	51.7	23.0	3.5	8
Age	139.0	61.4	40.0	7.0	7
Snu	88.0	58.0	33.5	9.3	6
Pvi	99.3	73.6	30.6	8.5	7
		June, 1962			
Asc	41.0	33.1	23.5	2.8	4
Age	42.8	33.5	21.3	5.9	6
Snu	52.1	35.3	25.7	7.1	5
Pvi	51.4	36.4	24.3	7.4	5
		July, 1962			
Asc	56.3	48.9	27.4	3.2	5
Age	70.6	50.2	33.9	6.4	8
Snu	60.7	47.4	33.9	8.3	6
Pvi	62.3	46.1	29.0	8.2	6
		August, 1962			
Asc	93.8	59.6	20.3	3.1	9
Age	112.7	57.4	32.8	6.4	9
Snu	80.6	64.6	36.8	8.0	7
Pvi	92.7	62.2	32.4	9.5	7

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 6 - Poor			
		June, 1961			
Sas	48.0	25.0	24.3	3.0	5
Bda	18.0	9.7	11.7	2.0	4
Bsa	65.0	51.0	10.5	6.3	7
Bgr	27.0	15.0	16.0	2.0	4
Cve	17.3	10.0	7.3	3.3	6
		July, 1961			
Sas	71.7	42.0	28.0	3.0	5
Bda	22.0	10.5	12.0	2.0	6
Bsa	86.7	42.5	14.7	6.5	11
Bgr	32.0	18.7	20.3	2.0	6
Cve	17.7	11.0	8.0	4.1	11
		August, 1961			
Sas	96.6	76.6	55.6	3.4	7
Bda	31.6	25.6	14.6	2.0	7
Bsa	106.5	64.6	12.5	6.0	13
Bgr	73.4	38.6	20.0	2.4	7
Cve	38.5	20.4	11.7	3.5	8
		June, 1962			
Sas	58.4	45.6	30.2	2.6	5
Bda	20.8	12.0	10.3	1.6	4
Bsa	68.7	32.3	13.9	6.3	5
Bgr	32.3	19.7	12.6	2.0	4
Cve	24.9	13.5	11.1	3.3	5
		July, 1962			
Sas	77.8	63.3	43.6	4.6	8
Bda	29.9	16.3	11.9	2.0	6
Bsa	90.3	45.2	14.8	5.3	7
Bgr	38.5	27.8	17.7	2.2	6
Cve	32.3	18.1	11.4	3.6	8
		August, 1962			
Sas	99.5	82.4	59.1	3.6	9
Bda	33.0	20.2	12.4	2.0	7
Bsa	113.8	73.6	13.1	6.1	9
Bgr	75.7	40.5	18.3	2.0	6
Cve	44.4	29.0	12.3	3.8	8

Sas - *Sporobolus asper*
Bda - *Buchloë dactyloides*
Bsa - *Bothriochloa saccharoides*
Bgr - *Bouteloua gracilis*
Cve - *Chloris verticillata*

APPENDIX B

MEASUREMENTS OF FORBS ON STUDY AREAS FOR THE SUMMERS OF 1961 AND 1962

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 1 - Native Meadow			
		June, 1961			
Aps	39.0	30.0	6.5	31.0	13
Pte	65.0	43.0	2.1	5.0*	Indef.
Vba	45.0	32.0	9.8	32.3	20
Saz	53.7	38.7	8.0	12.7	40
		July, 1961			
Aps	63.5	52.0	8.4	36.0	27
Pte	67.0	57.0	2.3	5.3*	Indef.
Vba	102.0	71.0	9.0	27.0	46
Saz	67.0	44.0	7.4	12.7	46
		August, 1961			
Aps	75.7	59.0	6.3	38.1	72
Pte**	---	---	---	---	---
Vba	99.3	76.0	8.8	30.8	46
Saz	108.3	73.5	6.2	6.0	58
		June, 1962			
Aps	29.9	21.6	4.6	24.4	12
Pte	68.3	51.4	3.2	30.5	Indef.
Vba	73.9	32.3	5.8	20.0	18
Saz	40.5	27.3	4.9	7.2	27
		July, 1962			
Aps	36.3	28.0	6.5	37.5	78
Pte	75.5	56.8	3.2	35.8	Indef.
Vba	96.4	75.2	9.3	36.7	59
Saz	72.3	53.0	9.9	12.3	111
		August, 1962			
Aps	52.4	36.0	6.3	34.3	120
Pte**	---	---	---	---	---
Vba	104.7	83.9	11.7	58.8	89
Saz	109.9	71.9	8.3	9.2	84

Aps - _Ambrosia psilostachya_ Pte - _Psoralea tenuiflora_
Vba - _Vernonia Baldwinii_ Saz - _Salvia azurea_

* Leaflet
** Past maturity

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 2 - Excellent June, 1961			
Aps	27.3	20.3	7.0	32.3	15
Aer	36.0	28.5	2.7	2.0	41
Keu	45.0	38.0	4.3	14.5	26
Gdr	41.7	27.3	3.0	4.0	40
		July, 1961			
Aps	40.7	31.0	5.1	22.7	30
Aer	39.0	30.0	2.3	2.0	743
Keu	51.0	34.5	5.0	15.3	37
Gdr	48.0	34.0	3.8	3.9	86
		August, 1961			
Aps	49.7	37.3	5.8	33.3	59
Aer	54.0	28.8	1.7	2.2	Indef.
Keu	67.8	49.7	3.7	12.8	110
Gdr	74.0	41.3	2.8	1.5	1200
		June, 1962			
Aps	36.2	23.5	5.7	30.4	15
Aer	46.4	33.4	3.0	2.4	Indef.
Keu	46.0	35.1	3.7	11.6	32
Gdr	34.1	22.7	2.7	3.2	25
		July, 1962			
Aps	50.6	37.3	6.1	30.4	36
Aer	52.7	36.4	2.0	2.3	Indef.
Keu	62.1	43.7	5.0	15.1	47
Gdr	54.0	41.5	3.5	2.5	131
		August, 1962			
Aps	58.3	42.2	6.5	31.7	98
Aer	57.4	40.6	3.1	2.7	Indef.
Keu	65.5	52.3	4.9	19.2	127
Gdr	70.4	50.7	3.8	2.9	Indef.
		Study Area 3 - Cemetery June, 1961			
Smi	35.6	27.3	7.9	10.0	27
Cgr	44.0	32.3	7.2	13.0	10
Aer	29.0	23.5	2.6	2.0	480
Eco	85.0	54.6	3.0	11.5	74
Ala	46.5	41.3	4.3	9.5	17

Aer - *Aster ericoides*
Gdr - *Gutierrezia dracunculoides*
Cgr - *Coreopsis grandiflora*
Ala - *Achillea lanulosa*
Keu - *Kuhnia eupatorioides*
Smi - *Solidago missouriensis*
Eco - *Euphorbia corollata*

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 3 - Cemetery (Cont.)			
		July, 1961			
Smi	58.5	37.0	7.5	10.5	30
Cgr	42.0	33.0	4.1	20.5	15
Aer	34.0	23.6	2.0	2.0	520
Eco	93.0	72.0	2.8	5.3	56
Ala	50.0	44.0	3.6	10.7	21
		August, 1961			
Smi	72.5	57.5	7.0	7.6	48
Cgr	40.0	34.0	5.0	40.0	28
Aer	40.0	30.6	3.0	2.0	Indef.
Eco	101.5	76.0	2.6	7.3	48
Ala	51.6	44.0	---*	---*	---*
		June, 1962			
Smi	33.0	22.5	7.4	8.5	15
Cgr	36.8	24.3	5.0	33.8	18
Aer	27.0	18.6	2.7	2.6	Indef.
Eco	65.4	41.6	3.1	7.6	60
Ala	40.9	13.1	11.8	13.2	4
		July, 1962			
Smi	49.1	26.2	5.1	8.5	23
Cgr	40.2	27.4	6.3	33.8	27
Aer	31.2	20.8	2.8	2.5	Indef.
Eco	75.3	57.5	3.4	6.8	60
Ala	40.7	15.8	13.5	19.2	6
		August, 1962			
Smi	57.8	31.3	7.2	10.5	29
Cgr	42.8	28.4	5.2	34.0	35
Aer	43.2	27.9	2.5	2.3	Indef.
Eco	87.2	70.3	3.3	8.1	62
Ala	41.4	17.6	14.2	16.0	5
		Study Area 4 - High Good			
		June, 1961			
Aps	30.7	22.5	6.6	40.8	16
Rhu	23.0	16.5	4.0	13.5	25
Vba	60.5	40.3	8.2	24.3	30
Gdr	33.0	23.5	3.5	3.7	36
Aer	36.5	27.3	3.0	2.3	Indef.

Rhu - *Ruellia humilis*

* Leaves gone

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 4 - High Good (Cont.)			
		July, 1961			
Aps	43.3	34.3	5.7	29.0	28
Rhu	24.0	20.3	4.6	13.0	29
Vba	92.0	50.0	6.7	26.3	41
Gdr	48.3	34.5	3.5	4.0	100
Aer	47.7	32.5	4.0	3.0	Indef.
		August, 1961			
Aps	48.3	38.6	6.3	33.3	69
Rhu	26.3	19.5	4.0	18.6	20
Vba	98.5	60.0	9.0	36.3	43
Gdr	66.0	51.0	3.0	3.0	680
Aer	50.0	40.0	2.1	2.0	Indef.
		June, 1962			
Aps	31.4	19.8	5.7	26.2	14
Rhu	15.5	9.2	3.7	12.5	12
Vba	67.1	42.3	7.4	22.7	30
Gdr	39.7	26.4	4.5	4.7	39
Aer	34.6	22.2	2.4	2.3	Indef.
		July, 1962			
Aps	41.6	31.7	5.0	25.6	30
Rhu	21.1	13.0	4.0	12.0	15
Vba	79.5	58.6	8.6	29.6	41
Gdr	56.4	37.5	3.6	3.1	131
Aer	40.9	26.1	2.5	2.3	Indef.
		August, 1962			
Aps	49.5	38.0	5.9	31.6	68
Rhu	22.8	13.9	3.3	9.6	18
Vba	86.6	67.1	7.8	31.6	45
Gdr	76.6	49.3	4.2	3.3	750
Aer	46.7	33.2	3.2	2.5	Indef.
		Study Area 5 - Low Good			
		June, 1961			
Aps	42.3	33.2	6.1	23.3	18
Vba	82.8	48.0	6.5	21.0	30
Alu	51.6	42.3	5.1	20.0	50
Saz	31.0	20.2	5.8	10.6	40
Pte	64.2	45.6	3.0	4.8	Indef.
		July, 1961			
Aps	54.6	40.4	8.0	38.0	35
Vba	106.0	56.5	7.3	27.5	42
Alu	61.0	46.0	5.5	26.3	168
Saz	52.0	33.7	6.8	11.5	54
Pte	73.7	53.0	2.0	5.7	574

Alu - <u>Artemisia ludoviciana</u>

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 5 - Low Good (Cont.)			
		August, 1961			
Aps	64.0	45.0	6.3	26.3	136
Vba	111.5	67.5	7.7	22.3	54
Alu	75.0	52.5	6.3	26.0	Indef.
Saz	55.0	38.3	6.3	14.8	76
Pte	65.3	56.0	2.4	31.6	Indef.
		June, 1962			
Aps	31.9	19.9	5.0	22.4	16
Vba	86.4	43.9	7.8	26.9	38
Alu	52.2	34.4	6.0	33.4	49
Saz	33.2	23.9	4.7	10.0	29
Pte	57.2	42.6	3.1	32.6	Indef.
		July, 1962			
Aps	40.7	27.4	6.8	35.2	45
Vba	98.6	63.1	8.4	32.2	60
Alu	62.0	48.8	6.0	48.8	230
Saz	54.6	37.0	6.1	10.3	39
Pte	62.8	50.4	2.1	27.7	Indef.
		August, 1962			
Aps	52.9	40.9	6.6	37.2	101
Vba	105.1	73.4	9.9	33.0	64
Alu	66.1	51.5	6.0	36.0	Indef.
Saz	63.7	43.8	7.1	10.3	49
Pte*	---	---	---	---	---
		Study Area 6 - Poor			
		June, 1961			
Aps	33.0	26.0	7.0	38.0	19
Alu	43.6	35.6	5.6	33.5	50
Vba	62.6	47.3	5.0	20.0	40
Saz	37.0	23.6	6.0	11.0	34
		July, 1961			
Aps	45.0	33.0	8.0	40.8	22
Alu	57.0	36.2	6.2	35.0	67
Vba	91.0	55.7	8.0	24.7	42
Saz	63.0	33.0	7.0	7.4	45
		August, 1961			
Aps	64.6	50.0	6.0	28.3	113
Alu	64.0	47.0	5.0	24.6	Indef.
Vba	112.3	80.0	10.0	21.5	49
Saz	103.0	53.0	5.4	7.3	70

* Past maturity

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study Area 6 - Poor (Cont.)			
		June, 1962			
Aps	30.7	21.0	5.4	23.0	23
Alu	47.5	31.3	6.1	37.6	24
Vba	80.0	44.7	8.3	22.7	34
Saz	37.0	28.3	4.2	8.8	29
Aer	36.9	17.9	5.1	3.5	Indef.
Keu	59.8	31.1	3.4	11.0	46
		July, 1962			
Aps	34.0	27.4	7.4	38.8	68
Alu	53.5	36.1	5.8	27.6	Indef.
Vba	89.7	64.9	8.9	29.5	62
Saz	50.2	35.2	7.8	8.2	46
Aer	39.8	27.2	3.8	2.9	Indef.
Keu	69.3	53.0	4.8	16.0	Indef.
		August, 1962			
Aps	44.2	35.2	6.0	30.4	85
Alu	61.3	44.5	5.7	20.0	Indef.
Vba	95.9	67.0	11.0	39.4	73
Saz	86.4	51.5	7.4	11.1	64
Aer	45.9	33.0	2.5	2.3	Indef.
Keu	83.6	60.0	3.6	11.6	Indef.
		Study Area 7 - Claypan			
		June, 1961			
Aps	31.0	22.0	7.4	39.6	15
Lpu	36.0	25.0	3.6	2.0	99
Ala	34.6	26.3	3.0	5.5	16
Aer	31.0	19.8	2.0	2.0	480
		July, 1961			
Aps	31.4	22.7	7.5	40.0	46
Lpu	52.0	32.4	4.7	2.4	124
Ala	39.7	28.0	2.7	6.2	22
Aer	41.4	22.0	2.2	2.2	520
		August, 1961			
Aps	34.0	27.0	6.0	31.0	85
Lpu	60.0	41.0	7.0	3.0	137
Ala	40.0	29.0	---*	---*	---*
Aer	40.5	32.3	1.5	2.0	Indef.

Lpu - *Liatris punctata*

* Leaves gone

Species	Max. Height cm	Avg. Height cm	Leaf Length cm	Leaf Width mm	No. Leaves
		Study area 7 - Claypan (Cont.) June, 1962			
Aps	24.9	18.6	5.0	21.4	14
Lpu	34.8	24.9	5.4	2.3	101
Ala	22.1	9.0	5.9	9.3	4
Aer	36.7	22.7	3.3	2.8	Indef.
Gdr	30.5	20.8	2.7	3.4	41
		July, 1962			
Aps	36.3	27.1	5.8	28.2	31
Lpu	54.0	36.2	4.8	2.2	119
Ala	38.5	11.7	10.4	13.3	5
Aer	46.1	31.2	2.4	2.2	Indef.
Gdr	50.0	35.4	3.4	2.6	220
		August, 1962			
Aps	45.3	35.7	6.0	31.0	78
Lpu	63.1	45.1	5.1	1.8	160
Ala	36.4	15.6	11.4	11.8	5
Aer	51.0	38.4	2.2	2.0	Indef.
Gdr	57.8	45.8	3.3	2.7	Indef.

VITA

Don B. Hazell

Candidate for the Degree of

Doctor of Philosophy

Thesis: FORAGE PRODUCTION, VEGETATIVE COMPOSITION AND PLANT VIGOR IN RELATION TO RANGE CONDITION

Major Field: Botany

Biographical:

Personal Data: Born in Penalosa, Kansas, November 5, 1934, the son of Mr. and Mrs. A. B. Hazell.

Education: Attended grade school in Penalosa, Kansas; graduated from Turon High School in 1952; received the Bachelor of Science degree from Fort Hays Kansas State College, with a major in Agriculture, in May, 1956; received the Master of Science degree from Fort Hays Kansas State College, with a major in Botany in May, 1960; completed requirements for the Doctor of Philosophy degree in August, 1963.

Professional Experience: Served with U. S. Army in 1957 and 1958, with 16 months of active duty in Italy; held a teaching assistantship at Fort Hays Kansas State College from September, 1959 to January, 1960; held a teaching assistantship at Oklahoma State University from September, 1960 to January, 1961.

Professional Organizations: Member of Oklahoma Academy of Science, Kansas Academy of Science, American Society of Range Management, Ecological Society of America, and associate member of Sigma Xi.