GROWTH AND DEVELOPMENT OF NATIVE RANGE PLANTS IN THE MIXED GRASS PRAIRIE OF WESTERN NORTH DAKOTA

BY

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INTRODUCTION

Native grassland is composed of many grass, sedge, and forb species, each with a different characteristic growth pattern. The seasonal development of the grassland from beginning of growth in spring through rapid early-season leaf growth, then stalk development and flowering, fruiting, and finally drying of leaves and stems and shedding of mature seed is a matter of common observation. However, very little is actually known of the behavior of the individual species and the part that their characteristic growth patterns play in the development of the overall growth pattern for the grassland as a whole. However, a knowledge of the growth pattern of the grassland as a whole and of the growth patterns of the major individual species that make up the grassland is essential to planning a sound program of range management. The stature, vigor, and persistence of the range plants are often dependent on the time and degree to which they are utilized by grazing animals. The establishment of proper times and degree of use of major forage species is one of the fundamental problems of scientific range management. All too often range management plans are developed on a rule-of-thumb basis without any essential knowledge of the growth requirements of the plants concerned.

Actually, very little information is available regarding the specific growth patterns of the most important species of the mixed prairie. Very few studies of even the simpler phases of the life histories of the major forage plants of the type have been made. Data on the actual seasonal progress in height growth of leaves and stalks

of these species seem to be almost entirely lacking. Yet this grassland type is the basic resource for the range grazing industry of western North Dakota.

This study was initiated to secure quantitative data on growth characteristics of the major species in the mixed grass prairie of western North Dakota; to determine the extent and range in yearly variations in growth patterns of the species and of the type as a whole; to assess the general influence of climate as a cause for seasonal and yearly variations in growth patterns; and to interpret the data obtained in terms of their possible application to the practical grazing management of these grasslands.

REVIEW OF LITERATURE

Phenology, the study of periodic events or developmental steps in an organism, had its beginning as a science in the early or mid 1800's, when it was applied extensively by D. N. Kaigaroff in the Soviet Union (Schmidt, 1926). Schmidt (1926) states that phenological studies are of greater importance in predicting events relating to plant adaptation to a certain area, or to the behavior of animals and insects. Huberman (1941) reports that Linnaeus first proposed the recording of epochal happenings in plants in 1751, and that Stillingfelt in England kept records of the return of birds as early as 1791. The observations of Linnaeus and Stillingfelt on the appearance of insects and animals, leafing and blossoming of plants, and thermometer readings raised the study of phenology to the status of a science.

Stevens (1956) published a nearly 50-year record of phenological observations on a wide variety of plant species in eastern North Dakota. The average flowering dates, together with the range of dates of observation in different years, are given. He states that individual plants vary in time of flowering for reasons which usually are not evident, this being especially true of midsummer plants. He concluded that where several years' data are available differences of more than three days in flowering date from a previous calculation, based on a 10-year average, are seldom evident. This conclusion is in accordance with the view of Leopold and Jones (1947) who said that the prediction of contemporary events is possible when flowering or phenological phenomena can be translated into actual calendar dates and applied to practical situations.

Observations of flowering dates of plants and correlation of these dates with bird migrations were reported by Leopold and Jones (1947) in a phenological record for Sauk and Dane counties, Wisconsin. Data taken over the 5-year period 1881-1885 were compared with data taken for the decade 1935-1945. Spring events were found to be two weeks earlier during the decade 1935-1945 than the events recorded during 1881-1885. Appreciable differences in flowering dates were observed when comparisons between a cool, dry June and a hot, wet June were made. In a dry or near-drought condition observed during July, the duration of the flowering period was shortened. An effort was made to compile a composite phenological record for the wild plants, birds, and mammals of the region.

Phenological data concerned with insect control have been collected extensively. Morris, et al. (1956) measured the annual shoot growth of balsam fir at various latitudes, longitudes, and elevations in order to correlate these observations with the development of the spruce-bud-worm larvae. He found initiation of growth and stage of growth closely related to phase of development of the larva, making control possible. Penfound, Hall, and Hess (1945) correlated the flowering dates of woody species of plants in and around reservoirs in northern Alabama with possible inauguration of mosquito breeding. These observations were made in relation to malaria control studies.

A 50-year record of flowering dates of plants usually recognized as field or pasture weeds of North Dakota has been compiled and published by Stevens (1956). He found that dates of flowering for numerous plants vary widely from year to year and may be influenced by

a combination of weather, growth conditions, and opportunity for observation.

Numerous phenological observations of woody species have been made in the United States in recent years. Phenological responses of 19 native tree species in northeastern Minnesota were recorded for five years by Ahlgren (1957). The responses observed were bud swell, leafing, flowering, pollination, seed fall, leaf-color change, leaf fall, and stem expansion. In the species studied, no obvious correlation appeared between current temperature levels and the beginning of either flowering or leafing. Dates of some phenological responses varied as much as one month from one year to the next.

Herman (1956) studied a pinyon-juniper woodland near Walnut Canyon, 10 miles southeast of Flagstaff, Arizona, at an elevation of 6,500 feet. Elongation of branches was studied for two years with measurements taken at intervals of one to two weeks. A close correlation between rainfall and growth was observed. Rate of elongation increased as temperature increased (from 60° F) until the moisture was depleted. Toward the end of the season growth became negligible whenever the temperature fell below 50° F, even though sufficient moisture was available.

Keinholz (1941) studied the seasonal course of height growth in hardwoods in Connecticut. Growth in height of trees starts in early spring, reaches a peak, and then falls off, ceasing in midsummer while the days are still long. Baldwin (1931) studied the period of height growth in some northeastern conifers under various conditions. Height growth is important in tree seedlings as it may determine whether or

not the seedling can survive and outstrip competitors of the same or other species. The times of beginning and ending of growth may also be significant in the choice of seed of local races for planting in a different region. Fully 90 per cent of the growth took place during a period of about six weeks. Growth was slow at first, then rose to a maximum, and sank again rapidly.

McMillan and Pagel (1958) studied 12 distinct clones of Symphoricarpus occidentalis near Lincoln, Nebraska. Stems from each clone were transplanted to a Lincoln garden, and both the plants in the garden and plants growing under native conditions were observed. Appearance of flower buds, conditions of leaf buds, and development of fruit were recorded. It was shown that certain clones were characteristically early in their behavior patterns and others were late. The site variable was less important than genetic differences in determining the phenological variation during any one year.

Greenhouse studies to determine variations within populations of the same species have been carried out. McMillan (1956b) compared five grassland community sites over a broad habitat gradient in Nebraska and a sixth in Iowa. Clones of several species of tall grasses were removed from each of the sites and transplanted both into a uniform garden and into the greenhouse under controlled light periods at Lincoln, Nebraska. All eastern clones showed a distinct number of hours required for flowering, while the western clones were somewhat less specific. Generally one to two hours leeway was common. The eastern species began growth early and flowered late. The western clones were the latest to begin growth in the spring but the earliest to flower.

The importance of light as affecting the growth and development of a plant, especially of the flower, has been demonstrated by Garner (1933). Other investigations of the influence of daylength on growth and flowering were carried out by Roberts and Struckmeyer (1939), Allard (1942), Evans and Wilsie (1946), Gall (1947), and Hiesey (1953).

Olmstead (1944) studied photoperiodic responses in 12 geographic strains of side-oats grama originating over a latitudinal range of approximately 17 degrees from San Antonio, Texas, to Cannonball, North Dakota. Plants were subjected to Chicago natural daylight and to 9-, 13-, 16-, and 20-hour photoperiods. Southern strains all flowered on short photoperiods and northern species on long photoperiods, indicating that plants grown in certain areas cannot satisfactorily be transplanted to regions removed from their points of origin.

Larsen (1947) tested the sensitivity of little bluestem to photoperiod. Plants obtained from northern states were transplanted to the south and southern plants to the north under artificial daylight. The northern strains again clearly were long-day plants and the southern species short-day plants. Growth and development was hampered wherever light conditions different from the originating area were approached. Cornelius (1947) cautions against use of little bluestem seed for revegetation purposes obtained from different sources representing different ecotypes. Adaptation and growth of these plants would probably end in failure if the plants were transplanted far enough distant from their native origin.

The phenology and development of native grasslands has been studied by several investigators. Growth and floral development of

five tall grass species in central Oklahoma were investigated by Rice (1950) during the growing season of 1948. Plots on a ridge-top, southeast slope, and northwest slope were fenced and culms collected from each plot each week to determine if inflorescences had formed. All species started growth within a week, little bluestem (Andropogon scoparius) and side-oats grama (Bouteloua curtinedula) being the earliest. Considerable variation in floral initiation and maturity existed between the different species and slope exposures.

Ahshapanek (1962) reports information on the life activities of important and characteristic species of a native tall grass prairie in central Oklahoma. Data on phenology and aspectation were collected for approximately one year. Various vegetative and reproductive stages of 15 characteristic grassland species were depicted monthly on a phenological chart. A correlation existed between the phenological activities of the plants and temperature and precipitation. The 1-year period was divided into four distinct periods--the hiemal season, characterized by the initiation of new growth by seeds or perennating structures; the vernal season, characterized by pronounced vegetative growth; the aestival period having the greatest number of flowering species; and the autumnal period, marked by maximum vegetative development, anthesis, formation of fruits and seeds, and dissemination for the major species.

Sampson (1918) pointed out that climate is one of the most important environmental factors affecting plant growth and development. He carried out one of the earlier investigations of the influence of climate upon range vegetation in the vicinity of the Great Basin Forest

and Range Experiment Station, located in the Wasatch Mountains in central Utah. Here, three distinct plant associations, going from foothills to the highest elevations (6,500-11,000), were studied. Mean annual temperature decreased gradually from the lowest to the highest vegetation, with a gradual decrease in the length of the period of growth with increase in elevation. Evaporation was highest at the lower elevations and precipitation highest in the middle zone. Wind movement was 11 per cent greater in the uppermost type than in the lowest type. Correlation was found between leaf length, total dry weight, and total evaporation. The high evaporation zone produced the shortest leaves and least dry matter per unit area. Stem elongation was greatest in the lowest type and least in the highest type, indicating that temperature was more important in control of this factor than was evaporation.

Lindsay and Newman (1956) used official weather data in a springtime temperature analysis of an Indiana phenological record. Fifty-one species, including both woody and herbaceous plants, were observed and for each year departures from normals in flowering date, daily mean temperature, and spring precipitation were compared. The temperature data correlated strikingly with flowering data, indicating a sufficiently close correlation existing between the official meteorological records and temperatures actually influencing the plant for such records to be ecologically useful when interpreted by a suitable method.

Rogler and Haas (1947) studied the relationship between range production, soil moisture, and precipitation on the Northern Great

Plains. Highly significant correlations were found between the amount of fall soil moisture in the surface 3 feet and surface 6 feet and native forage production in the following season. When soil moisture was above or below average, forage showed a positive relationship of being above or below average.

The effects of climate and grazing practices on shortgrass prairie vegetation was investigated in southern Alberta and southwestern Saskatchewan by Clark, Tisdale, and Skoglund (1943). Studies of the relation of climate to plant growth revealed that soil moisture is the principal limiting factor, with air and soil temperature being of prime importance for only a short interval in the spring. The vegetation normally completes its seasonal development prior to the beginning of the regular midsummer drought. A rather close relationship between the seasonal ratio of precipitation to evaporation and annual forage yields was found. Droughts generally reduced the basal area of all dominant grasses with the exception of Poa secunda.

Costello and Price (1939) studied the growth and development of the principal forage plants at different altitudinal zones at Ephraim Canyon, Utah. Mean temperature and precipitation varied widely over a relatively short distance going from lower to a higher elevation. This is an important factor in plant development and subsequent grazing practices which are based on time and rate of plant development. They concluded that a knowledge of the plant's date of mature height, flowering, and range readiness is indispensable to proper range management practices. Data gathered from the investigation could be used in determining the time when the various altitudinal zones are ready for

grazing under normal conditions. Variations in time when grasses start active growth in the spring varies as much as 45 days from year to year and must be considered when applying range management practices.

Budd and Campbell (1959) studied the local grassland flora near the Swift Current Experiment Station, Saskatchewan, along a 2-mile transect. Weekly records were maintained of all species for dates of first flowering, length of flowering season, and dates of latest bloom. Native plants were found to bloom over a period of 135-140 days and most species will bloom at or near the same date every year and for a period of from 20-40 days. They concluded that the date of range readiness in any year can be forecast by observing the date at which the crocus anemone (Anemone patens) blooms, and then protecting the range for an additional seven weeks or until Wood's rose commences flowering.

Blaisdell (1958) studied the seasonal development and yield of native plants on the Upper Snake River Plains near Dubois, Idaho, in relation to climatic factors, especially precipitation and temperature. Vegetation was composed of roughly 50 per cent shrubs and 25 per cent each of grasses and forbs. The most abundant species were Artemisia tripartita, Agropyron spicatum, and Balsamorhiza sagittata. Phasic development was generally early in forbs, intermediate in grasses, and late in shrubs; however, development of individual species within a particular group was variable. Differences between species were greatest among the shrubs and least among the grasses. In general, height growth of both grasses and forbs followed the sigmoid pattern, being relatively slow at the beginning and end of the season and rapid

during the intermediate period. Growth rates of grass and flower stalks were similar, but leaves of forbs grew proportionately faster than leaves of grass.

Blaisdell used correlation analysis to relate plant development and yield to climatic factors. In general, early phasic development of grasses and forbs was associated with high temperatures, low precipitation, and clear skies. Conversely, late development was associated with low temperatures, high precipitation, and cloudy skies. There was no apparent relation between phasic development and wind. With the exception of Balsamorhiza flower stalks, height was positively correlated with precipitation, especially that of the March-May period. Correlations of height with mean temperature of the growing season were negative.

Short and Woolfolk (1956) employed plant vigor as a criterion of range condition. Bluestem wheatgrass (Agropyron smithii) plants growing within and outside of pricklypear clumps were studied on ranges in poor and good condition for a period of three years at Miles City, Montana. Data gathered during the study period indicate that plant vigor, as expressed by bluestem wheatgrass heights, varied with range condition with protection afforded by pricklypear and with yearly precipitation. They stated that vigor can be easily determined on the Northern Great Plains ranges simply by utilizing the natural protection provided by plains pricklypear and comparing unprotected and protected plants. The wide fluctuations of weather from above normal precipitation to severe drought did not alter the established height between unprotected and protected plants. These findings demonstrate the

soundness of the vigor concept and show how it can be used at almost any time during the year on Northern Great Plains ranges to indicate current range condition. Primarily, the study established the usefulness of vigor, as reflected by plant height, as a criterion for the appraisal or estimation of range conditions.

Evanko and Peterson (1955) made a study in the comparisons of protected and unprotected grazed mountain rangelands in southwestern Montana. They found a vegetational change associated with heavy grazing and that apparent plant vigor was associated closely with varying degrees of grazing. Estimation by observation and actual measurements of plants, by way of comparison of these sites rather than cover estimation, was suggested for range condition estimation. The data indicate an appreciable difference in leaf height and flowering stalk maximum heights attained.

Bredemeier (1958) studied thoroughly the phenological development of a number of range grasses throughout an entire year at North Platte, Nebraska. Range species were measured at weekly intervals in 1955 and 1956. Measurements also were made throughout the winter but at irregular intervals as weather permitted. Total elongation, residual length, and green length were recorded.

The most important grasses in the study were western wheatgrass (Agropyron smithii), side-oats grama (Bouteloua curtipendula), little bluestem (Andropogon scoparius), needle-and-thread (Stipa comata), and prairie sandreed (Calamovilfa longifolia). It was concluded from this study that western wheatgrass and needle-and-thread, which start new growth in the fall, are in a state of pseudodormancy through the winter.

The time of beginning of the grand period of growth is essentially the same for five phenologically different but major grasses on the site. Little bluestem had the longest grand period of growth, which was three months.

Maximum elongation was attained by all five species at essentially the same time, the end of August in 1956. Differences in the time and amount of precipitation in 1955 and 1956 had little influence on the grand period of growth. The major percentage of forage was produced in essentially the same relatively short period of 40 to 50 days in both years.

Summary

A review of the literature pertinent to this study reveals that there has been very little close study of growth of the Northern Great Plains grassland species under natural conditions. Most studies have been primarily concerned with plant flowering and the use of this knowledge in correlations with happenings related to wildlife or insect activities. Climatic factors have been studied in relation to plant growth and development in some more recent investigations, which had as their primary objectives the correlation of plant growth with precipitation and temperature.

Studies concerned with phenological development of the native range species and their subsequent application to range management problems have been begun more recently. Data have been published from only a few such studies. These studies attempt to characterize the growth and development of the native grasses and forbs so that this

information may be of value to the range manager in determining grazing values of forage species and times of grazing. The use of plant heights as a measure of plant vigor on the range has been suggested by several investigators, but only a very few actual studies of range plant growth as measured by leaf and stalk heights have been made.

THE STUDY AREA

Location and Soils

This study was conducted on a piece of native mixed-grass range, approximately 40 acres in size, located on the Dickinson Experiment Station near the city of Dickinson in southwestern North Dakota. The study area is situated on a gentle, west-facing slope at an elevation of approximately 2,500 feet above sea level. An intricate soil pattern is developed throughout the area as a result of erosional forces which have exposed stratified sands, silts, and occasionally clays. The soil in the study-area is classified as Vebar-Morton, with a topsoil too sandy for Morton and a subsoil too silty for a typical Vebar series. The Bainville series, thin phase, is represented on the tops of two small hills on the area. The soils of the area, with the exception of these two broken slopes, is deep, light-textured, and moderately permeable. The horizon is a dark-brown to gray-brown sandy loam with fine-crumb to single-grain structure. The B horizon is brown to gray-brown, friable sandy loam with weak prismatic structure. Generally, a prominent Cc_a horizon extends from the 30- to 60-inch level.

The Morton and Vebar series and the Morton-Vebar combinations are rather common in southwestern North Dakota. The more level areas are often cultivated, while the steep slopes are primarily used for pasture. On the relatively gentle slopes below the native-grass study are contoured fields on which alternate crops of small grain and corn are grown. Late in the fall, after the crops have been harvested, cattle are allowed to graze over the entire area of both cropland and

rangeland. During this period the native grass commonly receives rather heavy utilization. The grassland vegetation has received this heavy late-fall grazing use for the past 10 years.

Two small exclosures have been fenced out of the native grass area. One of these exclosures has been fenced since 1958 and one was fenced in the fall of 1961. Data on growth and development of major grass and forb species were taken from both these exclosures, as well as from the general area outside the exclosures, during the course of the study.

Climatic Conditions

The Northern Great Plains region, in general, is characterized as having a semi-arid climate with long, cold winters and short, hot summers. The 70-year weather records at the Dickinson Experiment Station show an average precipitation of 15.50 inches, of which 9.08 inches is received from April through July. Two seasons of near drought conditions were experienced during the 8-year study period. The 1956 season was dry to the end of June before any appreciable amount of precipitation was received, and the 1961 season remained dry throughout the summer until September, when 3.05 inches of precipitation was received (Table 1). Associated with the low rainfall during these years were high maximum summer temperatures (Table 2) which resulted in a high rate of evaporation, causing additional stress to the plants.

A large variation existed in amounts of precipitation received and in seasonal distribution of precipitation during the eight years

TABLE 1. PRECIPITATION AT THE DICKINSON EXPERIMENT STATION DURING THE PERIOD 1955-1962 COMPARED WITH THE 70-YEAR AVERAGE FOR THE AREA

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	April-July
1955	0.29	0.70	0.15	1.91	2.45	4.70	1.08	0.81	1.53	0.18	0.72	0.13	14.65	10.14
1956	0.44	0.12	0.57	0.22	2.90	1.17	3.01	2.55	0.76	0.43	0.50	0.03	12.70	7.30
1957	0.41	0.21	0.32	2.59	2.10	6.61	3.46	1.49	1.98	1.94	0.88	0.16	22.15	14.76
1958	0.13	1.01	0.16	0.57	0.45	3.26	3.86	0.57	0.06	0.65	1.35	0.11	12.18	8.14
1959	0.24	0.84	0.11	0.16	1.94	3.08	0.97	0.54	4.54	0.33	0.52	0.18	13.45	6.15
1960	0.13	0.12	0.58	0.35	2.23	3.06	0.58	2.16	0.14	0.02	0.72	0.14	10.23	6.22
1961	0.05	0.59	0.50	1.89	1.44	2.82	1.66	1.68	3.05	0.11	T	0.11	13.90	7.81
1962	0.34	0.15	0.99	1.12	6.18	2.07	2.94	1.19	0.82[a]				14.38[a]	12.31
8-year Ave. 1953-1962	0.26	0.47	0.42	1.10	2.46	3.35	2.20	1.37	1.61	0.52	0.78	0.12	15.08	9.10
70-year Ave. 1892-1961	0.44	0.43	0.75	1.25	2.19	3.48	2.16	1.79	1.22	0.85	0.54	0.40	15.50	9.08

[a] A 25-day record.

TABLE 2. AVERAGE MAXIMUM, MINIMUM, AND MEAN MONTHLY TEMPERATURES AT THE DICKINSON EXPERIMENT STATION, 1955-1962

Year	January			February			March			April		
	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F
1955	27.6	3.9	15.8	20.7	-0.8	10.0	34.6	10.1	22.4	60.1	32.9	46.5
1956	21.5	-1.0	10.3	25.8	1.4	13.6	40.3	15.7	20.0	51.2	21.8	36.5
1957	14.6	-7.4	3.6	26.6	3.0	14.8	39.3	17.2	28.3	49.0	27.2	38.1
1958	36.5	11.9	24.2	27.3	3.8	15.6	32.1	15.2	23.7			43.5
1959	18.6	-3.3	7.7	18.6	-7.5	5.6	42.0	20.8	31.4	52.3	27.9	40.1
1960	22.4	-1.3	10.6	24.0	4.8	14.4	30.9	7.9	19.4	54.6	28.9	41.8
1961	28.7	7.5	18.1	35.7	11.2	23.5	45.0	22.9	34.0	49.3	24.7	37.0
1962	21.6	0.5	11.1	25.2	2.1	13.6	33.2	10.6	21.9	56.8	29.8	43.3
Ave.	23.9	5.4	12.6	25.5	9.0	16.5	37.2	15.1	26.1	53.3	27.6	40.9
70-yr. Ave.			10.7			13.9			23.9			41.3

TABLE 2 (Continued)

Year	May			June			July			August		
	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F
1955	69.7	43.1	56.4	71.1	49.1	60.1	83.9	56.3	70.1	88.1	56.0	72.1
1956	65.2	40.9	53.1	83.6	52.7	68.2	79.6	53.4	66.5	81.6	51.5	66.6
1957	66.9	40.7	53.8	72.1	48.8	60.5	87.0	58.9	73.0	79.8	55.2	67.5
1958	74.8	41.9	58.4	69.8	46.2	58.0	76.2	50.4	63.3	88.1	53.6	70.9
1959	63.7	37.6	50.7	79.7	51.0	65.4	86.8	56.5	71.7	87.1	52.4	69.8
1960	66.9	38.6	52.8	72.5	47.9	60.2	87.9	55.0	71.5	84.5	52.0	68.3
1961	65.1	39.9	52.5	84.5	52.0	68.3	84.4	55.7	70.1	89.1	55.9	72.5
1962	61.7	42.1	51.9	74.9	50.6	62.8	77.7	53.2	60.4	83.6	53.9	68.7
Ave.	66.7	40.6	53.7	76.0	49.8	62.9	82.9	53.7	68.3	85.2	53.8	69.6
70-yr. Ave.			53.1			61.4			69.8			67.1

TABLE 2 (Continued)

Year	September			October			November			December		
	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F	Average Maximum °F	Average Minimum °F	Mean °F
1955	72.9	41.2	57.1	63.8	32.0	47.9	26.8	5.5	16.2	19.9	-1.7	9.1
1956	70.4	41.3	55.9	64.2	31.9	48.1	41.2	20.5	30.8	34.2	10.7	22.5
1957	68.3	41.6	55.0	53.9	31.4	42.7	40.0	21.3	30.7	40.0	16.7	28.4
1958	73.9	40.5	57.2	61.7	30.4	46.1	39.5	17.8	28.7	27.5	5.1	16.3
1959	68.2	41.8	55.0	50.5	26.7	38.6	31.6	12.0	21.8	35.4	18.1	26.8
1960	75.3	42.3	58.8	62.0	28.6	45.3	41.3	14.0	27.7	27.2	6.4	16.8
1961	63.5	38.9	51.2	57.9	29.9	43.9	42.5	16.2	29.4	24.4	-4.2	10.1
1962	68.6[a]	41.2[a]	54.9[a]									
Ave.	70.1	41.1	55.6	59.1	30.1	44.7	37.6	15.3	26.5	29.8	10.2	18.6
70-yr. Ave.			56.4			44.8			27.9			17.5

[a]A 25-day record.

of the study. The amount of precipitation received during the active growth period (April-July) varied from a high of 14.76 inches in 1957 to a low of 6.15 inches during the 1959 growing season. Abundant precipitation during the April-July period was received during the years 1955, 1957, and 1962.

Variations in mean monthly temperatures were equally great during the 8-year period. The 1955 season was characterized by higher than average early spring temperatures, and the 1962 season remained relatively cool throughout the growing season. Average maximum temperatures during April ranged from 49.0° during 1957 to 60.1° in 1955. The 1956 and 1961 seasons indicate high average maximum temperatures of 83.6° and 84.5°, respectively, during the month of June. The average temperatures during June for these two years were 68.2° and 68.3°, considerably above the 70-year average of 61.4°. The fluctuations in the temperatures are appreciable and show wide variations, which are of significance in the growth and development of plants.

Vegetation

The native range vegetation of the Northern Great Plains is classified by Weaver and Clements (1938) as "mixed prairie". Although the vegetation of the mixed prairie is highly variable, a few principal species maintain their dominance throughout the range of the type. This association owes its name to the fact that both mid grasses, short grasses, and sedges occur in mixture throughout the climax. On the study area, the two most common mid grasses were western wheatgrass

(Agropyron smithii) and needle-and-thread (Stipa comata). One other mid grass, plains reedgrass (Calamagrostis montanensis), occurs frequently.

Blue grama (Bouteloua gracilis) was the abundant short grass throughout the study area. Needleleaf sedge (Carex eleocharis) was not nearly as abundant as blue grama, but it was nearly as well dispersed. Pennsylvania sedge (Carex pennsylvanica) is present but occurs infrequently and was not considered an important species in this study. Three species of bunch growth habit--Sandberg bluegrass (Poa secunda), prairie Junegrass (Koeleria cristata), and threadleaf sedge (Carex filifolia)--are of limited importance in the immediate study area, but are of considerable importance throughout the type.

Other bunchgrass species of minor importance in this mixed prairie study area are big needlegrass (Stipa spartea), red threeawn (Aristida longiseta), stonyhills muhly (Muhlenbergia cuspidata), and little bluestem (Andropogon scoparius). Two sod-forming tall grasses also are represented in this grassland type but are of minor importance. These are big bluestem (Andropogon gerardi) and plains sandreed (Calamovilfa longifolia). Approximately 95 species of forbs, composed mainly of perennials, were identified in this grassland type.

METHODS

Plant heights were determined by measuring leaves and stems of an average of 10 plants of each species to the nearest 1 cm at approximate 7- to 10-day intervals during the growing season. In all years of the study, measurements were begun by early May and carried through until late August or early September of each season. The interval of measurement was more regular after mid-May and during the months of June, July, and August than it was early in the season.

For species in which the leaves and stalks were distinctly separate, leaf heights were measured from ground level to the tips of the extended leaves. In the case of single-stalked species, such as western wheatgrass and plains reedgrass where the leaves are attached to a culm, height measurements were made by extending the leaves upward in a vertical position and measuring from ground level to the apex of the uppermost leaf. The fruiting stalk measurements were begun immediately following evidence of thickening of culms, and stalk heights were measured from ground level to the tip of the stalk or to the tip of the inflorescence after it had developed.

In addition to leaf-height and fruiting-stalk measurements, records of all phenological phenomena of the grass and sedge species were recorded. Included for each species were date of fruiting-stalk initiation, anthesis, seed development, seed maturity, earliest observed date of seed shedding, and estimation of percentage of leaf dry in relation to total leaf area. This was carried out in detail for eight growing seasons on the native grass study area. For the forbs, only height measurements and dates of flowering were recorded.

A study of yield increase in grasses in relation to the advance of seasonal growth was made. Two of the more important grasses of this range type were studied--western wheatgrass and blue grama grass. The study was made inside an exclosure situated in the study area. This exclosure was constructed in 1958 and the vegetation protected from grazing for five years. Three 1-square-foot plots located in relatively pure stands of each of the two species were clipped at ground level at 15-day intervals beginning in May and continuing until the end of August. Occasional later clippings were made up to September 15. The plants inside the square-foot plots were measured for leaf height and fruiting-stalk height before clipping. Separations of the species of grasses and forbs found within the square-foot plots were made while clipping. The yields were placed in separate paper bags, oven dried and weighed. Stalk counts were made in the western wheatgrass plots, and the results were reported on the basis of grams dry weight per 100 stalks. The blue grama grass yields were reported on the basis of grams per square-foot area of grass.

An exclosure fenced in 1961 was incorporated into the growth study in the spring of 1962. Measurements of the major grasses and sedges were made in this exclosure for comparison with the fall-grazed study area and the 5-year protected exclosure. Leaf growth and fruiting-stalk growth data for western wheatgrass, blue grama grass, needleleaf sedge, and needle-and-thread were compared from these three treatments.

Common and scientific plant names used in the text follow Stevens (1950), except where no common names were given. In these

cases, common names from Kelsey and Dayton (1942) were used.

RESULTS

General Growth Patterns of Grasses

The 8-year average individual leaf heights at approximate 7- to 10-day intervals throughout the growing season of the 13 species of perennial grasses and the two sedges studied are given in Table 3. Data on stalk heights are given in Table 4. Some adjustments have been made in order to eliminate irregularities in average heights attained by the grasses and sedges. The actual measurements taken each season for all species are given in Appendix Tables 1 through 15.

Irregularities in average heights for a given species at a certain date arise from the fact that the growth pattern for a grass, although similar in general from year to year, does show substantial differences in actual heights and time at which maximum heights are attained. As a result of this natural variation, an 8-year average height for a given date may be either more or less than the average height for the next subsequent date. The adjusted table involves small changes to smooth the curves of growth for the grasses and sedges in order to clarify the general picture of growth for each species.

In Tables 5 and 6, the average 8-year leaf and stalk heights at each date have been converted to a percentage-of-growth-attained figure, based on the average maximum leaf and stalk heights of the species. The tables show the average percentage of growth attained by each species at approximate 7- to 10-day intervals throughout the season.

TABLE 3. ADJUSTED 8-YEAR AVERAGE LEAF HEIGHTS IN cm OF GRASSES AND SEDGES AT APPROXIMATE 7- TO 10-DAY INTERVALS DURING THE GROWING SEASON (1955-1962)

Species	April					May					June					July					August					Maximum Average Ht. (cm)
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Western wheatgrass		2.0	4.0	6.0	6.7	7.5	10.3	12.8	15.9	16.3	18.7	19.0	19.2	20.6	22.0	22.0	22.0	22.1	22.2	23.8						23.8
Needle-and-thread		2.5	4.0	4.2	4.6	5.0	7.0	8.4	12.3	13.0	15.3	16.2	17.0	18.6	20.2	20.9										20.9
Blue grama			1.0	1.5	2.0	2.0	2.1	3.6	4.8	5.1	7.3	7.4	7.4	8.1	8.8	9.4	9.8	10.4	10.5	10.7						10.7
Needleleaf sedge		1.5	2.5	3.0	5.2	6.0	6.8	7.0	8.7	8.8	9.1	9.4	9.5	9.7	9.7	9.8										9.8
Threadleaf sedge		1.5	3.0	3.0	5.5	6.3	7.0	8.2	8.9	10.1	10.3	10.4	10.4	10.6												10.6
Sandberg bluegrass		2.0	4.0	4.0	4.9	5.9	6.2	8.0	8.8																	8.8
Prairie Junegrass		1.0	4.5	5.6	6.7	6.8	6.8	8.8	10.0	10.3	10.5	10.6	10.8	10.9	11.5	11.7	12.0	12.1	12.2	12.3						12.3
Green needlegrass		4.0	7.0	8.7	10.0	12.0	13.5	16.0	20.3	22.3	22.3	25.6	32.0	34.0												34.0
Plains reedgrass		1.0	8.5	9.8	11.0	11.8	12.8	14.3	15.3	16.3	18.0	18.5	19.0	19.6	19.8	19.9	20.0	20.2	20.5	20.9						20.9
Little bluestem							4.0	4.0	4.2	5.1	6.0	10.0	11.0	12.6	12.8	14.7	14.9	15.2	15.3							15.3
Prairie sandreed							3.0	7.3	9.0	17.5	20.3	25.0	30.4	33.9	39.0	40.0	42.0	42.5	42.8	44.0	44.5					44.5
Big bluestem									3.0	7.3	7.3	11.0	11.4	13.7	16.5	18.0	18.4	18.6	19.3	20.0	20.6					20.6
Stonyhills muhly					1.5	1.5	2.4	4.9	4.9	8.5	9.0	9.8	11.5	13.0	13.2	13.2	13.9	15.0	15.5	16.0	16.3	16.4	16.5			16.5
Red threeawn							5.0	6.1	7.2	8.5	9.7	11.0	13.8	15.5	15.6	15.8										15.8
Big needlegrass		2.5	3.1	4.0	4.8	5.0	9.5	10.4	11.0	11.5	15.0	19.5	23.3	25.3	26.3	30.0										30.0

TABLE 4. ADJUSTED 8-YEAR AVERAGE STALK HEIGHTS IN cm OF GRASSES AND SEDGES AT APPROXIMATE 7- TO 10-DAY INTERVALS DURING THE GROWING SEASON (1955-1962)

Species	April					May					June					July					August					Maximum Average Ht. (cm)
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Western wheatgrass													23.9	32.0	40.8	42.2	43.4	44.0	44.5	44.9						44.9
Needle-and-thread										17.7	19.0	25.1	30.4	36.6	38.2	42.8	45.1									45.1
Blue grama														16.0	16.0	16.5	17.0	18.8	21.0	22.0	23.5					23.5
Needleleaf sedge				3.0	5.0	6.9	8.7	9.3	10.1	10.6	11.3	11.3	11.7	12.0	12.3											12.3
Threadleaf sedge				2.5	4.0	6.5	8.8	11.7	11.8	12.2	13.0	13.4	14.4													14.4
Sandberg bluegrass							14.0	15.4	16.8	21.0	22.7	25.8														25.8
Prairie Junegrass								10.0	11.5	14.0	15.0	20.8	21.9	27.1												27.1
Green needlegrass									25.7	26.0	28.5	37.4	45.0	56.5												56.5
Plains reedgrass											16.3	23.0	24.3	25.6												25.6
Little bluestem														17.0	18.0	18.0	21.7	25.5	26.7	29.4	32.1	36.5				36.5
Prairie sandreed																60.0	62.4	64.7	70.0	75.0	77.3	79.0	79.9			79.9
Big bluestem																15.0	15.0	29.7	35.9	42.1	47.7	56.0	64.5	67.0		67.0
Stonyhills muhly															13.0	17.1	18.8	20.2	21.7	22.0	22.0	23.1				23.1
Red threeawn													16.0	20.0	21.0	21.5	22.0	22.8	22.8	23.0						23.0
Big needlegrass										22.0	22.5	22.6	27.8	40.6	43.2	49.2										49.2

TABLE 5. ADJUSTED LEAF GROWTH AS MEASURED BY PERCENTAGE OF MAXIMUM LEAF HEIGHT AT APPROXIMATE 7- TO 10-DAY INTERVALS DURING THE 1955-1962 PERIOD

Species	April					May					June					July					August					Maximum Average Ht. (cm)
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Western wheatgrass		8	17	25	28	32	43	54	67	69	79	80	81	87	92	92	92	93	93	100						23.8
Needle-and-thread		12	19	20	22	24	34	40	59	62	73	78	81	89	97	100										20.9
Blue grama			9	14	19	19	20	34	45	48	68	69	69	76	82	88	92	97	99	100						10.7
Needleleaf sedge		15	26	31	53	61	69	71	89	90	93	96	97	99	100											9.8
Threadleaf sedge		14	28	28	52	59	66	78	84	95	97	98	98	100												10.6
Sandberg bluegrass		23	46	46	56	67	71	91	100																	8.8
Prairie Junegrass		8	37	46	55	55	55	72	81	84	85	86	88	89	93	95	98	98	99	100						12.3
Green needlegrass		12	21	26	29	35	40	47	60	66	66	75	94	100												34.0
Plains reedgrass		5	41	47	53	57	61	68	73	78	86	88	91	94	95	95	96	97	98	100						20.9
Little bluestem							26	26	28	34	39	65	72	82	84	96	98	99	100							15.3
Prairie sandreed							7	16	20	39	46	56	68	76	88	90	94	95	96	99	100					44.5
Big bluestem									15	35	36	52	55	67	80	87	89	90	94	97	100					20.6
Stonyhills muhly					9	9	14	30	30	52	55	60	70	79	80	80	85	91	94	97	99	99	100			16.5
Red threeawn							32	39	46	54	61	70	87	98	99	100										15.8
Big needlegrass		8	10	13	16	17	32	35	37	38	50	65	78	84	88	100										30.0

TABLE 6. ADJUSTED STALK GROWTH AS MEASURED BY PERCENTAGE OF MAXIMUM STALK HEIGHT AT APPROXIMATE 7- TO 10-DAY INTERVALS DURING THE 1955-1962 PERIOD

Species	April					May					June					July					August					Maximum Average Ht. (cm)
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Western wheatgrass													53.5	71.3	90.9	93.9	96.7	97.9	99.1	100.0						44.9
Needle-and-thread										39.2	42.1	55.7	67.4	81.2	84.7	94.2	100.0									45.1
Blue grama														68.1	68.1	70.2	72.3	80.0	89.4	93.6	100.0					23.5
Needleleaf sedge				24.4	40.8	55.8	70.7	75.6	82.1	86.3	91.9	91.9	95.1	97.3	100.0											12.3
Threadleaf sedge				17.4	27.8	45.1	61.1	81.3	81.9	84.9	90.3	93.1	100.0													14.4
Sandberg bluegrass							54.3	59.7	65.1	81.4	88.0	100.0														25.8
Prairie Junegrass								36.9	42.4	51.7	55.4	76.8	80.8	100.0												27.1
Green needlegrass									45.4	46.0	50.4	66.2	79.6	100.0												56.5
Plains reedgrass											63.7	89.8	94.9	100.0												25.6
Little bluestem														46.5		49.3	49.3	59.5	69.9	73.2	80.5	87.9	100.0			36.5
Prairie sandreed																	75.1	78.1	81.0	87.6	93.9	96.8	98.9	100.0		79.9
Big bluestem																	22.4	22.4	44.3	53.6	62.9	71.2	83.6	96.3	100.0	67.0
Stonyhills muhly																56.3	74.0	81.4	87.4	93.9	95.2	95.2	100.0			23.1
Red threeawn													69.6	87.0	91.3	93.5	95.7	99.1	99.1	100.0						23.0
Big needlegrass										44.7	45.7	46.0	56.5	82.5	87.8	100.0										49.2

The data indicate that the growth patterns of the species fall into four distinct groups. The two sedges, needleleaf sedge and threadleaf sedge, and Sandberg bluegrass form a group of very early growing cool-season species. These species generally have completed their growth cycles by late May or early June (Tables 5 and 6 and Figure 1). Sandberg bluegrass appears to grow the most rapidly, attaining an average of 23 per cent of its mature leaf height during early April (Table 5) and 54.3 per cent of its stalk height by mid-May. The sedges studied are slightly later, generally having attained only about 15 per cent of their average leaf height by early April, at which time Sandberg bluegrass attains about 23 per cent of its mature leaf height. Most of the overall growth of Sandberg bluegrass is completed by May 15 and the sedges complete their growth by about June 8, over 20 days later.

The second group contains the grasses which reach maximum height later than the early growing cool-season group, but before midsummer when the shortgrass, blue grama, is reaching its maximum height. The species in this group begin growth early, but growth progresses more slowly than in the first group (Figure 1). Included in this group are the cool-season grasses--western wheatgrass, needle-and-thread, prairie Junegrass, green needlegrass, plains reedgrass, and big needlegrass. These species begin growth during early April and attain maximum mature height by early July (Tables 3 and 4). By May 1 the species of group 2 have attained on the average about 36 per cent of their leaf growth, while the species of group 1 have attained over 60 per cent of their growth (Figure 1). By June 1 the group 2 species have made over

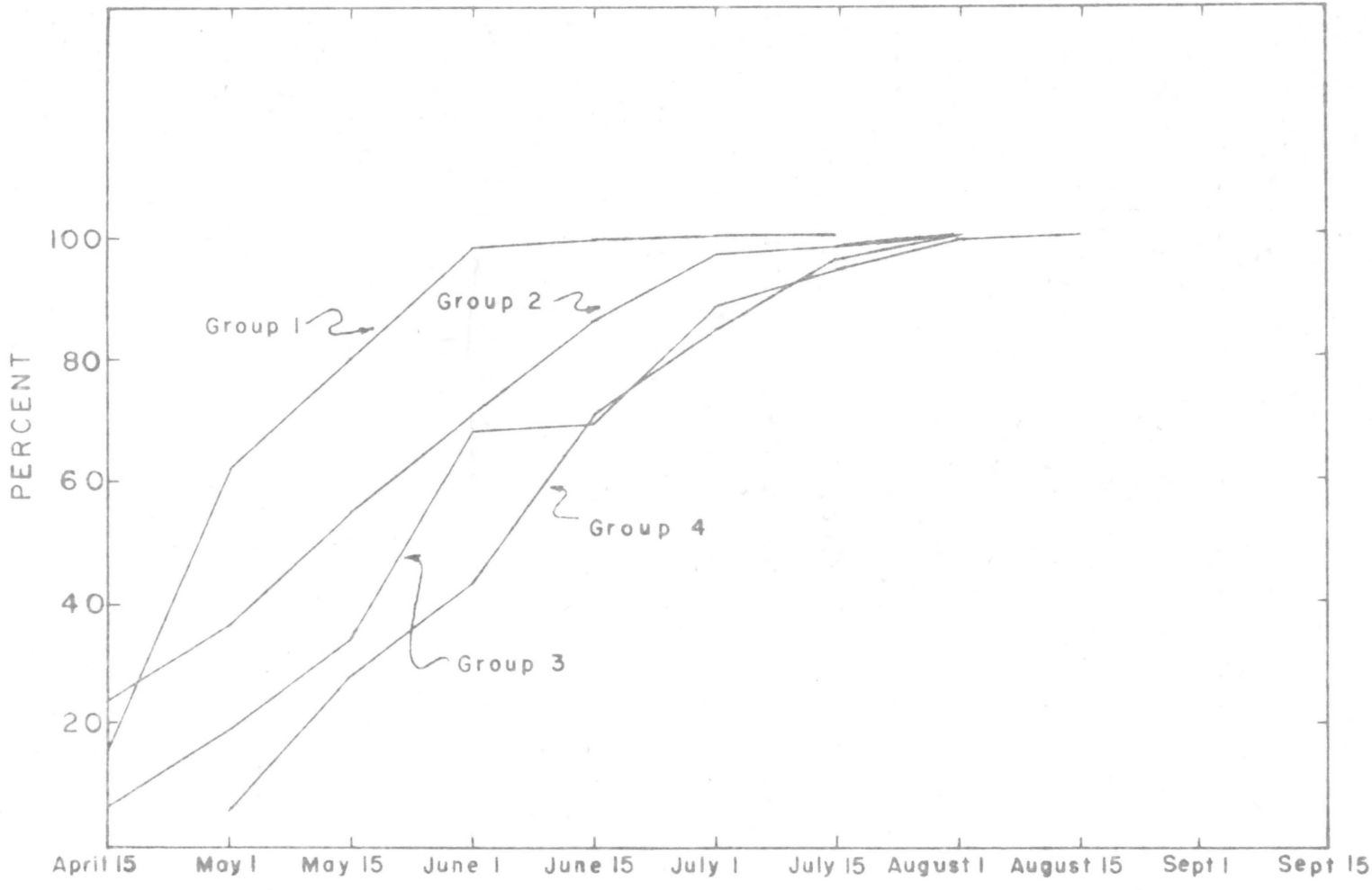

Figure 1. Eight-year average per cent of leaf growth attained at dates indicated for four groups of grass and sedge species. Group 1--needleleaf sedge, threadleaf sedge, and Sandberg bluegrass; Group 2--western wheatgrass, needle-and-thread, prairie Junegrass, green needlegrass, plains reedgrass, and big needlegrass; Group 3--blue grama; Group 4--little bluestem, prairie sandreed, big bluestem, stonyhills muhly, and red threeawn.

70 per cent of their leaf growth, but group 1 species have attained 97 per cent of their growth. Group 2 species did not reach 97 per cent of their leaf growth until after July 1.

Growth of blue grama grass, the only warm-season shortgrass on the area, is shown by itself on Figure 1. This species shows an appreciably later growth than is shown by the species of groups 1 and 2. Blue grama has made about 19 per cent of its growth by May 1, in contrast to an average of 36 per cent for group 2 and over 60 per cent for group 1. This species achieved about 97 per cent of its leaf growth by July 15, 15 days later than group 2 for the same degree of leaf growth and 45 days later than the species of group 1.

The late-growing warm season grasses--little bluestem, big bluestem, prairie sandreed, red threeawn, and stonyhills muhly--constitute group 4. Red threeawn is somewhat earlier than the other species in this group, but its general growth behavior is similar enough to that of the other species to warrant inclusion in this section. The species of group 4 begin leaf growth later than the species in the other groups and attain their maximum mature height later. The group has made only 5 per cent of its mature growth by May 1, 28 per cent by May 15, 47 per cent by June 1, and 70 per cent by June 15. Mature leaf height is reached approximately by July 25--56 days after group 1, 25 days after group 2, and 10 days after the leaves of blue grama attain their maximum growth (Figure 1).

Stalk height, expressed as a percentage of growth at a given time, follows closely the leaf growth pattern of the grasses and the sedges as indicated in Figure 2. The species in group 1 show the most

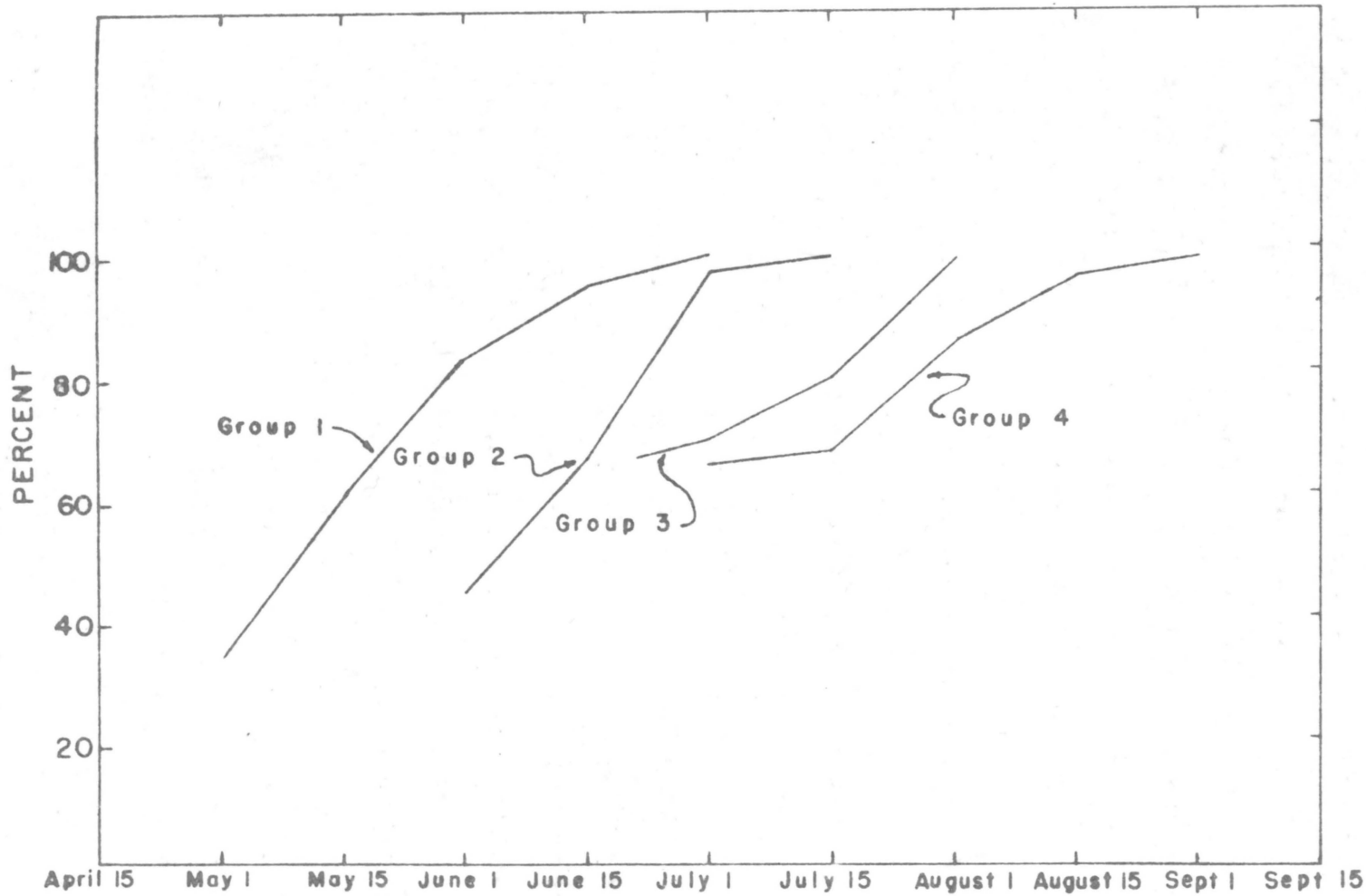

Figure 2. Eight-year average per cent of stalk growth attained at dates indicated for four groups of grass and sedge species. Group 1--needleleaf sedge, threadleaf sedge, and Sandberg bluegrass; Group 2--western wheatgrass, needle-and-thread, prairie Junegrass, green needlegrass, plains reedgrass, and big needlegrass; Group 3--blue grama; Group 4--little bluestem, prairie sandreed, big bluestem, stonyhills muhly, and red threeawn.

rapid stalk growth by a considerable degree, attaining maximum stalk height by approximately June 22. The species in group 2 attain their maximum mature height by July 12, about 20 days after group 1. Blue grama grass was treated separately, since it was the only warm-season shortgrass and had a growth pattern different from that of the other warm-season grasses studied. This species attained mature stalk height by August 1, about 38 days after group 1 and 19 days after group 2.

The species in group 4 were the latest to attain stalk maturity, reaching their mature height by approximately August 20--about 58 days after group 1, 39 days after group 2, and 20 days after blue grama.

Yearly Growth Variations

The 8-year average leaf and stalk heights of the grasses and sedges in Figures 3 and 4 indicate a rather continuous progression in height growth by the major species over the entire period. The actual growth pattern is characterized by wide differences in maximum mature heights attained by any given species during a season's growth (Table 7). Certain species are markedly affected by the seasonal climatic conditions, and these species show departures of considerable magnitude from the normal year's growth. The lack of sufficient early spring moisture frequently results in reduced height growth of the major species.

The 1961 growing season was a near-drought year and the height growth of all grasses was greatly reduced. However, the two sedges, needleleaf sedge and threadleaf sedge, and the very-early-growing

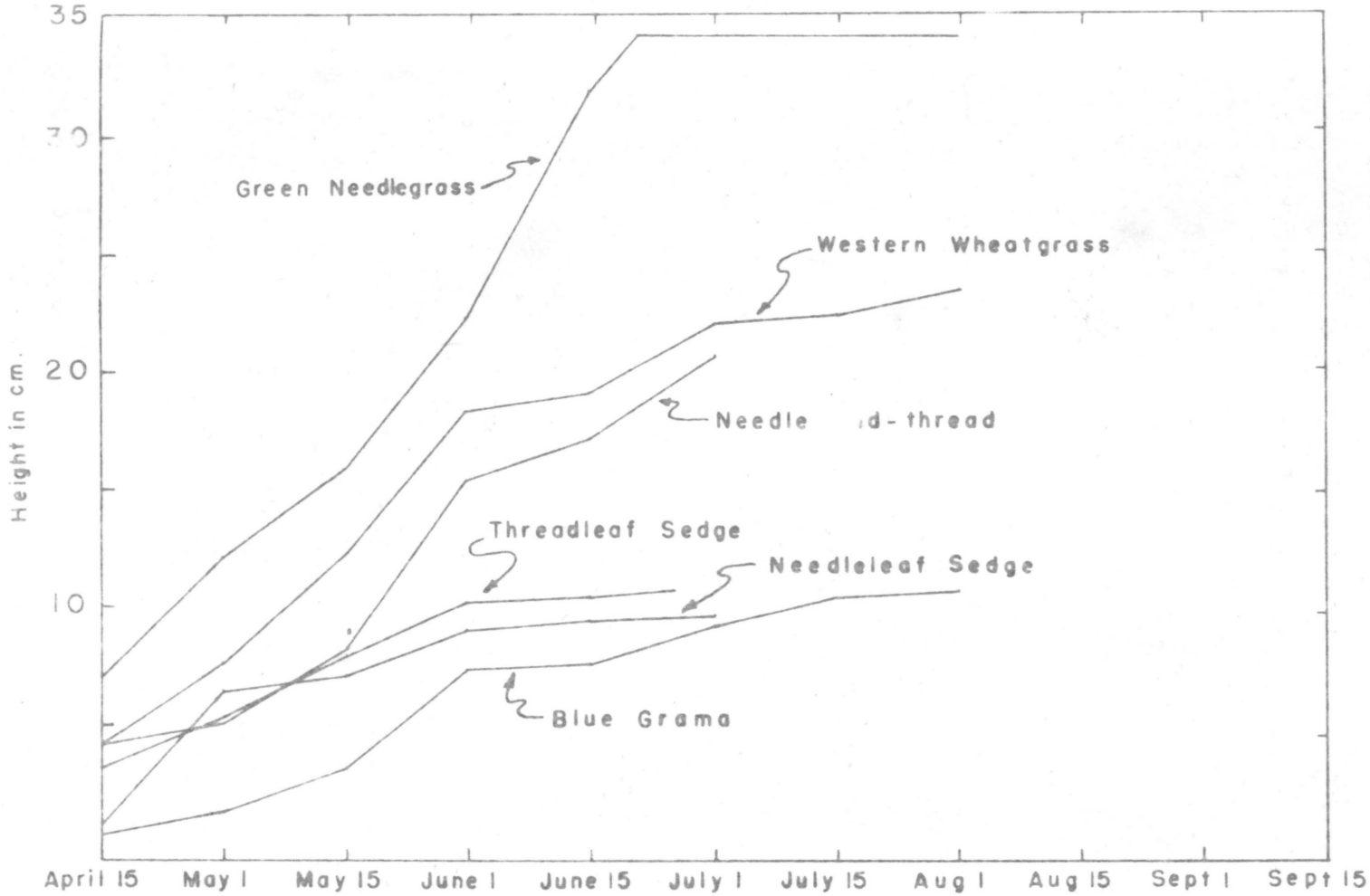

Figure 3. Average course of leaf growth by 2-week intervals for major grass and sedge species on the study area for the 8-year period, 1955-1962.

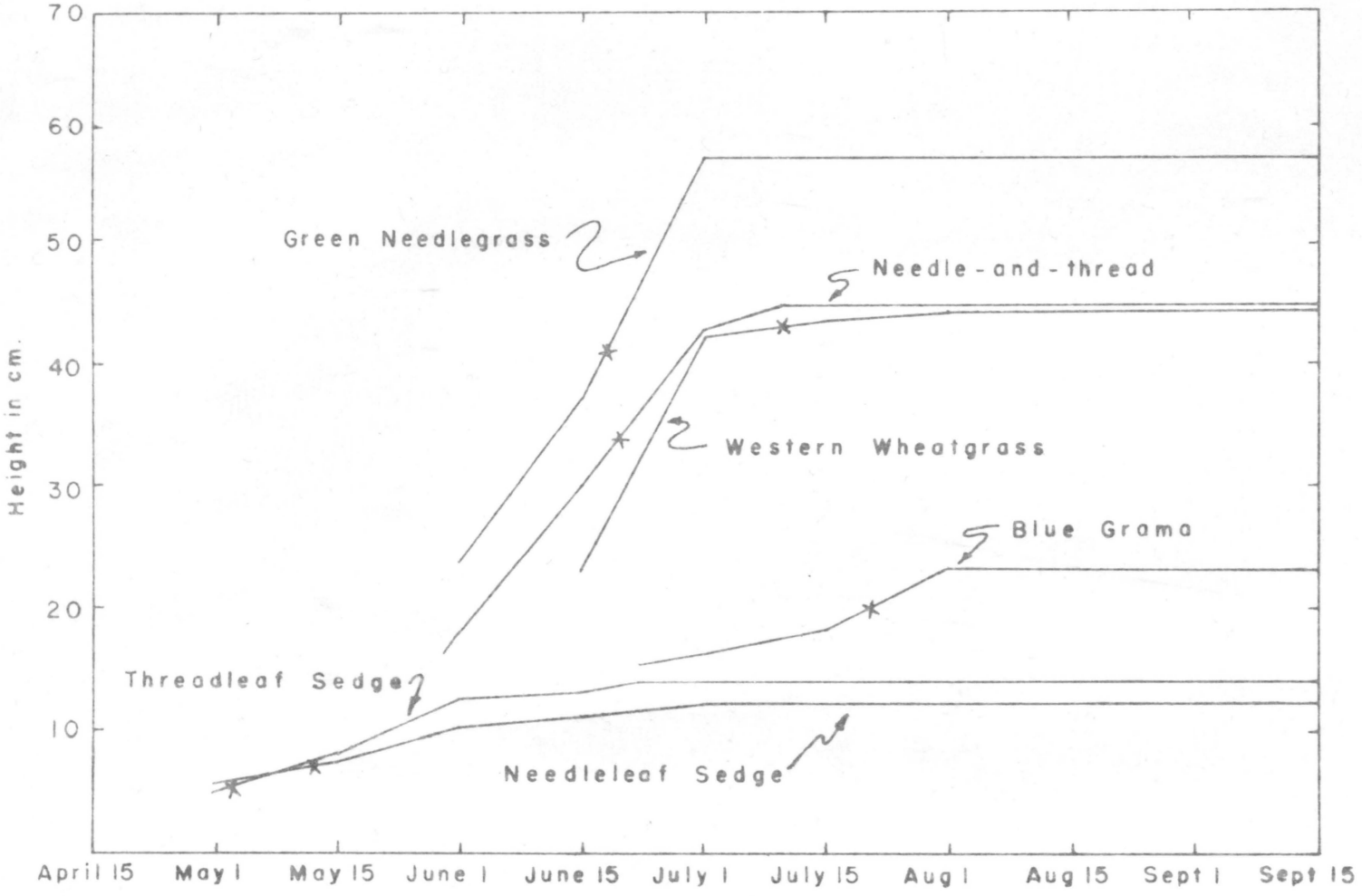

Figure 4. Average course of stalk growth by 2-week intervals for major grass and sedge species on the study area for the 8-year period, 1955-1962. The X marks on the curves indicate the average flowering dates for the species.

TABLE 7. MAXIMUM MATURE HEIGHTS OF LEAVES AND STALKS IN cm OF GRASSES AND SEDGES FOR EACH YEAR OF THE 8-YEAR STUDY PERIOD (1955-1962)

Species	1955		1956		1957		1958		1959		1960		1961		1962		Maximum Average Height	
	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks	Leaves	Stalks
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
Western wheatgrass	30.0	51.0	27.0	34.0	23.0	55.0	23.0	51.0	20.0	35.0	19.0	36.0	22.0		26.0	52.0	23.8	44.9
Needle-and-thread	23.0	48.0	26.0	35.0	24.0	70.0	19.0	51.0	19.0	39.0	17.0	54.0	16.0	30.0	23.0	34.0	20.9	45.1
Blue grama	11.0	20.0	16.0	24.0	12.0	30.0	11.0	27.0	9.0	20.0	8.0	20.0	7.0	17.0	11.5	29.0	10.7	23.5
Needleleaf sedge	8.0	11.0	12.0	13.0	10.0	10.0	12.0	16.0	9.0	12.0	9.0	12.0	9.0		11.0	12.0	9.8	12.3
Threadleaf sedge	12.0	13.0	12.0	14.0	12.0	16.0	13.0	15.0	10.0	13.0	8.0	13.0	10.0	15.0	12.0	16.0	10.6	14.4
Sandberg bluegrass	11.0	33.0	10.0	27.0	10.0	25.0	9.0	16.0	7.0	27.0	7.0	23.0	8.0	24.0	8.0	31.0	8.8	25.8
Prairie Junegrass	18.0	37.0	14.0	23.0	13.0	35.0	12.0	28.0	11.0	19.0	8.0	28.0	11.0	16.0	11.0	31.0	12.3	27.1
Green needlegrass	35.0	60.0	36.0	36.0	32.0	70.0	35.0	60.0	35.0	48.0	34.0	65.0	25.0	40.0	40.0	73.0	34.0	56.5
Plains reedgrass	27.0	30.0	19.0	19.0	22.0	32.0	21.0	21.0	18.0	13.0	18.0	29.0	18.0		24.0	35.0	20.9	25.6
Little bluestem	14.0	45.0	12.0	35.0	14.0	33.0	15.0	43.0	18.0	24.0	15.0	34.0	17.0	34.0	17.0	44.0	15.3	36.5
Prairie sandreed	46.0	85.0	38.0	70.0	33.0	85.0	42.0	87.0	45.0	66.0	50.0	65.0	36.0	70.0	66.0	101.0	44.5	79.9
Big bluestem	21.0	90.0	18.0		29.0	91.0	33.0	63.0	15.0		18.0	15.0	10.0	53.0	19.0	90.0	20.6	67.0
Stonyhills muhly	12.0	23.0	12.0	23.0	13.0	26.0	16.0	28.0	18.0	21.0	15.0	18.0	15.0	22.0	19.0	24.0	16.5	23.1
Red threeawn									17.0	20.0	16.0	20.0	13.0	25.0	17.0	27.0	15.8	23.0
Big needlegrass							30.0	64.0	26.0	40.0	32.0	53.0	30.0	45.0	32.0	44.0	30.0	49.2

Sandberg bluegrass were not greatly affected by the drought, mainly because their very early growth enabled them to complete their growth cycles during the period when a sufficient amount of moisture was still available. These species were further benefited by cooler temperatures prevailing during this period. In contrast to the dry season of 1961, the 1962 growing season was characterized by relatively cool temperatures and ample moisture throughout the entire growing period (Table 7). In this year, practically all species attained heights well above their normal average height.

Seed stalk production in most species is greatly affected by drought conditions such as were experienced during the 1961 growing season and, to a limited degree, during other years of the study--notably in 1956. Three species failed to produce seed stalks on the study area in 1961--western wheatgrass, needleleaf sedge, and plains reedgrass--and numerous other species produced only a few fruiting stalks. In 1956, which was dry until late June, very few fruiting stalks were produced, although maximum leaf and stalk heights were near average as the result of renewed growth following the rains (Table 7).

A knowledge of the approximate dates when a forage species can be expected to attain sufficient height to provide grazing for livestock is of great importance. Tables 8 and 9 show the number of days beyond April 15 when the grass and sedge species reached leaf heights of 5 cm and 10 cm, respectively. The most significant height from the standpoint of time to begin grazing is the 5-cm height. The data of Table 8 show that wide differences existed from year to year in the

TABLE 8. NUMBER OF DAYS AFTER APRIL 15 FOR LEAVES OF GRASSES AND SEDGES TO ATTAIN HEIGHTS OF 5 cm IN EACH YEAR OF THE STUDY

Species	Number of Days to Reach 5-cm Leaf Height							
	1955	1956	1957	1958	1959	1960	1961	1962
Western wheatgrass	0	0	10	13	0	0	24	5
Needle-and-thread	0	26	16	12	22	17	28	5
Blue grama	32	42	28	35	52	51	49	47
Needleleaf sedge	31	24	16	10	19	17	28	0
Threadleaf sedge	13	22	15	12	12	17	38	21
Sandberg bluegrass	4	18	16	10	22	19	25	17
Prairie Junegrass	2	23	16	13	22	36	28	10
Green needlegrass	0	0	10	0	0	0	0	5
Plains reedgrass	0	0	10	0	0	15	0	10
Little bluestem	32	0	38	35	0	41	0	29
Prairie sandreed	0	0	26	0	0	0	0	28
Big bluestem	0	47	40	40	0	43	47	0
Stonyhills muhly	0	39	38	35	41	0	31	31
Red threeawn	0	0	0	0	0	37	0	23
Big needlegrass	0	0	0	0	21	16	0	21

TABLE 9. NUMBER OF DAYS AFTER APRIL 15 FOR LEAVES OF GRASSES AND SEDGES TO ATTAIN HEIGHTS OF 10 cm IN EACH YEAR OF THE STUDY

Species	Number of Days to Reach 10-cm Leaf Height							
	1955	1956	1957	1958	1959	1960	1961	1962
Western wheatgrass	13	27	15	29	24	29	42	21
Needle-and-thread	36	38	23	30	0	43	47	20
Blue grama	86	55	77	79	74			75
Needleleaf sedge		43	43	56	52			53
Threadleaf sedge	48	39	31	35	74		66	54
Sandberg bluegrass	35	39	38					
Prairie Junegrass	26	39	32	58	54		57	72
Green needlegrass	10	26	14	13	12	26	28	
Plains reedgrass	5	37	23	13	22		31	25
Little bluestem	62	40	53	45	60	54	55	54
Prairie sandreed	30	40	38	36				
Big bluestem	48	56	50	45	56	54	66	
Stonyhills muhly	57	70	59	52	58	51	56	45
Red threeawn					55	47	53	47
Big needlegrass							31	36

time at which the major species reached this critical height. For instance, western wheatgrass required 24 days to reach the 5-cm height during the 1961 season, but did attain the 5-cm height by April 15 during four years out of the eight years of the study. Needle-and-thread did not attain the 5-cm height until 28 days after April 15 in 1961, and in only one year of the eight was the 5-cm height attained prior to April 15.

Another of the forage species, needleleaf sedge, reached the 5-cm height by April 15 in only one of the eight years--1962. For the most part, the leaves of this species did not reach the 5-cm height until well into May. Threadleaf sedge did not reach the 5-cm height in any of the eight years by April 15. However, in four out of the eight years this sedge had attained this height by May 1.

Blue grama grass did not attain the 5-cm height in any of the eight years of the study by April 15. In most years, more than a month was required after April 15 for this species to reach the 5-cm leaf height. The great variation in time required for this species to reach 5-cm height is illustrated by the fact that in 1957 the species reached this critical height 28 days after April 15, but 52 days were required in 1959 for the grass to reach 5 cm.

Similar interesting variations in time to reach the 5-cm height are shown by the other species. Surprisingly, prairie sandreed and red threeawn, species which complete their growth cycles late in the year, show early attainment of the 5-cm height, while Sandberg bluegrass, one of the earliest species to complete its growth cycle, is appreciably later in attaining this critical height. Little bluestem, big bluestem,

and stonyhills muhly show great yearly variations in number of days after April 15 to reach the 5-cm height.

If the 5-cm height is accepted as a critical time for beginning grazing on this type, it would appear as though a date somewhere between May 1 and May 15 would be the general time of range readiness for this type of vegetation. However, other factors would have to be considered also, especially the degree of clump-fill in the bunchgrasses and the number of shoots near average height for the sod-formers. Conservative range use, which would perhaps envision allowing the taller-growing range species to reach 10 cm in height, would of course involve a much later time of beginning grazing. The data of Table 9 show that this height, in the species which normally reach this or greater height, would, on the average, not be attained until about June 1. Again the number of days after April 15 for the species to reach the 10-cm height varies greatly from year to year.

Growth Patterns of Individual Grasses

Western Wheatgrass

Western wheatgrass (Figure 5), one of the dominant cool-season grasses studied, normally begins leaf growth in early April and continues active leaf growth to mid-July, when an average leaf height of 23.8 cm was attained (Table 3). The period of most active leaf growth was from early April to late June, after which growth became progressively slower until maximum leaf height was reached in mid-July. Fluctuations in leaf height measurements beyond mid-July may be due to changes in the moisture status of the soil causing some renewed or late

Figure 5. Western wheatgrass, a single-stalked, rhizomatous, cool-season mid grass, began growth in early April and attained an average mature leaf height of 23.8 cm by mid-July.

growth during certain years. Maximum mature leaf heights for this species varied from a high of 27.0 cm during 1956 to a low of 19.0 cm during 1960 (Table 7).

The stalk growth became evident about June 15, and the stalk attained an average maximum mature height of 44.9 cm by approximately July 25. Stalk growth was rapid from June 15 to mid-July, after which it became slower until the mature height was reached. The yearly variation in maximum height is appreciable and rather vividly reflects the two years of drought (1956 and 1961) experienced during this study. In 1956, a maximum flowerstalk height of 34.0 cm was attained, but no stalks were produced during 1961 (Table 7).

Needle-and-Thread

Needle-and-thread (Figure 6), another important cool-season mid grass, appears to make more rapid early leaf growth than western wheatgrass (Figure 3). Growth begins in early April and an average maximum leaf height of 20.9 cm was attained by June 25 (Table 3). Growth was rapid from early April until the mature leaf height was attained. This grass completed its leaf growth approximately 15 days ahead of western wheatgrass. Yearly maximum leaf heights vary considerably as in all other species (Table 7). The greatest mature leaf height, 26.0 cm, was recorded in 1956 and the least, 16.0 cm, in 1961. The leaves of this bunchgrass at maximum height are shorter than those of western wheatgrass, but each individual clump of grass contains numerous leaves, which results in a high over-all volume of foliage. The flower stalks become evident in late May and reach an average mature height of 45.1 cm

Figure 6. Needle-and-thread, a cool-season bunchgrass, began leaf growth in early April and attained an average mature leaf height of 20.9 cm by early July.

by late June or early July (Table 4). Growth is rapid from initiation of the stalk to maturity and is generally accomplished over a period of approximately 35-40 days. Yearly variations in maximum heights attained are great (Table 7). The greatest mature stalk height of 70.0 cm was attained in 1957, with the shortest mature height, 30.0 cm, occurring in 1961.

Blue Grama

Blue grama (Figure 7) is the only important warm-season shortgrass on the study area and is the main shortgrass in the mixed grass prairie. On the site it began its growth in mid-April, which is considerably later than either western wheatgrass or needle-and-thread. An average maximum mature leaf height of 10.7 cm was attained by approximately July 25 (Table 3). Leaf growth is slow early in the season but becomes rather rapid in early June (Figure 3), and the leaves continue active growth to mid-July when an abrupt reduction in rate of growth is noticeable. This grass responds rather quickly to increases in soil moisture if such increases occur after a dry period, and it may continue its leaf growth even after having reached apparent dormancy. This is true, to a lesser extent, in both western wheatgrass and needle-and-thread. Yearly variations in maximum leaf height attained are considerable. The maximum mature leaf height attained by this species during the study period was 16.0 cm in 1956, and the minimum mature height was 7.0 cm in 1961 (Table 7).

Fruiting stalks became evident in mid to late June and attained a maximum mature height of 23.5 cm by late July (Table 4). The rate of

Figure 7. Blue grama, the only warm-season shortgrass on the study area, began leaf growth by mid-April and attained an average mature leaf height of 10.7 cm by late July.

stalk growth is relatively steady with no observable periods of rapid growth such as occur so prominently in some of the mid grasses (Figure 4). The annual variation in maximum stalk height attained was from a high of 29.0 cm in 1962 to a low of 17.0 cm in 1961.

The sedges--needleleaf sedge and threadleaf sedge--are the two most important sedges in this range type (Figure 8). Needleleaf sedge is the more common of the two and constitutes a considerable portion of the total volume of forage early in the season. The sedges generally are considered as the ecological equivalent of shortgrasses.

Needleleaf sedge began growth in early April and reached an average mature leaf height of 9.8 cm by early to mid-June (Table 3). Growth is rapid during early and mid-May, but gradually becomes slower until the mature height is attained. The yearly variation of maximum mature leaf heights was from a high of 12.0 cm during 1956 to a low of 8.0 cm during 1955 (Table 7). The stalks appeared in late April and reached an average maximum mature height of 12.3 cm in late June. The yearly variation of mature fruiting stalk heights was from 16.0 cm during 1958 to 10.0 cm in 1957. No flower stalks were produced during the 1961 season.

Threadleaf sedge began growth in early April and attained an average mature maximum leaf height of 10.6 cm by mid-June, at approximately the same time as needleleaf sedge attained maximum leaf height (Figure 3). Rate of growth was quite uniform throughout the active growing period. The yearly variations in maximum leaf heights are not as great as in the other important species, a high of 13.0 cm being recorded in 1958 and a low of 8.0 cm in 1960 (Table 3). Flower stalks

Figure 8. Threadleaf sedge, a very early, cool-season, clump-forming sedge species, began leaf growth by late March or early April and reached an average mature leaf height of 10.6 cm by late May or early June.

were apparent in late April and attained an average mature height of 14.4 cm by early June (Table 4). The yearly variations in stalk heights were not great, ranging from a high of 16.0 cm attained in 1957 and 1962 to a low of 13.0 cm attained during the years 1959 and 1960 (Table 7).

Stalk production is normally low in both species, and very few were produced during a large percentage of the years of the study. The relative abundance of threadleaf sedge is low in relation to other grass and sedge species on the study area, and it contributes little to the forage volume. Both sedges complete their growth cycles early in the season, and by early to mid-June severe drying is commonplace. Once drying has begun in the sedges, normally it will advance steadily until the plant dries completely.

Sandberg Bluegrass

Sandberg bluegrass is a short, early-growing, perennial bunchgrass, which attained an average maximum mature leaf height of 8.8 cm by late May. Growth normally begins in early April, and maturity is reached ahead of all other grasses or sedges on the study area. On a percentage basis of maximum height attained at a given date, this grass completed approximately 80 per cent of its growth by late April, well ahead of the sedges and prairie Junegrass (Table 5). The mature height of the leaves of Sandberg bluegrass is less than that of any of the other grasses and sedges studied (Table 3). Drying of leaves is rapid in this species and takes place over a relatively short period of time. The leaves are subject to easy breakage once dry, and often only the

base of the grass clump remains as the growing season advances. The yearly variations in maximum leaf height were not great, ranging from a high of 11.0 cm during 1955 to a low of 7.0 cm during 1959 and 1960 (Table 7).

Fruiting stalks of this species grow tall in proportion to the leaves and reach an average maximum mature height of 25.8 cm by late mid-June (Table 4). Stalk growth continues for an appreciable period after the leaves have reached maturity, but elongation of the seed stalks, however important for the propagation of the species, has no real value in terms of usable forage. Yearly variations in maximum mature stalk heights ranged from a high of 33.0 cm, reached during 1955, to a low of 16.0 cm attained during 1958.

Prairie Junegrass

Prairie Junegrass (Figure 9) is a cool-season bunchgrass normally beginning growth in early April and reaching maturity by early July. The average maximum leaf height attained was 12.3 cm (Table 3). Growth was rather steady from early spring to maturity and no period of obvious rapid growth was noticeable. The yearly variations in maximum mature height recorded are considerable, ranging from a high of 18.0 cm in 1955 to a low of 8.0 cm in 1960 (Table 7). The leaves of this species are not very palatable and it is not a particularly desirable forage species. The leaves are extremely resistant to drying and, although their growth may be nearly complete by the end of June, they may remain green for almost the entire season.

Fruiting stalks reached their average maximum height of 27.1 cm

Figure 9. Prairie Junegrass, a cool-season bunchgrass, began leaf growth by early April and attained an average mature leaf height of 12.3 cm by the end of June.

by the end of July (Table 4). Yearly variations in maximum height attained are considerable, ranging from a high of 37.0 cm during 1955 to a low of 16.0 cm during 1961.

Green Needlegrass

Green needlegrass (Figure 10) is a fairly palatable cool-season bunchgrass of this region. It occurs somewhat sparingly in native Northern Great Plains rangeland under grazing and, therefore, does not constitute a large percentage of the total forage volume. This species begins its growth at approximately the same time in early spring as does needle-and-thread, the recorded average leaf-height reaching 34.0 cm by the end of June or early July. The yearly variations in maximum mature leaf height attained ranged from a low of 25.0 cm during 1961 to a high of 40.0 cm in 1962 (Table 7).

The average maximum fruiting-stalk height of 56.5 cm was generally attained by the end of June, but fluctuations in available soil moisture affects stalk growth considerably. The yearly maximum mature height varied from 36.0 cm in 1956 to 73.0 cm in 1962 (Table 7). This species may be severely injured by heavy grazing, and under this treatment it soon becomes a minor species in the grassland association.

Plains Reedgrass

Plains reedgrass (Figure 11) is a cool-season, single-stalked species beginning its growth in early April at approximately the same time as most of the other mid grasses found in this grassland. The average maximum mature leaf height of 20.9 cm was generally attained

Figure 10. Green needlegrass, a cool-season bunchgrass, was sparingly represented on the study area. It began its leaf growth in early April and reached a mature height of 34.0 cm by early July.

Figure 11. Plains reedgrass, a single-stalked, cool-season grass, began leaf growth in early April and reached an average mature leaf height of 20.9 cm by the end of June.

by approximately July 20 (Table 3). Yearly variations in maximum mature leaf height were rather great, ranging from a high of 27.0 cm during 1955 to a low of 18.0 cm during 1959, 1960, and 1961 (Table 7). The average maximum mature leaf height of plains reedgrass is near to that of western wheatgrass. The leaves of plains reedgrass are somewhat narrower and appear somewhat lighter in color as compared to western wheatgrass. They acquire a reddish tinge on the margins as seasonal growth advances.

Fruiting stalks are seldom numerous and are not much taller on the average than are the leaves. The average maximum height of stalks was 25.6 cm, attained in late June (Table 4). Yearly variations in maximum mature height ranged from 35.0 cm during the 1962 season to 13.0 cm during 1959. No stalks were produced on the study area during the 1961 season (Table 7).

Little Bluestem

Little bluestem (Figure 12) is a warm-season bunchgrass, beginning growth in early May and completing its growth by early to mid-August. Average maximum leaf height for the 8-year period was 15.3 cm (Table 3). Growth was rapid from mid-May to mid-June, then much slower until maturity was reached. The yearly variations in maximum mature leaf height during the study period were not great, ranging from a high of 18.0 cm during 1959 to a low mature leaf height of 12.0 cm during 1956 (Table 7).

The leaves and stalks have a reddish tinge early in the season, which becomes progressively darker and more widespread on the plant

Figure 12. Little bluestem, a warm-season bunchgrass, began leaf growth in early May and reached a mature leaf height of 15.3 cm by early to mid-August.

as the seasonal growth advances. The grass clumps normally have only a few leaves early in the season but fill out rapidly as the season progresses. This grass is not considered an important species in this type of range grassland because of its relatively low abundance and apparent low palatability to livestock. This grass was restricted to the soils in the upper portions of the broken slopes in the study area.

Prairie Sandreed

Prairie sandreed (Figure 13) is a warm-season, rhizomatous, tall grass which forms an open sod. It began its leaf growth in mid-May and attained a maximum leaf height of 44.5 cm by late July (Table 3). Yearly variations of the average maximum mature leaf height attained ranged from a high of 66.0 cm during 1962 to a low of 33.0 cm during the 1956 season (Table 7). Growth, once begun, is rapid until maturity is reached. The species is of limited importance in the study area as a forage grass, and is not very palatable because of the fibrous nature of its leaves. This grass is fairly abundant in sandy soils and may be of great importance locally. It has a distinct yellow-green appearance which makes it rather conspicuous on the range.

The flower stalks appeared in early July and attained an average maximum height of 79.9 cm by approximately mid-August. Elongation of stalks was rapid during the period following their appearance until maturity was reached. Yearly variations in the average maximum mature stalk heights ranged from 101.0 cm during 1962 to 65.0 cm during the 1960 season.

Figure 13. Prairie sandreed, a coarse, warm-season rhizomatous grass, began leaf growth in early May and attained an average mature leaf height of 44.5 cm by late July or early August.

Big Bluestem

Big bluestem is a warm-season, tall grass normally found in this area only on sites having better than average soil and moisture conditions. The species is not of any great importance in the native grassland of this region. The leaves attained an average maximum mature height of 20.6 cm by late July (Table 3). The maximum mature leaf heights ranged from 29.0 cm in 1957 to 10.0 cm during the 1961 season (Table 7). Leaf growth began in late May, and the leaves reached their maximum height by approximately mid-July.

The fruiting stalks appeared in early to mid-July and attained an average mature height of 67.0 cm by mid-August. The yearly variations in maximum stalk height ranged from a high of 91.0 cm during the 1957 season to a low of 15.0 cm during 1960. Stalks are produced in great numbers during a climatically favorable season, but then may be entirely absent during seasons of unfavorable conditions (Table 7). The leaves are apparently a delicacy for livestock, and the grass is generally sought after and grazed heavily.

Stonyhills Muhly

Stonyhills muhly (Figure 14) is a cool-season bunchgrass normally found on broken slopes and shallow soils on the study area. Leaf growth began in late April, and an average maximum height of 16.5 cm was attained by mid to late July (Table 3). Leaf growth in this species is rather slow but the rate is relatively steady from initiation to maturity. The yearly variation of maximum leaf heights ranged from 19.0 cm in the 1962 season to 12.0 cm during the years 1955 and 1956

Figure 14. Stonyhills muhly, a cool-season bunchgrass, began growth in early to mid-April and attained an average mature leaf height of 16.5 cm by early July.

(Table 7). Flower stalks began to appear by early July, and an average maximum height of 23.1 cm was attained by mid-August (Table 4). Annual variations of maximum mature stalk heights ranged from a high of 28.0 cm during the 1952 season to a low of 18.0 cm during 1960 (Table 7).

The leaves, which are very narrow, are somewhat yellowish-green and appear fibrous. The inflorescence characteristically develops prominent orange-colored galls in the florets early in the season. These galls are caused by an insect. Stonyhills muhly is of minor importance as a forage plant and is seldom eaten by livestock.

Red Threeawn

Red threeawn (Figure 15) is a warm-season bunchgrass occurring sparingly on hillsides in the range grassland. Leaf growth in this species generally began during early May and reached an average mature height of 15.8 cm by mid-June. Leaf growth is rapid and maximum height is attained over a relatively short period of time (Table 3). The yearly variations in the average maximum leaf heights attained ranged from 17.0 cm during 1959 to 13.0 cm in the 1961 growing season (Table 7). Observations were made on this grass only for the last four years of the study.

The flower stalks began to appear by mid-June and attained an average maximum height of 23.0 cm by mid to late July (Table 4). Average maximum mature stalk height ranged from 27.0 cm attained during the 1959 and 1960 seasons (Table 7). The species is easily recognized by its close bunch habit and characteristically narrow,

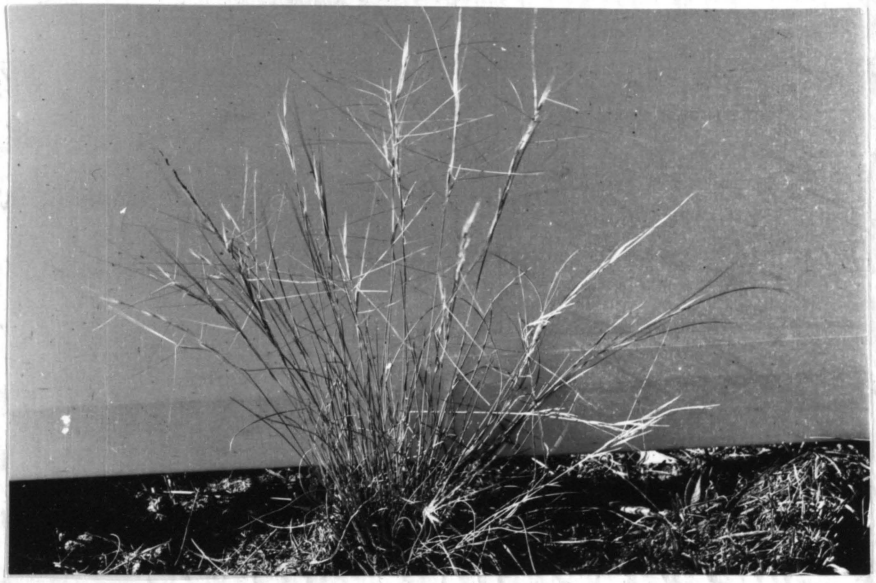

Figure 15. Red threeawn, a warm-season bunchgrass, began leaf growth by early May and attained an average mature leaf height of 15.8 cm by early July.

pointed leaves which have reddish tips. The fruit is a needle-like grain with a curled three-pronged awn, which gives it its name. In the early stages of seed development, the tips of the awn are reddish or near scarlet in color, but this fades as the plant matures. It is a minor species of low palatability, and is of no great importance as a forage plant in this area.

Big Needlegrass

Big needlegrass or porcupine grass is a cool-season bunchgrass occurring only rarely on hillsides in the study area. Leaf growth began in late March or early April, and an average maximum leaf height of 30.0 cm was attained by early July (Table 3). Yearly variations in maximum leaf heights ranged from 32.0 cm during the 1960 and 1962 seasons to 26.0 cm in the 1959 season (Table 7). The leaves are longer, generally less rolled, lighter in color, and considerably wider than the leaves of needle-and-thread.

Fruiting stalks appeared by late May and attained an average maximum height of 49.2 cm by late June (Table 4). The yearly variations of the average maximum mature stalk heights ranged from a high of 64.0 cm in the 1958 season to a low of 40.0 cm during the 1959 growing season (Table 7). The species is moderately palatable but, due to its very low abundance, it cannot be classed as an important forage plant in this range type.

Forage Production and Height Growth

It would be expected that the total dry weight of vegetation would increase as the height of the species that composed the vegetation increased with the progress of seasonal growth. In order to get a measure of the increase in yield with the seasonal progression of growth, square-foot plots of two of the most important grasses were clipped at 15-day intervals from May 15 to September 1. The two grasses clipped were blue grama grass and western wheatgrass.

A small exclosure was established in 1958, and three 1-ft.^{2} plots of each species were clipped at ground level in the exclosure at each date of clipping. The blue grama plots were located in an area in the exclosure where a nearly pure stand of blue grama occurred, and the data given in Table 10 are the average yields per square foot of all the vegetation occurring in these plots. Small amounts of other species were present in the plots and the actual composition of the yields is given in Appendix Tables 16 and 17. No areas of pure western wheatgrass occurred in the exclosure, and the yields of this species were converted to yields per 100 stalks, so that yields at each of the clipping dates would be on a comparable basis. These converted yields are given in Table 13, page 73. The composition of the total yields from these plots is given in Appendix Tables 18 and 19.

The yields of blue grama per square foot at 15-day intervals, as given in Table 10, show a fairly steady progression as the season advances up to early July. The average yields on each date as percentage of the maximum yield produced by the species are given in Table 11.

TABLE 10. FIVE-YEAR (1958-1962) AVERAGE PRODUCTION OF BLUE GRAMA GRASS PER SQUARE-FOOT AT SUCCESSIVE 2-WEEK INTERVALS

Year	Dates of Plot Clipping							
	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1
	dry weight yield per square-foot (grams)							
1958	2.8		6.8	8.1	7.9	9.9	11.2	12.4
1959		5.4	5.4	7.2	11.9	8.3	10.5	8.2
1960	5.0	5.1	9.4	14.8	11.2	11.1	12.7	7.7
1961		2.9	5.0	5.7	9.4	6.5	9.1	8.9
1962	4.9	9.4	15.9	19.2	23.7	27.7	29.4	24.5
Ave. Yield	4.3[a]	5.7	8.5	11.0	12.9	12.7	14.6	12.4

[a]Three-year average due to variation in earliness of growth initiation.

TABLE 11. FIVE-YEAR (1958-1962) AVERAGE PER CENT PRODUCTION OF BLUE GRAMA GRASS PER SQUARE-FOOT AT SUCCESSIVE 2-WEEK INTERVALS

Year	Dates of Plot Clipping							
	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1
	per cent of yield							
1958	22.9		55.0	65.8	63.6	80.0	90.3	100.0
1959		45.0	45.3	60.4	100.0	69.3	88.0	69.0
1960	33.7	34.5	63.2	100.0	75.7	74.8	85.4	51.9
1961		31.3	53.7	60.5	100.0	69.4	97.4	95.3
1962	16.8	31.9	54.2	65.3	80.8	94.2	100.0	83.5
Ave. Yield	29.5[a]	39.0	58.2	75.3	88.4	87.0	100.0	84.9

[a]Three-year average due to variation in earliness of growth initiation.

An even better picture of the curve of production based on average values for the 5-year period is given in Figure 16.

As would be expected, great variations occurred from year to year in total production of the species and in time at which maximum production was reached. In 1958 the maximum production of 12.4 gm/ft.^{2} was not reached until September 1. In 1959 a maximum production of 11.4 gm/ft.^{2} was reached on July 15, while in the following year (1960) the peak production of 14.3 gm/ft.^{2} was attained by July 1. In 1961, a drought year, maximum production of 9.4 grams was reached on July 15 and in 1962, an especially favorable year, a production of 29.4 gm/ft.^{2} was attained by August 15. The greatest production during the 5-year period of the clipping trial was thus over three times that of the lowest production and over twice that of production in the next most favorable year, 1960.

Blue grama is a relatively late growing species, and in two out of the five years of the trial this species had not made sufficient growth by May 15 to justify clipping (Table 10). Disregarding the fact that wide variations in actual production will occur from year to year at any given date, on the average 40 per cent of the total yield of blue grama was produced by June 1, approximately 60 per cent by June 15, 75 per cent by July 1, and nearly 90 per cent by July 15. Additional production after July 15 could come from both leaf growth and stalk growth, since maximum heights of leaves and stalks of this species are not usually attained until August (Table 12).

Although, on the average, 90 per cent of the total yield is reached by July 15, 98.2 per cent of the height growth of leaves is

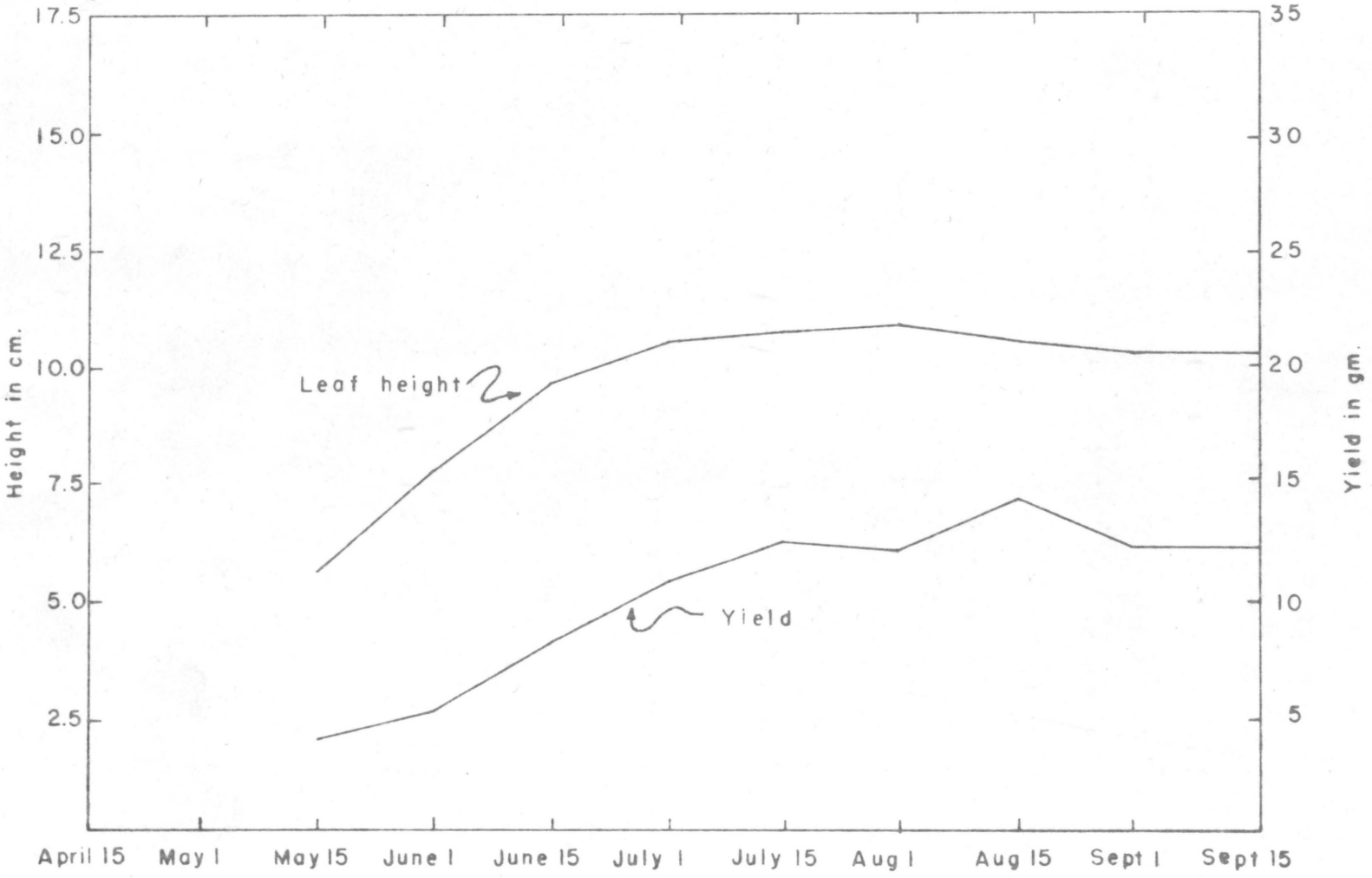

Figure 16. Average leaf height and square-foot yields of blue grama grass as related to seasonal growth pattern for the 5-year period, 1958-1962.

TABLE 12. PER CENT OF TOTAL LEAF HEIGHT ATTAINED BY BLUE GRAMA GRASS AT 2-WEEK INTERVALS DURING THE 1958-1962 STUDY PERIOD

Year	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1	Yearly Maximum
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Height in cm
1958	72.3		74.2	88.1	73.2	100.0	90.4	84.3	8.3
1959		61.2	69.0	76.3	91.7	100.0	88.9	66.7	12.0
1960	55.1	63.0	78.7	91.9	84.0	57.5	76.1	100.0	12.7
1961		52.6	100.0	75.2	80.5	77.4	60.2	52.6	13.3
1962	32.0	47.1	60.3	84.7	92.3	100.0	97.9	97.9	17.7
Average Per Cent of Height Growth	53.2[a]	69.4	87.4	95.5	98.2	100.0	95.5	93.7	12.8

[a]Three-year average due to variation in earliness of growth initiation.

already completed (Table 12). The yield appears not to correspond directly with the height growth but rather lags behind the height growth approximately 15 days (Figure 16). The increase in stalk growth later in the season apparently does not appreciably affect the total yield of the grass (Figure 16). The added weight from the stalks seems to be largely offset by loss of weight from leaf-breakage or other causes.

The data of Table 10 show that serious losses of dry matter occur in blue grama after maximum production is reached. In all but one year (1958) substantial losses in yield were recorded after the maximum yield was reached. Losses of total dry matter could be attributed to breakage of brittle leaves and stalks, to shedding of mature seed, to insect activity, or possibly even to translocation of food materials from leaves to crowns and roots. The data show that under most conditions these losses may be initiated as early as the end of July or the first part of August.

Yields of western wheatgrass in grams per 100 stalks at the 2-week clipping intervals are given in Table 13, and the yields at each clipping in terms of per cent of the season's maximum yield are given in Table 14. A better picture of the relationship between height growth and increase in yield as an average over the 5-year period is given in Figure 17.

Western wheatgrass showed wide yearly variations in time of attaining a given percentage of yield. In 1958 and 1959, maximum yields of 16.5 and 12.6 grams per 100 stalks, respectively, were not reached until September 1. Maximum production during the 1961 and 1962

TABLE 13. FIVE-YEAR (1958-1962) AVERAGE PRODUCTION OF WESTERN WHEATGRASS PER 100 STALKS AT SUCCESSIVE 2-WEEK INTERVALS

Year	Dates of Plot Clippings							
	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1
	dry weight yield per 100 stalks (grams)							
1958	6.9		7.4	11.1	12.0	10.3	14.2	16.5
1959		6.2	8.8	7.0	10.2	11.4	9.7	12.6
1960	8.2	9.1	10.8	17.1	18.8	18.6	15.6	18.1
1961		6.3	6.9	8.5	9.0	7.6	10.0	8.2
1962	7.1	11.3	19.3	27.1	30.2	30.2	32.9	30.7
Ave. Yield	7.4[a]	8.2	10.6	14.6	16.0	15.6	16.5	17.2

[a]Three-year average due to variation in earliness of growth initiation.

TABLE 14. FIVE-YEAR (1958-1962) AVERAGE PERCENTAGE PRODUCTION OF WESTERN WHEATGRASS PER 100 STALKS AT SUCCESSIVE 2-WEEK INTERVALS

Year	Dates of Plot Clipping							
	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1
	per cent of yield							
1958	41.9		45.1	67.3	72.9	62.3	86.4	100.0
1959		49.3	69.4	65.0	81.2	90.1	72.2	100.0
1960	43.4	48.4	57.2	90.9	100.0	99.1	82.9	96.4
1961		62.2	69.0	85.1	89.6	76.4	100.0	81.5
1962	21.6	34.4	58.7	82.4	91.9	91.9	100.0	93.4
Ave. Yield	43.0[a]	47.7	61.6	84.9	93.0	90.7	95.9	100.0

[a]Three-year average due to variation in earliness of growth initiation.

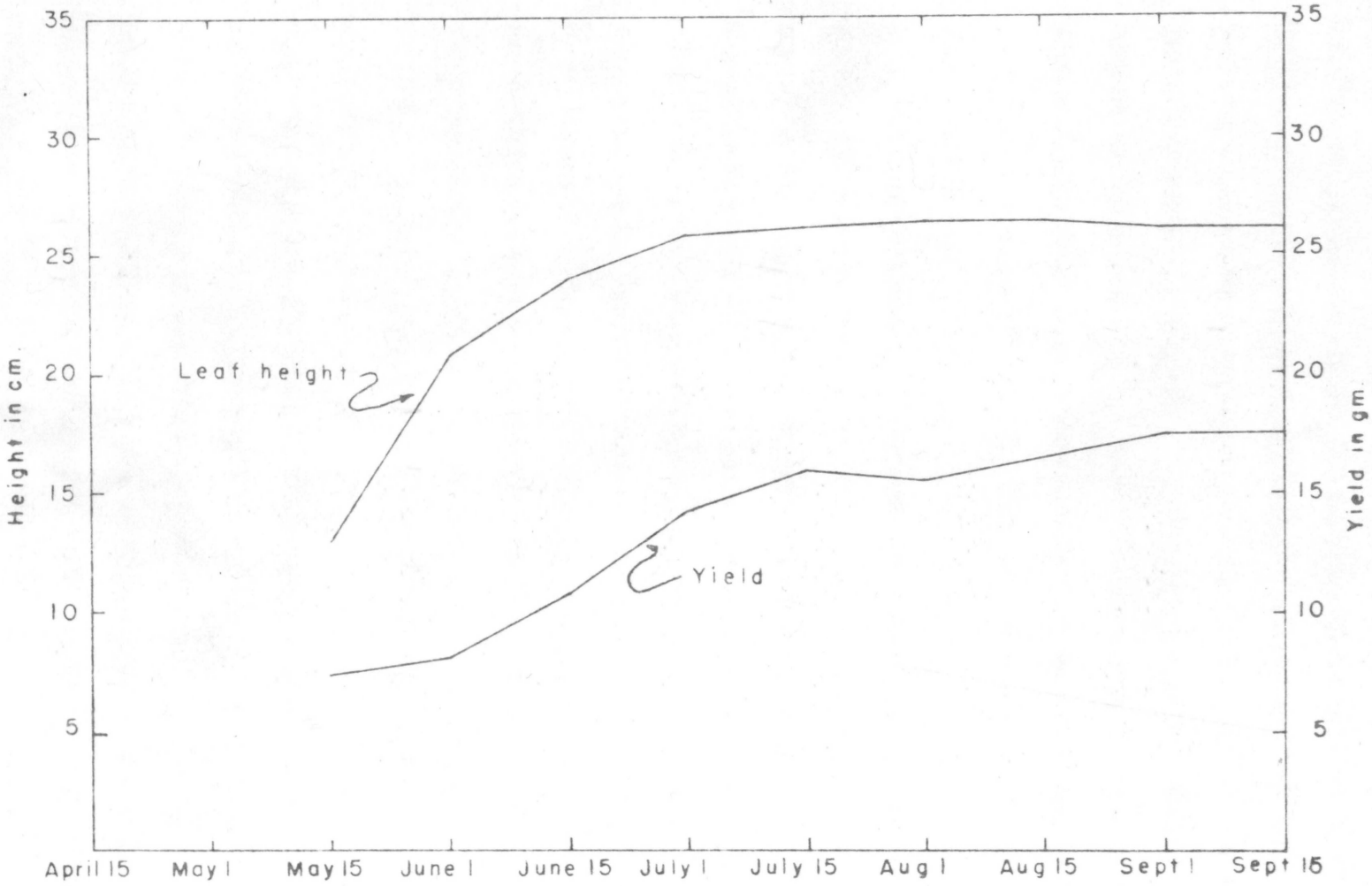

Figure 17. Average leaf height and yield per 100 stalks of western wheatgrass as related to seasonal growth pattern for the 5-year period, 1958-1962.

seasons was reached by August 15, with yields of 8.2 gm in 1961 and 30.7 gm during 1962. Apparently drought during the 1961 season, while reducing yields, did not greatly influence the length of the growing period for western wheatgrass. Maximum production of 18.8 gm was reached by July 15 during the growing season of 1960. A difference of approximately 45 days exists between the earliest date when maximum production was reached (July 15, 1960) and the latest dates (September 1, 1958 and 1959).

Data on percentage of maximum production reached at a given date by western wheatgrass are given in Table 14. As stated earlier, an appreciable variation in yearly production is apparent, but the 5-year averages show the approximate per cent of yield at a given time during the growing season. Almost 62 per cent of the total yield is reached by June 15 and 96 per cent by August 15. It would be justified to state that for all practical purposes production by this species is nearly complete before the end of July. Yearly variations in actual time when maximum heights were attained were quite great. During 1959 and 1961, the maximum leaf height was reached by June 15, during 1960 and 1962 by August 15, and in 1958 by September 1 (Table 15). While time of attaining maximum leaf height and time of maximum production are closely related in this species during some of the years, the relation is not absolute. Continued stalk growth no doubt affected total yield more in some years than in other years. On the average, the relation between leaf height and stalk growth is quite close as shown in Figure 17.

TABLE 15. PER CENT OF TOTAL LEAF HEIGHT ATTAINED BY WESTERN WHEATGRASS AT 2-WEEK INTERVALS DURING THE 1958-1962 STUDY PERIOD

Year	May 15	June 1	June 15	July 1	July 15	August 1	August 15	September 1	Yearly Maximum
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Height in cm
1958	57.8		57.8	83.9	92.6	97.0	90.8	100.0	23.0
1959		68.6	100.0	95.7	86.7	91.2	88.2	88.2	22.3
1960	62.4	84.8	84.8	92.9	91.9	96.6	100.0	100.0	28.3
1961		92.1	100.0	100.0	96.0	90.9	80.2	72.3	25.3
1962	33.6	57.6	83.9	89.5	94.2	91.1	100.0	99.0	41.7
Average Per Cent of Height Growth	57.3[a]	82.8	91.6	98.9	99.6	100.0	100.0	99.6	28.1

[a]Three-year average due to variation in earliness of growth initiation.

Losses in dry matter in western wheatgrass after having reached maximum production were appreciable in some years. The losses in dry matter could be attributed to the same factors as indicated for the loss of dry matter in blue grama; that is, breakage of brittle leaves and stalks, shedding of mature seed, insect activity, and possibly even translocation of food materials from leaves to crowns and roots.

Phenological Phenomena in the Grasses

Phenological events other than the actual march of growth of the grasses were observed and recorded on the study area over the 8-year period. These observations included first appearance of fruiting stalk, date of head emergence, time of anthesis, time of beginning of leaf-tip drying, various percentages of dry-leaf area, date of approximate seed maturity, and observable beginning of seed shedding. The average dates of these phenomena over the 8-year period are given in Table 16. In Table 16 the grass and sedge species are arranged in the order of similarity in phenological behavior.

The grasses and sedges studied on this native range grassland may be grouped into four rather distinct groups by observing the phenological phenomena of each species. These groups are the same as the groups referred to in the section on growth patterns. The first group, including needleleaf sedge, threadleaf sedge, and Sandberg bluegrass, contains species which complete their growth cycles considerably sooner than any of the other species studied.

The second group comprises six species, two of which are of major importance--western wheatgrass and needle-and-thread. This

TABLE 16. EIGHT-YEAR AVERAGE DATE OF FIRST OBSERVATION OF SIGNIFICANT PHENOLOGICAL EVENTS IN GRASSES AND SEDGES (1955-1962)

Species	Average Earliest Observed Dates of Phenological Events									
	Initiation of Fruiting Stalk	Head Emergence	Anthesis	Leaf-tip Drying	Leaves 0-25% Dry	Leaves 25-50% Dry	Leaves 50-75% Dry	Leaves Over 75% Dry	Seeds Reach Maturity	Seeds Begin to Shed
Needleleaf sedge		5/2	5/12	6/13	7/8	7/22	8/10	8/23	6/28	8/18
Threadleaf sedge	4/29		5/5	6/13	6/29	7/10	8/7	9/9	6/9	6/17
Poa secunda	5/14	5/18	6/11	6/7		6/25	7/9	7/27	7/2	7/11
Western wheatgrass	6/19	6/30	7/14	6/13	7/25	8/13	8/24	9/9	8/5	8/16
Prairie Junegrass	5/20	6/5	6/26	7/15	8/14	8/13	8/22	9/9	7/17	8/14
Plains reedgrass	5/22	6/7	6/29	6/18	8/5	8/24	8/21	9/21	7/26	8/13
Needle-and-thread	5/29	6/9	6/23	7/31	8/17	8/25	9/9		7/22	7/14
Green needlegrass	5/26	6/12	6/16	6/19	7/29	8/26	9/11		7/2	7/12
Big needlegrass	6/2	6/14	6/28	6/29	8/2	8/24	8/28		6/27	7/9
Blue grama	6/26	7/4	7/18	6/25	8/5	8/21	8/27	9/21	8/12	8/28
Little bluestem	6/30	7/19	8/2	7/24	9/5	8/26	9/7		8/18	8/30
Prairie sandreed	6/18	7/18	7/25	7/9	8/25	8/31		10/2	8/23	9/9
Big bluestem	7/17	7/29	8/4	7/11	7/20	8/7	8/20	9/11	8/30	9/7
Stonyhills muhly	6/17	7/11	8/12	7/24	8/28				8/26	9/12
Red threeawn	6/16	6/28	a	7/10	8/28	9/10			7/26	8/9

[a]Actual date of flowering not determined, but apparently this event took place in July.

entire group is somewhat later than the first group but earlier than the warm-season grasses. Other species in this group are prairie Junegrass, green needlegrass, plains reedgrass, and big needlegrass.

Blue grama is considered separately because it is the only warm-season shortgrass on the study area and because of its importance as one of the dominant grasses in this range type. The early phenological events in this species closely parallel those of the other warm-season species, but drying of leaf tips is somewhat earlier.

The last group of grasses includes little bluestem, stonyhills muhly, prairie sandreed, red threeawn, and big bluestem. Growth of leaves of all these species begins in early to mid-May and maturity is generally considerably later than for the cool-season grasses.

It becomes apparent from the data of Table 16 that the species vary markedly from each other in time of occurrence of specific events. Differences in actual overall growth and drying periods, for instance, between the three major grass species and the early spring upland sedges and Sandberg bluegrass, are appreciable. Sandberg bluegrass normally begins leaf growth by early April at approximately the same time as the sedges (Table 3), but it grows and develops more rapidly than the sedges (Table 16). Flowering stalks appear in Sandberg bluegrass by May 14, which is slightly later than in the sedges. However, in all other events, Sandberg bluegrass is far ahead of all other species in its phenological sequence. By June 25, 25-50 per cent of its leaf area is already dry. The other grasses do not reach this degree of drying until mid to late August. The sedges are somewhat similar to Sandberg bluegrass reaching 25-50 per cent dry-leaf area

by mid-July (Table 16). Needleleaf sedge and threadleaf sedge are the earliest flowering species on the study area. Both species flower at approximately the same time, May 5 to May 12. Sandberg bluegrass flowers approximately 30 days later, the average flowering date being June 11 although its leaves are already nearing mature growth (Table 3).

Western wheatgrass, prairie Junegrass, plains reedgrass, and the three species of the genus Stipa--needle-and-thread, green needlegrass, and big needlegrass--may be considered as a group later than the sedges or Sandberg bluegrass but earlier than the bluestems, stonyhills muhly, prairie sandreed, and red threeawn.

Flower stalks of western wheatgrass were initiated on the average by June 19 (Table 16). The spike generally emerges by the end of June and anthesis follows approximately two weeks later (Table 16). The flowering stalks of needle-and-thread, by way of comparison, appeared on the average by May 29, approximately two weeks earlier than western wheatgrass; the panicle emerged by June 9, 20 days ahead of western wheatgrass and the average date of anthesis was June 23, 21 days earlier than the wheatgrass. The leaves of western wheatgrass showed 25 per cent dry-leaf area by July 25, while needle-and-thread did not reach the 25 per cent level until August 17 (Table 16). Ability of a species to maintain green foliage during the grazing season is an important factor in assessing the relative value of a range grass.

The fruits of needle-and-thread mature more rapidly and are generally shed a full month ahead of the beginning of seed-shed in western wheatgrass. The average beginning-of-shedding date for western wheatgrass is August 16, and that for needle-and-thread is approximately

July 14. Western wheatgrass sheds its seed slowly, requiring air movement and possible effects from other climatic factors; while needle-and-thread sheds its seed rapidly, the seed being loosely concentrated in the upper portion of the panicle. The other members of this group--prairie Junegrass, plains reedgrass, green needlegrass, and big needlegreas--have a sequence of events similar in time of occurrence to needle-and-thread; that is, slightly earlier than western wheatgrass in all events, with the exception of leaf-tip drying which follows more closely the drying pattern of western wheatgrass (Table 16). On the average, prairie Junegrass begins to show signs of leaf-tip drying by July 15, which is approximately 20 days later than the other species in this group but 15 days earlier than needle-and-thread (Table 16).

Blue grama is the only warm-season short grass of any real importance in the grassland type. Leaf growth begins in this species by approximately April 15, about 15 days later than in the cool-season grasses (Table 3). The phenological sequence of blue grama remains approximately 10-15 days slower than the sequence in the cool-season grasses of group 2. Flower stalks emerge by June 26, which is approximately 25 days later than in the group 2 species. This same relationship holds true for the two other phenological dates of head emergence and date of anthesis. An exception to this is western wheatgrass, which has a later date of events than other species in group 2, but averages approximately eight days earlier than blue grama (Table 16). Evidence of leaf-tip drying becomes apparent quite early in blue grama, generally by June 25, and follows the same general leaf-drying pattern

as in the cool-season grasses.

Five additional grasses studied may be grouped as warm-season species being the latest to begin growth and to attain maturity (Table 3). The five species ranked according to their relative importance are little bluestem, prairie sandreed, big bluestem, stony-hills muhly, and red threeawn. Little bluestem, prairie sandreed, stonyhills muhly, and red threeawn have essentially the same sequence of phenological events occurring at approximately the same dates or within 8-10 days of each other. The average appearance of fruiting stalks is approximately June 20, with little bluestem slightly later at June 30. Head emergence is generally during early July for the four species, and the earliest observable date when leaf-tip drying becomes apparent is approximately July 15 (Table 16).

Big bluestem is a member of the warm-season group, but is later than the other species in this group on an average by approximately 15-18 days. The fruiting stalks are apparent about July 17. Head emergence of big bluestem is approximately 10 days later than the average date of emergence for the other species of the group. However, maturation of the inflorescence is rapid and flowering begins at about the same date as in the other species of this group, the average date being approximately August 4 (Table 16). In this area, leaf drying proceeds rapidly in big bluestem and reaches 25 per cent by July 20, approximately 30 days ahead of the other species in this group.

The phenological phenomena reported in Table 16 may be summarized in the following manner. During the month of April, only one sedge shows visible evidence of stalk formation; during May, five grass species show

stalk formation; seven species begin to produce stalks in June, and one in July. Head or inflorescence emergence is observable in two species during May, seven species in June, and five in July. This indicates a considerable difference in length of time required for some species to begin stalk growth and emergence of the head or inflorescence.

Flowering dates for the grass and sedge species vary to an even greater degree. Two of the 15 species flower during May, six during June, four during July, and three during the month of August. The sedges and Sandberg bluegrass are earliest and bloom during the month of May. Nearly all of the cool-season grasses bloom during June, while the warm-season grasses continue into late July and early August. A record of the flowering of red threeawn is unavailable.

Slightly over 50 per cent (8 out of 15 species) of all grasses and sedges studied show leaf-tip drying to begin about June 15, and all species studied indicate varying degrees of dryness by late July. For the greater percentage of the species studied, 25-50 per cent of the leaf area is dry by late August. Date when seed maturity is reached appears to follow closely the phenological sequence of each individual species. That is, in general, early growing and maturing species in all other phenological events have an early seed maturity date. This, however, is not the case in the seed shedding process. No definite pattern appears to exist for this process; rather the date of shedding is greatly influenced by the structure and constitution of the inflorescence and floral parts.

The annual records indicate that wide yearly variations in all phenological events are prevalent in all species. Western wheatgrass,

for instance, shows a range of 27 days over which fruiting stalk initiation became evident, 16 days during which head emergence was observed, and 37 days during which flowering was observed. The variations in dates for head emergence of blue grama ranged over a period of 26 days, and the dates of flowering over a period of 21 days. Needle-and-thread, as one of the major species, also shows a variation in phenological events, but this variation is appreciably less than in some of the other species. For needle-and-thread, the dates of observable fruiting stalk initiation ranged over a period of 26 days; dates when heads first became observable, over nine days; and the dates of flowering, over a period of nine days. Variations in time of phenological phenomena are equally as great in the other species on the study area as in the three major species discussed.

Grazed and Protected Plant Heights

Plant vigor, as a criterion of range condition based upon height growth measurements comparing grazed and ungrazed sites, was applied to Northern Great Plains ranges at Miles City, Montana, by Short and Woolfolk (1956). Bluestem wheatgrass (Agropyron smithii) plants growing within and outside of pricklypear clumps on ranges in good and poor condition were observed. Their data show that plant vigor, as expressed by bluestem wheatgrass heights, varied with range condition, with protection afforded by the pricklypear, and with yearly precipitation. Primarily, the study established the usefulness of plant height as a vigor criterion for the appraisal of range condition. Wide fluctuations of weather conditions from above normal precipitation to

severe drought did not alter the established relation between unprotected plants.

In the present study, comparisons were made of the maximum leaf heights attained by the four species of major importance inside the 5-year exclosure and on the fall-grazed range (Table 17). Comparisons of the maximum leaf and stalk heights attained during the 1962 growing season of the major species in the 5-year exclosure, the 1-year exclosure, and the fall-grazed range were also made (Tables 18 and 19).

The data from the 5-year exclosure indicate that the leaf heights were greater inside the exclosure than outside on the grazed rangeland (Table 17). This was true for the four major grass and sedge species compared during the 5-year period. In the first season immediately following the establishment of the exclosure (1958), there was no consistent positive height advantage for the species in the exclosure over those on the grazed range. After 1958, the species in the exclosure reached greater mature leaf heights than did the grazed species, with some years showing considerable difference in leaf heights between the species inside and outside the exclosure. This was true for all the species studied, irrespective of the moisture conditions during the growing season.

Western wheatgrass was abundant both inside and outside the 5-year exclosure. The leaves of western wheatgrass attained a 5-year average maximum height of 28.1 cm inside the exclosure and 22.0 cm outside the exclosure during the study period (Table 17). In the favorable moisture season of 1962, leaves of western wheatgrass averaged 41.7 cm inside the exclosure and only 26.0 cm outside. The shortest growth

TABLE 17. YEARLY MAXIMUM LEAF HEIGHTS ATTAINED BY THE MAJOR SPECIES STUDIED OUTSIDE AND INSIDE THE 5-YEAR EXCLOSURE DURING THE FIVE SEASONS, 1958-1962

Species	1958		1959		1960		1961		1962		5-Year Average Height in cm	
	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Average Height Outside	Average Height Inside
Western wheatgrass	23.0	23.0	20.0	22.3	19.0	28.3	22.0	25.3	26.0	41.7	22.0	28.1
Needle-and-thread	19.0	14.3	19.0	20.0	17.0	16.5	16.0	18.6	23.0	25.0	18.8	19.4
Blue grama	11.0	8.3	9.0	12.0	8.0	12.7	7.0	13.3	11.5	17.7	9.3	12.8
Needleleaf sedge	12.0	6.0	9.0	10.7	9.0	8.7	9.0	13.3	11.0	16.3	10.0	11.0

TABLE 18. COMPARISONS OF THE MAXIMUM MATURE LEAF HEIGHTS ATTAINED BY THE FOUR MAJOR SPECIES DURING THE 1962 GROWING SEASON ON THE FALL-GRAZED RANGE, THE 1-YEAR EXCLOSURE, AND THE 5-YEAR EXCLOSURE

Species	Outside Exclosure Mature Leaf (height in cm)	Inside 1-Year Exclosure Mature Leaf (height in cm)	Inside 5-Year Exclosure Mature Leaf (height in cm)
Western wheatgrass	26.0	39.0	41.7
Needle-and-thread	23.0	27.0	29.5
Blue grama	11.5	17.0	25.0
Needleleaf sedge	11.0	13.0	16.3
Average	17.8	24.0	28.1

TABLE 19. COMPARISONS OF THE MAXIMUM MATURE STALK HEIGHTS ATTAINED BY THE FOUR MAJOR SPECIES DURING THE 1962 GROWING SEASON ON THE FALL-GRAZED RANGE, THE 1-YEAR EXCLOSURE, AND THE 5-YEAR EXCLOSURE

Species	Outside Exclosure Mature Stalk (height in cm)	Inside 1-Year Exclosure Mature Stalk (height in cm)	Inside 5-Year Exclosure Mature Stalk (height in cm)
Western wheatgrass	43.5	66.0	47.4
Needle-and-thread	41.0	60.0	76.0
Blue grama	22.6	34.0	25.0
Needleleaf sedge	13.0	16.0	20.0
Average	30.0	44.0	42.1

inside the exclosure occurred in the 1959 season when western wheatgrass leaves averaged 22.3 cm. In this season, leaf heights of western wheatgrass outside the exclosure averaged 20.0 cm. Shortest growth outside the exclosure occurred in 1960 (19.0 cm), while height inside that year was 28.3 cm.

Blue grama leaves also averaged taller inside the 5-year exclosure than outside on the fall-grazed rangeland, except for the 1958 season. The leaves attained a 5-year average mature height of 12.8 cm inside and an average of 9.3 cm outside the exclosure (Table 17). Yearly variations in mature leaf height attained were rather great, the maximum mature height attained inside the exclosure being 17.7 cm during the 1962 season. Height of leaves of this species outside the exclosure in 1962 was 11.5 cm--the greatest height attained by grama leaves outside the exclosure during the study period. The shortest leaf growth for this species in the exclosure was recorded in 1958 at 8.3 cm, with the leaves outside measuring 11.0 cm in that year. Leaf heights of blue grama were greater inside the exclosure than outside for the remainder of the study period. The shortest recorded height for grama leaves outside the exclosure was 7.0 cm during the 1961 season.

Needle-and-thread was sparingly represented inside the 5-year exclosure and was not the object of intensive study as were western wheatgrass and blue grama. The data indicate, however, the same general differences between protected and grazed heights as shown by the other species. The 5-year average leaf height was 19.4 cm inside the exclosure and 18.8 cm outside the exclosure (Table 17). Yearly variations in leaf height are of a lesser magnitude than is the case in

the two previously mentioned species. This appears to be true throughout the study period including the near drought year of 1961.

Needleleaf sedge was present in abundance inside and outside the exclosure and was included in the comparisons. The average maximum leaf height over the 5-year period indicates that needleleaf sedge was more vigorous under protection of the exclosure. Leaf heights were found to average 11.0 cm inside the exclosure and 10.0 cm outside the exclosure (Table 17).

The data from the 1-year comparison of leaf and stalk heights made in 1962 are given in Tables 18 and 19. The 1-year exclosure was fenced out of the fall-grazed range during the summer of 1961 for the purpose of studying microclimatic effects upon the existing vegetation and the establishment of seedlings. By early June, 1962, however, it became increasingly apparent that a marked difference in leaf and stalk growth existed between the fall-grazed and the 1-year protected range. Table 18 indicates the mature leaf height attained by the species during the 1962 growing season. Mature leaf heights were least for all species outside the exclosures, greatest inside the 5-year exclosure, and in a median position in the 1-year exclosure. Fruiting stalk heights under protection were much greater than were the heights of the fruiting stalks on the fall-grazed range. However, stalks of western wheatgrass and blue grama apparently grew more vigorously after only one year protection than they did after five years of protection (Table 19).

The results of this study indicate a surprisingly great reduction in vigor of plants on a range subjected to late fall grazing. This becomes especially apparent after only one year of protection, as

may be readily seen from the data of Table 18. The leaves of the species studied inside the 1-year exclosure showed definitely greater height than the leaves of the same species on the fall-grazed range. When the four major species are compared under the three different situations, the following results are noted. The leaf height of western wheatgrass was 50 per cent greater after only one year of protection than it was under continuous fall grazing, and 60 per cent greater after five years of protection. Needle-and-thread leaves were 17 per cent greater in total leaf height after one year protection than the plants outside the exclosure, and 28 per cent greater after five years protection. Leaf heights of blue grama were 48 per cent greater after one year of protection than under fall grazing, and 85 per cent greater after five years protection. Needleleaf sedge showed an 18 per cent advantage in leaf height after one year of protection and a 48 per cent advantage after five years of protection. Leaf height of the four major species averaged as a group was 33.2 per cent greater after one year of protection and 48 per cent greater after five years protection than the average height of the four species outside the exclosure. The actual average group leaf heights were 17.8 cm outside the exclosure, 24.0 cm after one year of protection, and 28.1 cm after five years of protection.

Fruiting stalk heights were even more influenced by the 1-year protection afforded them by the exclosure (Table 19). Western wheatgrass, after only one year of protection, showed an increase in total stalk height of 52 per cent over the height of the plants outside the exclosure. However, after five years of protection, the stalk height

of western wheatgrass was only 9 per cent greater in the exclosure than outside under fall grazing. Needle-and-thread showed an increase in stalk height of 46 per cent after one year of protection and 85 per cent after five years of protection. Height of blue grama grass stalks in the 1962 season was 50 per cent greater inside the 1-year exclosure than the outside, but only 6 per cent greater in the 5-year exclosure. Stalk height of needleleaf sedge was 23 per cent greater after one year of protection than the stalk height of this species outside the exclosure, and 53 per cent greater after five years protection. Averaged as a group, stalk heights of the four major species increased from 30.0 cm outside the exclosure to 44.0 cm after one year of protection. Average stalk height for the four species after five years of protection, however, was only 42.0 cm. On a percentage basis, group stalk height increased 42.8 per cent after one year of protection. Average group stalk height of the four major species in the 5-year exclosure, however, was only 38.5 per cent greater than average stalk height of the same species under fall grazing.

Growth Patterns of Forbs

Growth and phenological observations were made on 93 species of forbs on the study area. The various species of forbs have been placed in three groups according to time when maximum mature height is attained. Phenological and growth data on plants which attain maximum height during April, May, and June are presented in Table 20. This group includes 25 species, approximately 27 per cent of the total number of species observed, of which three attain mature height during

TABLE 20. HEIGHTS, BLOOMING DATES, AND SEASONAL DEVELOPMENT OF FORBS ATTAINING MAXIMUM HEIGHT GROWTH IN APRIL, MAY, AND JUNE AS OBSERVED OVER THE 8-YEAR PERIOD 1955-1962

Species	Plant Height in cm			Blooming Dates		Average Per Cent of Total Growth Attained					
	Minimum Observed Mature Height	Maximum Observed Mature Height	8-Year Average Mature Height	Observed Date of Earliest Bloom	Observed Average Date of Earliest Bloom	April	May	June	July	August	September
Actinella acaulis	10.0	15.0	10.2	5/7	6/5	100.0					
Agoseris cuspidata	4.0	24.0	12.2	5/7	5/17	100.0					
Anemone patens	8.0	19.0	12.6	4/15	4/18	74.8	100.0				
Heuchera hispida	32.0	36.0	34.0	7/2	7/2	100.0					
Antennaria parviflora	6.0	11.0	9.0	5/22	6/10		77.9	100.0			
Arabis hirsuta	21.0	55.0	38.0	6/4	6/4			100.0			
Arabis holboellii	35.0	60.0	51.4	5/7	5/24	8.0	67.8	100.0			
Astragalus caryocarpus	14.0	22.0	17.2	5/12	5/16		97.6	100.0			
Castilleja sessiliflora	10.0	20.0	14.6	5/16	5/18		97.9	100.0			
Cymopterus acaulis	5.0	7.0	6.3	5/9	5/9			100.0			
Descurainia sophia	30.0	46.0	40.8	6/10	7/30			100.0			
Draba nemorosa	7.0	10.0	8.7	5/7	5/16		94.5	100.0			
Lappula redowski	12.0	21.0	16.5	6/7	6/16			100.0			
Lithospermum linearifolium	7.0	15.0	11.7	5/19	5/23		88.1	100.0			
Lesquerella arenosa	6.0	30.0	11.3	5/9	5/22			100.0			
Lomatium foeniculaceum	6.0	17.0	11.3	4/8	4/25	38.9	84.4	100.0			
Mertensia lanceolata	8.0	21.0	13.9	5/6	5/23	40.0	93.7	100.0			
Musineon divaricatum	6.0	20.0	9.6	5/1	5/26	42.9	93.8	100.0			
Orobanche ludoviciana	5.0	9.0	7.2	6/18	7/2			100.0			
Oxytropis lamberti	10.0	31.0	18.1	5/1	5/26	40.0	65.9	100.0			
Penstemon angustifolius	17.0	20.0	18.7	6/10	6/21			100.0			
Phlox hoodii	3.0	6.0	4.6	4/28	5/24	42.2	93.3	100.0			
Potentilla concinna	3.0	7.0	6.7	5/7	5/9	14.3	90.5	100.0			
Senecio canus	7.0	38.0	18.7	5/29	6/13		69.0	100.0			
Viola nuttallii	5.0	12.0	7.8	5/1	5/21	54.1	70.3	100.0			
Average	11.1	22.9	16.4			54.1	85.6	100.0			

April, only one during May, and 21 during June. A wide variation exists between the different plants as to maximum height attained during the same period of growth. Of the 21 species attaining maturity during June, eight species are below 15.0 cm in average mature height, 10 are between 15.0 and 20.0 cm in average mature height, and three range between 38.0 and 51.4 cm in height.

Large variations in mature height attained in different years by individual species in the early group were observed over the 8-year study period. Numerous species showed a variation of 50-60 per cent, or in some instances even more, between the minimum observed mature height and the maximum observed mature height. Periodical measurements of height were recorded each season for most species. Eight species of this group attained an average of 54.1 per cent of their growth during April, 15 of the species attained an average of 85.6 per cent of their growth during May, and full mature height was reached for all 21 species by the end of June.

Phenological and growth data on forbs attaining maximum mature height in July are given in Table 21. This group includes 43 species, approximately 46 per cent of the total number of species observed, some of which begin growth early but grow slowly and do not reach mature height until July. Nine species of this group attained an average of 44.5 per cent of their growth during April, 26 attained an average of 52.5 per cent during May, 34 species attained an average of 82.8 per cent of their growth during June, and all species reached mature height by the end of July (Table 21).

TABLE 21. HEIGHTS, BLOOMING DATES, AND SEASONAL DEVELOPMENT OF FORBS ATTAINING MAXIMUM HEIGHT GROWTH IN JULY AS OBSERVED OVER THE 8-YEAR PERIOD 1955-1962

Species	Plant Height in cm			Blooming Dates		Average Per Cent of Total Growth Attained					
	Minimum Observed Mature Height	Maximum Observed Mature Height	8-Year Average Mature Height	Observed Date of Earliest Bloom	Observed Average Date of Earliest Bloom	April	May	June	July	August	September
Achillea lanulosa	20.0	46.0	32.2	6/11	6/19	14.5	38.6	85.0	100.0		
Allium reticulatum	10.0	11.0	10.3	5/12	5/20	65.6	85.7	93.9	100.0		
Astragalus striatus	12.0	30.0	19.4	6/13	6/23	30.0	66.5	93.1	100.0		
Brauneria angustifolia	26.0	35.0	30.0	6/18	6/25		24.4	63.7	100.0		
Campanula rotundifolia	23.0	36.0	30.0	6/14	6/23	2.8	34.0	89.0	100.0		
Cerastium arvense	8.0	12.0	11.1	5/12	5/27	28.3	71.0	96.7	100.0		
Chenopodium album	20.0	45.0	29.5	7/24	7/24			55.8	100.0		
Chenopodium leptophyllum	25.0	43.0	34.4	6/8	6/22		11.9	75.6	100.0		
Collomia linearis	8.0	15.0	11.7	6/10	6/14			98.0	100.0		
Commandra pallida	8.0	11.0	9.4	5/19	6/1		69.1		100.0		
Erigeron canadensis	9.0	58.0	33.0	6/10	6/14			83.3	100.0		
Eriogonum flavum	12.0	17.0	13.9	6/4	6/18	7.7	29.5	87.5	100.0		
Eriogonum multiceps	13.0	16.0	14.0	6/18	6/27				100.0		
Erysimum asperum	19.0	36.0	28.5	5/13	6/1	18.9	34.7	92.7	100.0		
Erysimum parviflorum	15.0	30.0	22.5	5/27	6/15		33.3	92.7	100.0		
Gaillardia aristata	15.0	31.0	23.2	6/19	6/23			82.3	100.0		
Helianthus annuus	30.0	40.0	36.7	6/27	7/19				100.0		
Helianthus petiolaris	29.0	51.0	40.0	7/5	7/18			86.3	100.0		
Hymenopappus tenuifolius	24.0	33.0	29.0	6/13	6/23		15.6	80.4	100.0		
Lactuca pulchella	21.0	43.0	28.6	6/27	7/16		27.5	87.3	100.0		
Lepidium densiflorum	16.0	28.0	23.5	6/10	6/19		50.0	90.5	100.0		
Linum rigidum	7.0	24.0	16.5	6/20	6/21				100.0		
Lychnis drummondii	25.0	48.0	35.0	6/14	6/14				100.0		
Oenothera nuttallii	14.0	41.0	33.3	6/28	7/13			76.1	100.0		
Opuntia fragilis	3.0	9.0	7.3	6/21	7/4			93.7	100.0		
Orthocarpus luteus	9.0	25.0	18.3	7/20	7/26				100.0		
Paronychia sessiliflora	2.0	3.0	2.4	6/21	7/3				100.0		
Penstemon albidus	13.0	25.0	18.1	5/29	6/8		70.6	89.4	100.0		
Penstemon eriantherus	13.0	13.0	13.0	6/25	7/6				100.0		
Penstemon gracilis	17.0	44.0	28.8	6/10	6/28		18.2	96.7	100.0		
Petalostemum candidum	8.0	20.0	15.5	6/20	7/2			88.9	100.0		
Plantago purshii	9.0	22.0	14.0	6/18	7/11			68.6	100.0		
Polygala alba	13.0	19.0	16.1	6/19	7/6			97.5	100.0		
Potentilla pennsylvanica	5.0	29.0	19.8	6/21	7/5	10.3	42.1	70.3	100.0		
Prunus pumila	7.0	14.0	10.8	5/7	5/15	78.6	81.8		100.0		
Psoralea argophylla	18.0	30.0	24.8	6/13	7/3		37.1	68.3	100.0		
Psoralea esculenta	11.0	24.0	17.1	6/10	6/21		29.6	96.4	100.0		
Ratibida columnifera	18.0	43.0	28.7	7/14	7/22		26.4	64.7	100.0		
Rosa arkansana	13.0	25.0	18.9	6/13	6/19		49.9	79.1	100.0		
Sisymbrium altissimum	36.0	61.0	49.0	6/7	6/24			93.3	100.0		
Sphaeralcea coccinea	10.0	13.0	11.8	6/4	6/13		52.1	85.9	100.0		
Thermopsis rhombifolia	17.0	31.0	20.9	5/9	5/28		82.6	85.7	100.0		
Vicia sparsifolia	9.0	19.0	13.8	5/6	5/22		70.6	94.5	100.0		
Average	14.9	29.0	22.0			44.5	52.5	82.8	100.0		

Of the 43 species in this group, only three remain below 10.0 cm at maturity; 19, or nearly 50 per cent, are between 11.0 and 20.0 cm at maturity; 13 are between 21.0 and 30.0 cm; seven are between 31.0 and 40.0 cm; and only two species attain a height of 40.0 to 50.0 cm at maturity. Individual species showed wide variations in maximum mature height from season to season during the 8-year period. For instance, the observed minimum mature height of horseweed (Erigeron canadensis) was 9.0 cm and the maximum observed mature height of this species was 58.0 cm. Prairie cinquefoil (Potentilla pennsylvanica) had a minimum observed mature height of 5.0 cm and a maximum recorded mature height of 29.0 cm. Prairie plantain (Plantago purshii) had a minimum observed mature height of 9.0 cm and a maximum mature height of 22.0 cm. Blanket flower (Gaillardia aristata) had a minimum observed mature height of 15.0 cm and a maximum observed mature height of 31.0 cm.

The forbs attaining their mature height during the month of August or early September are grouped in Table 22. Twenty-five species reached maximum mature height during August; this is approximately 27 per cent of the species observed on the study area. Ten species in this group begin their growth during April, and three of the 10 do not attain their maximum mature height until September. Seven species in this group reach 15 per cent of their growth during April, 20 species attain an average of 32.9 per cent of their growth during May, all species (25) attain an average of 91.3 per cent of their growth during July, and 22 attain full maximum height during August.

Of the 25 species studied in this group, no species remained below 10.0 cm at mature height, nine species remained at or below

TABLE 22. HEIGHTS, BLOOMING DATES, AND SEASONAL DEVELOPMENT OF FORBS ATTAINING MAXIMUM HEIGHT GROWTH IN AUGUST AND SEPTEMBER AS OBSERVED OVER THE 8-YEAR PERIOD 1955-1962

Species	Plant Height in cm			Blooming Dates		Average Per Cent of Total Growth Attained					
	Minimum Observed Mature Height	Maximum Observed Mature Height	8-Year Average Mature Height	Observed Date of Earliest Bloom	Observed Average Date of Earliest Bloom	April	May	June	July	August	September
Allionia hirsuta	19.0	35.0	28.6	7/25	8/3		18.7	31.2		100.0	
Aplopappus spinulosus	15.0	20.0	17.3	7/6	7/23		36.3	71.2	92.0	97.1	100.0
Artemisia caudata	25.0	46.0	35.4	8/7	8/23	7.5	17.3	48.1	80.0	97.4	100.0
Artemisia frigida	17.0	40.0	20.0	8/12	8/27	15.9	23.3	54.1	81.3	93.4	100.0
Artemisia glauca	32.0	47.0	42.5	5/7	5/16			79.0	93.7	100.0	
Artemisia ludoviciana	16.0	39.0	26.3	7/16	8/12	10.0	24.2	45.0	84.7	100.0	
Aster ericoides	11.0	43.0	24.9	7/29	8/10	34.8	47.2	81.2	91.0	100.0	
Aster ptarmicoides	12.0	23.0	19.5	7/11	7/21			47.1	87.8	100.0	
Cirsium undulatum	30.0	59.0	43.6	6/28	7/7	25.0	27.9	74.1	96.7	100.0	
Chrysopsis villosa	20.0	27.0	23.5	6/28	7/6	8.6	29.0	70.3	95.8	100.0	
Gaura coccinea	12.0	22.0	18.0	6/10	6/10		45.5	80.6	98.6	100.0	
Glycyrrhiza lepidota	22.0	35.0	29.7					71.7	91.3	100.0	
Grindelia squarrosa	16.0	30.0	22.1	7/25	8/8		51.2	68.5	92.6	100.0	
Gutierrezia sarothrae	11.0	21.0	14.0	7/20	7/30		35.0	67.6	90.9	100.0	
Helianthus rigidus	19.0	35.0	28.6	7/25	8/3		18.7	31.2		100.0	
Liatris punctata	17.0	23.0	19.9	7/31	8/5		30.0	57.8	95.2	100.0	
Lotus americanus	11.0	45.0	20.0	6/21	7/4		14.3	59.7	94.5	100.0	
Lygodesmia juncea	26.0	38.0	31.3	7/2	7/20		50.9	78.0	93.3	100.0	
Oenothera serrulata	14.0	19.0	16.6	6/9	6/25		46.0	80.9	98.9	100.0	
Petalostemum purpureum	19.0	28.0	25.8	6/25	7/13		19.8	64.6	99.3	100.0	
Salsola kali	7.0	35.0	23.7	6/19	7/15			34.5	94.9	100.0	
Solidago missouriensis	12.0	31.0	21.0	7/5	7/19	3.2	28.7	47.6	88.0	100.0	
Solidago mollis	15.0	35.0	26.0	6/22	7/15		27.9	55.7	73.1	100.0	
Solidago nemoralis	15.0	23.0	18.6	7/18	8/1			55.1	88.2	100.0	
Tragopogon dubius	27.0	45.0	34.4	6/18	7/2		65.6	81.3	98.6	100.0	
Average	17.6	33.4	21.3			15.0	32.9	61.4	91.3	100.0	

20.0 cm, 11 species ranged between 21.0 and 30.0 cm, three ranged between 31.0 and 40.0 cm, and only two species attained maximum heights between 41.0 and 50.0 cm. Variations in average observed mature heights of species were not as great as in the two earlier groups. However, differences in minimum and maximum mature heights attained in certain individual species were rather great. For instance, the observed minimum mature height of white prairie aster (Aster ericoides) was 12.0 cm and the maximum observed mature height of this species was 43.0 cm. Stiff sunflower (Helianthus rigidus) had a minimum observed mature height of 19.0 cm and a maximum recorded mature height of 35.0 cm. Prairie bird's-foot trefoil (Lotus americanus) had a minimum observed mature height of 11.0 cm and a maximum mature height of 45.0 cm. Russian thistle (Salsola kali) had a minimum observed height of 7.0 cm and a maximum observed mature height of 35.0 cm.

Comparisons of the three groups as to average observed minimum mature heights of all species in each group, average maximum mature heights, and 8-year average mature heights show that the April-May-June maturing group had an average minimum mature height of 11.1 cm, an average maximum mature height of 22.9 cm, and an 8-year average mature height of 16.4 cm. Average heights were found to be greater in the July group than in the early group, the average minimum mature height being 14.9 cm, average maximum mature height 29.0 cm, and the 8-year average mature height being 22.0 cm.

The August and September group showed an average minimum mature height of 17.6 cm, an average maximum mature height of 33.4 cm, and an 8-year average height of 21.3 cm. The average minimum and the average

maximum heights in this group are greater than in either the early group or the July group. The 8-year average mature height, however, is slightly less in this group than in the July group. The trend for all groups as a whole, however, is for the species to become progressively taller in relation to the lateness of the season at which maximum height is attained.

The distribution of forb species within the plant families is of some interest. While observations of all the forb species on the area were not made during the period of this study, most of the species were observed. The 93 species of forbs observed on the area were found to be from 22 different plant families. Thirty-one species were in the Asteraceae, 11 in the Fabaceae, nine in the Brassicaceae, six in the Scrophulariaceae, and the remaining 36 were distributed among 18 families with from one to four species per family.

The species in the early-growing group, April-May-June maturing plants, represented 11 families of which Asteraceae and Brassicaceae were the more important from the standpoint of having the highest number of species, about 36 per cent of the 25 species in the group. Five species were found in the Brassicaceae and four species were in the Asteraceae. The remaining 16 species were found to be from nine different families.

The species in the July-maturing plant group represented 17 families. Of the 17 families, two families contributed a considerably larger number of species than were contributed by the other 15 families in the group. Asteraceae was represented by nine species and the Fabaceae by six species. The two families, Asteraceae and Fabaceae,

contributed about 37 per cent of the 43 species found in the July group.

The species in the August- and September-maturing group represented only five families. Asteraceae was represented by 19 species, 75 per cent of the total number (25) of species found in this group. Fabaceae was represented by three species and the three remaining families contributed one species each.

Individual Growth Patterns

Pasque-flower (Anemone patens) is a low-growing, normally single-stalked species occurring abundantly on the hillsides of this native range type. The species attained an average mature height of 12.6 cm and flowered by April 18. The species is very showy due to its bright lavender-colored petals and its earliness on the range. Other species in the early-growing group generally do not attain mature height or flower until considerably later than pasque-flower. Some of the other early flowering species which are found on the study area are: Yellow wild parsley (Lomatium foeniculaceum) which attained a mature height of 11.3 cm and bloomed by April 25. Nutall's violet (Viola nuttallii), easily recognized because of its tufted growth form, dark green spatulate leaves and bright yellow flowers, attained a maximum mature height of 7.8 cm and flowered on the average by May 21. Hood's phlox (Phlox hoodii) is a very low-growing, relatively scarce plant in the study area. It attained an average mature height of only 4.6 cm and flowered by May 24.

Locoweed (Oxytropis lamberti) is a tufted, grayish-green-leaved

leguminous plant found throughout the study area. It attained an average mature height of 11.3 cm during the month of June. The average flowering date has been recorded as May 26, but flowering may be observed for a relatively long period of time after first flowering occurs. The species has no apparent forage value and is considered a poisonous plant. Livestock normally do not graze this plant, but if forage becomes scarce it may be eaten.

Potentilla concinna is the only other species in the early-growing group of forbs which reaches its mature height during June. Potentilla concinna is a conspicuous, silvery-leaved, low-growing plant. It began growth by early April and reached an average maximum height of 6.7 cm by mid-June (Table 20). The average flowering date was May 9. The plant is not abundant, but because of its silvery color and bright yellowish flowers it is readily identified.

The species of forbs attaining mature height during the month of July have been listed in Table 21. This group comprises approximately 50 per cent of all the forbs observed and studied. Only the more important species will be described.

Prairie cinquefoil (Potentilla pennsylvanica) is a fairly tall-growing species, has dark green leaf surfaces, and reaches a maximum mature height of 19.8 cm (Table 21). The plant has a flowering date of July 5, or 57 days after Potentilla concinna. This species is not important as a forage plant in this region.

Purple coneflower (Brauneria angustifolia)(Figure 18) is an important forb in this range type from the standpoint of abundance. It began its growth in late April and attained an average height of

Figure 18. Purple coneflower, an abundant single-stalked species on the study area, reached an average mature height of 30.0 cm by mid-July.

30.0 cm by mid-July (Table 21). The species is very conspicuous and sometimes deceptive when in bloom, for it appears to cover vast areas of grassland. Actually, the individual plants of this species are quite far apart. The average flowering date was June 25. From the forage standpoint, the plant is unimportant because of its unpalatable nature. The plant may have some medicinal value, as its root has pain-relieving properties.

Bluebells (Campanula rotundifolia) is a clump-forming species, but was relatively scarce on the study area (Figure 19). It is a rather inconspicuous plant, but the masses of blue flowers make it stand out when it is in bloom. It reached an average height of 30.0 cm, attaining maturity by mid-July and blooming about June 23 (Table 21). The species is unimportant as a forage plant.

Western wall-flower (Erysimum asperum) is a tall-growing, single-stalked, branched biennial species beginning growth in the summer of one year and continuing its growth from the rosette form the following season. Growth from the rosette generally begins in mid or late April and the plant completes its growth cycle by the end of June. The average flowering date was June 1. The average mature height attained was 28.3 cm (Table 21). The species is quite conspicuous because of its bright yellow flowers and long pods, but it dried rapidly with advance in maturity. The species is unimportant as a forage plant.

Blanket flower (Gaillardia aristata) is a relatively scarce but very conspicuous plant in this grassland type. It begins its growth in early May and, on the average, attained a maximum mature height of 30.0 cm by mid-July (Table 21). Its average flowering date was June 23.

Figure 19. Bluebells, a clump-forming, many-flowered species, began growth in early spring and reached an average mature height of 30.0 cm by mid-July.

From the standpoint of forage value, the plant is unimportant.

The genus Penstemon was represented on the study area by four members of the genus--white beardtongue (Penstemon albidus), crested beardtongue (Penstemon eriantherus), narrow-leaved beardtongue (Penstemon angustifolius), and slender beardtongue (Penstemon gracilis). Only two of the species given are of importance on the study area, white beardtongue and slender beardtongue, respectively. The two species differ in leaf shape and color of flower, white beardtongue having a short, broad leaf and white flowers while slender beardtongue has longer, linear leaves and blue to lavender colored flowers. White beardtongue becomes very conspicuous when in full bloom. It is an early-growing species generally beginning growth sometime in mid-April. It attained an average mature height of 18.7 cm by mid-July and flowered by June 8 (Table 21).

Slender beardtongue is a later-growing species than white beardtongue. The species is taller-growing, attaining an average mature height of 28.8 cm. Flowering is also later with the species generally flowering by June 28, approximately 20 days after white beardtongue. The Penstemons are relatively unimportant as forage species and are not very palatable.

Silverleaf scurfpea (Psoralea argophylla) and Indiana breadroot (Psoralea esculenta) are the only two species representing the genus Psoralea on the study area. A difference of considerable magnitude as to time of growth and development between the two leguminous species is evident. Indian breadroot is an early, rapidly-growing species, reaching mature height generally by mid-May or early June. The average

maximum height attained was 17.7 cm. Silverleaf scurfpea also begins growth early but grows over a longer period, reaching mature height by mid or late July (Table 21). A minimum mature height of 18.0 cm was recorded for this species and a maximum mature height of 30.0 cm was noted. Average mature height was 24.8 cm. Indian breadroot blooms by June 21, while silverleaf scurfpea blooms about July 3. The species are not important from the standpoint of livestock forage. Indian breadroot has a tuberous root which was utilized as a food by the Indians.

Long-headed coneflower (Ratibida columnifera) is a single-stalked, tall-growing, perennial species of moderate abundance. It began its growth during late April, bloomed about July 22, and attained a maximum mature height of 28.7 cm generally by the end of July (Table 21). The species is conspicuous when in bloom because of its relative height and bright yellow reflexed petals. It is found throughout the study area but has no apparent value as a forage plant.

Prairie wild rose (Rosa arkansana) usually occurs as a single-stalked, bushy-crowned plant found throughout the study area. It is a relatively early plant beginning its growth in mid or late April. An average mature height of 18.9 cm was attained by the end of July (Table 21). The average flowering date for the species was June 19. The plant has little forage value, largely because of its woody and prickly nature.

Red mallow (Sphaeralcea coccinea) is a low-growing, bushy-crowned species of relatively high abundance on the study area. It is a conspicuous plant when in bloom because of its bright brick-red

petals and silvery leaves. It begins its growth in mid to late April. It attained an average mature height of 11.8 cm by the end of July (Table 21). The average flowering date was June 13. The species is found throughout this range type with no apparent soil preference. The plant is of no value as forage for livestock.

The forbs attaining their maximum mature heights during the month of August or early September are grouped in Table 22. Twenty-one species attain maximum mature height during the month of August.

Ironplant goldenweed (Aplopappus spinulosus) is a rather low-growing, many-stemmed plant of moderate abundance in the study area. It began growth in late May and attained an average mature height of 17.3 cm by late August or early September (Table 22). The average flowering date for this species was July 23. The plant is easily recognized by its thin needle-like leaves and showy bright-yellow flowers. The plant has no apparent forage value. This species has one of the longest growing periods of any of the plants in the study area, and may still be flowering even in September.

Additional important long-growing species in this mid grass vegetation are the sages--fringed sage (Artemisia frigida), the biennial sage (Artemisia caudata), white sage (Artemisia ludoviciana) (Figures 20, 21, and 22), and green sage (Artemisia glauca). Fringed sage is sometimes listed as an indicator species, increasing sharply when overgrazing takes place. It begins growth early in the spring and continues to grow throughout the summer under favorable conditions until early September. It attained an average mature height of 20.0 cm (Table 22). Artemisia caudata, a biennial, and white sage, a

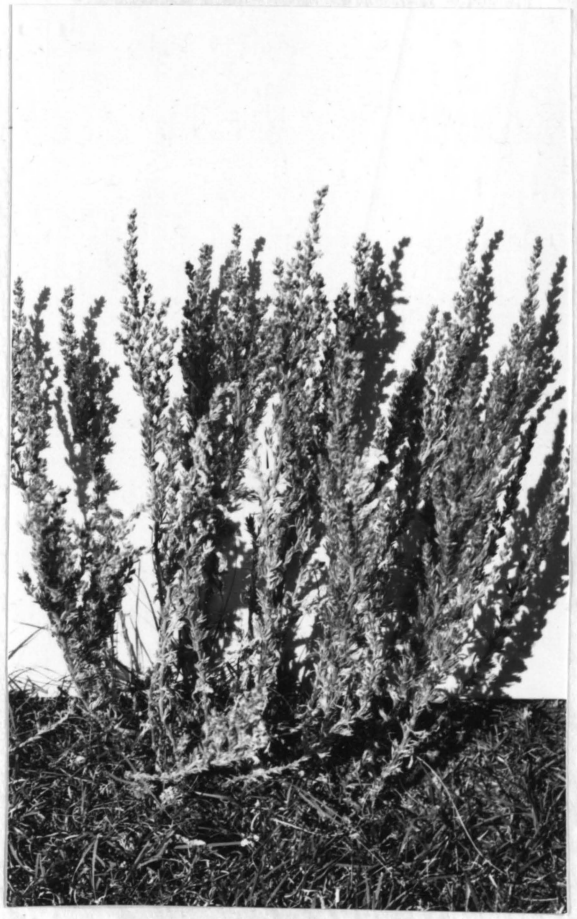

Figure 20. Fringed sage, a clump-forming, semi-woody species, began growth in early spring and attained an average mature height of 20.0 cm by late August or early September.

Figure 21. *Artemisia caudata*, a biennial species, began growth from a rosette in early spring and reached an average mature height of 35.4 cm by late August or early September.

Figure 22. White sage, a rhizomatous, open-sod-forming species, began growth in early spring and reached an average mature height of 42.5 cm by late August or early September.

perennial, follow essentially the same pattern, growing from early spring to late summer. Artemisia caudata attained an average mature height of 35.4 cm, while white sage attained an average mature height of 42.5 cm (Table 22). The sages as a group are unimportant from the standpoint of forage, as they are relatively unpalatable. The flowering date for the three species--fringed sage, white sage, and Artemisia caudata--is approximately August 20. Green sage, which has the same long-growing habit as the other listed sages, flowers early, the approximate flowering date being May 16, 90 days earlier than the other sages in this group (Table 22).

Two species of aster were observed in this study. These two species are white prairie aster (Aster ericoides) and white upland aster (Aster ptarmicoides). White prairie aster is the more important of the two because of its relatively high abundance. It reached its maximum height of 24.9 cm normally by mid-August and flowered by August 10 (Table 22). White upland aster is a less abundant species and on the study area was restricted to the broken slopes. It attained an average mature height of 19.5 cm, which was 5.4 cm less than the average mature height of white prairie aster. The flowering date is earlier than that of white prairie aster, with the average date of flowering being July 21, 20 days ahead of the white aster. As forage, these species are relatively unimportant, being rather coarse stemmed and unpalatable for livestock.

Golden aster (Chrysopsis villosa) is a semi-prostrate plant with numerous stems (Figure 23). It begins growth quite early in the spring, generally by the end of April. Growth progresses slowly

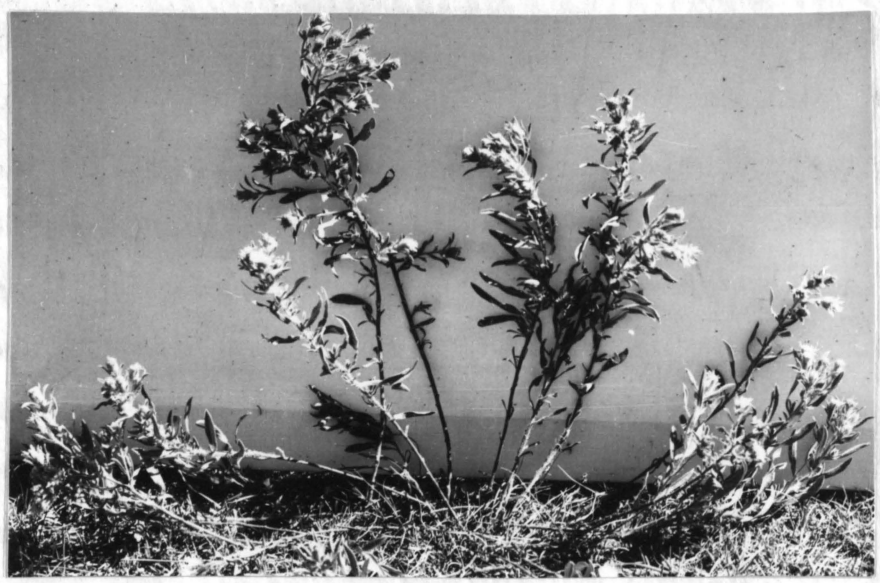

Figure 23. Golden aster, a numerous-stemmed, semi-prostrate plant, began growth by late April and reached an average mature height of 23.5 cm by the end of August.

throughout the summer. The average mature height attained was 23.5 cm, with flowering beginning as early as July 6 and continuing into September (Table 22). The plant was well dispersed on the study area, but it is of little apparent forage value. The short, villous leaves and somewhat woody stems make it rather unpalatable.

Scarlet gaura (Gaura coccinea) is an inconspicuous, low-branching plant beginning growth in late April. It attained an average mature height of 20.0 cm by mid-August (Table 22). The general growth pattern is similar to that of golden aster and the sages. This species begins growth early and growth progresses at a relatively even rate throughout the season. The average flowering date was June 15. The species is of little or no value as a forage plant.

Broomweed (Gutierrezia sarothrae) (Figure 24) is a low bunch-growth-form, semi-woody species generally found on shallow soils. It usually begins growth by mid-May. The species reached a mature height of 14.0 cm by early August (Table 22). It is a conspicuous plant because of its dark green stem, leaf color, and yellowish flowers which appear about the end of July. The plant is not common in the study area, but it may be quite abundant locally. It is often considered poisonous, and it may be an indicator of the presence of selenium in the soil.

Stiff sunflower (Helianthus rigidus) (Figure 25) is locally abundant in this type and is mainly found on the shallow soils of the broken slopes in the study area. It is a fairly tall-growing species attaining an average height of 30.0 cm by the end of August. Growth is slow early in the season, but stem elongation takes place rapidly

Figure 24. Broomweed, a low-growing, semi-woody species, began growth by mid-May and reached an average mature height of 14.0 cm by early August.

Figure 25. Stiff sunflower, a single-stalked, fairly tall-growing species, began growth in early summer and reached an average mature height of 30.0 cm by mid-July.

in late July. The species flowers late in the summer, the average flowering date being August 8 (Table 22).

Narrow-leaved blazing star (Liatrus punctata) (Figure 26) is an abundant, 2- to 3-stalked species of this native grassland type. It began growth in early May and attained an average mature height of 19.9 cm by mid-August (Table 22). The species has a conspicuous lavender-colored flower when in bloom. The average flowering date was August 5. The plant has little value as a forage species because of its hard-leaved nature.

Tooth-leaved evening primrose (Oenothera serrulata) is a slender-stemmed, semi-woody plant also commonly associated with the shallow soils on the slopes of the study area. The plant is rather conspicuous when in bloom, having moderately large yellow flowers. It blooms fairly early in the season, the average date being June 25. Growth begins early and an average mature height of 16.6 cm was attained by the end of July (Table 22). The plant has no apparent forage value, as its stems are quite woody and unpalatable. Another member of the genus, white-stemmed evening primrose (Oenothera nuttallii), was also found in the study area, but it was extremely scarce. Its maximum height was about twice that of tooth-leaved evening primrose, averaging 33.3 cm (Table 21). The average date of flowering for this species was July 15.

The genus Petalostemum was represented on the study area by two species, purple prairie-clover (Petalostemum purpureum) and white prairie-clover (Petalostemum candidum). Purple prairie-clover is the only one of the two species that is abundant in this type. This

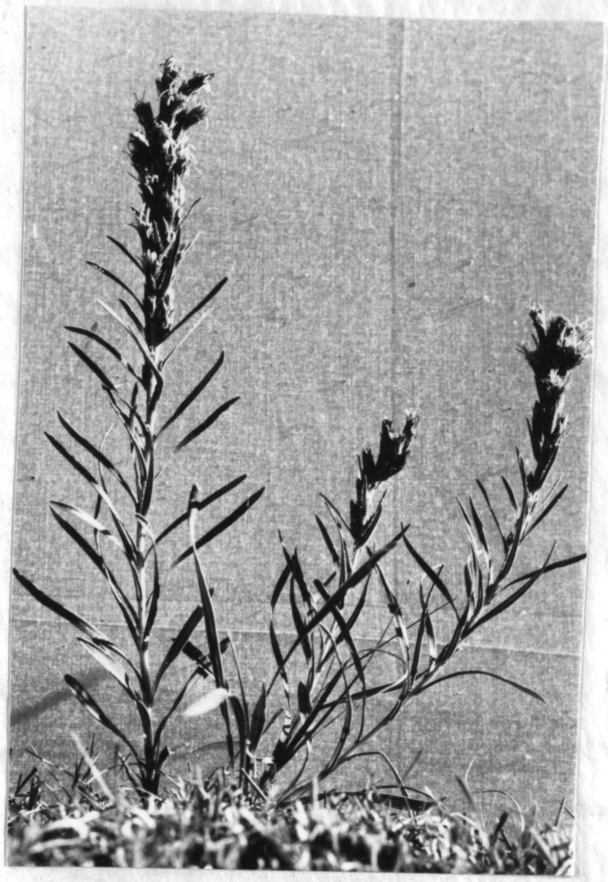

Figure 26. Narrow-leaved blazing star, a 2-3 stalked species, began growth in early May and reached an average mature height of 19.9 cm by mid-August.

semi-prostrate leguminous plant is a rather early-growing species. It began its growth in early May and reached an average mature height of 25.8 cm by late July. July 13 is the average flowering date for this species (Table 22). White prairie-clover flowers slightly earlier; generally by July 3. Its mature height is also less, the average being 15.5 cm (Table 21). Both species are rather inconspicuous even when in bloom. The species are of no apparent value as forage, possibly due to the bitter taste of the plants.

The genus Solidago is represented in the study area by three species--soft goldenrod (Solidago mollis), early goldenrod (Solidago missouriensis), and gray goldenrod (Solidago nemoralis). Soft goldenrod (Figure 27) began its growth in mid-April and reached an average mature height of 26.0 cm by the end of July or early August. The average flowering date for the species was July 15. Early goldenrod (Figure 28) also began its growth in mid-April and attained an average mature height of 21.0 cm by early July or mid-August. The average flowering date of this species was July 19. The third species, gray goldenrod, is somewhat later than are the previously mentioned species, beginning its growth by mid to late May and attaining an average mature height of 18.6 cm by mid-August. Gray goldenrod has an average flowering date of August 1, approximately 15 days later than the other two species (Table 22). Soft goldenrod and early goldenrod are well-distributed throughout the study area, but gray goldenrod is restricted to the broken slopes within the study area. The leaves of the Solidago species may be eaten by livestock while the plants are relatively immature, but these species are of limited importance as

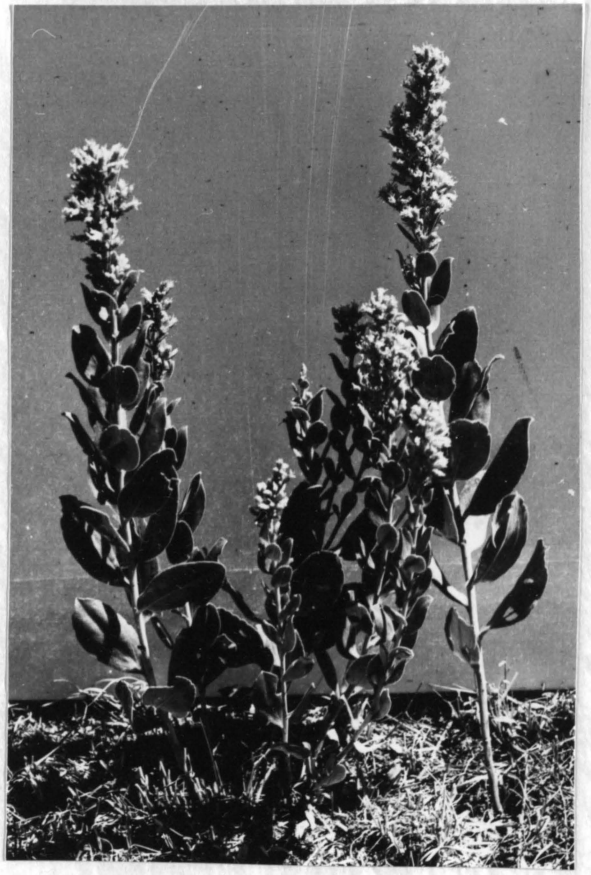

Figure 27. Soft goldenrod began growth in mid-April and reached an average mature height of 26.0 cm by the end of July or early August.

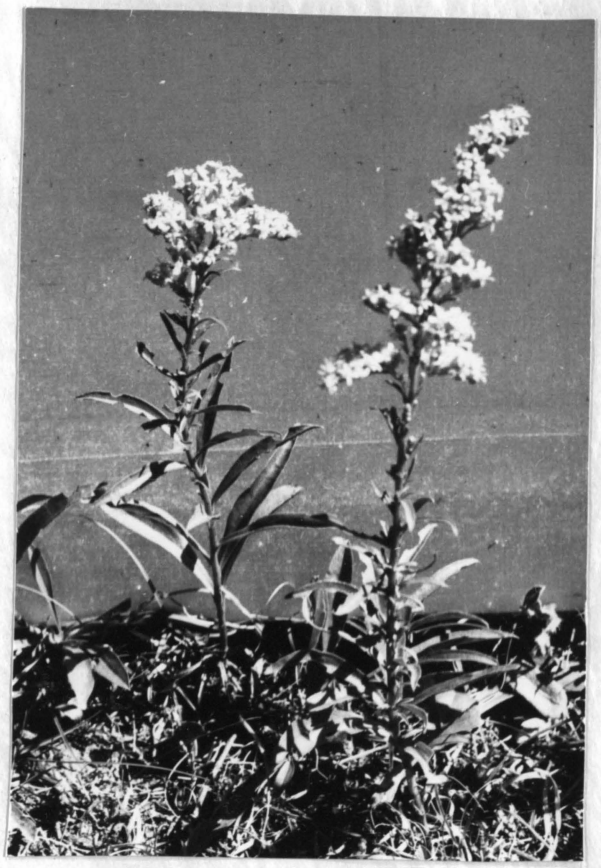

Figure 28. Early goldenrod began growth in mid-April and reached an average mature height of 21.0 cm by early July or mid-August.

forage plants.

Large goatsbeard (Tragopogon dubius) is a single-stalked, relatively tall-growing, lactiferous plant having a widely-branched crown. It is a common plant, but it is not abundant in the study area. It begins its growth in early April from the rosette established the previous year (biennial). It attained an average height of 34.4 cm by mid or late July (Table 22). The average flowering date of the species is July 2, but new flower buds are formed throughout the season. The species is of little value as a forage plant, but the rosettes frequently appear to have been grazed.

DISCUSSION

The fact that a native grassland is not composed of grasses which all grow at an even rate and attain a similar height or stage of development at a given time is an obvious fact even to the casual observer. The 8-year study of the growth and development of grasses, sedges, and forbs on this typical piece of mixed grass prairie has served to characterize the growth pattern for this type of vegetation under the prevailing climatic conditions in western North Dakota. In all, 15 grasses and sedges and 93 forb species were carefully observed over the study period. This is not all of the species occurring on the area, or by any means all the species found in mixed grass vegetation in this region, but it is by far the major portion of the species on the area, and includes most of the species of importance in the type as it occurs on upland sites.

This study has shown that growth of this type begins early in the spring, usually by late April with the rapid development of a group of early-growing grasses and sedges, including particularly needleleaf sedge, threadleaf sedge, and Sandberg bluegrass. Maturity of these species is reached early, and they are relatively short as compared to most of the later-developing grasses.

A second group composed of several cool-season grasses begins growth somewhat later than the early species and continues to develop beyond the time when the species in the first group have already reached their mature height, flowered, and begun to dry. Generally speaking, the species in this group attain greater mature leaf heights

than do the species in the early group. The most important species in this group are western wheatgrass, needle-and-thread, prairie Junegrass, green needlegrass, and plains reedgrass. These species provide the bulk of the forage for the type.

The warm-season shortgrass, blue grama, is different from all other species in the type. It begins growth rather late in the spring, with maximum leaf height being attained late in July at the same approximate time that flower stalks are reaching their maximum development. This species is of great importance on this range type as it is one of the major summer forage contributors. The fourth group is composed of several taller warm-season species which mostly begin growth quite early but grow slowly at first and then develop rapidly in mid-summer, completing their growth cycles by late mid-summer. The most important species in this group are little bluestem, prairie sandreed, stonyhills muhly, and red threeawn.

The heights attained by the various grass and sedge species at maturity differ greatly. However, the overall appearance of the upland grassland at maturity is largely determined by the heights of the major species and the extent to which they have developed fruiting stalks during the season. Whitman (1954) pointed out that on the average blue grama grass and the upland sedges provide about 70 per cent of the cover in the type, and western wheatgrass and needle-and-thread about 15 per cent. About 10 per cent of the cover is provided by all the remaining grasses found in the type on upland sites. Thus at maturity the overall appearance of the type is determined in large part by the relative proportions of blue grama grass, sedges, western wheatgrass,

and needle-and-thread. On the basis of average leaf heights, the type shows a mature height of about 8.0 inches (20.0 cm) and, considering stalk heights, about 14.4 inches (36.0 cm). As a rough average, it could be said that on upland sites the type reaches a mature height of about 11.0 inches (28.0 cm).

Yield of the type roughly parallels the height development pattern of the major species. Thus the clipping data from the square-foot plots show that on the average by June 1 about 609 pounds per acre dry weight of plant material had been produced. This was about 41 per cent of the average total yield of the type. By July 1, about 81 per cent of the yield had been produced, with average production being 1,200 pounds per acre. Practically all the yield of the type has been produced by August 1, the 5-year average clipping figures showing a production by this date of 1,243 pounds per acre, or about 84 per cent of the total yield. The maximum production, 1,492 pounds per acre, was reached on the average by August 15.

As the growing season advances into midsummer, the characteristic dry aspect or "golden" appearance of the prairie becomes apparent. At this time, for all practical purposes, maturity has been reached by the important forage species. The data obtained in the study clearly show that over 90 per cent of all leaf and stalk growth of all grasses and sedges had been attained by late July. Some of the late-growing warm-season grasses are still green at this time, but even most of these species are beginning to show evidences of leaf-tip drying, leaf-discoloration, and stalk maturity. Since these species make up only a small percentage of the bulk of the plant material produced on the

prairie, they have little overall influence in its coloration and serve mainly to provide variety in the vast sea of brown and gold.

The growth and development of the forbs accompanies the growth of the grasses from very early in the spring, and many of the forbs continue to grow even well beyond the period when all grasses and sedges have completed their growth. The forbs in this type have little or no forage value, but their ecological significance may be considerable. The leguminous plants, of which there are a relatively large number, may play an important part in the overall nitrogen supply available to the grasses and sedges. The sudden increase or decrease of certain forb and grass species may serve as an indicator of successional changes in the grassland type as the result of grazing or climatic influences. Following the maturity of the grasses and sedges, drying becomes rather rapid in a large number of species and consequent breakage of leaves and stalks causes the native range to appear less in height, and forb species appear considerably taller as the autumnal season advances.

Early spring ushers in a low-growing group of forbs which develop rapidly and mature before the taller-growing species attain any appreciable height. Many of these species are ephemeral and largely disappear by early summer. The species in this group represent a large number of families, including the Brassicaceae which is not represented in the group of late-growing forbs, as well as the Asteraceae, which is the only family of importance in the late-summer group. A second group of forbs is a taller-growing group which reaches maturity by the end of July. This is by far the largest of the three forb groups recognized

in this range type. The Aster and Pea families are the two most important families contributing species to this group. However, other families such as the Scrophulariaceae are also fairly well represented. The latest-growing group of forbs is made up almost entirely of composites. Many of the species in this late-flowering group begin growth rather early in the spring, but do not mature until late summer or early fall.

From the standpoint of grazing use and potential nutritive value of the forage, this grassland type is one which has a remarkably short growth period. Actually, the primary growing period is less than 90 days, including essentially the months of May, June, and July with forage drying frequently already severe by the end of the latter month. There is thus only a short period during which grazing animals can utilize the vegetation while it is in prime condition. Studies concerned with the nutritive status of range plants from this grassland type have been carried out by Whitman, et al. (1951) in the vicinity of this study. It was found that carotene, protein, and phosphorous are high in native grasses in relation to animal requirements only in the spring and early summer period. During midsummer, these constituents are generally adequate for proper nutrition. By early fall, however, protein and phosphorous are generally at or below deficiency levels. The mature, dry forage, as it enters the winter period, is generally deficient in all three constituents, there being practically no carotene in it, an average of about 5.5 per cent protein and about 0.1 per cent phosphorous. It is virtually impossible to plan a grazing program which will completely utilize this vegetation when its

growth is active and its nutritive status is at its highest level. The limitations of the climate and the economics of livestock production in the area demand that native grass be available for grazing at periods when its supply of basic nutrients other than energy may be too low to meet animal requirements. Ultimately, proper supplementation of the native grass vegetation will become one of the primary considerations in livestock production in this region.

Heady (1957) gives a rather thorough review of the uses of plant heights in range management. He lists some of the uses of plant heights as measures of growth, vigor, competition, adaptability, resistance to grazing, range readiness, forage utilization, range condition and trend, site classification, and yield. Plant heights, when properly reported, are of great importance in describing vegetation. Usually height data are given only in a general way and often only by inference, relying on the reader's knowledge of the vegetation described to supply an approximate height picture.

It has been demonstrated in this study that the heights of the major species found in this range type are directly related to the total volume of forage produced by these species. Of special significance are the leaf heights of the major species, as the leaves most often are the only portion of the plants which are eaten by livestock on the range. Other determinants of the volume of material available to the livestock for grazing are of importance, of course; especially the number of individual parts per plant (i.e., leaves, stems) and the size of the individual clumps. That a tremendous difference in plant heights exists from year to year has been clearly demonstrated in this

study. This variation is directly related to the volume of forage available for grazing and is of importance when planning the season's grazing. In this range type, early spring moisture, or a good supply of soil moisture accumulated the previous fall, is necessary in order to have the cool-season grasses attain optimum growth and maximum mature heights, thus producing maximum yields of forage. Spring drought may not only reduce maximum mature heights, but clump-fill in the bunchgrasses may be drastically reduced.

An indication of range readiness may be drawn from the data concerned with plant height. Vegetation which has reached a height of 5.0 cm has been assumed to be available to grazing animals and is essentially ready for grazing. The data given in Table 8 show that in most years many of the cool-season species have not reached this height by May 1. Consequently, a later date of beginning grazing on this type is clearly indicated. However, by June 1 practically all grass and sedge species are in their major period of rapid growth and some of the earliest species are nearing maturity. The obvious conclusion is that an average date of range readiness must be somewhere near the middle of May. This conclusion is in agreement with general range grazing practice in the area, for an average date of May 15 for beginning grazing is widely accepted as a standard practice. The data of the table do show, however, that the actual dates when major cool-season species reach a height of 5.0 cm may vary from year to year by as much as 23 days.

Blue grama as a warm-season grass is somewhat later in reaching its most productive stage, but again, all factors being equal, its

range readiness would not be a critical factor if the other grass and sedge species had made adequate growth before livestock grazed the type. Variations in time when livestock may be grazed depend considerably upon the relative species composition of the native range type. In other words, a native range type consisting mainly of blue grama would be ready for grazing later than a native grassland dominated by sedges and Sandberg bluegrass, or even one dominated by such cool-season species as western wheatgrass and needle-and-thread. The advantages in judicious grazing earlier in the season lies in the more adequate nutritive requirements supplied by the rapidly developing species. For the most part, the warm-season grasses in this type are not affected by the earlier grazing practices, as they are mostly species which are not especially palatable to livestock, the exception being blue grama grass which occupies an intermediate position between the early and late warm-season grasses.

The heights attained by plants are also of significance in this region because of the amount of late-fall and winter grazing. During winters having relatively mild weather and little snow cover, livestock are often allowed to graze throughout the winter on this type of native grassland. Cattle most often are fed hay on range supplements, but horses commonly feed on the range throughout the winter, pawing the snow in order to reach the forage. Where snow has covered much of the shorter forage, the leaves of the taller grasses and the mature fruiting stalks of both short and taller species may still be available as feed for livestock. Grasses such as blue grama would often be almost entirely covered by snow early in the season, leaving only the

taller grasses available for forage.

Species of grasses which are subject to severe leaf breakage upon reaching maturity are of limited use as winter forage. The sedges, blue grama, and to a limited extent the leaves of western wheatgrass are subject to this source of loss. An advantage in the Northern Great Plains, however, is the clearing of snow by winds from vast grassland areas and deposition of the snow in coulees and draws. This allows livestock to obtain forage otherwise lost because of low mature height or severe leaf breakage.

The use of plant heights has been widely accepted as a means of comparing the vigor of a given species on one site in relation to its vigor on another ecologically similar site which may have received different grazing use. The establishment of the normal height of a plant is sometimes extremely difficult and requires careful study. A direct comparison of plant heights on a relict or protected site with heights on similar sites under various degrees of grazing is a means of establishing what the normal plant height might be. Direct comparisons were made in this study between the heights of mature plants of the major species inside a 5-year exclosure, inside a 1-year exclosure, and on the fall-grazed native range. Considerable differences in mature height were noted in all species thus compared. By comparing the species inside the 5-year exclosure to the species on the fall-grazed range immediately outside the exclosure, plant heights were found to be considerably greater inside the exclosure. The species inside the 1-year exclosure were significantly taller than the species on the unprotected fall-grazed range. Fruiting stalk heights were

markedly affected after only the 1-year protection. These results substantiate the conclusion that plants are sensitive indicators of use as reflected by differences in total height. However, height must be used with caution when statements regarding range condition are made. The almost immediate response in height growth to lightening of the grazing load or to favorable change in climatic conditions cannot be directly interpreted as indicating an overall improvement in range condition. In order to make valid comparisons in relation to plant vigor under different degrees of grazing plant heights on a large number of sites equivalent as to soil type, exposure, water relationships, degree of slope, previous grazing records, and similar initial species composition must be compared.

The course of seasonal plant growth from initial leaf production to final maturity of leaves, stems, and seeds and the ultimate achievement of mature leaf and stalk height, without doubt, are factors of major importance in determining many aspects of the grazing use of this grassland type. It should be pointed out, however, that there are no fixed barriers imposed by characteristic growth patterns of the plants or by climate which prevent the type being used for grazing at any time of the year. In all honesty, it must be said that this grassland type is yearlong range and practical considerations of livestock husbandry and economics are the final determinants of its pattern of use.

SUMMARY

The native mixed grass prairie of western North Dakota in the vicinity of the Dickinson Experiment Station was characterized as to species of plants present and their rates of growth and development over the 8-year period, 1955-1962. Measurements of leaf and stalk heights of 15 major grass and sedge species were made at approximate 7- to 10-day intervals from early May to mid-September of each of the growing seasons during this period.

Phenological observations were made on the grass and sedge species, including dates of fruiting stalk initiation, anthesis, seed development, seed maturity, earliest observed date of seed shedding, and estimation of degree of leaf drying.

For the 93 forbs observed, only height measurements and dates of flowering were recorded.

A study of yield increase with advance of seasonal growth was made for western wheatgrass and blue grama grass by clipping square-foot plots at 2-week intervals throughout the growing season over the 5-year period, 1958-1962.

Comparisons of leaf and stalk heights of grasses and sedges under late-season grazing, under five year's protection from grazing, and with only one season's protection were made.

In general, the earliest grasses and sedges began growth in late April or early May and, for all practical purposes, grass growth was complete by early to mid-July. Some of the later grasses made minor growth after this time, and some forbs continued to grow well

into the fall period.

The grasses and sedges have been placed into four groups according to time of the season when greatest leaf and stalk development is attained. The first group includes the sedges, needleleaf sedge and threadleaf sedge, and the very early-growing grass species, Sandberg bluegrass. These species reach maximum development by approximately June 10-15. Average maximum leaf height of threadleaf sedge was 10.6 cm, of needleleaf sedge 9.8 cm, and of Sandberg bluegrass 8.8 cm. The species in the second group include western wheatgrass, needle-and-thread, green needlegrass, prairie Junegrass, plains reedgrass, and big needlegrass. The species in this group attain maximum development by about July 15-20. Average maximum leaf height of western wheatgrass was 23.8 cm, of needle-and-thread 20.9 cm, of green needlegrass 34.0 cm, of prairie Junegrass 12.3 cm, of plains reedgrass 20.9 cm, and of big needlegrass 30.0 cm.

One species, blue grama grass, is a warm-season shortgrass which is slightly later in beginning growth than the two earlier mentioned groups, but earlier than the warm-season grasses in group four. This species is treated separately. Blue grama is slower in development than the cool-season species and it reaches maximum development later, generally about July 20-25. Average maximum leaf height for this species was 10.7 cm.

The species in group four are all warm-season grasses. These species, in general, show slower developmental patterns than the other grasses, although they reach maturity at almost the same time as blue grama. Included in this group are prairie sandreed, little bluestem,

big bluestem, stonyhills muhly, and red threeawn. The species in this group are of minor importance in this type of grassland. Average leaf heights attained were: prairie sandreed 44.5 cm, little bluestem 15.3 cm, big bluestem 20.6 cm, stonyhills muhly 16.5 cm, and red threeawn 15.8 cm.

Maximum leaf and stalk heights attained during the 8-year study period varied considerably from season to season. A direct relationship exists between early-season precipitation or late-fall moisture and the heights attained by the grass, sedge, and forb species. Extremely dry growing seasons were experienced during the course of this study in which maximum leaf and stalk heights were greatly reduced. Time of occurrence of the different phenological phenomena also varied greatly from year to year. Differences of 15-20 days in phenological events of the same species from season to season was not uncommon.

The 93 forbs studied were placed into three groups according to the time when growth was completed. The first group of 25 species (27 per cent) matured during April, May, and June. Of this group, 21 species matured during June. The second group of species matured during July--this included 43 species. This is the largest group of forbs and constituted approximately 46 per cent of the total number of forbs found on the study area. Group three included the August-September maturing species. This group consisted of 25 species, only three of which attained maturity during September. Observed minimum mature heights of all species in each group, average mature heights, and 8-year average mature heights indicated that the trend for each

group was for the species to become progressively taller in relation to the lateness of the season at which maximum height was attained.

The species in the early-growing forb group (April-May-June maturing plants) represented 11 families of which the Asteraceae and Brassicaceae were the most important from the standpoint of having the greatest number of species. The species in the July-maturing group were largely representatives of the Asteraceae and Fabaceae. Seventy-five per cent of the total number of species in the August-September group were from the Asteraceae.

The total dry weight of vegetation increased as the height of the species increased with the advance of the seasonal growth. With blue grama, an average of 40 per cent of its growth had been completed by June 1, 60 per cent by June 15, and nearly 90 per cent by July 15. Some additional increase in production after July 15 was noted and may be attributed to continuance of stalk growth.

Western wheatgrass attained 62 per cent of its total production by June 15 and 96 per cent by August 15. Considerable variation in time of attaining maximum production was noted for both species from season to season.

For the type as a whole, dry weight yield averaged 609 pounds per acre by June 1, 40.8 per cent of the total seasonal production; 1,200 pounds per acre by July 1, 80.5 per cent; and 1,243 pounds per acre by August 15, full production.

Leaf and stalk heights of some of the major grass and sedge species measured inside and outside fenced exclosures indicated a marked reduction in vigor on the continuously fall-grazed native range.

It was found that the leaf height of western wheatgrass was 60 per cent greater inside the 5-year exclosure than on the fall-grazed range; needle-and-thread leaves were 28 per cent greater; blue grama leaves 85 per cent greater; and needleleaf sedge leaves 18 per cent greater after five years protection. Fruiting stalks were affected in similar degree to that of the leaves of the species concerned.

After only one year of protection, western wheatgrass leaves were 50 per cent greater in total leaf height, needle-and-thread leaves 17 per cent greater, blue grama leaves 48 per cent greater, and needleleaf sedge leaves 18 per cent greater than the leaf heights of the same species on fall-grazed range.

The actual growing season for the grasses and sedges of this region is extremely short, generally less than 90 days. Growth may be observed in some species during early April but, for all practical purposes, active growth is from early May until mid- to late July.

From the data obtained, it is possible to approximate the date of range readiness by observing the heights of leaves of grasses and sedges attained at a given date. A height of 5.0 cm was considered to be an adequate height to begin grazing the native species in this area. The date when this height was reached varied considerably from year to year. However, the average date of range readiness was approximately May 15.

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APPENDIX

APPENDIX TABLE 1. MEASURED LEAF AND STALK HEIGHTS OF WESTERN WHEATGRASS (AGROPYRON SMITHII) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			7.0		10.0			16.0			22.0		27.0		29.0		30.0			30.0			30.0	30.0	30.0	30.0
1956							9.5		19.0		21.0	25.0		25.0		25.0		25.0		27.0		27.0				27.0
1957				6.0			12.0	14.0	15.0	18.0		20.0		23.0	23.0		23.0		23.0	23.0		23.0		23.0	23.0	23.0
1958					9.0			14.0	18.0	19.0		20.0		21.0		21.0		21.0	23.0		23.0		23.0	23.0		23.0
1959							8.5					17.0	18.0	19.0	19.0		19.0	20.0	20.0	20.0		20.0	20.0	20.0	20.0	20.0
1960						7.5				14.0		14.0	14.0	16.0	16.0	19.0	19.0	19.0	19.0		19.0	19.0	19.0	19.0		19.0
1961		2.0						7.0			13.0	17.0	17.0	17.0		17.0	17.0	17.0	22.0	22.0		22.0	22.0	22.0	22.0	22.0
1962				6.0			11.0			14.0		16.0	20.0	23.0	23.0		24.0	24.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
Average Height	2.0	7.0	6.0	9.5	7.5	10.3	12.8	17.3	16.3	18.7	18.4	19.2	20.6	22.0	20.5	22.0	21.0	22.2	24.7	22.7	22.8	23.3	23.3	24.2	23.8	
Stalk Heights (cm)																										
1955														37.0		45.0			51.0			51.0	51.0	51.0	51.0
1956															27.0		33.0		33.0		34.0		34.0	34.0	34.0
1957													29.0	42.0		52.0		55.0	55.0		55.0		55.0	55.0	55.0
1958																				35.0		51.0	51.0	51.0	51.0
1959																32.0	35.0	35.0	35.0		35.0	35.0	35.0	35.0	35.0
1960												18.0	20.0	32.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
1961																										
1962												30.0	47.0	52.0		52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0
Average Height												24.0	32.0	40.8	31.5	43.4	39.0	44.5	45.2	41.0	42.4	45.0	46.7	46.2	44.6

APPENDIX TABLE 2. MEASURED LEAF AND STALK HEIGHTS OF NEEDLE-AND-THREAD (STIPA COMATA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
											Leaf Heights (cm)															
1955			4.0		7.0			9.0			15.0		19.0		23.0		23.0			23.0			23.0	23.0	23.0	23.0
1956							6.0		12.0		19.0	24.0		24.0		24.0		26.0		26.0		26.0				26.0
1957				3.5			9.0	11.0	12.0	16.0		17.0		18.0	20.0		20.0		24.0	24.0		24.0		24.0	24.0	24.0
1958					6.0			9.0	13.0	13.0		14.0		16.0		18.0		19.0	19.0		19.0		19.0	19.0		19.0
1959							5.0					14.0	16.0	16.0	18.0		19.0	19.0	19.0	19.0		19.0	19.0	19.0	19.0	19.0
1960						5.0				9.0		15.0	16.0	17.0	17.0	17.0	17.0	17.0	17.0		17.0	17.0	17.0	17.0	17.0	17.0
1961		2.5						4.5			12.0	13.0	15.0	16.0		16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
1962				5.0			8.0			14.0		16.0	19.0	23.0	23.0		23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Average Height	2.5	4.0	4.2	6.5	5.0	7.0	8.4	12.3	13.0	15.3	16.2	17.0	18.6	20.2	25.0	23.6	20.0	19.7	21.8	18.8	20.8	19.5	20.2	20.3	23.9	
											Stalk Heights (cm)															
1955										21.0		30.0		40.0		48.0			48.0			48.0	48.0	48.0	48.0	48.0
1956											29.0		33.0		35.0		35.0		35.0		35.0					35.0
1957										19.0	30.0		42.0	46.0		70.0		70.0	70.0		70.0		70.0	70.0	70.0
1958											23.0		51.0		51.0		51.0	51.0		51.0		51.0	51.0		51.0
1959											22.0	30.0	33.0	38.0		39.0	39.0	39.0	39.0		39.0	39.0	39.0	39.0	39.0
1960										14.0	22.0	31.0	33.0	33.0	54.0	54.0	54.0	54.0		54.0	54.0	54.0	54.0	54.0	54.0
1961											17.0	24.0	27.0	30.0		30.0	30.0	30.0	30.0	30.0		30.0	30.0	30.0	30.0	30.0
1962										20.0		26.0	34.0	34.0	34.0		34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Average Height										17.7	19.0	25.1	30.4	36.6	38.2	42.5	45.8	40.5	46.3	42.7	46.3	43.7	42.6	46.6	45.8	45.1

APPENDIX TABLE 3. MEASURED LEAF AND STALK HEIGHTS OF BLUE GRAMA (BOUTELOUA GRACILIS) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			1.0		2.0			5.5			8.0		8.0		9.0		10.0			11.0			11.0	11.0	11.0	11.0
1956							1.5		4.5		9.0	11.0		12.0		13.0		16.0		16.0		16.0				16.0
1957				0.5			2.5	4.5	5.0	5.5		6.5		8.0	9.0		9.0		11.0	11.0		12.0		12.0	12.0	12.0
1958					2.0			3.0	5.0	6.0		7.0		7.0		10.0		11.0	11.0		11.0		11.0	11.0		11.0
1959							1.5					6.0	8.0	8.0	9.0		9.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0	9.0
1960						1.0				4.0		6.0	6.0	6.5	7.0	8.0	8.0	8.0	8.0		8.0	8.0	8.0	8.0		8.0
1961								1.5			5.0	5.0	6.0	6.0		6.5	7.0	7.0	7.0	7.0		7.0	7.0	7.0	7.0	7.0
1962							3.0			5.0		8.0	9.0	9.0	10.0		11.0	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Average Height			1.0	0.5	2.0	1.0	2.1	3.6	4.8	5.1	7.3	7.0	7.4	8.1	8.8	9.4	9.0	10.4	9.6	10.9	10.2	10.6	9.6	9.9	10.1	12.2
Stalk Heights (cm)																										
1955																	15.0			20.0			20.0	20.0	20.0	20.0
1956																		17.0		20.0		24.0				24.0
1957																	18.0		26.0	30.0		30.0		30.0	30.0	30.0
1958																			20.0		27.0		27.0	27.0		27.0
1959																		20.0	20.0	20.0		20.0	20.0	20.0	20.0	20.0
1960															14.0	14.0	20.0	20.0	20.0		20.0	20.0	20.0	20.0		20.0
1961																7.0	9.0	12.0	12.0	13.0		15.0	17.0	17.0	17.0	17.0
1962														16.0	18.0		23.0	25.0	28.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0
Average Height														16.0	16.0	10.5	17.0	18.8	21.0	22.0	25.3	23.0	22.2	23.2	23.2	23.5

APPENDIX TABLE 4. MEASURED LEAF AND STALK HEIGHTS OF NEEDLELEAF SEDGE (CAREX ELEOCHARIS) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			2.5		3.5			6.0			7.0		8.0		8.0		8.0			8.0			8.0	8.0	8.0	8.0
1956							6.0		9.0		11.0	11.0		11.0		11.0		12.0		12.0		12.0				12.0
1957				3.0			7.0	8.0	8.0	9.0		10.0		10.0	10.0		10.0		10.0	10.0		10.0		10.0	10.0	10.0
1958					7.0			9.0	9.0	9.0		9.0		9.0		12.0		12.0	12.0		12.0		12.0	12.0	12.0	12.0
1959							6.0					9.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0	9.0
1960						5.0				8.0		8.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0	9.0	9.0
1961		1.5						5.0			7.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0	9.0		9.0	9.0	9.0	9.0	9.0
1962				3.0			8.0			9.0		10.0	10.0	11.0	11.0		11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Average Height	1.5	2.5	3.0	5.2	5.0	6.8	7.0	8.7	8.8	8.3	9.4	9.0	9.7	9.4	10.3	9.3	13.3	10.0	9.8	10.7	10.0	9.7	9.7	9.7	10.0	
Stalk Heights (cm)																										
1955				2.0			9.0			11.0		11.0		11.0		11.0			11.0			11.0	11.0	11.0	11.0
1956								10.0		13.0	13.0		13.0		13.0		13.0		13.0		13.0				13.0
1957						6.0	7.0	7.0	10.0		10.0		10.0	10.0		10.0		10.0	10.0		10.0		10.0	10.0	10.0
1958				4.0			10.0	11.0	11.0		11.0		11.0		16.0		16.0	16.0		16.0		16.0	16.0		16.0
1959						3.0					12.0	12.0	12.0	12.0		12.0	12.0	12.0	12.0		12.0	12.0	12.0	12.0	12.0
1960					2.5					9.5		12.0	12.0	12.0	12.0	12.0	12.0	12.0		12.0	12.0	12.0	12.0			12.0
1961																										
1962						10.0				10.0		10.0	10.0	12.0	12.0		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Average Height				3.0	2.5	9.5	8.7	9.3	10.1	11.5	11.3	11.3	11.7	11.4	13.7	11.4	13.0	12.4	11.6	13.3	11.8	12.6	12.2	11.3	12.3	

APPENDIX TABLE 5. MEASURED LEAF AND STALK HEIGHTS OF THREADLEAF SEDGE (CAREX FILIFOLIA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			3.0		5.0			8.0			10.0		11.0		12.0		12.0			12.0			12.0	12.0	12.0	12.0
1956							7.0		10.0		12.0	12.0		12.0		12.0		12.0		12.0		12.0				12.0
1957				3.0			8.0	11.0	12.0	12.0		12.0		12.0	12.0		12.0		12.0	12.0		12.0		12.0	12.0	12.0
1958					6.0			9.0	10.0	10.0		10.0		13.0		13.0		13.0	13.0		13.0		13.0	13.0		13.0
1959							7.0					9.0	9.5	10.0	10.0		10.0	10.0	10.0	10.0		10.0	10.0	10.0	10.0	10.0
1960						5.0				8.0		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0		8.0	8.0	8.0	8.0		8.0
1961		1.5						5.0			9.0	9.0	10.0	10.0		10.0	10.0	10.0	10.0	10.0		10.0	10.0	10.0	10.0	10.0
1962				3.0			6.0			9.0		10.0	10.0	12.0	12.0		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Average Height	1.5	3.0	3.0	5.5	5.0	7.0	8.3	10.7	9.8	10.3	10.0	9.7	11.0	10.8	10.8	10.7	10.8	10.8	11.3	11.0	10.7	10.8	11.0	11.2	11.1	
Stalk Heights (cm)																										
1955				2.0			9.0			11.0		13.0		13.0		13.0				13.0			13.0	13.0	13.0	13.0
1956						5.0		12.0		14.0	14.0		14.0		14.0		14.0		14.0		14.0					14.0
1957						7.0	10.0	12.0	12.0		12.0		15.0	16.0		16.0		16.0	16.0		16.0		16.0	16.0	16.0
1958				3.0			10.0	11.0	11.0		12.0		15.0		15.0		15.0	15.0		15.0		15.0	15.0		15.0
1959						7.0					13.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0	13.0
1960					4.0				11.0		13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0		13.0
1961							6.0			14.0	14.0	15.0	15.0		15.0	15.0	15.0	15.0	15.0		15.0	15.0	15.0	15.0	15.0
1962						7.0			13.0		13.0	13.0	16.0	16.0		16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Average Height				2.5	4.0	6.5	8.8	11.7	11.8	16.3	13.0	13.4	14.4	14.2	14.3	14.3	14.3	14.7	14.5	14.7	14.5	14.2	14.4	14.6	14.4	

APPENDIX TABLE 6. MEASURED LEAF AND STALK HEIGHTS OF SANDBERG BLUEGRASS (POA SECUNDA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			4.0		8.0			10.0			11.0		11.0		11.0		11.0			11.0			11.0	11.0	11.0	11.0
1956							7.0		10.0		10.0	10.0		10.0		10.0		10.0		10.0		10.0				10.0
1957				4.0			7.0	9.0	10.0	10.0		10.0		10.0	10.0		10.0		10.0	10.0		10.0		10.0	10.0	10.0
1958					6.0			7.0	8.0	8.0		8.0		9.0		9.0		9.0	9.0		9.0		9.0	9.0		9.0
1959							5.0					7.0	7.0	7.0	7.0		7.0	7.0	7.0	7.0		7.0	7.0	7.0	7.0	7.0
1960						4.0				6.0		7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0		7.0	7.0	7.0	7.0		7.0
1961		2.0						6.0			7.0	7.0	8.0	8.0		8.0	8.0	8.0	8.0	8.0		8.0	8.0	8.0	8.0	8.0
1962				4.0			6.0			7.0		7.0	8.0	8.0	8.0		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Average Height		2.0	4.0	4.0	7.0	4.0	6.2	8.0	9.3	10.3	9.3	8.0	8.2	8.4	8.6	8.5	8.5	8.1	9.8	9.0	8.0	8.3	8.3	8.6	8.8	8.8
Stalk Heights (cm)																										
1955								14.0			21.0		31.0		32.0		33.0			33.0			33.0	33.0	33.0	33.0
1956									16.0		23.0	27.0		27.0		27.0		27.0		27.0		27.0				27.0
1957									9.0	17.0		24.0		25.0	25.0		25.0		25.0	25.0		25.0		25.0	25.0	25.0
1958									9.0	11.0		12.0		16.0		16.0		16.0	16.0		16.0		16.0	16.0		16.0
1959												27.0	27.0	27.0	27.0		27.0	27.0	27.0	27.0		27.0	27.0	27.0	27.0	27.0
1960										15.0		23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0		23.0	23.0	23.0	23.0		23.0
1961											19.0	19.5	24.0	24.0		24.0	24.0	24.0	24.0	24.0		24.0	24.0	24.0	24.0	24.0
1962										24.0		26.0	31.0	31.0	31.0		31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0
Average Height								14.0	11.3	16.8	21.0	22.7	27.2	24.7	27.6	22.5	27.2	24.7	24.3	27.8	23.3	26.2	25.7	25.6	28.0	25.8

APPENDIX TABLE 7. MEASURED LEAF AND STALK HEIGHTS OF PRAIRIE JUNEGRASS (KOELERIA CRISTATA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY PERIOD

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			4.5		8.5			13.0			15.0		16.0		17.0		18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
1956							7.0		11.0		13.0	14.0		14.0		14.0		14.0		14.0		14.0				14.0
1957				3.0			7.0	10.0	11.0	11.0		11.0		13.0	13.0		13.0		13.0	13.0		13.0		13.0	13.0	13.0
1958					5.0			8.0	8.0	9.0		10.0		11.0		12.0		12.0	12.0	12.0	12.0		12.0	12.0		12.0
1959							5.0					8.0	11.0	11.0	11.0		11.0	11.0	11.0	11.0		11.0	11.0	11.0	11.0	11.0
1960						3.0				7.0		7.0	7.0	7.0	8.0	8.0	8.0	8.0	8.0		8.0	8.0	8.0	8.0		8.0
1961		1.0						4.0			7.0	10.0	11.0	11.0		11.0	11.0	11.0	11.0	11.0		11.0	11.0	11.0	11.0	11.0
1962				4.0			8.0			8.0		8.0	9.0	9.0	11.0		11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Average Height		1.0	4.5	3.5	6.7	3.0	6.8	8.8	10.0	8.8	11.7	9.7	10.8	10.9	12.0	11.3	12.0	11.2	11.0	13.0	10.3	11.3	11.8	12.0	12.8	12.3
Stalk Heights (cm)																										
1955											17.0		24.0		35.0		37.0			37.0			37.0	37.0	37.0	37.0
1956												22.0		23.0		23.0		23.0		23.0		23.0				23.0
1957										14.0		16.0		29.0	35.0		35.0		35.0	35.0		35.0		35.0	35.0	35.0
1958									10.0	11.0		11.0		16.0		28.0		28.0	28.0		28.0		28.0	28.0		28.0
1959												11.0	18.0	19.0	19.0		19.0	19.0	19.0	19.0		19.0	19.0	19.0	19.0	19.0
1960										8.0		11.0	17.0	20.0	28.0	28.0	28.0	28.0	28.0		28.0	28.0	28.0	28.0		28.0
1961											11.0	14.0	15.0	16.0		16.0	16.0	16.0	16.0	16.0		16.0	16.0	16.0	16.0	16.0
1962										13.0		20.0	30.0	30.0	31.0		31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0
Average Height									10.0	11.5	14.0	15.0	20.8	21.9	29.6	23.8	27.7	24.2	26.1	26.8	29.0	25.3	26.5	27.7	27.6	27.1

APPENDIX TABLE 8. MEASURED LEAF AND STALK HEIGHTS OF GREEN NEEDLEGRASS (STIPA VIRIDULA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			7.0		11.0			20.0			27.0		34.0		34.0		35.0			35.0			35.0	35.0	35.0	35.0
1956						11.0		19.0		27.0	30.0		30.0		30.0		36.0			36.0		36.0				36.0
1957				6.0		16.0	18.0	22.0	23.0		29.0		29.0	32.0		32.0			32.0	32.0		32.0		32.0	32.0	32.0
1958					9.0			16.0	20.0	20.0		23.0		30.0		35.0		35.0	35.0		35.0		35.0	35.0		35.0
1959						12.0					20.0	33.0	33.0	33.0		35.0	35.0	35.0	35.0		35.0	35.0	35.0	35.0	35.0	35.0
1960					8.0					20.0	30.0	32.0	34.0	34.0	34.0	34.0	34.0	34.0		34.0	34.0	34.0	34.0	34.0	34.0	34.0
1961	4.0							10.0		13.0	20.0	25.0	25.0		25.0	25.0	25.0	25.0	25.0		25.0	25.0	25.0	25.0	25.0	25.0
1962			5.0			15.0			26.0		27.0	36.0	37.0	40.0		40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Average Height	4.0	7.0	5.5	10.0	8.0	13.5	16.0	20.3	22.3	22.3	25.6	32.0	36.3	34.6	31.0	33.5	34.1	40.2	33.8	36.3	33.7	34.0	39.3	33.5	38.9	
Stalk Heights (cm)																										
1955												36.0		55.0		60.0			60.0			60.0	60.0	60.0	60.0
1956													31.0		31.0		36.0		36.0		36.0				36.0
1957											32.0		45.0	60.0		70.0		70.0	70.0		70.0		70.0	70.0	70.0
1958											26.0		47.0		52.0		60.0	60.0		60.0		60.0	60.0		60.0
1959											26.0	30.0	41.0	47.0		48.0	48.0	48.0	48.0		48.0	48.0	48.0	48.0	48.0
1960											25.0	40.0	44.0	62.0	65.0	65.0	65.0	65.0		65.0	65.0	65.0	65.0		65.0
1961										26.0	28.0	31.0	40.0		40.0	40.0	40.0	40.0	40.0		40.0	40.0	40.0	40.0	40.0
1962									28.0		34.0	50.0	67.0	73.0		73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
Average Height									28.0	26.0	28.5	37.4	45.0	59.4	47.0	59.3	53.2	71.2	54.5	66.0	55.3	57.7	59.4	58.2	56.5	

APPENDIX TABLE 9. MEASURED LEAF AND STALK HEIGHTS OF PLAINS REEDGRASS (CALAMAGROSTIS MONTANENSIS) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955			8.5		12.0			19.0			23.0		23.0		27.0		27.0			27.0			27.0	27.0	27.0	27.0
1956							7.5		11.0		15.0	16.0		19.0		19.0		19.0		19.0		19.0				19.0
1957				5.5			11.0	14.0	16.0	16.0		16.0		17.0	17.0		17.0		20.0	22.0		22.0		22.0	22.0	22.0
1958					10.0			15.0	19.0	19.0		21.0		21.0		21.0		21.0	21.0		21.0		21.0	21.0		21.0
1959							9.0					14.0	18.0	18.0	18.0		18.0	18.0	18.0	18.0		18.0	18.0	18.0	18.0	18.0
1960						6.0				14.0		14.0	15.0	15.0	17.0	18.0	18.0	18.0	18.0		18.0	18.0	18.0	18.0		18.0
1961		1.0						9.0			16.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0		18.0	18.0	18.0	18.0	18.0
1962				4.0			9.0			16.0		17.0	21.0	22.0	22.0		22.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Average Height	1.0	8.5	4.7	11.0	6.0	9.1	14.3	15.3	16.3	18.0	19.3	19.0	21.7	19.8	19.0	20.0	19.7	19.7	21.3	21.0	19.7	21.0	21.1	21.8		18.6
Stalk Heights (cm)																										
1955														30.0		30.0			30.0			30.0	30.0	30.0	30.0
1956											14.0		19.0		19.0		19.0		19.0		19.0					19.0
1957											17.0		24.0	30.0		32.0		32.0	32.0		32.0		32.0	32.0		32.0
1958											14.0		20.0		20.0		21.0	21.0		21.0		21.0	21.0			21.0
1959													10.0	13.0		13.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0	13.0	13.0
1960												18.0	24.0	27.0	27.0	29.0	29.0	29.0		29.0	29.0	29.0	29.0			29.0
1961																										
1962											20.0	28.0	33.0	33.0		33.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Average Height											16.3	23.0	21.7	26.6	22.0	27.4	23.4	26.0	25.8	28.3	25.6	25.6	26.7	27.5		25.6

APPENDIX TABLE 10. MEASURED LEAF AND STALK HEIGHTS OF LITTLE BLUESTEM (ANDROPOGON SCOPARIUS) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955								5.0			8.0		10.0		12.0		12.0			14.0			14.0	14.0	14.0	14.0
1956									2.5		7.0	10.0		11.0		12.0		12.0		12.0		12.0				12.0
1957								4.0	5.0	8.0		9.0		13.0	13.0		13.0		14.0	14.0		14.0		14.0	14.0	14.0
1958							3.0	5.0	8.0		11.0		15.0		15.0		15.0	15.0		15.0		15.0	15.0			15.0
1959								8.0	10.0	11.0	12.0		15.0	16.0	17.0	18.0		18.0	18.0	18.0	18.0	18.0				18.0
1960									4.0		10.0	11.0	12.0	14.0	15.0	15.0	15.0	15.0		15.0	15.0	15.0	15.0	15.0		15.0
1961										3.0	12.0	13.0	14.0		17.0	17.0	17.0	17.0	17.0		17.0	17.0	17.0	17.0	17.0	17.0
1962					4.0				9.0		10.0	11.0	12.0	13.0		15.0	16.0	16.0	16.0	16.0	16.0	17.0	17.0	17.0	17.0	17.0
Average Height					4.0	4.0	4.2	7.2	6.0	10.0	11.0	12.6	12.8	14.7	14.5	15.2	15.7	15.2	15.3	15.3	16.0	15.7	16.0	15.3		
Stalk Heights (cm)																										
1955															18.0				32.0			45.0	45.0	45.0	45.0
1956																16.0			18.0		35.0					35.0
1957															18.0		27.0	33.0			33.0			33.0	33.0	33.0
1958																32.0	32.0		39.0			43.0	43.0			43.0
1959																19.0	21.0	24.0			24.0	24.0	24.0	24.0	24.0	24.0
1960															16.0	24.0	28.0		33.0	34.0	34.0	34.0				34.0
1961																17.0	20.0	24.0			29.0	31.0	34.0	34.0	34.0	34.0
1962													19.0		20.0	22.0	25.0	29.0	32.0	38.0	44.0	44.0	44.0			44.0
Average Height													19.0		18.0	21.7	25.5	26.7	34.7	32.1	36.8	36.7	36.0	36.5		

APPENDIX TABLE 11. MEASURED LEAF AND STALK HEIGHTS OF PRAIRIE SANDREED (CALAMOVILFA LONGIFOLIA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955								12.0			25.0		30.0		35.0		40.0			40.0			46.0	46.0	46.0	46.0
1956									8.0		14.0	30.0		35.0		38.0		38.0		38.0		38.0				38.0
1957							4.0	8.0	10.0	18.0		23.0		32.0	33.0		33.0		33.0	33.0		33.0		33.0	33.0	33.0
1958								2.0	9.0	18.0		29.0		31.0		35.0		42.0	42.0		42.0		42.0	42.0		42.0
1959											18.0	26.0	31.0	32.0		34.0	38.0	40.0	40.0		45.0	45.0	45.0	45.0	45.0	45.0
1960									13.0		20.0	25.0	30.0	41.0	48.0	48.0	48.0	50.0		50.0	50.0	50.0	50.0			50.0
1961										22.0	26.0	32.0	33.0		35.0	35.0	36.0	36.0	36.0		36.0	36.0	36.0	36.0	36.0	36.0
1962					2.0				21.0		29.0	39.0	45.0	57.0		62.0	62.0	63.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0
Average Height					3.0	7.3	9.0	17.5	20.3	25.0	30.4	33.9	39.6	39.0	42.0	44.0	44.0	42.1	52.7	44.7	47.5	45.4	45.2	44.5		
Stalk Heights (cm)																										
1955																		65.0			85.0	85.0	85.0	85.0	85.0
1956																	31.0			60.0		70.0				70.0
1957																50.0		70.0		75.0		85.0		85.0	85.0	85.0
1958																	55.0	58.0			65.0		87.0	87.0		87.0
1959																		50.0	60.0			66.0	66.0	66.0	66.0	66.0
1960																	56.0	63.0		65.0	65.0	65.0	65.0			65.0
1961																	43.0	52.0	65.0		67.0	70.0	70.0	70.0	70.0	70.0
1962																70.0	84.0	95.0	95.0	95.0	95.0	101.0	101.0	101.0	101.0	101.0
Average Height																60.0	53.8	64.7	70.0	75.0	74.7	79.0	79.9	81.4	79.9	

APPENDIX TABLE 12. MEASURED LEAF AND STALK HEIGHTS OF BIG BLUESTEM (ANDROPOGON GERARDI) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955											10.0		13.0		18.0		20.0			20.0			21.0	21.0	21.0	21.0
1956											6.0	12.0		13.0		16.0		18.0		18.0		18.0				18.0
1957						3.0	7.0		12.0			15.0	18.0		20.0		25.0	29.0		29.0			29.0	29.0		29.0
1958						3.0	10.0		14.0			19.0		28.0		32.0	32.0		33.0		33.0	33.0				33.0
1959									8.0	11.5	12.0	14.0		15.0	15.0	15.0	15.0			15.0	15.0	15.0	15.0	15.0		15.0
1960							5.0		9.0	11.0	13.0	16.0	18.0	18.0	18.0	18.0			18.0	18.0	18.0	18.0	18.0			18.0
1961								6.0	9.0	10.0	10.0		10.0	10.0	10.0	10.0	10.0			10.0	10.0	10.0	10.0	10.0	10.0	10.0
1962																										
Average Height						3.0	7.3	7.3	10.7	11.4	13.7	16.5	18.0	16.6	18.6	20.0	18.4	25.5	18.0	19.4	21.0	18.8	20.6			
Stalk Heights (cm)																										
1955																	35.0			59.0	90.0	90.0	90.0			
1956																										
1957																26.0	55.0		75.0		76.0	91.0	91.0			
1958																		47.0		63.0	63.0		63.0			
1959																										
1960														15.0	15.0	15.0		15.0	15.0	15.0	15.0	15.0	15.0			
1961																48.0	53.0		53.0	53.0	53.0	53.0	53.0			
1962																				90.0	90.0	90.0	90.0			
Average Height														15.0	15.0	29.7	47.7	31.0	47.7	56.0	64.5	67.8	67.0			

APPENDIX TABLE 13. MEASURED LEAF AND STALK HEIGHTS OF STONYHILLS MUHLY (MUHLENBERGIA CUSPIDATA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 8-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1955	1.5			8.0			8.0		12.0		12.0		12.0			12.0			12.0			12.0	12.0	12.0		12.0
1956			1.0		5.0		7.0	9.0		10.0		10.0		12.0		12.0					12.0					12.0
1957			1.5	4.0	5.0	7.0		8.0		12.0	13.0		13.0		13.0	13.0					13.0		13.0	13.0		13.0
1958	1.5			4.0	5.0	8.0		11.0		16.0		16.0		16.0	16.0		16.0					16.0	16.0			16.0
1959			3.0					7.0	12.0	12.0	12.0		14.0	15.0	17.0	18.0					18.0	18.0	18.0	18.0		18.0
1960		1.5				9.0		10.0	10.0	10.0	10.0	12.0	12.0	14.0	15.0		15.0				15.0	15.0	15.0			15.0
1961				4.0			7.0	11.0	15.0	15.0		15.0	15.0	15.0	15.0	15.0					15.0	15.0	15.0	15.0		15.0
1962			4.0			11.0		14.0	16.0	19.0	19.0		19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Average Height	1.5	1.5	2.4	5.0	5.0	8.7	7.3	10.0	13.0	13.4	13.2	13.3	14.2	15.2	15.8	14.8	16.7	15.3	15.8	13.9	15.4	15.0				
Stalk Heights (cm)																										
1955													16.0			21.0			23.0	23.0	23.0	23.0				
1956												13.0		20.0		22.0		23.0								
1957													15.0		21.0	22.0		26.0		26.0	26.0	26.0				
1958														16.0	18.0		24.0		26.0	28.0		28.0				
1959													19.0	19.0	20.0	21.0		21.0	21.0	21.0	21.0	21.0				
1960												13.0	15.0	17.0	18.0		18.0	18.0	18.0	18.0		18.0				
1961													17.0	19.0	20.0	20.0		20.0	22.0	22.0	22.0	22.0				
1962													21.0	22.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0				
Average Height												13.0	17.1	18.8	20.2	21.7	22.0	22.0	22.4	23.1	23.2	23.1				

APPENDIX TABLE 14. MEASURED LEAF AND STALK HEIGHTS OF RED THREEAWN (ARISTIDA LONGISETA) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 4-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1959												8.0	13.0	16.0	16.0		17.0	17.0	17.0	17.0		17.0	17.0	17.0	17.0	17.0
1960										7.0		12.0	13.0	16.0	16.0	16.0	16.0	16.0	16.0		16.0	16.0	16.0	16.0		16.0
1961											8.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0	13.0		13.0	13.0	13.0	13.0	13.0
1962							5.0			10.0		11.0	16.0	17.0	17.0		17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Average[a] Height							5.0			8.5	8.0	11.0	13.8	15.5	16.3	14.5	15.8	15.8	15.8	15.7	16.5	15.8	15.8	15.8	15.7	15.8
Stalk Heights (cm)																										
1959																	18.0	19.0	19.0	20.0		20.0	20.0	20.0	20.0	20.0
1960																20.0	20.0	20.0	20.0		20.0	20.0	20.0	20.0		20.0
1961													16.0	20.0		25.0	25.0	25.0	25.0	25.0		25.0	25.0	25.0	25.0	25.0
1962															21.0		25.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
Average[a] Height													16.0	20.0	21.0	22.5	22.0	22.8	22.8	24.0	23.5	23.0	23.0	23.0	24.0	23.0

[a]Four-year average.

APPENDIX TABLE 15. MEASURED LEAF AND STALK HEIGHTS OF BIG NEEDLEGRASS (*STIPA SPARTEA*) AT DATES OF OBSERVATION DURING EACH SEASON OF THE 4-YEAR STUDY

Year	April					May					June					July					August					Maximum Height Attained
	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	1	8	15	22	29	
Leaf Heights (cm)																										
1959							6.0					18.0	22.0	24.0	24.0		25.0	25.0	26.0	26.0		26.0	26.0	26.0	26.0	26.0
1960						5.0				16.0		20.0	22.0	24.0	27.0	32.0	32.0	32.0	32.0		32.0	32.0	32.0	32.0	32.0	32.0
1961		2.0						9.0			15.0	22.0	26.0	30.0		30.0	30.0	30.0	30.0	30.0		30.0	30.0	30.0	30.0	30.0
1962		3.0					13.0			17.0		18.0	23.0	23.0	28.0		31.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0
Average[a] Height		2.5				5.0	9.5	9.0		11.5	15.0	19.5	23.3	25.3	26.3	31.0	29.5	29.8	30.0	29.3	32.0	30.0	30.0	30.0	30.0	30.0
Stalk Heights (cm)																										
1959													28.0	30.0	40.0		40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
1960												12.0	16.0	26.0	44.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0
1961											21.0	27.0	30.0	45.0		45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
1962										22.0	23.0	33.0	37.0	40.0	41.0		44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
Average[a] Height										22.0	22.5	24.0	27.8	35.2	42.7	49.0	45.5	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	45.5

[a]Four-year average.

APPENDIX TABLE 16. LEAF AND STALK HEIGHTS OF SPECIES IN BLUE GRAMA CLIPPED PLOTS IN THE 5-YEAR EXCLOSURE (1958-1962)

Time Plot	Species	1958 Ave. Leaf ht-cm	1958 Ave. Stalk ht-cm	1958 Total No. of Stalks	1959 Ave. Leaf ht-cm	1959 Ave. Stalk ht-cm	1959 Total No. of Stalks	1960 Ave. Leaf ht-cm	1960 Ave. Stalk ht-cm	1960 Total No. of Stalks	1961 Ave. Leaf ht-cm	1961 Ave. Stalk ht-cm	1961 Total No. of Stalks	1962 Ave. Leaf ht-cm	1962 Ave. Stalk ht-cm	1962 Total No. of Stalks	Ave. Leaf ht-cm 5-year	Ave. Stalk ht-cm 5-year	Total No. of Stalks	Ave. No. of Stalks
May 1	Blue grama	6.00															6.00			
	Needleleaf sedge	7.67															7.67			
	Threadleaf sedge	9.67															9.67			
May 15	Blue grama	5.00						7.00						5.67			5.89			
	Needleleaf sedge	7.67						11.00	5.30					6.67			8.45	5.30		
	Threadleaf sedge	8.00																		
	Western wheatgrass							17.00		53				13.00		8	15.00		61	30.5
	Needle-and-thread	12.00		4 clps.													12.00		4 clps.	
	Sandberg bluegrass							6.00	15.50								6.00	15.50		
June 1	Blue grama				7.33			8.00			7.00			8.33			7.67			
	Needleleaf sedge				8.67			9.33	14.00		9.70			10.00			9.43	14.00		
	Threadleaf sedge																			
	Western wheat grass				17.00		50	17.67		25				20.00		21	18.22		96	32.0
	Sandberg bluegrass							7.00	23.00								7.00	23.00		
June 15	Blue grama	6.16			8.33			10.00			13.30			10.67			9.66			
	Needleleaf sedge	7.00			9.67			9.67	16.00		16.30			7.50			10.03	16.00		
	Needle-and-thread	11.67	23.00	8 clps.													11.67	23.00	8 clps.	
	Western wheatgrass				21.67		30	32.67		58				20.67		25	25.00		113	37.7
	Sandberg bluegrass				6.00	21.00	1 clp.	7.33	29.30								2.67	25.15	1 clp.	
	Carex filifolia	9.00															9.00			
July 1	Blue grama	7.33			9.16			11.67	10.00		10.00			15.00	19.00		10.63	24.50		
	Needleleaf sedge	8.67			10.00			12.00	19.00		14.00			10.00			10.93	19.00		
	Needle-and-thread	13.33	30.33	8 clps.										26.00			19.67	30.33		
	Western wheatgrass				23.67		18	29.30	32.67	72				29.00		16	27.32	32.67	106	35.3
	Sandberg bluegrass							6.50	31.50								6.50	31.50		
July 15	Blue grama	6.00	11.33		11.00			10.67			10.70	12.00		16.33	34.33		10.94	19.22		
	Needleleaf sedge	7.00			10.67			11.00	21.00		12.70			13.00			10.87	21.00		
	Needle-and-thread	12.33	33.00	15 clps.							18.00						15.16	33.00	15 clps.	
	Green needlegrass	14.00	30.00	1 clp.													14.00	30.00	1 clp.	
	Western wheatgrass				27.33		37	28.00	40.00	67				28.33		19	27.89	40.00	123	41.0
	Sandberg bluegrass							7.00	31.50								7.00	31.50		
Aug. 1	Blue grama	8.33	20.67		12.00	16.67		7.30			10.30	13.00		17.67	40.00		11.12	22.59		
	Needleleaf sedge	6.00			10.67			8.67	20.00		13.30			16.33			10.99	20.00		
	Needle-and-thread	13.00	35.00	5 clps.				8.00	32.33								10.50	33.67	5 clps.	
	Western wheatgrass				26.33	50.00	18	27.00		41				40.0		4	31.11	50.00	63	21.0
	Sandberg bluegrass							6.00	28.00								6.00	28.00		
	Prairie Junegrass										13.00						13.00			

APPENDIX TABLE 16 (Continued)

Time Plot	Species	1958 Ave. Leaf ht-cm	1958 Ave. Stalk ht-cm	1958 Total No. of Stalks	1959 Ave. Leaf ht-cm	1959 Ave. Stalk ht-cm	1959 Total No. of Stalks	1960 Ave. Leaf ht-cm	1960 Ave. Stalk ht-cm	1960 Total No. of Stalks	1961 Ave. Leaf ht-cm	1961 Ave. Stalk ht-cm	1961 Total No. of Stalks	1962 Ave. Leaf ht-cm	1962 Ave. Stalk ht-cm	1962 Total No. of Stalks	Ave. Leaf ht-cm 5-year	Ave. Stalk ht-cm 5-year	Total No. of Stalks	Ave. No. of Stalks
Aug. 15	Blue grama	7.50	29.67		10.67	16.00		9.67	14.00		8.00	19.00		17.33	32.33		10.63	22.22		
	Needle leaf sedge	7.67			10.67	16.00		9.00	13.50		9.00			17.33			10.73	14.75		
	Needle-and-thread	14.33	30.33	9 clps.	20.00	30.00	1 clp.	16.50	31.00		18.60	28.00		25.00			19.36	29.83	10 clps.	
	Western wheatgrass				27.50		6	25.67	35.00	16				42.33	62.00	19	31.85	48.50	41	13.6
	Sandberg bluegrass							7.00	39.00								7.00	39.00		
	Prairie Junegrass										9.00						9.00			
Sept. 1	Blue grama	7.00	22.00		8.00			12.67	10.00		7.00	24.30		17.33	33.67		10.40	22.49		
	Needle leaf sedge	7.00			9.00	10.67		11.00	16.00		7.00			16.33			10.07	13.34		
	Needle-and-thread	8.33	28.50	13 clps.	16.00		1 clp.				13.70						12.68	28.50	14 clps.	
	Western wheatgrass							24.67		34	18.70			33.33	50.00	21	25.57	50.00	55	27.5
	Sandberg bluegrass							6.50	32.50								6.50	32.50		
Sept. 15	Blue grama				9.00									15.67	35.67		12.34	35.70	25	
	Needle leaf sedge				9.70									13.50			11.58	11.00		
	Western wheat grass													37.00	55.00	25	37.00	55.00	25	12.5
	Sandberg bluegrass				6.00	20.00											6.00	20.00		
	Threadleaf sedge													11.00	20.00		11.00	20.00		

APPENDIX TABLE 17. AVERAGE YIELD OF SPECIES PER FT.^{2} AND PER CENT COMPOSITION OF YIELDS IN BLUE GRAMA CLIPPED PLOTS IN THE 5-YEAR EXCLOSURE (1958-1962)

Time Plot	Species	1958 Yield of Species-grams	1958 Per Cent Yield of Plot	1959 Yield of Species-grams	1959 Per Cent Yield of Plot	1960 Yield of Species-grams	1960 Per Cent Yield of Plot	1961 Yield of Species-grams	1961 Per Cent Yield of Plot	1962 Yield of Species-grams	1962 Per Cent Yield of Plot	Average Yield of Species	Average Per Cent Yield of Plots
May 15	Blue grama	1.73	58.43			1.72	34.33			4.36	88.45	2.60	60.40
	Western wheatgrass					1.47	29.33			0.47	9.45	0.97	19.39
	Needle-and-thread	0.13	4.49									0.13	4.49
	Sandberg bluegrass					0.15	2.93					0.15	2.93
	Needleleaf sedge	0.70	23.60			0.90	18.07			0.10	2.09	0.57	14.59
	Forbs	0.27	8.99			0.77	15.33					0.52	12.16
	Total	2.83	100.00			5.00	100.00			4.93	100.00	4.25	
June 1	Blue grama			1.87	34.78	4.80	43.68	1.59	54.32	7.73	82.53	4.00	78.83
	Western wheatgrass			1.40	26.09	0.83	9.58			1.33	14.24	1.20	16.64
	Sandberg bluegrass					0.44	5.06					0.44	5.06
	Needleleaf sedge			1.60	29.81	2.09	24.06	1.14	38.86	0.24	2.52	0.91	23.81
	Forbs			0.50	9.32	1.53	17.62	0.20	6.82	0.07	0.71	0.57	8.62
	Total			5.37	100.00	5.11	100.00	2.93	100.00	9.37	100.00	4.49	
June 15	Blue grama	3.83	54.25	3.37	56.11	3.78	33.92	3.13	58.40	14.27	89.15	5.68	58.37
	Western wheatgrass			3.13	18.89	3.83	34.43			1.63	10.21	2.20	21.18
	Needle-and-thread	1.30	18.40									1.30	18.40
	Sandberg bluegrass			T	T	0.79	7.10					0.79	7.10
	Needleleaf sedge	1.67	23.80	0.90	15.00	0.97	8.68	1.90	35.40	0.04	0.20	1.09	16.57
	Total	6.80	100.00	5.40	100.00	9.37	100.00	5.03	100.00	15.93	100.00	8.51	
July 1	Blue grama	3.80	46.91	4.10	59.94	6.14	41.39	3.68	64.90	15.77	82.26	6.70	58.48
	Western wheatgrass			1.23	17.13	4.83	32.58			1.90	9.91	2.66	19.87
	Needle-and-thread	2.23	27.57							0.13	0.70	1.17	14.18
	Sandberg bluegrass					0.88	0.55					0.88	0.55
	Needleleaf sedge	1.57	19.34	0.97	13.43	0.59	3.98	1.79	31.50			1.23	17.06
	Forbs	0.50	6.17	0.90	12.50	6.37	4.00	0.20	3.50	1.37	7.13	1.87	6.66
	Total	8.10	100.00	7.20	100.00	14.83	100.00	5.67	100.00	19.17	100.00	10.99	
July 15	Blue grama	3.90	49.58	5.67	47.49	4.87	43.43	5.59	59.80	21.00	88.50	8.21	57.76
	Western wheatgrass			3.63	30.45	4.33	38.62			2.50	10.53	3.49	26.53
	Needle-and-thread	2.27	28.81					0.87	0.90			1.01	14.85
	Green needlegrass	0.07	0.85									0.07	0.85
	Needleleaf sedge	1.20	15.25	1.13	9.50	0.50	4.43	1.75	18.70	0.03	0.27	0.93	9.63
	Forbs	0.43	5.51	1.50	12.57	1.33	11.88	1.93	20.60	0.17	0.70	1.07	10.25
	Total	7.87	100.00	11.93	100.00	11.22	100.00	9.37	100.00	23.73	100.00	12.82	

APPENDIX TABLE 17 (Continued)

Time Plot	Species	1958 Yield of Species-grams	1958 Per Cent Yield of Plot	1959 Yield of Species-grams	1959 Per Cent Yield of Plot	1960 Yield of Species-grams	1960 Per Cent Yield of Plot	1961 Yield of Species-grams	1961 Per Cent Yield of Plot	1962 Yield of Species-grams	1962 Per Cent Yield of Plot	Average Yield of Species	Average Per Cent Yield of Plots
Aug. 1	Blue grama	7.07	71.38	4.70	56.85	2.89	26.04	3.85	59.20	25.19	91.05	8.74	60.90
	Western wheatgrass			1.63	19.76	2.47	22.22			0.90	3.25	1.67	15.07
	Needle-and-thread	1.0	10.10			2.02	18.20					1.51	14.15
	Sandberg bluegrass					0.09	0.81					0.09	0.81
	Prairie Junegrass							0.77	1.20			0.08	1.20
	Needleleaf sedge	1.60	16.16	0.53	6.45	0.80	7.21	1.64	25.20	0.91	3.29	1.03	11.66
	Forbs	0.23	2.36	1.40	16.94	2.83	25.53	0.93	14.40	0.67	2.41	1.21	12.33
	Total	9.90	100.00	8.27	100.00	11.10	100.00	6.50	100.00	27.67	100.00	12.69	
Aug. 15	Blue grama	6.30	56.42	8.03	76.51	8.50	67.13	6.21	68.00	22.18	75.52	10.24	68.72
	Western wheatgrass	T	T	0.63	6.03	1.37	10.79			4.06	13.84	2.02	10.22
	Needle-and-thread	2.83	25.37	T	T	1.09	8.66	1.51	16.50			1.81	16.84
	Sandberg bluegrass					0.37	2.95					0.37	2.95
	Prairie Junegrass							0.09	1.00			0.03	1.00
	Needleleaf sedge	1.27	11.34	0.67	6.35	0.46	3.63	1.26	13.80	1.76	5.99	1.09	8.22
	Forbs	0.77	6.87	1.17	11.11	0.87	6.84	0.07	0.70	1.37	4.65	0.85	6.03
	Total	11.17	100.00	10.50	100.00	12.67	100.00	9.13	100.00	29.37	100.00	14.57	
Sept. 1	Blue grama	7.37	59.57	7.40	89.88	4.32	56.10	7.13	79.81	17.61	71.81	8.77	71.43
	Western wheatgrass	T	T			1.63	21.21	0.23	2.54	3.07	12.50	1.65	12.08
	Needle-and-thread	2.73	22.10	T	T			0.61	6.87			1.67	14.48
	Sandberg bluegrass					0.47	6.06					0.47	6.06
	Needleleaf sedge	1.37	11.05	0.43	5.26	0.45	5.80	0.33	3.69	1.75	7.13	0.87	6.59
	Forbs	0.90	7.28	0.40	4.86	0.83	10.82	0.63	7.09	2.10	8.56	0.97	7.72
	Total	12.37	100.00	8.23	100.00	7.70	100.00	8.93	100.00	24.53	100.00	12.35	
Sept. 15	Blue grama			5.33	78.05					20.23	76.55	12.78	77.30
	Western wheatgrass									4.37	16.52	4.37	16.52
	Sandberg bluegrass			0.17	2.44							0.17	2.44
	Needleleaf sedge			1.30	19.02					0.60	2.27	0.95	10.64
	Threadleaf sedge									0.26	1.00	0.26	1.00
	Forbs			0.03	0.49					0.96	3.66	0.50	2.07
	Total			6.83	100.00					26.43	100.00	16.63	

APPENDIX TABLE 18. LEAF AND STALK HEIGHTS OF SPECIES IN WESTERN WHEATGRASS CLIPPED PLOTS IN THE 5-YEAR EXCLOSURE (1958-1962)

Time Plot	Species	1958			1959			1960			1961			1962			Ave. Leaf ht-cm 5-year	Ave. Stalk ht-cm 5-year	Total No. of Stalks	Ave. No. of Stalks
		Ave. Leaf ht-cm	Ave. Stalk ht-cm	Total No. of Stalks[a]	Ave. Leaf ht-cm	Ave. Stalk ht-cm	Total No. of Stalks[a]	Ave. Leaf ht-cm	Ave. Stalk ht-cm	Total No. of Stalks[a]	Ave. Leaf ht-cm	Ave. Stalk ht-cm	Total No. of Stalks[a]	Ave. Leaf ht-cm	Ave. Stalk ht-cm	Total No. of Stalks[a]				
May 1	Western wheatgrass	13.00		55													13.00		55	55.0
	Blue grama	4.83															4.83			
	Needleleaf sedge	8.00															8.00			
May 15	Western wheatgrass	13.30		82				17.67		180				14.00		249	14.99		511	170.3
	Blue grama	4.00						5.17						4.33			4.50			
	Needleleaf sedge	8.33						9.67						6.33			8.11			
June 1	Western wheatgrass				15.30		111	24.00		193	23.30		108	24.00		273	21.66		685	171.3
	Blue grama				8.00			6.67			8.70			4.67			7.01			
	Sandberg bluegrass													6.00	22.00		6.00	22.00		
	Needleleaf sedge				8.67			8.00			10.30			10.00			9.24			
June 15	Western wheatgrass	13.30		105	22.30		113	24.00		184	25.30		94	35.00	36.33	314	23.99	36.33	810	162.0
	Blue grama	5.00			9.33			8.00			9.70			8.33			8.07			
	Sandberg bluegrass										6.00						6.00			
	Needleleaf sedge	6.67			10.00			10.33	13.50		10.00			13.00			8.20	13.50		
July 1	Western wheatgrass	19.30		111	21.33		175	26.33	40.30	165	25.30	23.00	95	37.33	58.00	310	25.92	40.43	856	171.4
	Blue grama	6.00			10.67			8.67			9.00			10.00			8.87			
	Sandberg bluegrass							5.67	31.00								5.67	31.00		
	Needleleaf sedge	7.00			10.00			8.00	17.00		7.70			12.00			8.94	17.00		
July 15	Western wheatgrass	21.30		144	19.33		123	26.00	56.30	166	24.30		124	39.33	58.67	257	26.05	56.99	814	162.8
	Blue grama	6.67			10.33			10.67			9.70	15.00		11.00	30.00		9.67	22.50		
	Sandberg bluegrass																			
	Needleleaf sedge	7.33			7.67			10.00	11.33		9.70			13.67			9.67	11.33		

APPENDIX TABLE 18 (Continued)

Time Plot	Species	1958 Ave. Leaf ht-cm	1958 Ave. Stalk ht-cm	1958 Total No. of Stalks[a]	1959 Ave. Leaf ht-cm	1959 Ave. Stalk ht-cm	1959 Total No. of Stalks[a]	1960 Ave. Leaf ht-cm	1960 Ave. Stalk ht-cm	1960 Total No. of Stalks[a]	1961 Ave. Leaf ht-cm	1961 Ave. Stalk ht-cm	1961 Total No. of Stalks[a]	1962 Ave. Leaf ht-cm	1962 Ave. Stalk ht-cm	1962 Total No. of Stalks[a]	Ave. Leaf ht-cm 5-year	Ave. Stalk ht-cm 5-year	Total No. of Stalks	Ave. No. of Stalks
Aug. 1	Western wheatgrass	22.30		146	20.33		103	27.33		140	23.00		98	38.00	54.67	280	26.19	54.67	767	153.4
	Blue grama	7.00			7.67			8.67			7.30			10.67	12.00		8.26	12.00		
	Sandberg bluegrass							6.00	30.00		7.00						6.50	30.00		
	Needleleaf sedge	7.33			7.67			7.33	21.00		7.30			10.00			7.93	21.00		
	Green needlegrass										25.00						25.00			
Aug. 15	Western wheatgrass	20.89		156	19.67		118	28.33	40.50	179	20.30		111	41.67	66.67	303	26.17	53.59	867	173.4
	Blue grama	6.33	20.00		9.00			9.67	6.00		7.30	18.00		12.00	16.00		8.86	15.00		
	Sandberg bluegrass																			
	Needleleaf sedge	7.00			7.33	11.00		7.67	11.00		6.30			10.33			7.73	11.00		
Sept. 1	Western wheatgrass	23.00		164	19.67		138	28.33	52.50	177	18.30		91	41.33	59.00	284	26.12	55.75	854	170.8
	Blue grama	6.00	20.00		8.33			12.00			6.70	17.30		14.00	30.00		9.41	22.43		
	Sandberg bluegrass										5.00			4.00	24.00		4.50	24.00		
	Needleleaf sedge	7.33			8.67	13.00		11.67	19.00		7.00			13.00			9.53	16.00		
Sept. 15	Western wheatgrass				20.00		178							40.33	58.67	282	30.17	58.67	460	230.0
	Blue grama				8.33									14.00	35.00		11.16	35.00		
	Sandberg bluegrass													6.00	42.00		6.00	42.00		
	Needleleaf sedge				8.33									8.67			8.50			

[a]Total number of stalks in three 1-ft.^{2} plots.

APPENDIX TABLE 19. AVERAGE YIELD OF SPECIES PER FT.^{2} AND PER CENT COMPOSITION OF YIELDS IN WESTERN WHEATGRASS CLIPPED PLOTS IN THE 5-YEAR EXCLOSURE (1958-1962)

Time Plot	Species	1958		1959		1960		1961		1962		Average Yield of Species	Average Per Cent Yield of Plots
		Yield of Species-grams	Per Cent Yield of Plot	Yield of Species-grams	Per Cent Yield of Plot	Yield of Species-grams	Per Cent Yield of Plot	Yield of Species-grams	Per Cent Yield of Plot	Yield of Species-grams	Per Cent Yield of Plot		
May 1	Western wheatgrass	1.70	32.80									1.70	32.80
	Blue grama	1.40	28.30									1.40	28.30
	Needleleaf sedge	1.20	23.00									1.20	23.00
	Forbs	0.80	15.80									0.80	15.80
	Total	5.10	100.00									5.10	
May 15	Western wheatgrass	1.90	46.30			4.60	65.30			5.90	72.70	4.20	61.40
	Blue grama	0.90	21.10			0.70	9.70			1.70	21.20	2.00	17.40
	Needleleaf sedge	0.80	19.50			1.10	16.10			0.50	6.20	0.80	13.90
	Forbs	0.50	13.00			0.60	8.90					0.60	11.00
	Total	4.10	100.00			7.10	100.00			8.20	100.00	6.50	
June 1	Western wheatgrass			2.30	40.70	5.80	62.60	2.20	52.80	10.30	76.50	5.20	58.20
	Blue grama			2.00	35.50	1.10	11.50	1.40	32.80	1.50	11.00	1.50	22.70
	Needleleaf sedge			0.90	15.10	1.60	17.30	0.50	11.30	1.50	10.50	1.90	13.60
	Sandberg bluegrass									0.30	2.00	0.30	2.00
	Forbs			0.50	8.70	0.80	8.60	0.10	3.20			0.50	6.90
	Total			5.70	100.00	9.30	100.00	4.50	100.00	13.50	100.00	8.20	
June 15	Western wheatgrass	2.60	42.40	3.30	52.10	6.60	53.70	2.20	52.00	20.50	83.60	7.10	56.80
	Blue grama	1.80	29.90	2.40	37.40	2.20	17.90	1.70	39.20	1.40	5.80	1.90	26.00
	Sandberg bluegrass							0.03	0.80			0.03	0.80
	Needleleaf sedge	1.50	23.90	0.50	7.90	2.30	18.70	0.20	4.80	2.40	10.00	1.40	13.10
	Forbs	0.20	3.80	0.20	2.60	1.20	9.80	0.10	3.20	0.20	0.70	0.40	4.00
	Total	6.10	100.00	6.30	100.00	12.30	100.00	4.20	100.00	24.60	100.00	10.70	
July 1	Western wheatgrass	4.10	52.80	4.10	52.60	9.40	64.10	2.70	55.80	28.00	83.70	9.80	61.80
	Blue grama	3.00	35.60	3.30	39.10	2.10	14.50	1.90	38.80	3.00	8.90	2.60	27.40
	Sandberg bluegrass					0.10	0.70					0.10	0.70
	Needleleaf sedge	0.90	11.20	0.30	4.00	2.20	15.10	0.10	2.70	1.50	4.90	1.00	7.50
	Forbs	0.03	0.40	0.40	4.40	0.80	5.70	0.10	2.70	1.00	3.00	0.50	3.20
	Total	8.30	100.00	8.40	100.00	15.00	100.00	4.90	100.00	33.40	100.00	14.00	
July 15	Western wheatgrass	5.70	56.70	4.20	56.80	10.40	68.80	3.70	57.00	25.90	83.50	10.00	64.50
	Blue grama	2.90	29.30	3.00	40.50	2.00	12.90	2.60	39.80	4.60	14.90	3.00	27.50
	Needleleaf sedge	1.30	13.30	0.20	2.70	2.10	13.80	0.10	1.90	0.50	1.50	0.80	6.70
	Forbs	0.10	0.70			0.70	4.40	0.10	1.30	0.10	0.20	0.20	1.70
	Total	10.00	100.00	7.40	100.00	15.70	100.00	6.60	100.00	31.30	100.00	14.00	

APPENDIX TABLE 19 (Continued)

Time Plot	Species	1958 Yield of Species-grams	1958 Per Cent Yield of Plot	1959 Yield of Species-grams	1959 Per Cent Yield of Plot	1960 Yield of Species-grams	1960 Per Cent Yield of Plot	1961 Yield of Species-grams	1961 Per Cent Yield of Plot	1962 Yield of Species-grams	1962 Per Cent Yield of Plot	Average Yield of Species	Average Per Cent Yield of Plots
Aug. 1	Western wheatgrass	5.00	54.70	3.90	62.60	8.70	68.80	2.50	51.70	28.20	85.50	9.70	64.70
	Blue grama	3.30	35.90	1.90	31.00	3.10	24.60	1.90	38.80	4.10	12.40	2.90	28.50
	Sandberg bluegrass					0.10	0.60	0.03	0.60			0.05	0.60
	Green needlegrass							0.04	0.90			0.04	0.90
	Needleleaf sedge	0.80	9.10	0.20	2.70	0.30	2.40	0.10	2.40	0.22	0.70	0.40	3.40
	Forbs	0.03	0.40	0.20	3.70	0.50	3.70	0.30	5.60	0.50	1.40	0.30	3.00
	Total	9.20	100.00	6.20	100.00	12.70	100.00	4.80	100.00	32.90	100.00	13.20	
Aug. 15	Western wheatgrass	7.40	51.90	3.80	55.60	9.30	62.80	3.70	53.30	33.20	84.40	11.50	61.60
	Blue grama	6.00	41.60	2.80	40.60	4.60	31.10	3.00	43.60	5.00	12.70	4.30	33.90
	Needleleaf sedge	0.10	2.50	0.10	1.50	0.60	3.70	0.10	1.60	0.90	2.30	0.40	2.30
	Forbs	0.10	0.30	0.20	2.50	0.40	2.50	0.10	1.40	0.20	0.60	0.20	1.50
	Total	14.30	100.00	6.90	100.00	14.90	100.00	7.00	100.00	39.30	100.00	16.50	
Sept. 1	Western wheatgrass	9.00	67.60	5.80	57.50	10.70	70.90	5.50	53.30	29.80	82.50	12.10	66.40
	Blue grama	3.40	25.90	4.00	39.50	3.70	24.50	4.00	39.00	5.20	14.50	4.00	28.70
	Sandberg bluegrass							0.03	0.30	0.02	0.10	0.02	0.20
	Needleleaf sedge	0.70	5.00	0.10	1.30	0.50	3.30	0.30	2.90	0.30	1.20	0.40	11.80
	Forbs	0.20	1.50	0.20	1.70	0.20	1.30	0.50	4.50	0.70	2.00	0.40	2.20
	Total	13.30	100.00	10.00	100.00	15.10	100.00	10.30	100.00	36.10	100.00	16.90	
Sept. 15	Western wheatgrass			4.90	70.80					26.50	78.40	15.70	74.10
	Blue grama			1.80	25.90					6.40	19.10	4.10	22.70
	Sandberg bluegrass									0.02	0.05	0.02	0.05
	Needleleaf sedge			0.20	2.40					0.20	0.70	0.20	1.60
	Forbs			0.03	0.50					0.60	1.80	0.30	1.10
	Total			7.00	100.00					33.80	100.00	20.40	