Use of regression equations to determine utilization of shortgrass rangeland

by Sylvester Smoliak

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Range Management
Montana State University

Abstract:
The study was initiated to ascertain the relationships that exist among basal area, maximum height, number of flowering stalks, wrapped diameter and weight of Stipa comata, Koeleria cristata and Agropyron smithii plants; to study the height-weight distribution of the three species; and to develop a formula by regression analysis to estimate utilization.

The study areas were located at the Manyberries Experimental Farm,. Foremost and Brooks, Alberta, and Maple Creek, Saskatchewan. All sites were within the brown soil zone and supported the Bouteloua-Stipa type of vegetation. The climate is characterized by low precipitation, great extremes of temperature, high and frequent winds and long hours of sunshine.

Variability within groups of plants of the three species was high in basal area, number of flowering stalks and weight and low for maximum height and wrapped diameter. In most instances individual plant variability was greater than that between locations, stages of maturity or years.

The height-weight distributions of groups of plants, on the basis of average maximum height, showed considerable differences between the various groups within species. These variations were reduced, but still persisted, when height-weight distributions were based upon average leaf height.

Variations between groups of plants, determined by the analysis of variance, were greatest between years for most of the characteristics studied. There were no location differences in height or weight of Stipa comata, height of Koeleria cristata. Agropyron smithii plant groups.

Correlation coefficients determined for certain relationships showed a significant and homogeneous association between height and weight of all species. The highest correlation was found for Stipa comata plants on the basis of leaf height.

Covariance analysis of certain associations consistently showed homogeneity of regression for groups of Stipa comata plants collected at maturity. Regression analysis of per cent of weight removed on leaf height removed, on an intra-plant basis, gave a cubic equation of $Y = 147.91 - 54.76X + 6.99X2 - 0.30x3$, where Y is the estimated percentage utilization and X is the stubble height in inches.

Utilization estimates obtained by the regression method when compared with those obtained by the cage method, on a percentage weight basis, showed excellent agreement. Differences in the estimated percentage utilization values varied by less than 0.5 of 1 per cent.

USE OF REGRESSION EQUATIONS TO DETERMINE UTILIZATION OF 'SHORTGRASS' RANGELAND

by

S. SMOLIAK

A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Master of Science in Range Management

at

Montana State College

Approved:

Head, Major Department

Chairman, Examining Committee

Dean, Graduate Division

Bozeman, Montana
June, 1961

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Dr. G. F. Payne of the Animal Industry and Range Management Department and Dr. F. A. Branson, formerly of the same Department of the Montana State College, Bozeman, Montana, for suggestions and assistance during the study and to Dr. J. A. B. McArthur, formerly at Experimental Farm, Manyberries, Alberta, for his assistance in the initiation of the study.

Thanks is also due to Dr. H. F. Peters of the Experimental Farm, Manyberries, Alberta, for his advice and assistance with the study and the statistical analysis.

The author also wishes to express his appreciation to Rose Emily Smoliak for recording the data collected and to others who aided in the analysis of the data.

TABLE OF CONTENTS

INDEX TO FIGURES AND TABLES

Page

ABSTRACT

The study was initiated to ascertain the relationships that exist among basal area, maximum height, number of flowering stalks, wrapped diameter and weight of Stipa comata, Koeleria cristata and Agropyron smithii plants; to study the height-weight distribution of the three species; and to develop a formula by regression analysis to estimate utilization.

The study areas were located at the Manyberries Experimental Farm, Foremost and Brooks, Alberta, and Maple Creek, Saskatchewan. All sites were within the brown soil zone and supported the Bouteloua-Stipa type of vegetation. The climate is characterized by low precipitation, great extremes of temperature, high and frequent winds and long hours of sunshine.

Variability within groups of plants of the three species was high in basal area, number of flowering stalks and weight and low for maximum height and wrapped diameter. In most instances individual plant variability was greater than that between locations, stages of maturity or years.

The height-weight distributions of groups of plants, on the basis of average maximum height, showed considerable differences between the various groups within species. These variations were reduced, but still persisted, when height-weight distributions were based upon average leaf height.

Variations between groups of plants, determined by the analysis of variance, were greatest between years for most of the characteristics studied. There were no location differences in height or weight of Stipa comata, height of Koeleria cristata, Agropyron smithii plant groups.

Correlation coefficients determined for certain relationships showed a significant and homogeneous association between height and weight of all species. The highest correlation was found for Stipa comata plants on the basis of leaf height.

Covariance analysis of certain associations consistently showed homogeneity of regression for groups of Stipa comata plants collected at maturity. Regression analysis of per cent of weight removed on leaf height removed, on an intra-plant basis, gave a cubic equation of $Y = 147.91 - 54.76X + 6.99X^2 - 0.30X^3$, where Y is the estimated percentage utilization and X is the stubble height in inches.

Utilization estimates obtained by the regression method when compared with those obtained by the cage method, on a percentage weight basis, showed excellent agreement. Differences in the estimated percentage utilization values varied by less than 0.5 of 1 per cent.

INTRODUCTION

Many methods have been proposed to measure, interpret and control utilization of range forage for sustained production. Of the methods proposed only a few are simple, rapid and accurate. These requirements are demanded by the rancher, administrator and the technician to evaluate utilization on large range units. However, it should be recognized that in obtaining a measure of utilization the best we can acquire is an estimate of the ungrazed forage from which an attempt is made to calculate the amount of forage removed.

To obtain a satisfactory method which would have a high degree of reliability a fundamental study about the important range grass plants and their environment is needed. Such a study was undertaken for this thesis.

The objectives of the study were to collect basic information on the distribution of weight in relation to height of range grasses at one-inch intervals; to ascertain some relationships that exist in each species; to examine the variations of certain growth characteristics of the grasses as affected by differences in stages of maturity, locations and years; to develop a formula by regression analysis which will estimate utilization; and to test the proposed method of measuring utilization with other established methods.

The three grasses used in this study were *Stipa comata*, *Koeleria cristata*, and *Agropyron smithii*.

REVIEW OF LITERATURE

The use of linear measurement of height of range plants to determine utilization began with simple measurements of heights of plants before and after grazing. This method was based on the premise that percentage utilization of grass plants is equal to the reduction in average leaf height as a result of grazing. It was later shown that this assumption was invalid (Pechanic and Pickford, 1937).

Further contributions to linear measurements were the successive studies on height-weight distribution of the principal range grasses. Lommasson and Jensen (1938) were the first to correlate height-weight relationships of range grasses. Grass specimens were wrapped spirally with a string, measured for height, cut into one-inch segments and weighed. The data were then summarized and form-factor curves constructed to show height-weight relationships of range grasses. Grass specimens were wrapped spirally with a string, measured for height, cut into one-inch segments and weighed. The data were then summarized and form-factor curves constructed to show height-weight relationships. Detailed instructions on methods of constructing tables and sliding scales are given by Lommasson and Jensen (1942, 1943). A contemporary study by Crafts (1938) on the southwestern range grasses employed a measure of volume utilization directly while measuring the stubble height. The conclusions reached were: (a) in all the grasses studied there was a similar concentration of herbage volume at lower height levels; (b) because volume is not evenly distributed throughout the height it is erroneous to apply volume palatability percentages without using a converting factor; (c) line charts which relate height to volume offer a simple and fairly satisfactory field method of determining volume utilization of grasses; and (d) the accuracy with which height measurements can be made in the field and the variation in volume distribution by height classes are limiting factors that need further study.

Campbell (1942) and Lommasson and Jensen (1942, 1943) gave instructions on constructing and using the tables and scales needed to determine utilization by the height-weight method. The latter authors tested their method and concluded that height alone could be used as the variable for determining the required number of plants necessary to construct height-weight tables. They concluded that the "form factor" or height-weight principal, when properly used, was sound and more accurate and uniform than the ocular estimate method for utilization determination. Reid and Pickford (1941) compared the ocular-estimate-by-plot method with the height-weight method on Festuca viridula range and found that on uniform stubble the degree of utilization was the same. The results varied when use of forage was uneven, but the ocular method gave the best estimates. The authors presented a height-weight distribution curve for this species.

Work conducted by Heady (1950) on five species of grasses in Montana showed that estimates derived by the height-weight method were valid, and useful, if the limitations and variations of the method were taken into consideration. He found that, generally, the shorter the plant as a result of differences in habitat or weather the greater was the percentage of weight in the basal portion. The shift of percentage of weight toward the base of the plants was found in all species studied. Another study on the height-weight relationship was conducted by McArthur (1951) on Andropogon scoparius.

The data were statistically analyzed and the estimate of utilization was determined by means of regression equations, which in turn were converted to a slide rule. In a test to determine the reliability of the regression of stubble-heights on total height of plant method, estimates could be duplicated using the same or other plants. When the ocular estimate-by-average plants method was used the same person was not able to duplicate his estimates on the same or different plants at any time.

An adaptation to the height-weight method was proposed by Collins and Hurtt (1943) working on shortgrass range in Montana. The number of grazed and ungrazed plants were counted but only the grazed plants were measured for height. Average stubble height of the grazed plants was converted to percentage of weight remaining by reference to height-weight curves. To obtain utilization the percentage of weight removed was multiplied by the percentage of grazed plants. Another modification was introduced by Valentine (1946). Instead of taking measurements and converting them to weight remaining or removed, the percentage of utilization was read directly from a scale placed beside the plant, thus eliminating part of the measurements and calculations necessary. Woolfolk (1949) determined herbage utilization on experimental sheep ranges by measuring grazed stubble-heights and recording numbers of key plants grazed. Previously recorded ungrazed heights and height-weight tables for each species made possible the conversion of stubble-heights and percentage of total numbers of plants grazed to percentage of herbage removed by grazing. Height growth was found to be an important factor affecting utilization from year to year even though grazed stubble and percentage of the number of plants taken remained fairly constant.

The height-weight method is based on the principle that, for a given grass species, the distribution in weight in relation to height is reasonably constant in different individuals. Some workers have found variations in the growth-form principle. Collins and Hurtt (1943) and Holscher and Woolfolk (1953) have indicated that the height-weight distribution and ratio of culmed to culmless plants varied greatly from year to year. Caird (1945) demonstrated the variability in growth of some grasses. He found that a small proportion of the foliage occurred above the first inch in plants growing on poor sites, while a larger proportion was found above the first inch in plants on better sites. Bouteloua gracilis, B. curtipendula and Buchloe dactyloides showed proportionate differences in height from good, average and poor sites. Of ten species investigated by Clark (1945) Agropyron trachycaulum showed the least variability in growth form and Poa pratensis the greatest. Errors as great as 10 to 25 per cent could be introduced by applying an average scale to growth form. He noted that the weather in different years was responsible for greater changes in growth form than were other factors. Heady (1950) found that variations were much greater for Agropyron spicatum growing in different sites than those growing in different years. There was also more variation in average height of plants in the same year in different sites than in those plants growing in the same habitat in different years. He indicated that height-weight scales have the greatest use as aids in training personnel to see correctly the relations between stubble height and total height and the distribution of weight in the plants.

The use of regression analysis in determining percentage utilization of range forage was demonstrated by Roach (1950), McArthur (1951) and Mattox (1955). Shultz (1956) cites examples where adaptations of the regression method of analysis are advantageous in that precision is increased.

DESCRIPTION OF THE AREA

Experimental Areas

Four study areas were located within the brown soil zone but with differences in climate and in composition of vegetation. These areas, supporting *Stipa comata*, *Koeleria cristata* and *Agropyron smithii* stands, were designated as the Manyberries, Foremost, Brooks and Maple Creek locations or sites.

The Manyberries site was located four miles south of the Experimental Farm headquarters, Manyberries, Alberta. The field in which this site was located was used as a cattle breeding pasture for six weeks during the summer for the past five years. It was lightly grazed throughout this period. Prior to this time the field was used as a summer cattle pasture. The Foremost site is located five miles west of Foremost, Alberta. The site was located on a winter sheep pasture which was managed as such for the past 25 years. The Brooks site was located two miles north of Brooks, Alberta. The area on which this site was located was farmed until 1924 and then abandoned. Native vegetation has almost completely taken over with the exception of *Bouteloua gracilis* and *Selaginella densa*. This field is also used as a winter pasture for a small flock of sheep. The Maple Creek site is located within the Bitter Lake Community Pasture and is eleven miles north of Maple Creek, Saskatchewan. The pasture was established by the Prairie Farm Rehabilitation Act in 1943. The particular field in which this site was located has been used as a summer cattle pasture. The locations of the study areas are shown in Figure 1.

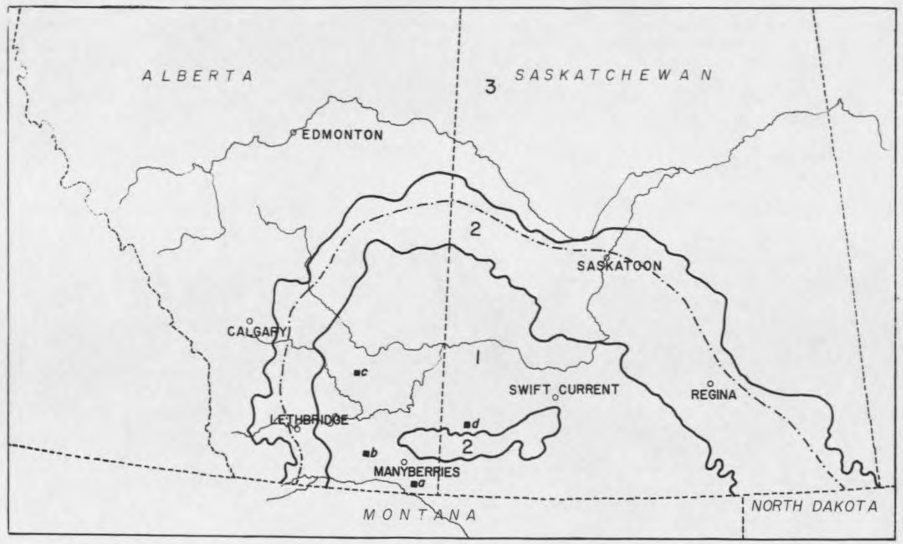

Figure 1. Outline map of southern Alberta and Saskatchewan, showing the relationship between the extent of the mixed prairie association (below the broken line) and the soil zones (solid lines) marked 1, brown soil; 2, dark brown soil; and 3, black and grey wooded soil. Study areas were located at a, Manyberries Experimental Farm; b, Foremost; c, Brooks; and d, Maple Creek. (After Wyatt et al., 1937, 1941; Mitchell et al., 1944; and Coupland, 1950).

Climate

The climate of all locations is typical of the climate of the high plains region of Western Canada. It is characterized by long, bright, moderately warm summer weather and bright, cold, dry winter weather. There are occasional high winds. All the study locations are in the path of the chinooks or warm south-west winds, although they do not occur as frequently as they do nearer to the Rocky Mountains. They do, however, occasionally melt the snow enough to permit winter grazing.

Complete records of climatological data for all locations are unavailable; however, the 28-year records for the Experimental Farm, Manyberries, Alberta, may be indicative of the general climate. Total hours of bright sunshine per year at Manyberries averages 2252. The most sunshine occurs during July (10.8 hours per day) and the least during December (3.0 hours per day). The prevailing winds are westerly. The chinooks from the southwest and the colder northwest winds are most typical. The wind velocity is quite high, averaging 11.5 miles per hour. The windiest months are April and May; the months with least wind are July and August. The evaporation from a free water surface averages about 30 inches from the first of May to the end of September.

Precipitation and mean temperature data were available for all locations near the study areas and are shown in Table I. The distances varied from two to eleven miles but the data are indicative of the general trend in precipitation and mean temperature patterns. Precipitation and temperature data for Foremost, Alberta, were unavailable for the five winter months, November to March, inclusive.

Table I. Summary of precipitation (inches) and mean temperature (°F) data on areas in which study sties were located.

Month	Manyberries, Alta. 1955	1956	Av. 28 yr.	Foremost, Alta. 1955	1956	Av. 26 yr.	Brooks, Alta. 1955	1956	Av. 18 yr.	Maple Creek, Sask. 1955	1956	Av. 31 yr.
Jan.	0.37	0.35	0.61	----	----	----	0.60	1.67	0.57	0.20	0.80	0.74
Feb.	0.86	1.03	0.52	----	----	----	0.50	0.59	0.60	1.10	1.45	0.72
Mar.	0.20	0.70	0.81	----	----	----	0.20	0.99	0.84	0.60	0.40	0.64
April	4.24	0.42	1.01	1.08	0.31	1.17	1.11	0.37	0.81	4.33	0.40	0.87
May	3.34	1.08	1.38	4.19	1.07	1.76	2.72	0.90	1.73	2.24	0.99	1.57
June	1.18	3.27	2.48	0.90	3.01	2.75	0.13	2.00	1.97	1.56	3.34	2.65
July	4.52	3.42	1.47	5.34	1.95	1.41	1.24	0.97	1.58	5.17	1.45	1.78
Aug.	0.02	2.02	0.95	0.00	3.79	1.39	0.89	4.45	1.70	0.00	0.81	1.28
Sept.	0.06	0.53	1.02	0.74	0.89	1.41	1.43	1.32	1.30	0.80	0.93	1.34
Oct.	0.33	0.63	0.66	0.62	0.62	0.64	0.60	0.35	0.86	0.57	1.98	0.73
Nov.	0.44	0.33	0.54	----	----	----	0.26	0.10	0.61	0.55	0.21	0.82
Dec.	0.50	0.60	0.56	----	----	----	0.34	0.77	0.71	0.30	0.80	0.65
Total (Apr. to Oct., incl.)	13.69	11.37	8.97	12.87	11.64	10.60	8.12	10.36	9.95	14.67	9.90	10.22
Annual	16.06	14.38	12.01	----	----	----	10.02	14.48	13.28	17.42	13.56	13.79
Mean temp. (Apr. to Oct.)	52.7	54.4	55.0	53.1	54.6	55.5	52.8	53.3	54.8	55.4	55.2	55.1

In 1955, the amounts of precipitation recorded during April to October, inclusive, exceeded the long-term averages at all locations except Brooks, Alberta. During the same period in 1956, Maple Creek, Saskatchewan, was the only location at which the recorded precipitation was below that of the long-term average. The mean temperature during both the study years (April to October, inclusive) was warmer at Maple Creek and cooler at the other three locations.

Geology and Soils

The geological formations which occur at the surface or immediately below the unconsolidated deposits are all Upper Cretaceous in age. There are three formations represented in the study areas, which in order of age, from the youngest formation to the oldest are the Bearpaw formation, the Oldman formation and the Foremost formation (Russell and Landes, 1940). The Bearpaw formation is predominantly shale, which is dark grey or brownish grey, not very plastic and tending to weather into small angular fragments or flakes. Ironstone, bentonite and beds of impure sandstone occur in the formation. Marine fossils are often abundant in the sandstone beds. The Oldman formation consists chiefly of soft, coloured shales and some sandstones. The coarser sandstones commonly show striking crossbedding and other evidences of stream deposition. The Foremost formation consists of soft sandstones and shales. A distinctive characteristic is the coloration which is generally drab but varies from grey to reddish to yellowish. The soft character of the shales and sandstones in these formations have influenced the overlying soils in the area.

The study areas were located in the brown soil zone. Detailed descriptions of the soil are given by locations.

Manyberries

The soil at Manyberries is a find sandy loam, developed from weathered Oldman formation sandstone. The area in general is a level crown practically stone free. The lime carbonate horizon is found 12 inches from the surface.

Foremost

The soil at Foremost is a heavy loam, a medium textured sorted soil on glacial till overlying the Foremost formation. The profile is fairly deep and quite friable. The lime layer occurs 12 inches below the surface.

Brooks

The soil at Brooks is a loam, developed largely on the Bearpaw formation shales. This soil has a hard B solonetz-like horizon developed within one foot of the surface and a broken surface topography due to patchy removal by erosion of varying percentages of the A horizon. The soil contains few stones. Blow-outs are common. The lime layer occurs 14 inches below the surface.

Maple Creek

The soil at Maple Creek is a fine sandy loam; distinctly sandy and frequently gravelly. The soil is apparently derived from material deposited by glacial streams (outwash) and from the soft sandstone of the underlying Oldman formation. The topography is undulating. The lime layer is 18 inches below the surface.

Vegetation

The vegetation in the area where these studies were conducted was classed by Clarke et al. (1942) and Hubbard (1950) as "Short Grass prairie" and by Coupland (1950) and Moss (1955) as "Mixed prairie". Coupland (1950) recognizes six well-defined types in the mixed prairie. The Bouteloua - Stipa type occurs throughout the study areas.

The Bouteloua - Stipa type is characterized by the dominance of the short grass, Bouteloua gracilis, interspersed with several mid-grasses, the most abundant of which is Stipa comata. Agropyron smithii, Koeleria cristata, Carex eleocharis and C. filifolia are associated with the dominants. Forbs and shrubs are abundant. The most conspicuous shrub is Artemisia cana, while the most abundant forbs are Artemisia frigida and Phlox hoodii. Selaginella densa is present throughout the area.

Other grasses and sedges which occur in this vegetation type include, in approximate order of their abundance, Poa secunda, Calamagrostis montanensis, Calamovilfa longifolia, Muhlenbergia squarrosa, M. cuspidata, Sporobolus cryptandrus, other Poa spp. and Carex heliophila. Other important forbs are, in order of abundance, Malvastrum coccineum, Gutierrezia diversifolia, Comandra pallida, Psoralea lanceolata, Chrysopsis villosa, Solidago dumetorum, Sideranthus spinulosis, and Opuntia polyacantha. Eurotia lanata and Atriplex nuttallii are important shrubs in the area.

Species which are regarded as poisonous plants include Zygadenus gramineus, Oxytropis spp., Astragalus pectinatus, A. bisulcatus, Triglochin maritima and Sarcobatus vermiculatus (Campbell et al., 1956).

METHODS OF STUDY

Study areas of known past management that were moderately to lightly grazed and contained Stipa comata, Koeleria cristata and Agropyron smithii were chosen arbitrarily at each of the four locations previously described.

Soil samples were obtained on each site and analyzed for texture, pH, nitrogen and phosphorus contents and exchangeable sodium. The results are summarized in Table II.

The components of the vegetation were studied by the point quadrat method proposed by Levy and Madden (1933) and later modified by Clarke et al. (1943). Only basal point contacts were recorded along diagonals of each site. The basal density of the vegetation at each location is shown in Table III.

Twenty-five plants of each of the three species were collected on each site at anthesis and at maturity in 1955 and 1956. No grazed plants or seedlings were taken. The plant specimens were randomly selected along five paced transects spaced 100 feet apart. The plant nearest the center on the toe of the right shoe was collected and tagged every twenty-five steps along a transect until five plants were obtained. Twenty-five plants were thus collected. The same transects and procedure were used for each of the three species in 1955 and 1956.

The basal area of each plant was measured with a diameter rule and recorded in square centimeters to the nearest one-half centimeter. The plants were then dug and taken to the laboratory complete with roots.

Each individual plant was air-dried and all old or dead vegetation, and the seed from Stipa comata plants, was removed, thus leaving the current

Table II. Analyses of soils at the four study locations.

Soil Characteristics		Manyberries		Foremost		Brooks		Maple Creek	
		0"-6"	6"-12"	0"-6"	6"-12"	0"-6"	6"-12"	0"-6"	6"-12"
pH	%	7.79	7.80	7.42	7.65	7.71	7.68	7.99	8.01
P	%	0.040	0.031	0.038	0.048	0.036	0.032	0.038	0.039
N	%	0.101	0.067	0.133	0.115	0.115	0.083	0.119	0.074
Exch. Na	%	3.4	4.2	3.0	4.0	6.0	6.0	13.6	T
Sand	%	57.0	---	36.0	---	79.0	---	76.0	---
Silt	%	32.0	---	38.0	---	20.0	---	16.0	---
Clay	%	11.0	---	26.0	---	1.0	---	8.0	---
Class		SL	---	L	---	LS	---	SL	---
Cond. mmhos/ cm. Sat		2.53	1.13	0.81	0.66	0.40	0.38	0.36	0.39
Dist. H.C. In./hr.		0.64	0.55	0.36	0.26	2.04	2.77	2.07	0.96

Table III. Vegetational cover (percentage of area) of the four study areas as determined by point sampling in 1955 and 1956.

Species	Many-berries	Fore-most	Brooks	Maple Creek
Bouteloua gracilis	3.46	3.29	0.21	3.62
Stipa comata	2.58	2.12	5.54	2.46
Koeleria cristata	1.67	1.79	1.08	0.75
Agropyron smithii	1.04	1.58	0.54	1.04
Poa secunda	0.08	0.58	0.17	0.04
Calamagrostis montanensis	0.21	----	----	0.08
Carex eleocharis	0.25	0.91	0.46	0.75
Carex filifolia	0.17	----	0.21	0.25
Artemisia frigida	0.71	0.42	1.50	0.79
Artemisia cana	----	----	0.08	0.17
Eurotia lanata	0.42	0.88	----	----
Phlox hoodii	0.71	0.12	----	0.04
Malvastrum coccineum	0.12	0.38	0.04	0.12
Antennaria dimorpha	0.04	----	----	----
Antennaria parviflora	----	0.42	----	0.33
Thermopsis rhombifolia	----	----	0.04	----
Petalostomen candidus	----	----	----	0.38
Plantago purshii	----	----	0.17	----
Lygodesmia juncea	0.04	----	----	----
Erigeron caespitosus	----	----	0.08	0.25
Selaginella densa	22.17	21.91	0.29	30.25

year's growth. The number of flowering stalks were counted and recorded. Maximum total and leaf height measurements were taken to the nearest inch. The plants were then wrapped spirally with a string. The diameter of the base of the wrapped plant was taken with a micrometer to the nearest one-hundredth of an inch. This measurement is called wrapped diameter in the thesis.

Each plant specimen of the three species was then sectioned with a large paper cutter into one-inch segments. The first step in sectioning was to cut off the roots near ground level thus leaving the entire current year's growth for further sectioning. All plants were sectioned from bottom to top. If the top or last segment ranged from one-half to one inch long it was considered a segment. Each cut segment was placed into a numbered coin envelope. The segments were oven-dried (120°C for 2 hours) before weighing individually to the nearest milligram and the weights were recorded. A total of 400 plants of each of the three species were sectioned in this manner.

The various data collected were tabulated and subjected to statistical analysis. Statistical procedures were based upon methods described by Goulden (1939, 1952) and Snedecor (1946, 1956).

RESULTS AND DISCUSSION

Variations Within Groups of 25 Plants

The data collected for each group of 25 plants of the three species were subjected to statistical analyses and the range, mean, standard deviation and coefficient of variation determined. These results are summarized in Tables IV to XVIII.

The basal area of Stipa comata ranged from 4 to 35 square centimeters, with the coefficient of variation varying from about 22 to 49 per cent. Koeleria cristata plants ranged from 1 to 25 square centimeters in basal area with a coefficient of variation varying from about 27 to 70 per cent. Basal areas did not vary greatly in Agropyron smithii plants.

Height variations in Stipa comata plants ranged from 5 to 30 inches but the coefficients of variations were low. The greatest differences in maximum heights occurred between years. In 1955 all plants had flowering stems while in 1956 the reverse was true. Koeleria cristata plants ranged in height from 2 to 18 inches. The coefficients of variation for plants in 1955 were low but were greater for plants in 1956. Heights of Agropyron smithii plants ranged from 6 to 33 inches, with fairly low coefficients of variations.

The greatest variations between plants occurred in number of flowering stalks present. All species had more flowering stalks in 1955 than in 1956. A few or no flowering stalks were present in plants collected in 1956.

Wrapped diameter variations were smallest within groups of Stipa comata plants. Variations in wrapped diameter of Koeleria cristata and Agropyron smithii plants were greatest between locations.

Table IV. Basal area (square centimeters) variations in groups of 25 plants of Stipa comata by years, locations and stages of maturity.

Year	Location	Stage of maturity	Basal area (square centimeters)			
			Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	6-20	10.60	4.56	43.02
		Mature	6-15	9.96	2.79	28.01
	Foremost	Anthesis	7-35	13.68	6.79	49.63
		Mature	6-20	13.04	3.89	29.83
	Brooks	Anthesis	5-30	14.48	6.92	47.79
		Mature	6-30	13.04	5.27	40.41
	Maple Creek	Anthesis	6-18	10.28	3.20	31.13
		Mature	4-20	9.84	4.15	42.17
1956	Manyberries	Anthesis	6-15	10.20	3.40	33.33
		Mature	4-20	10.72	3.48	32.46
	Foremost	Anthesis	10-20	13.52	3.07	22.71
		Mature	6-20	11.08	4.35	39.26
	Brooks	Anthesis	10-30	16.72	4.73	28.29
		Mature	6-20	14.20	4.20	29.58
	Maple Creek	Anthesis	8-22	12.24	4.35	35.54
		Mature	6-20	11.32	3.88	34.28

Table V. Basal area (square centimeters) variations in groups of 25 plants of *Koeleria cristata* by years, locations and stages of maturity.

Year	Location	Stage of maturity	Basal area (square centimeters) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	1-16	8.44	4.10	48.58
		Mature	4-20	10.12	3.71	36.66
	Foremost	Anthesis	2-20	9.64	4.26	44.19
		Mature	2-20	11.72	4.11	35.07
	Brooks	Anthesis	5-15	8.76	3.25	37.10
		Mature	6-25	11.04	5.89	53.35
	Maple Creek	Anthesis	1-15	5.56	3.90	70.14
		Mature	1-10	4.44	2.62	59.01
1956	Manyberries	Anthesis	3-15	9.32	3.50	37.55
		Mature	5-15	8.80	2.40	27.27
	Foremost	Anthesis	6-25	13.64	5.28	38.71
		Mature	4-15	10.04	3.51	34.96
	Brooks	Anthesis	6-20	13.08	3.76	28.75
		Mature	6-20	11.92	4.19	35.15
	Maple Creek	Anthesis	4-12	8.46	3.11	36.76
		Mature	4-12	8.24	2.67	32.40

Table VI. Basal area (square centimeters) variations in groups of 25 plants of Agropyron smithii by years, locations and stages of maturity.

			Basal area (square centimeters)			
Year	Location	Stage of maturity	Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.5-1.0	0.68	0.24	35.29
		Mature	0.5-1.0	0.62	0.22	35.48
	Foremost	Anthesis	0.5-1.0	0.76	0.25	32.89
		Mature	0.5-1.0	0.68	0.24	35.29
	Brooks	Anthesis	0.5-1.0	0.56	0.17	30.36
		Mature	0.5-1.0	0.60	0.20	33.33
	Maple Creek	Anthesis	0.5-1.0	0.56	0.20	35.71
		Mature	0.5-1.0	0.56	0.20	35.71
1956	Manyberries	Anthesis	0.5-1.0	0.54	0.14	25.92
		Mature	0.5-1.0	0.52	0.10	19.23
	Foremost	Anthesis	0.5-1.0	0.54	0.14	25.92
		Mature	0.5-1.0	0.58	0.31	53.45
	Brooks	Anthesis	0.5-1.0	0.54	0.14	25.92
		Mature	0.5-1.0	0.58	0.19	32.76
	Maple Creek	Anthesis	0.5-0.5	0.50	0.00	00.00
		Mature	0.5-0.5	0.50	0.00	00.00

Table VII. Height (inches) variations in groups of 25 plants of <u>Stipa comata</u> by years, locations and stages of maturity.

			Height (inches)			
Year	Location	Stage of maturity	Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	14-23	17.64	2.58	14.62
		Mature	12-30	22.72	4.36	19.19
	Foremost	Anthesis	10-20	14.96	2.42	16.18
		Mature	14-27	21.20	3.42	16.13
	Brooks	Anthesis	12-23	15.56	3.76	24.16
		Mature	15-23	18.68	2.34	12.53
	Maple Creek	Anthesis	12-19	15.32	1.82	11.88
		Mature	12-25	18.16	3.50	19.27
1956	Manyberries	Anthesis	6-9	7.24	0.97	13.40
		Mature	5-8	6.36	0.95	14.94
	Foremost	Anthesis	5-8	6.12	0.78	12.74
		Mature	5-8	6.28	0.89	14.17
	Brooks	Anthesis	6-11	7.88	1.24	15.74
		Mature	5-13	7.76	1.64	21.13
	Maple Creek	Anthesis	5-11	7.12	1.42	19.94
		Mature	6-10	7.40	1.04	14.05

Table VIII. Height (inches) variations in groups of 25 plants of <u>Koeleria cristata</u> by years, locations and stages of maturity.

Year	Location	Stage of maturity	Height (inches) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	7-15	11.52	1.83	15.88
		Mature	10-18	13.76	1.88	13.66
	Foremost	Anthesis	8-13	10.44	1.39	13.31
		Mature	10-17	12.80	1.80	14.06
	Brooks	Anthesis	9-14	11.12	1.45	13.04
		Mature	8-16	12.40	1.68	13.55
	Maple Creek	Anthesis	6-12	8.44	1.44	17.06
		Mature	10-16	12.52	1.85	14.78
1956	Manyberries	Anthesis	3-7	4.44	0.92	20.72
		Mature	2-6	3.48	1.00	28.74
	Foremost	Anthesis	3-7	4.32	1.28	29.63
		Mature	2-6	3.56	1.12	31.46
	Brooks	Anthesis	8-15	10.64	1.73	16.26
		Mature	3-16	7.00	2.93	41.86
	Maple Creek	Anthesis	3-14	6.76	2.42	35.80
		Mature	3-9	6.28	1.51	24.04

Table IX. Height (inches) variations in groups of 25 plants of Agropyron smithii by years, locations and stages of maturity.

Year	Location	Stage of maturity	Height (inches) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	16-29	24.32	3.45	14.18
		Mature	19-33	26.48	3.25	12.27
	Foremost	Anthesis	18-24	21.08	1.75	8.30
		Mature	18-30	23.00	3.15	13.70
	Brooks	Anthesis	15-21	17.36	1.68	9.68
		Mature	14-24	21.04	2.32	11.03
	Maple Creek	Anthesis	20-27	22.48	2.28	10.14
		Mature	19-29	23.40	2.86	12.22
1956	Manyberries	Anthesis	6-9	7.48	0.82	10.96
		Mature	6-11	8.36	1.29	15.43
	Foremost	Anthesis	6-9	7.52	0.87	11.57
		Mature	7-19	9.76	2.71	27.77
	Brooks	Anthesis	6-9	7.72	0.84	10.88
		Mature	7-16	8.96	2.30	25.67
	Maple Creek	Anthesis	6-10	7.88	1.30	16.50
		Mature	7-12	9.64	1.11	11.51

Table X. Variations in number of flowering stalks in groups of 25 plants of <u>Stipa comata</u> by years, locations and stages of maturity.

Year	Location	Stage of maturity	Number of flowering stalks: Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	2-22	5.80	4.02	69.31
		Mature	3-10	5.92	2.23	37.67
	Foremost	Anthesis	2-28	7.88	6.35	80.58
		Mature	2-17	8.76	4.28	48.86
	Brooks	Anthesis	1-16	5.24	3.06	58.40
		Mature	2-20	7.04	4.35	61.79
	Maple Creek	Anthesis	2-11	4.12	2.11	51.21
		Mature	2-11	4.72	2.51	53.18
1956	Manyberries	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-0	0.00	0.00	0.00
	Foremost	Anthesis	0-1	0.08	0.28	350.00
		Mature	0-0	0.00	0.00	0.00
	Brooks	Anthesis	0-1	0.16	0.37	231.25
		Mature	0-1	0.12	0.33	275.00
	Maple Creek	Anthesis	0-1	0.16	0.37	231.25
		Mature	0-2	0.16	0.47	293.75

Table XI. Variations in number of flowering stalks in groups of 25 plants of *Koeleria cristata* by years, locations and stages of maturity.

Year	Location	Stage of maturity	Number of flowering stalks: Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	1-25	8.04	5.52	68.66
		Mature	4-20	10.04	4.89	48.70
	Foremost	Anthesis	2-65	17.84	15.73	88.17
		Mature	9-38	22.56	8.71	38.61
	Brooks	Anthesis	3-32	16.28	7.82	48.03
		Mature	6-36	20.68	7.74	37.43
	Maple Creek	Anthesis	1-12	3.88	2.65	68.30
		Mature	1-8	4.04	1.85	45.79
1956	Manyberries	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-1	0.04	0.20	500.00
	Foremost	Anthesis	0-4	0.80	1.35	168.75
		Mature	0-5	1.00	1.19	119.00
	Brooks	Anthesis	1-17	5.16	3.89	75.39
		Mature	0-17	2.40	3.85	160.42
	Maple Creek	Anthesis	0-1	0.04	0.20	500.00
		Mature	0-2	0.16	0.47	293.75

Table XII. Variations in number of flowering stalks in groups of 25 plants of *Agropyron smithii* by years, locations and stages of maturity.

Year	Location	Stage of maturity	Number of flowering stalks: Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	1-2	1.08	0.28	25.92
		Mature	1-2	1.04	0.20	19.23
	Foremost	Anthesis	1-3	1.40	0.64	45.91
		Mature	1-2	1.08	0.28	25.92
	Brooks	Anthesis	1-1	1.00	0.00	0.00
		Mature	1-2	1.12	0.33	29.46
	Maple Creek	Anthesis	1-1	1.00	0.00	0.00
		Mature	1-1	1.00	0.00	0.00
1956	Manyberries	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-0	0.00	0.00	0.00
	Foremost	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-1	0.08	0.28	350.00
	Brooks	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-1	0.16	0.37	231.25
	Maple Creek	Anthesis	0-0	0.00	0.00	0.00
		Mature	0-0	0.00	0.00	0.00

Table XIII. Wrapped diameter (inches) variations in groups of 25 plants of <u>Stipa comata</u> by years, locations and stages of maturity.

Year	Location	Stage of maturity	Wrapped diameter (inches)			
			Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.18-0.60	0.318	0.100	31.45
		Mature	0.23-0.41	0.302	0.052	17.22
	Foremost	Anthesis	0.24-0.51	0.327	0.061	18.65
		Mature	0.22-0.38	0.294	0.045	15.31
	Brooks	Anthesis	0.22-0.52	0.352	0.084	23.86
		Mature	0.21-0.50	0.305	0.071	23.28
	Maple Creek	Anthesis	0.13-0.53	0.300	0.089	29.67
		Mature	0.16-0.47	0.256	0.069	26.95
1956	Manyberries	Anthesis	0.22-0.40	0.322	0.054	16.77
		Mature	0.22-0.48	0.314	0.056	17.83
	Foremost	Anthesis	0.20-0.44	0.304	0.051	16.78
		Mature	0.24-0.48	0.316	0.053	16.77
	Brooks	Anthesis	0.19-0.44	0.318	0.061	19.18
		Mature	0.25-0.41	0.323	0.050	15.48
	Maple Creek	Anthesis	0.21-0.44	0.315	0.069	21.90
		Mature	0.22-0.48	0.314	0.053	16.88

Table XIV. Wrapped diameter (inches) variations in groups of 25 plants of *Koeleria cristata* by years, locations and stages of maturity.

Year	Location	Stage of maturity	Wrapped diameter (inches) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.12-0.43	0.255	0.069	27.06
		Mature	0.15-0.44	0.272	0.066	24.26
	Foremost	Anthesis	0.16-0.43	0.267	0.072	26.97
		Mature	0.23-0.50	0.338	0.066	19.53
	Brooks	Anthesis	0.13-0.47	0.332	0.096	28.92
		Mature	0.19-0.44	0.310	0.064	20.64
	Maple Creek	Anthesis	0.14-0.38	0.240	0.085	35.42
		Mature	0.11-0.34	0.178	0.049	27.53
1956	Manyberries	Anthesis	0.13-0.34	0.218	0.061	27.98
		Mature	0.13-0.30	0.197	0.042	21.32
	Foremost	Anthesis	0.21-0.43	0.289	0.066	22.84
		Mature	0.16-0.34	0.244	0.045	18.44
	Brooks	Anthesis	0.16-0.49	0.328	0.080	24.39
		Mature	0.23-0.50	0.326	0.070	21.47
	Maple Creek	Anthesis	0.09-0.28	0.157	0.048	30.57
		Mature	0.05-0.28	0.154	0.053	34.42

Table XV. Wrapped diameter (inches) variations in groups of 25 plants of <u>Agropyron smithii</u> by years, locations and stages of maturity.

			Wrapped diameter (inches)			
Year	Location	Stage of maturity	Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.07-0.17	0.098	0.026	26.53
		Mature	0.07-0.17	0.110	0.028	25.45
	Foremost	Anthesis	0.10-0.24	0.155	0.044	28.39
		Mature	0.06-0.21	0.126	0.044	34.92
	Brooks	Anthesis	0.08-0.18	0.119	0.029	24.37
		Mature	0.07-0.21	0.115	0.035	30.43
	Maple Creek	Anthesis	0.05-0.14	0.093	0.023	24.73
		Mature	0.06-0.14	0.088	0.022	25.00
1956	Manyberries	Anthesis	0.03-0.12	0.057	0.021	36.84
		Mature	0.03-0.09	0.050	0.018	36.00
	Foremost	Anthesis	0.03-0.09	0.046	0.019	41.30
		Mature	0.03-0.17	0.061	0.033	54.10
	Brooks	Anthesis	0.03-0.09	0.062	0.020	32.26
		Mature	0.04-0.13	0.071	0.027	38.03
	Maple Creek	Anthesis	0.03-0.07	0.044	0.016	36.36
		Mature	0.04-0.09	0.050	0.011	22.00

Table XVI. Weight (grams) variations of groups of 25 plants of *Stipa comata* by years, locations and stages of maturity.

Year	Location	Stage of maturity	Weight (grams) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.769-6.361	2.3050	1.3621	59.09
		Mature	1.246-4.283	2.4888	0.8772	35.24
	Foremost	Anthesis	1.005-6.020	2.1462	1.1193	52.15
		Mature	1.119-4.491	2.4589	0.9309	37.86
	Brooks	Anthesis	0.915-5.664	2.3779	1.1073	46.57
		Mature	0.926-5.671	2.3305	1.1333	48.63
	Maple Creek	Anthesis	0.339-5.594	1.7200	1.0729	62.38
		Mature	0.674-4.971	1.7230	0.9186	53.31
1956	Manyberries	Anthesis	0.912-3.075	1.9666	0.6182	31.43
		Mature	0.659-3.645	1.6382	0.6012	36.70
	Foremost	Anthesis	0.824-2.641	1.4920	0.4316	28.93
		Mature	0.941-3.189	1.5258	0.5138	33.67
	Brooks	Anthesis	0.581-3.191	1.9179	0.6052	31.56
		Mature	0.747-2.898	1.6876	0.5820	34.49
	Maple Creek	Anthesis	0.732-3.857	1.8386	0.8897	48.39
		Mature	0.867-4.568	1.6883	0.7562	44.79

Table XVII. Weight (grams) variations of groups of 25 plants of Koeleria cristata by years, locations and stages of maturity.

Year	Location	Stage of maturity	Weight (grams) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.241-3.618	1.5951	0.9925	62.22
		Mature	0.514-4.185	1.6945	0.9114	53.78
	Foremost	Anthesis	0.307-4.535	1.7447	1.2344	70.75
		Mature	0.766-4.923	2.1154	0.9920	46.89
	Brooks	Anthesis	0.361-5.582	2.7816	1.3442	48.32
		Mature	0.589-4.602	2.2610	1.0593	46.85
	Maple Creek	Anthesis	0.161-1.596	0.7280	0.4621	63.48
		Mature	0.263-2.748	0.7771	0.5404	69.54
1956	Manyberries	Anthesis	0.238-1.655	0.7503	0.3655	48.71
		Mature	0.179-1.187	0.5269	0.2271	43.10
	Foremost	Anthesis	0.630-2.430	1.2179	0.6360	52.22
		Mature	0.306-1.694	0.8206	0.3771	45.95
	Brooks	Anthesis	0.858-4.910	2.3782	1.0944	46.02
		Mature	0.585-3.330	1.6090	0.7157	44.48
	Maple Creek	Anthesis	0.200-2.269	0.6414	0.4469	69.68
		Mature	0.067-1.262	0.5158	0.2939	56.98

Table XVIII. Weight (grams) variations of groups of 25 plants of _Agropyron smithii_ by years, locations and stages of maturity.

Year	Location	Stage of maturity	Weight (grams) Range	Mean	Standard deviation	Coefficient of variation
1955	Manyberries	Anthesis	0.271-1.262	0.6059	0.2724	44.96
		Mature	0.342-1.097	0.7474	0.1943	26.00
	Foremost	Anthesis	0.329-1.455	0.8036	0.3243	40.36
		Mature	0.403-1.665	0.7048	0.3166	44.92
	Brooks	Anthesis	0.339-1.177	0.6027	0.1981	32.87
		Mature	0.332-1.399	0.7198	0.3017	41.91
	Maple Creek	Anthesis	0.301-0.985	0.5586	0.1683	30.13
		Mature	0.423-1.139	0.7281	0.1877	25.78
1956	Manyberries	Anthesis	0.059-0.767	0.1846	0.1352	73.24
		Mature	0.075-0.494	0.1970	0.0929	47.16
	Foremost	Anthesis	0.061-0.299	0.1290	0.0509	39.46
		Mature	0.090-0.708	0.2456	0.1433	58.35
	Brooks	Anthesis	0.100-0.338	0.1891	0.0702	37.12
		Mature	0.106-0.665	0.2550	0.1289	50.55
	Maple Creek	Anthesis	0.063-0.254	0.1409	0.0462	32.79
		Mature	0.105-0.341	0.2296	0.0586	25.52

Variations in weight of single plants were large. The variations between groups of Stipa comata plants were smaller than those of the other two species at the various locations, years and stages of maturity.

Although the variations indicated were similar to those reported by others (Clark, 1945; Heady, 1950) the data are included to indicate the variable population sampled.

Variation in Height-Weight Relationships

Variations in the distribution of weight at 1-inch intervals of the average maximum height of Stipa comata, Koeleria cristata and Agropyron smithii plants collected in 1955 and 1956 at each location at anthesis and maturity are shown in Tables XIX, XX and XXI, respectively. A greater difference in the height-weight distribution occurred between years for all species than between locations or stages of maturity.

In 1955 there were large variations in the height-weight distributions between Stipa comata plants collected at the different locations and stages of maturity. Differences as great as 10 per cent were found in the second inch above ground level. Greater differences were found at higher stubble heights. The differences between height-weight distributions were smaller for Koeleria cristata and Agropyron smithii plants. In 1956 the height-weight distributions of Stipa comata plants varied by more than 10 per cent at the 3- and 4-inch stubble height at the various locations and stages of maturity. Height-weight variations of Koeleria cristata plants were greater between locations and stages of maturity. The differences in Agropyron smithii plants were greater above the 2-inch stubble height. Variations in the height-weight distributions were larger between the two years for all

Table XIX. Average cumulative percentage of weight of Stipa comata towards soil level at various locations and stages of maturity in 1955 and 1956.

Maximum height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1955				
23		0.2						
22		0.4						
21		0.7		0.2				
20		1.0		0.4				
19		1.4		0.7		0.1		
18	0.1	2.0		1.2		0.3		0.2
17	0.4	2.7		1.8		0.6		0.5
16	0.8	3.6		2.6	0.1	1.1		0.9
15	1.4	4.7	0.2	3.7	0.2	1.8	0.1	1.4
14	2.2	6.0	0.5	5.1	0.5	2.7	0.4	2.2
13	3.3	7.6	1.0	6.9	1.0	3.8	0.9	3.2
12	4.8	9.5	2.0	9.0	1.7	5.4	1.6	4.5
11	6.7	11.5	3.3	11.4	2.7	7.1	2.7	6.0
10	8.8	13.8	5.3	14.2	4.0	9.3	4.2	7.7
9	11.1	16.2	8.0	17.1	5.7	11.8	6.1	9.7
8	13.7	19.0	11.3	20.3	7.9	14.8	8.5	12.2
7	17.0	22.8	15.2	23.8	11.0	18.8	11.5	15.6
6	21.6	27.9	19.8	28.2	15.3	24.3	15.5	20.7
5	28.1	35.0	25.5	34.2	21.5	31.7	21.2	28.3
4	37.3	44.7	33.5	43.1	30.9	41.9	29.8	39.0
3	50.3	57.9	46.1	56.6	45.3	56.2	43.0	54.0
2	70.3	75.2	67.2	75.3	68.1	75.6	65.7	73.9
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XIX. (Continued)

Maximum height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1956				
8					0.7	0.3		
7	0.8				2.6	1.2	1.0	0.6
6	3.2	1.2	0.8	0.7	6.6	3.6	3.6	2.3
5	9.0	4.8	3.9	3.4	13.9	9.2	9.4	6.6
4	19.7	13.0	12.4	11.0	25.5	19.5	20.1	15.6
3	37.3	29.0	30.0	27.4	42.8	36.5	37.6	32.2
2	64.0	56.7	60.0	57.3	67.3	62.9	64.0	59.3
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XX. Average cumulative percentage of weight of Koeleria cristata towards soil level at various locations and stages of maturity in 1955 and 1956.

Maximum height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1955				
14		1.6						
13		4.4		1.2				1.0
12	3.0	7.8		3.6		2.2		2.6
11	7.4	11.6		7.3	2.1	6.2		5.8
10	13.5	14.6	5.7	11.8	6.5	11.5		9.6
9	18.4	17.1	13.8	16.4	13.0	16.8		13.4
8	22.0	19.5	21.6	20.8	20.0	21.6	5.5	16.4
7	24.9	22.3	27.5	24.9	26.1	26.3	12.2	19.6
6	28.2	25.7	31.9	29.0	31.4	31.1	19.3	23.9
5	32.3	30.2	36.3	33.9	37.6	36.8	27.0	30.0
4	38.9	37.1	42.4	40.5	45.2	44.7	34.7	39.9
3	50.8	49.4	52.1	51.5	56.5	56.6	48.6	55.4
2	70.9	70.8	70.9	71.5	74.6	74.7	69.7	76.2
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				1956				
11					0.6			
10					1.9			
9					3.7			
8					5.4			
7					6.9	0.5	1.8	
6					8.7	1.2	5.2	1.5
5					13.0	2.4	11.9	4.8
4	4.5		2.2	1.0	22.5	6.0	23.9	13.0
3	20.1	8.6	13.4	8.5	39.6	18.0	42.8	31.1
2	53.0	38.4	45.4	40.0	66.3	51.0	68.7	61.9
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XXI. Average cumulative percentage of weight of Agropyron smithii towards soil level at various locations and stages of maturity in 1955 and 1956.

Maximum height in inches	Manyberries Anthesis	Manyberries Mature	Foremost Anthesis	Foremost Mature	Brooks Anthesis	Brooks Mature	Maple Creek Anthesis	Maple Creek Mature
				1955				
26		1.6						
25		3.4						
24	1.7	6.2						
23	3.0	8.9		0.6				2.1
22	4.4	11.0		1.5			2.1	4.2
21	5.6	12.1	1.6	3.6		3.6	4.5	8.0
20	6.6	13.3	3.7	6.5		7.1	7.4	12.0
19	7.9	14.9	5.4	8.2		9.8	10.3	15.3
18	9.4	16.6	6.9	9.5		12.0	12.5	17.5
17	11.0	18.6	8.2	10.8	3.4	13.7	14.5	19.2
16	12.8	20.7	9.5	12.0	6.9	15.3	16.4	21.0
15	14.7	22.6	10.7	13.4	10.0	17.2	18.7	23.0
14	16.8	24.8	12.0	15.1	13.2	19.5	21.1	25.3
13	19.0	27.2	13.6	17.0	15.1	22.0	23.8	27.9
12	21.5	29.9	15.4	19.3	17.2	24.7	26.9	30.9
11	24.3	32.8	17.5	21.8	19.7	27.7	30.3	34.3
10	27.8	36.2	19.8	24.5	22.5	31.3	33.9	38.4
9	32.0	40.2	22.6	27.6	26.1	35.6	38.1	43.0
8	37.2	45.1	26.1	31.5	30.3	40.6	43.2	48.2
7	43.5	50.9	30.7	36.8	35.6	46.5	49.2	54.0
6	51.2	57.6	37.1	43.7	42.3	53.4	56.2	60.7
5	59.8	65.1	45.7	52.5	50.9	61.5	64.1	68.1
4	69.2	73.1	56.6	63.1	61.4	70.0	73.0	76.1
3	79.2	81.6	69.7	74.6	73.6	79.7	82.0	84.5
2	88.8	90.6	83.7	86.9	87.0	89.8	90.7	92.4
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XXI. (Continued)

Maximum height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1956				
10				1.0				2.1
9				3.4		1.8		7.1
8		4.8	1.3	8.6	2.0	5.2	3.1	15.7
7	6.1	13.3	5.8	16.9	7.9	11.2	6.9	27.9
6	16.8	25.4	14.6	28.5	18.6	21.4	18.3	41.9
5	31.9	40.8	28.0	42.6	33.6	35.5	34.0	55.5
4	49.8	56.8	45.9	57.6	50.8	52.6	52.0	68.1
3	67.9	72.3	65.5	70.4	67.7	69.9	69.6	79.7
2	84.4	86.7	82.9	83.5	84.5	85.7	85.2	90.1
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

species.

To determine whether these differences existed in the height-weight distributions of the plants of the three species, when based on average leaf heights, height-weight relationships were calculated. These results are summarized in Tables XXII, XXIII, and XXIV. The weights of the flowering culms, if present, were included in the segment weights until average leaf height was obtained.

The variations in the height-weight distributions were considerably smaller, when comparing the years, than those based on average maximum height but still existed in all species. Similar variations were observed by Lommasson and Jensen (1942) and Heady (1950), who attempted to reduce the variations by developing the scales on a height-class basis.

Height-class tables were constructed for *Stipa comata* plants collected at maturity and are presented in Table XXV. There was a greater concentration of weight near the ground level in shorter plants. This was observed by other authors (Clark, 1945; Valentine, 1946; Lommasson and Jensen, 1943; and Heady, 1950). The percentages at the 4-inch stubble-heights in the height-class tables were compared with the corresponding height-classes for plants collected at maturity at the various locations and years. The extremes of variations were a negative 8.3 per cent and a positive 8.3 per cent; the average difference was nil.

Variations Among Groups of Plants

The differences among mean values of basal area, maximum height, number of flowering stalks, wrapped diameter and weight of the three species at the various collections were determined by the analysis of variance. The

Table XXII. Average cumulative percentage of weight, based on leaf height, of Stipa comata plants towards soil level at various locations and stages of maturity in 1955 and 1956.

Leaf height in inches	Manyberries Anthesis	Manyberries Mature	Foremost Anthesis	Foremost Mature	Brooks Anthesis	Brooks Mature	Maple Creek Anthesis	Maple Creek Mature
1955								
8								2.0
7	2.7	3.9			2.8	4.0	2.9	5.6
6	7.9	10.4	5.0	5.6	7.3	10.4	7.1	11.3
5	15.5	19.2	11.6	13.5	14.1	19.2	13.4	19.8
4	26.4	31.2	21.2	25.2	24.4	31.3	22.8	31.9
3	41.6	47.6	36.1	42.9	40.1	48.2	37.4	48.5
2	65.1	69.2	56.7	67.5	65.1	71.2	62.2	70.8
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1956								
8					0.7			
7	0.8				2.6	0.9	1.0	0.5
6	3.2	1.2	0.8	0.7	6.6	3.3	3.6	2.3
5	9.0	4.8	3.9	3.4	13.9	8.9	9.4	6.6
4	19.7	13.0	12.4	11.0	25.5	19.2	20.1	15.6
3	37.3	29.0	30.0	27.4	42.8	36.3	37.6	32.2
2	64.0	56.7	60.0	57.3	67.3	62.8	64.0	59.3
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XXIII. Average cumulative percentage of weight, based on leaf height, of Koeleria cristata plants towards soil level at various locations and stages of maturity in 1955 and 1956.

Leaf height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1955				
6		3.3						
5	5.4	8.9		5.3		6.8		7.5
4	14.5	18.0	9.4	14.8	9.8	17.8	10.5	20.5
3	31.2	34.1	24.6	30.5	28.5	35.6	29.5	40.9
2	59.3	62.0	54.2	59.2	58.2	62.5	58.5	68.5
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				1956				
6							3.0	1.3
5					4.5		9.4	4.5
4	4.5		2.1		14.9	3.6	27.5	12.8
3	20.1	8.6	13.4	7.5	33.7	15.9	45.6	30.9
2	53.0	38.4	45.4	39.4	63.0	49.8	70.2	61.8
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XXIV. Average cumulative percentage of weight, based on leaf height, of Agropyron smithii plants towards soil levels at various locations and stages of maturity in 1955 and 1956.

Leaf height in inches	Manyberries		Foremost		Brooks		Maple Creek	
	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature	Anthesis	Mature
				1955				
11								3.3
10	3.7		1.6		2.0	2.7	3.9	8.4
9	8.8	5.6	4.4	3.3	5.8	7.6	9.4	14.6
8	15.5	13.2	8.4	8.4	10.7	14.6	16.8	21.9
7	24.0	22.4	14.1	15.5	17.6	23.1	25.5	30.7
6	34.2	33.0	22.1	24.8	26.2	33.1	35.8	40.8
5	45.8	44.8	32.7	36.6	37.1	44.7	47.5	51.9
4	58.6	57.5	46.3	50.7	50.6	57.0	60.4	64.0
3	72.0	71.0	62.5	66.1	66.2	70.9	73.6	76.7
2	84.9	85.2	79.9	82.5	83.4	85.3	86.3	88.6
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				1956				
10								2.1
9				2.4				7.1
8		4.8	1.3	7.6	2.0	3.5	3.1	15.7
7	6.1	13.3	5.8	16.1	7.9	9.6	6.9	27.9
6	16.8	25.4	14.6	27.8	18.6	20.0	18.3	41.9
5	31.9	40.8	28.0	42.1	33.6	34.3	34.0	55.5
4	49.8	56.8	45.9	57.1	50.8	51.7	52.0	68.1
3	67.9	72.3	65.5	70.1	67.7	69.4	69.6	79.7
2	84.4	86.7	82.9	83.3	84.5	85.5	85.2	90.1
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table XXV. Percentage of cumulative weight of *Stipa comata* towards soil level in 1955 and 1956 at maturity.

Height in inches	Height class in inches, leaf height basis					
	5	6	7	8	9	10
10						0.6
9					1.3	1.5
8				1.9	3.3	3.2
7			2.4	4.8	6.7	9.3
6		3.1	6.2	9.3	12.2	10.6
5	1.7	8.3	12.5	16.7	20.2	18.6
4	7.7	17.9	23.0	27.8	31.5	30.3
3	22.8	35.0	39.8	44.1	47.5	46.5
2	52.8	61.9	65.2	63.7	69.6	70.1
1	100.0	100.0	100.0	100.0	100.0	100.0

Table XXV. (Continued)

Height in inches	Height class in inches, maximum height basis							
	12	14	16	18	20	22	24	26
26								0.1
25								0.2
24							0.1	0.5
23							0.4	0.8
22						0.1	0.7	1.1
21						0.3	1.1	1.5
20					0.1	0.5	1.5	1.8
19					0.3	0.9	2.1	2.3
18				0.2	0.7	1.3	2.7	2.9
17				0.5	1.1	1.9	3.5	3.9
16			0.2	1.0	1.7	2.7	4.7	5.0
15			0.4	1.6	2.6	3.7	6.0	6.3
14		0.3	0.9	2.6	3.8	5.0	7.7	8.0
13		0.9	1.6	3.8	5.4	6.5	9.8	9.8
12	0.1	1.8	2.6	5.2	7.3	8.4	12.0	11.6
11	0.4	3.2	4.1	7.0	9.3	10.6	14.0	13.6
10	1.0	5.0	6.3	9.1	11.6	12.8	15.9	15.8
9	1.9	7.4	8.7	11.3	14.2	15.1	18.1	18.2
8	3.5	10.2	11.1	13.7	17.2	17.6	20.6	21.1
7	6.3	13.5	14.4	16.6	20.9	21.0	24.1	24.8
6	10.6	17.8	19.0	20.8	25.8	26.0	28.9	30.1
5	17.8	25.0	25.8	27.3	32.6	32.9	36.1	37.3
4	27.7	36.0	36.0	36.5	42.1	42.8	46.2	47.4
3	43.3	51.7	51.2	52.2	55.8	56.8	59.7	60.7
2	64.2	72.9	73.1	73.4	74.6	75.4	77.1	77.4
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

resulting mean squares, with corresponding degrees of freedom, are tabulated in Tables XXVI, XXVII and XXVIII.

Basal area, number of flowering stalks and wrapped diameter of Stipa comata plants differed significantly at the various locations. Maximum height and wrapped diameter showed significant stage of maturity differences. Significant year differences were found in maximum height, number of flowering stalks and weight.

Basal area, number of flowering stalks, wrapped diameter and weight of Koeleria cristata plants showed significant location differences. Year differences were significant for maximum height, number of flowering stalks and weight. The various characteristics studied were not affected by stage of maturity.

Significant location differences in Agropyron smithii plants were found for maximum height and wrapped diameter. Maximum height showed significant stage of maturity differences. Year differences were significant for all the characteristics studied. The averages of basal area, maximum height, number of flowering (seed) stalks, wrapped diameter and weight of the three species at the various locations, stages of maturity and years are summarized in Table XXIX. The significant differences indicated were determined by the fiducial interval (Snedecor, 1946, p. 221). Groups of Stipa comata plants on certain locations that had larger basal areas generally had more flowering stalks and larger wrapped diameters. Groups of Koeleria cristata plants on certain locations that had larger basal areas also had more flowering stalks, larger wrapped diameters and greater weight. Maximum heights of Stipa comata and Agropyron smithii plants were greater at maturity

Table XXVI. Analysis of variance of some characteristics of groups of *Stipa comata* plants.

Variation	D.F.	Mean squares				
		Basal area	Maximum height	No. of flowering stalks	Wrapped diameter	Weight
Total	15	--	--	--	--	--
Location (L)	3	14.92*	1.81	2.46*	0.00054*	0.104
Stage of maturity (S)	1	4.54	17.47*	0.67	0.00109*	0.001
L X S (Error 1)	3	0.74	0.62	0.12	0.00004	0.018
Year (Y)	1	1.61	484.88**	148.84**	0.00032	0.938**
Y X S	1	0.30	19.89*	0.77	0.00137*	0.069*
Y X L	3	1.80	3.88	2.74*	0.00038	0.133**
Residual (Error 2)	3	0.40	0.83	0.13	0.00010	0.004

* Significant at the 0.05 per cent level.
** Significant at the 0.01 per cent level.

Table XXVII. Analysis of variance of some characteristics of groups of *Koeleria cristata* plants.

Variation	D.F.	Mean squares				
		Basal area	Maximum height	No. of flowering stalks	Wrapped diameter	Weight
Total	15	--	--	--	--	--
Location (L)	3	18.93**	4.76	80.60**	0.01499**	1.805*
Stage of maturity (S)	1	0.01	1.06	4.93	0.00029	0.148
L X S (Error 1)	3	0.53	1.54	0.95	0.00036	0.092
Year (Y)	1	11.70	135.26**	549.43**	0.00476	1.728**
Y X S	1	6.66	15.60**	11.70	0.00035	0.147
Y X L	3	2.45	7.80**	45.13*	0.00083	0.142
Residual (Error 2)	3	1.95	0.21	2.40	0.00144	0.017

* Significant at the 0.05 per cent level.
** Significant at the 0.01 per cent level.

Table XXVIII. Analysis of variance of some characteristics of groups of Agropyron smithii plants.

Variation	D.F.	Mean squares				
		Basal area	Maximum height	No. of flowering stalks	Wrapped diameter	Weight
Total	15	--	--	--	--	--
Location (L)	3	0.0084	5.93*	0.015	0.00064**	0.002
Stage of maturity (S)	1	0.0001	13.69**	0.000	0.00000	0.023
L X S (Error 1)	3	0.0012	0.26	0.012	0.00002	0.003
Year (Y)	1	0.0324**	781.76**	4.494**	0.01353**	0.951**
Y X S	1	0.0016	0.41	0.014	0.00016	0.000
Y X L	3	0.0039	7.45*	0.010	0.00038	0.003
Residual (Error 2)	3	0.0008	0.56	0.009	0.00017	0.006

* Significant at the 0.05 per cent level.
** Significant at the 0.01 per cent level.

Table XXIX. Averages of basal area, maximum height, number of flowering stalks, wrapped diameter, and weight of three grass species at various locations, stages of maturity and years.

	Locations				Stages of maturity		Years	
	Many-berries	Fore-most	Brooks	Maple Creek	An-thesis	Ma-turity	1955	1956
Stipa comata								
Basal area (sq. cm.)	10.37	12.83 1/	14.61 1/	10.92	12.72	11.65	11.86	12.50
Height (in.)	13.49	12.14	12.47	12.00	11.48	13.57 2/	18.03 3/	7.02
No. of seed stalks	2.93	4.18 4/	3.14 4/	2.29	2.93	3.34	6.18 3/	0.08
Diameter (in.)	0.314 4/	0.310 4/	0.324 4/	0.296	0.320 5/	0.303	0.307	0.316
Weight (gm.)	2.080	1.906	2.078	1.742	1.961	1.943	2.194 3/	1.710
Koeleria cristata								
Basal area (sq. cm.)	9.17 4/	11.26 6/	11.20 6/	6.65	9.60	9.54	8.72	10.42
Height (in.)	8.30	7.78	10.29	8.50	8.46	8.98	11.62 3/	5.81
No. of seed stalks	4.53 4/	10.55 6/	11.13 6/	2.03	6.50	7.62	12.92 3/	1.20
Diameter (in.)	0.236 4/	0.285 6/	0.324 6/	0.182	0.261	0.252	0.274	0.239
Weight (gm.)	1.142	1.475 4/	2.257 1/	0.660	1.480	1.287	1.712 3/	1.055
Agropyron smithii								
Basal area (sq. cm.)	0.59	0.64	0.57	0.53	0.58	0.58	0.63 3/	0.54
Height (in.)	16.66 1/	15.34 1/	13.77	15.85 1/	14.48	16.33 2/	22.40 3/	8.42
No. of seed stalks	0.53	0.64	0.57	0.50	0.56	0.56	1.09 3/	0.03
Diameter (in.)	0.078	0.097 7/	0.092 7/	0.069	0.085	0.084	0.113 3/	0.055
Weight (gm.)	0.434	0.471	0.442	0.414	0.402	0.478	0.684 3/	0.196

1/ Significantly higher ($P < 0.05$) than other locations.
2/ Significantly higher ($P < 0.05$) than at anthesis.
3/ Significantly higher ($P < 0.01$) than 1956.
4/ Significantly higher ($P < 0.05$) than Maple Creek.
5/ Significantly higher ($P < 0.05$) than at maturity.
6/ Significantly higher ($P < 0.01$) than Maple Creek.
7/ Significantly higher ($P < 0.01$) than other locations.

than at anthesis, indicating that some elongation had occurred since the earlier sampling. The growing conditions were more favorable for plant development in 1955 than in 1956.

The greatest variations in the measured growth characteristics of the three species occurred between locations and years. Environmental factors influenced greatly the stature and volume of all species at the various locations and years. Other work (Smoliak, 1956) has indicated that yield of native vegetation is highly correlated with May plus June, April to July, inclusive, and annual precipitation. Heady (1950) also showed plant variations between years on all sites studied.

Differences among maximum leaf height and weight, based upon leaf height, of the three species at the various collections were determined by the analysis of variance. The mean squares, with the degrees of freedom, are shown in Table XXX. The average values are summarized in Table XXXI. Significant location differences in maximum leaf height and significant year differences in weight of Stipa comata plants were found. There were significant location differences in maximum leaf height and weight and year differences in maximum leaf height of Koeleria cristata plants. Year differences were significant for both the characteristics of Agropyron smithii plants.

Group Relationships

Group relationships among certain associations of the measured characteristics were determined by correlation analysis for the three species at each location, stage of maturity and year. The simple correlation coefficients are presented in Tables XXXII, XXXIII and XXXIV.

To test the hypothesis that the correlation coefficients, obtained from

Table XXX. Analysis of variance of maximum leaf height and weight, based upon leaf height, of groups of *Stipa comata*, *Koeleria cristata* and *Agropyron smithii* plants.

		Mean squares					
		Stipa comata		*Koeleria cristata*		*Agropyron smithii*	
Variation	D.F.	Height	Weight	Height	Weight	Height	Weight
Total	15	--	--	--	--	--	--
Location (L)	3	0.799*	0.074	1.117*	1.025*	0.328	0.005
Stage of maturity (S)	1	0.002	0.038	0.032	0.053	1.369	0.005
L X S (Error 1)	3	0.081	0.011	0.100	0.038	0.256	0.001
Year (Y)	1	0.012	0.138*	0.672**	0.123	10.176**	0.327**
Y X S	1	0.185	0.010	2.624**	0.204*	1.513	0.004
Y X L	3	0.167	0.065*	2.140**	0.123	0.211	0.006
Residual (Error 2)	3	0.083	0.004	0.008	0.016	0.066	0.003

* Significant at the 0.05 per cent level.
** Significant at the 0.01 per cent level.

Table XXXI. Averages of maximum leaf height and weight, based on leaf height, of three grass species at various locations, stages of maturity and years.

		Locations				Stages of maturity		Years	
		Many-berries	Fore-most	Brooks	Maple Creek	An-thesis	Ma-turity	1955	1956
Stipa comata									
Leaf height	(in.)	6.84	6.28	7.23[1/]	7.22[1/]	6.88	6.90	6.92	6.86
Weight	(gm.)	1.885	1.704	1.948	1.668	1.850	1.752	1.894[2/]	1.708
Koeleria cristata									
Leaf height	(in.)	4.76	4.06	4.65	5.35[1/]	4.66	4.75	4.91[3/]	4.50
Weight	(gm.)	0.938	1.165[5/]	1.769[4/]	0.561	1.166	1.050	1.196	1.020
Agropyron smithii									
Leaf height	(in.)	9.02	8.88	8.83	9.46	8.76	9.34	9.84[3/]	8.25
Weight	(gm.)	0.324	0.384	0.343	0.298	0.319	0.356	0.480[3/]	0.194

1/ Significantly higher ($P \leq 0.05$) than Foremost.
2/ Significantly higher ($P < 0.05$) than 1956.
3/ Significantly higher ($P < 0.01$) than 1956.
4/ Significantly higher ($P < 0.05$) than other locations.
5/ Significantly higher ($P < 0.05$) than Maple Creek.

Table XXXII. Simple correlation coefficients[1/] of certain relationships between a, basal area; b, maximum height; c, number of flowering stalks; d, wrapped diameter; and e, weight of stipa comata plants collected in 1955 and 1956 on four locations during anthesis and maturity.

Year and location	Stage of maturity	r_{ab}	r_{ad}	r_{ae}	r_{be}	r_{de}	r_{bc}	r_{ce}
1955								
Manyberries	Anthesis	0.235	0.804**	0.812**	0.515**	0.984**	0.483*	0.783**
	Mature	0.642**	0.633**	0.817**	0.613**	0.910**	0.442*	0.638**
Foremost	Anthesis	0.164	0.820**	0.756**	0.524**	0.926**	0.409*	0.899**
	Mature	0.031	0.674**	0.554**	0.418*	0.918**	0.171	0.658**
Brooks	Anthesis	-0.120	0.843**	0.756**	0.268	0.927**	0.091	0.572**
	Mature	-0.063	0.788**	0.707**	0.257	0.934**	0.014	0.644**
Maple Creek	Anthesis	0.428*	0.732**	0.698**	0.532**	0.940**	0.261	0.733**
	Mature	0.754**	0.873**	0.891**	0.295	0.937**	0.219	0.703**
1956								
Manyberries	Anthesis	0.360	0.887**	0.263	0.590**	0.915**	0.000	0.000
	Mature	0.358	0.882**	0.659**	0.459*	0.949**	0.000	0.000
Foremost	Anthesis	0.233	0.271	0.347	0.672**	0.911**	-0.046	-0.081
	Mature	0.521**	0.114	0.826**	0.435*	0.904**	0.000	0.000
Brooks	Anthesis	-0.070	0.586**	0.631**	0.117	0.928**	0.674**	0.084
	Mature	-0.162	0.581**	0.569**	0.107	0.928**	0.515**	0.042
Maple Creek	Anthesis	0.338	0.714**	0.829**	0.552**	0.918**	0.588**	0.298
	Mature	0.493*	0.643**	0.686**	0.644**	0.880**	0.542**	0.254

1/ 23 degrees of freedom.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

Table XXXIII. Simple correlation coefficients[1/] of certain relationships between a, basal area; b, maximum height; c, number of flowering stalks; d, wrapped diameter; and e, weight of *Koeleria cristata* plants collected in 1955 and 1956 on four locations during anthesis and maturity.

Year and location	Stage of maturity	r_{ab}	r_{ad}	r_{ae}	r_{be}	r_{de}	r_{bc}	r_{ce}
1955								
Manyberries	Anthesis	0.557**	0.832**	0.828**	0.602**	0.868**	0.381	0.795**
	Mature	0.423*	0.803**	0.790**	0.707**	0.972**	0.264	0.527**
Foremost	Anthesis	0.472*	0.699**	0.565**	0.714**	0.761**	0.578**	0.684**
	Mature	0.324	0.513**	0.421*	0.700**	0.928**	0.536**	0.567**
Brooks	Anthesis	0.473*	0.552**	0.568**	0.516**	0.905**	0.265	0.598**
	Mature	0.149	0.701**	0.698**	0.478*	0.964**	0.336	0.589**
Maple Creek	Anthesis	0.178	0.802**	0.727**	0.555**	0.827**	0.417*	0.845**
	Mature	0.252	0.826**	0.785**	0.532**	0.959**	0.541**	0.621**
1956								
Manyberries	Anthesis	0.162	0.794**	0.772**	0.408*	0.924**	0.000	0.000
	Mature	0.093	0.582**	0.474*	0.452*	0.932**	0.522**	-0.010
Foremost	Anthesis	0.399*	0.620**	0.623**	0.470*	0.876**	0.494*	0.264
	Mature	0.323	0.814**	0.796**	0.585**	0.947**	0.468*	-0.033
Brooks	Anthesis	-0.130	0.580**	0.483*	0.108	0.919**	0.189	0.468*
	Mature	0.122	0.809**	0.828**	0.179	0.921**	0.203	0.486*
Maple Creek	Anthesis	0.289	0.817**	0.678**	0.769**	0.834**	0.193	-0.122
	Mature	-0.141	0.609**	0.598**	0.549	0.954**	0.226	-0.063

[1/] 23 degrees of freedom.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

Table XXXIV. Simple correlation coefficients[1/] of certain relationships between a, basal area; b, maximum height; c, number of flowering stalks; d, wrapped diameter; and e, weight of Agropyron smithii plants collected in 1955 and 1956 on four locations during anthesis and maturity.

Year and location	Stage of maturity	r_{ab}	r_{ad}	r_{ae}	r_{be}	r_{de}	r_{bc}	r_{ce}
1955								
Manyberries	Anthesis	0.373	0.590**	0.610**	0.686**	0.827**	0.321	0.676**
	Mature	-0.202	0.754**	0.399*	0.157	0.650**	-0.195	0.347
Foremost	Anthesis	0.190	0.228	0.390	0.464*	0.807**	0.228	0.756**
	Mature	0.000	0.578**	0.652**	0.307	0.873**	0.096	0.387
Brooks	Anthesis	0.293	0.269	0.526**	0.487*	0.754**	0.000	0.000
	Mature	-0.009	0.817**	0.846**	0.276	0.873**	-0.006	0.619**
Maple Creek	Anthesis	-0.300	0.631**	0.574**	0.220	0.785**	0.000	0.000
	Mature	-0.141	0.487*	0.576**	0.325	0.759**	0.000	0.000
1956								
Manyberries	Anthesis	0.190	0.554**	0.740**	0.616**	0.813**	0.000	0.000
	Mature	0.104	0.470*	0.666**	0.566**	0.710**	0.000	0.000
Foremost	Anthesis	-0.007	0.546**	0.744**	0.109	0.804**	0.000	0.000
	Mature	-0.001	0.457*	0.441*	0.344	0.923**	0.914**	0.173
Brooks	Anthesis	-0.079	0.343	0.409*	0.507**	0.745**	0.000	0.000
	Mature	-0.283	0.644**	0.579**	0.366	0.820**	0.831**	0.224
Maple Creek	Anthesis	0.000	0.000	0.000	-0.049	0.793**	0.000	0.000
	Mature	0.000	0.000	0.000	-0.150	0.583**	0.000	0.000

1/ 23 degrees of freedom.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

data collected at the different locations, years and stages of maturity are from the same population Fisher's transformation of r to z method was used.

The correlation coefficients r_{ab}, r_{ad}, r_{ae} and r_{ce} showed highly significant ($P \leq 0.01$) differences and r_{bc} showed significant ($P \leq 0.05$) differences among groups of <u>Stipa</u> <u>comata</u> plants. The correlation coefficients r_{be} and r_{de} showed homogeneous characteristics, with the combined correlation coefficients having values of 0.448 and 0.935, respectively. This indicates a significant correlation between height and weight and wrapped diameter and weight of all <u>Stipa</u> <u>comata</u> plants collected.

The correlation coefficients r_{ad}, r_{de} and r_{ce} showed highly significant ($P < 0.01$) heterogeneity among groups of <u>Koeleria</u> <u>cristata</u> plants. The correlation coefficients r_{ab}, r_{ae}, r_{be} and r_{bc} showed homogeneity with combined correlation coefficient values of 0.251, 0.677, 0.533 and 0.355, respectively. All the combined correlation coefficients were significant at the 1 per cent level.

Heterogeneity among groups of <u>Agropyron</u> <u>smithii</u> plants was shown in the correlation coefficients r_{ad}, r_{ae}, r_{bc} and r_{ce}. The correlation coefficients r_{ab}, r_{be} and r_{de} were homogeneous when grouped with values of 0.008, 0.344 and 0.767, respectively; the latter two were significant at the 1 per cent level.

For each of the three species there were homogeneous correlation coefficients between the relationship of maximum height and weight. There were heterogeneous correlation coefficients between the relationships of basal area with height and number of flowering stalks with weight.

To ascertain the relationships that existed between certain characteristics, when height and weight were based upon maximum leaf height, simple and partial correlation coefficients were determined for groups of Stipa comata and Koeleria cristata plants. These correlation coefficients are tabulated in Tables XXXV and XXXVI. Correlation coefficient values for the relationship between certain characteristics of Agropyron smithii plants, when maximum height and weight were based upon leaf heights, were not determined because the grouped correlation coefficient of the relationship between maximum total height and weight was lower than those of the other two species.

Groups of Stipa comata plants showed heterogeneous correlation coefficients for the relationships between number of flowering stalks with leaf height, wrapped diameter with leaf height and number of flowering stalks with weight, based upon leaf height. Homogeneous correlation coefficients in the various groups of plants were found in the relationships between leaf height with weight, leaf height with basal area and wrapped diameter with weight, based upon leaf height, with the grouped correlation coefficients of 0.611, 0.433 and 0.934, respectively.

Groups of Koeleria cristata plants showed heterogeneity for the relationships between number of flowering stalks and weight, based upon leaf height and wrapped diameter and weight. The remaining relationships showed homogeneity. The combined correlation coefficients for the relationships of basal area with leaf height, number of flowering stalks with leaf height, wrapped diameter with leaf height and leaf height with weight, based upon leaf height were 0.289, 0.112, 0.408 and 0.581, respectively.

On the basis of leaf height, the combined correlation coefficients of the relationship between height and weight were greater for both species than

Table XXXV. Simple and partial correlation coefficients[1] of certain relationships between a, basal area; c, number of flowering stalks; d, wrapped diameter; f, weight based on leaf height; and l, maximum leaf height of *Stipa comata* plants collected in 1955 and 1956 on four locations during anthesis and maturity.

Year and location	Stage of maturity	r_{al}	r_{cl}	r_{dl}	r_{cf}	r_{df}	r_{fl}	$r_{fl.c}$
1955								
Manyberries	Anthesis	0.423*	0.498*	0.736**	0.749**	0.989**	0.704**	0.576**
	Mature	0.681**	0.417*	0.883**	0.508**	0.910**	0.698**	0.621**
Foremost	Anthesis	0.601**	0.521**	0.709**	0.882**	0.940**	0.736**	0.688**
	Mature	0.553**	0.443*	0.748**	0.497*	0.936**	0.784**	0.724**
Brooks	Anthesis	0.548**	0.395	0.789**	0.538**	0.938**	0.755**	0.701**
	Mature	0.345	0.157	0.485*	0.595**	0.945**	0.651**	0.703**
Maple Creek	Anthesis	0.736**	0.384	0.785**	0.710**	0.943**	0.791**	0.797**
	Mature	0.566**	0.365	0.518**	0.668**	0.949**	0.659**	0.599**
1956								
Manyberries	Anthesis	0.288	0.000	0.346	0.000	0.915**	0.590**	0.590**
	Mature	0.358	0.000	0.436*	0.000	0.949**	0.458*	0.458*
Foremost	Anthesis	0.235	-0.046	0.257	-0.080	0.911**	0.672**	0.671**
	Mature	0.521**	0.000	0.164	0.000	0.904**	0.435*	0.435*
Brooks	Anthesis	-0.092	-0.437*	0.129	0.074	0.931**	0.250	0.315
	Mature	0.166	-0.290	0.283	0.031	0.928**	0.490*	0.525**
Maple Creek	Anthesis	0.427*	0.185	0.536**	0.291	0.919**	0.680**	0.665**
	Mature	0.375	-0.157	0.355	0.248	0.880**	0.448*	0.509**

1/ 23 and 22 degrees of freedom, respectively.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

Table XXXVI. Simple and partial correlation coefficients[1] of certain relationships between a, basal area; c, number of flowering stalks; d, wrapped diameter; f, weight based on leaf height; and l, maximum leaf height of *Koeleria cristata* plants collected in 1955 and 1956 on four locations during anthesis and maturity.

Year and location	Stage of maturity	r_{al}	r_{cl}	r_{dl}	r_{cf}	r_{df}	r_{fl}	$r_{fl.c}$
1955								
Manyberries	Anthesis	0.572**	0.581**	0.380	0.721**	0.918**	0.604**	0.328
	Mature	0.503*	0.301	0.610**	0.437*	0.967**	0.664**	0.620**
Foremost	Anthesis	0.315	0.392	0.552**	0.777**	0.952**	0.639**	0.577**
	Mature	0.180	0.244	0.456*	0.432*	0.928**	0.674**	0.650**
Brooks	Anthesis	0.335	-0.193	0.454*	0.384	0.957**	0.533**	0.646**
	Mature	0.374	0.414*	0.574**	0.515**	0.958**	0.723**	0.654**
Maple Creek	Anthesis	0.221	0.141	0.404*	0.766*	0.863**	0.534**	0.636**
	Mature	0.505**	0.236	0.685**	0.574**	0.956**	0.744**	0.765**
1956								
Manyberries	Anthesis	0.162	0.000	0.148	0.000	0.924**	0.408*	0.408*
	Mature	0.036	-0.087	0.361	0.376	0.933**	0.537**	0.613**
Foremost	Anthesis	0.264	-0.026	0.118	0.242	0.874**	0.359	0.388
	Mature	0.448*	0.057	0.373	-0.053	0.948**	0.580**	0.583**
Brooks	Anthesis	0.089	0.106	0.357	0.387	0.903**	0.583**	0.591**
	Mature	-0.054	-0.018	0.038	0.448*	0.925**	0.437*	0.498*
Maple Creek	Anthesis	0.424*	-0.158	0.367	-0.157	0.845**	0.582**	0.543**
	Mature	0.170	-0.299	0.548**	-0.088	0.953**	0.670**	0.614**

1/ 23 and 22 degrees of freedom, respectively.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

the combined correlation coefficient based upon total height, but the increase was greatest for Stipa comata plants. Both the correlation coefficients were highly significant.

Height was significantly correlated with weight in all species, thus indicating that taller plants produced more forage yield than shorter plants. This supports the height-weight principle. When the effects of number of flowering stalks were eliminated the association of height and weight, based upon leaf height, of Stipa comata and Koeleria cristata plants varied little from the simple association. Regardless of the great differences in height and weight of all species between years the growth form appeared rather constant as shown by the homogeneity of the correlation coefficients between the various groups.

Analyses of Group Variations by Covariance and Regression

Variations in groups of Stipa comata plants were determined by regression and covariance analysis and an analysis of error of estimate from average regression within groups was made of the relationship of height (X) to weight (Y). The highly significant ($P<0.01$) average regression of weight on height was 0.158 grams per inch of height for the 16 groups of plants. However, the differences among lot regressions were significant only at the 5 per cent level. When an analysis of error of estimate from average regression within groups was made for lots of plants collected on the various locations in 1955, 1956, at anthesis or at maturity there were no significant differences between lot regressions in any of the four groupings, indicating that the four groupings were sampled from a homogeneous population. The highly significant ($P<0.01$) average regressions of weight on height were 0.146, 0.338, 0.238

and 0.119 grams per inch of height for plants collected in 1955, in 1956 at anthesis and at maturity, respectively.

Analysis of error of estimate from average regression within groups of Koeleria cristata plants was made for the relationship of height and weight. When the 16 groups of plants were subjected to the test a highly significant ($P<0.01$) difference was found among the lot regressions. Differences among lot regressions of the groups of plants collected at various locations in 1955 were significant at the 5 per cent level, those collected in 1956 were homogeneous in regressions while those collected at anthesis and at maturity were highly significant ($P<0.01$).

Covariance analysis, on an intra-plant basis, of cumulative stubble height and cumulative weight (by segments) of Stipa comata and Koeleria cristata plants on the various locations showed highly significant ($P<0.01$) heterogeneity within groups of plants and between groups when combined by year or by stage of maturity.

On the basis of leaf height, covariance analysis and an analysis of error of estimate from average regression within groups were performed for Stipa comata and Koeleria cristata plants for the relationship of leaf height and weight (based upon leaf height).

When groups of Stipa comata plants collected at the various locations were combined for years and stages of maturity there were highly significant ($P<0.01$) differences among the lot regressions. When groups of plants grown in 1955 were combined the regressions were homogeneous, with the highly significant ($P<0.01$) average regression of weight on leaf height of 0.610 grams per inch of height. Combining all plants grown in 1956 showed all groups to be homogeneous, with a highly significant ($P < 0.01$) average regression of 0.339 grams per inch of height. Plants collected at anthesis showed highly significant ($P < 0.01$) differences among the group regressions. Plants collected at maturity were homogeneous with a highly significant ($P < 0.01$) average regression of 0.416 grams per inch of height.

When groups of Koeleria cristata plants collected at the four locations were combined by years and stages of maturity, the lot regressions were heterogeneous. Groups of plants collected in 1956, at anthesis or at maturity also showed highly significant ($P < 0.01$) heterogeneity of regressions. Only groups of Koeleria cristata plants collected in 1955 showed homogeneity of regressions. The highly significant ($P < 0.01$) average regression of weight on leaf height was 0.439 grams per inch of height for plants collected in 1955. Since there were significant differences between years no further analysis were made for Koeleria cristata plants.

Covariance analysis and an analysis of error of estimate from average regression within groups was made for Stipa comata plants on the basis of leaf height for the relationship of stubble height and weight, at 50 per cent use. When groups of plants collected on the four locations in the two years and two stages of growth were combined the differences among the regressions were significant at the 5 per cent level. When grouped on the basis of plants collected in 1955, in 1956 or at anthesis, the differences among the lot regressions were highly significant ($P < 0.01$). However, groups of plants collected at maturity showed homogeneity of regressions. The highly significant ($P < 0.01$) average regression of stubble height, when 50 per cent of the weight was removed, on weight at 50 per cent use was 0.653 grams per inch of stubble height. This analysis suggested a definite relationship between stubble height and per cent utilization of Stipa comata plants collected on the various locations when mature.

Analyses of covariance and error of estimate from average regression within groups were made for Stipa comata plants, on an intra-plant and maximum total height basis, for stubble height at the various increments with the corresponding per cent of weight removed. The data analyzed were the same as those used to obtain the average cumulative percentage of weight at the stubble heights shown in Table XIX. The data of groups of Stipa comata plants collected at the various locations subjected to covariance analysis of height removed and per cent of weight removed gave inconsistent results. Some of the groups of plants collected at anthesis or maturity on the various locations were heterogeneous in regressions while others were homogeneous in regressions. Combining the various groups by year or by stage of maturity also showed significant ($P<0.01$) heterogeneity.

Analysis of data based upon leaf heights, averages of which were presented in Table XXII, showed heterogeneity of regressions for Stipa comata plants collected at the various locations in 1955, at anthesis and when years and stages of maturity were grouped. Homogeneity of regressions were found at each location with the average regression of per cent of weight removed on leaf height removed of -15.314, -17,110, -14.439 and -14.338 per cent per inch of height removed at Manyberries, Foremost, Brooks and Maple Creek, respectively. Homogeneous regressions were found in groups of plants collected in 1956 and at the mature stage of growth. The highly significant ($P<0.01$) average regressions of per cent of weight removed on leaf height removed were -15.341 and -15.176 per cent per inch of leaf height removed for plants collected in 1956 and those collected in both years at the mature stage of growth, respectively.

The covariance and regression analyses indicated that Stipa comata plants collected at maturity during both years and on all locations were homogeneous in the regressions of weight and height; stubble height, when 50 per cent of the weight was removed, and weight at 50 per cent use; and stubble height, at the various increments, and the corresponding per cent of weight removed. Regression equations for determining utilization and employing height and weight, on the basis of leaf height, could be developed for Stipa comata plants.

Regression Equation for Estimating Utilization

The data employed in the calculation of the regression of per cent of weight removed on leaf height removed for Stipa comata plants collected at maturity also were used to determine the regression equation. The method of Goulden (1952) was used to fit a polynomial to the data, where the values of Y have unequal weight. An analysis of variance, the mean squares of which are shown in Table XXXVII, to test the increase in the sum of squares for regression due to each degree of fitting indicated that there was a highly significant linear regression and also highly significant quadratic and cubic regressions. The regression equation would have to be a third-degree curve. Additional fitting was not justified in that it appeared unlikely that the residual sum of squares would be reduced appreciably.

The regression equation developed for determining per cent utilization, is $Y = 147.91 - 54.76 X + 6.99X^2 - 0.30X^3$, where Y is the estimated percentage

Table XXXVII. Mean squares for testing the goodness of fit of the regression of per cent of weight removed on leaf height removed of mature Stipa comata plants.

Source of variation	D.F.	Mean square
Linear regression	1	1,278,700**
Excess due to quadratic	1	228,249**
Excess due to cubic	1	14,647**
Residual	1377	47
Total	1380	

utilization and X is the stubble height of Stipa comata plants. The graph of the curve is shown in Figure 2.

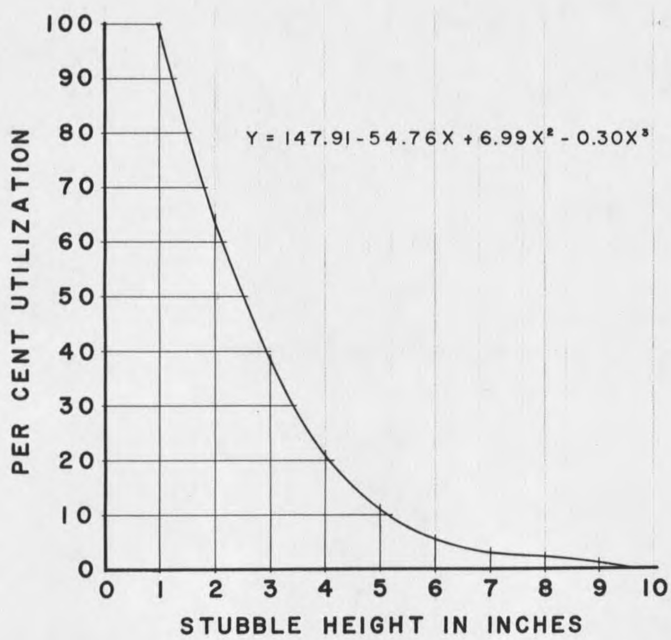

Figure 2. Graph of regression equation, $Y = 147.91 - 54.76X + 6.99X^2 - 0.30X^3$, with per cent utilization (Y) and stubble height in inches (X) based upon leaf heights of Stipa comata plants collected at maturity.

The stubble heights of Stipa comata, at one-half inch increments, with corresponding percentage of use based upon leaf height, are shown in Table XXXVIII.

Table XXXVIII. Stubble heights with corresponding percentage use of Stipa comata plants collected at maturity and based upon leaf height.

Stubble height in inches	Per cent Stipa comata use	Stubble height in inches	Per cent Stipa comata use
1.0	99.8	5.5	7.9
1.5	80.5	6.0	5.7
2.0	63.9	6.5	4.3
2.5	50.0	7.0	3.4
3.0	38.4	7.5	2.9
3.5	28.9	8.0	2.5
4.0	21.4	8.5	1.9
4.5	15.5	9.0	1.0
5.0	11.1	9.5	0.0

Test of Method

The use of the key species, Stipa comata, in determining percentage utilization of the Bouteloua-Stipa type of vegetation was tested and compared with the "difference" or movable-cage technique proposed by Klingman, Miles and Mott (1943). Three fields, each grazed by mature ewes and their lambs during the summer at 0.83 acre, 1.0 acre and 1.25 acres per head per month, respectively, during the past ten years were used as the study areas.

Ten cages located at random in each field, in the spring of 1960, protected the vegetation from being grazed. In the fall, areas enclosed by the cages and adjacent similar areas exposed to grazing were clipped. The difference in the yield of forage between the two areas is a measure of the amount of herbage consumed. Percentage utilization of each site was thus determined and the results summarized in Table XXXIX. Leaf stubble heights

Table XXXIX. Comparison of per cent utilization values obtained by the cage or difference method and the regression method on fields grazed at three intensities.

	0.83 acre per head per month		1 acre per head per month		1.25 acres per head per month	
Site	Cage	Regression	Cage	Regression	Cage	Regression
1	100	100	95	95	80	82
2	100	100	80	79	72	68
3	65	68	64	62	37	40
4	83	90	50	51	80	84
5	90	84	78	70	77	78
6	71	68	50	49	68	69
7	75	77	58	61	46	42
8	90	87	57	60	57	59
9	100	100	80	78	57	58
10	100	100	96	100	76	74
Average	87.4	87.4	70.7	70.5	65.0	65.4

of 20 *Stipa comata* plants were recorded to the nearest one-half inch on each site. Every five steps along the circumference of a circle, with the cage as center, the plant nearest the toe of the right shoe was measured for stubble height, regardless of whether the plant was grazed or ungrazed, until 20 plants were thus recorded on each site. This procedure was continued for all sites in which the cages were located. The percentage utilization was then determined for each plant by reference to the chart (Figure 1) and the height-per cent use table (Table XXXVIII) and the total for the 20 plants

was averaged for each site. The percentages determined for each site within each of the three fields are included in Table XXXIX.

Differences between pairs of per cent use values in each field were analyzed by the t-test, while the relationship between pairs of values were determined by correlation coefficients. The differences between pairs of values in the fields, grazed at 0.83, 1.0 and 1.25 acres per head per month, were non-significant with P values of less than 0.9, 0.7 and 0.6 respectively. The correlation coefficients were 0.963, 0.980 and 0.984, in the fields grazed at 0.83, 1.0 and 1.25 acres per head per month, respectively. An r to z transformation of the three correlation coefficients showed that they were homogeneous ($P < 0.6$), with the average correlation coefficient of 0.977.

The analyses indicated that the per cent use values determined by the use of the regression equation were not different from those determined by the "difference" or movable cage technique. The mean utilization values in each field were very close with differences of less than 0.5 of 1 per cent. The use of Stipa comata as a key species in determining utilization of the total vegetation of the Bouteloua-Stipa type is justified on the basis of the above analysis.

The importance of Stipa comata in the Bouteloua-Stipa type of vegetation was shown in studies conducted by Peters et al. (1953). Yield studies of the principal grass and sedge species indicated that Stipa comata produced 45 per cent of the total forage, Koeleria cristata 23 per cent and Agropyron smithii 12 per cent. Other studies (Clarke et al. 1942, 1943) also emphasize the dominance of Stipa comata in composition and productivity.

SUMMARY AND CONCLUSIONS

The objectives of the study were to ascertain some relationships that exist in _Stipa comata_, _Koeleria cristata_ and _Agropyron smithii_ plants; to collect basic information on the distribution of weight in relation to height of the three grasses at one-inch intervals; to examine the variations of certain growth characteristics of the three species as affected by differences in stages of maturity, locations and years; to develop a formula by regression analysis which will estimate utilization; and to test the proposed method of measuring utilization with other established methods.

Twenty-five plants of each species were collected at anthesis and maturity in 1955 and 1956 at Manyberries, Foremost and Brooks, in Alberta, and Maple Creek, in Saskatchewan. The sites were located within the brown soil zone and the _Bouteloua-Stipa_ type of vegetation. Basal area, maximum height, number of flowering stalks and wrapped diameter data were recorded. Each plant was sectioned at one-inch intervals and each segment was weighed.

Variability within groups of plants of the three species was high in basal area, number of flowering stalks and weight and low for height and wrapped diameter, as measured by the coefficient of variation. The variations for the various characteristics were greater within groups of plants than between locations, stages of maturity or years, indicating that individual plant response to environmental conditions is highly variable. The only pronounced yearly environmental effect was in the number of flowering stalks produced. Climatic conditions were more favorable for culm production in 1955 than in 1956--a phenomenon frequently encountered in the general area.

Height-weight relationships determined for each species on the basis of average maximum height exhibited great differences in the height-weight distribution between groups of plants collected in the two years. Height-weight distributions based upon leaf height showed less variation between years and locations or stages of maturity for all species. Since the variations within groups of Stipa comata plants were lowest, height class tables were constructed for this species collected at maturity. Comparisons of the height class tables with the average height-weight distributions showed uniformity between locations and years. The very low variability in height-weight distribution when compared with height class tables of Stipa comata plants collected at maturity offers possibilities of using this device as a means of approximating the percentage of forage utilization in the areas sampled. In all three species there was a gradual increase among shorter plants in the percentage of weight in the basal parts.

Variations between groups of plants, determined by analysis of variance, were greatest between years for most of the characteristics studied. Plants of the three species grown in 1955 were taller, heavier and had more flowering stalks than plants grown in 1956. No location differences were found in height or weight of Stipa comata plants, height of Koeleria cristata plants, and basal area, number of flowering stalks or weight of groups of Agropyron smithii plants. Plants of Stipa comata and Agropyron smithii collected at maturity were taller than those collected at anthesis, indicating that considerable plant elongation occurred in these two species since the earlier sampling.

On the basis of leaf height, there were location differences in average height of Stipa comata plants and in average height and weight of Koeleria cristata plants. In 1955 Stipa comata plants were heavier, Koeleria cristata plants were taller and Agropyron smithii plants were taller and heavier than those collected in 1956.

Plants growing under different environments do exhibit definite growth characteristics. Stipa comata plants that had larger basal areas were correspondingly larger in wrapped diameter and had more flowering stalks. Koeleria cristata plants having larger basal areas also were heavier, had larger wrapped diameter and had more flowering stalks. The conformity to the growth characteristics noted also were evident within group collections of the two species. The growth characteristics of Agropyron smithii did not appear to conform to a certain pattern.

Group relationships between certain associations of basal area, maximum height, wrapped diameter, weight and number of flowering stalks were determined for all species. Fisher's transformation of r to z method was used to test the homogeneity of the correlation coefficients obtained at the various locations, stages of maturity and years. Weight was significantly correlated with height and with wrapped diameter of all Stipa comata plants. The grouped correlation coefficients were homogeneous. There were homogeneous and significant correlations of basal area with height, basal area with weight, height with weight and height with number of flowering stalks of Koeleria cristata plants. Groups of Agropyron smithii plants were homogeneous and significantly correlated for height with weight and weight with wrapped diameter. On the basis of leaf height, homogeneous correlation coefficients in the various groups of Stipa comata were found in the relationships between leaf height and weight, leaf height and basal area and weight and wrapped diameter. Groups of Koeleria cristata plants were homogeneous and had significant correlations between basal area and leaf height, number of flowering stalks and leaf height, wrapped diameter and leaf height and weight and leaf height. The homogeneity of the correlation coefficients of the relationship of height and weight in the various groups indicates that the growth form of all species remains rather constant.

Groups of Stipa comata plants collected at maturity on the various locations in 1955 and 1956 showed homogeneity of regressions for the relationships of height (X) and weight (Y); stubble height (X), when 50 per cent of the weight was removed, and weight (Y), at 50 per cent use; and leaf stubble height (X), at the various increments, and the corresponding per cent of use (Y), on an intra-plant basis. Covariance analysis of Koeleria cristata plant data showed homogeneity of regression for some relationships within years only, hence further analyses were not made. Regression equations employing height and weight, on leaf height basis, could be developed to determine utilization of Stipa comata plants at maturity.

An equation developed from the regression of per cent of weight removed on leaf height removed of Stipa comata plants collected at maturity showed that the relationship was a cubic regression. The equation is $Y = 147.91 - 54.76X + 6.99X^2 - 0.30X^3$, where Y is the estimated percentage utilization and X is the stubble height in inches.

The regression method of estimating per cent utilization, employing Stipa comata as a key species, when compared with the "difference" or cage method on a percentage weight basis, gave mean utilization values with differences of less than 0.5 of 1 per cent. These two estimates made on fields grazed at three different intensities of grazing gave almost identical utilization values. On the basis of the results presented, the use of Stipa comata, as a key species, to determine percentage utilization of the total vegetation is justified. The dominant role of Stipa comata in the vegetative complex is further justification in its use as a key species. Hence, if the percentage of weight of Stipa comata that may be removed without damage to the plant is set at 50 per cent then the other plants will receive optimum use.

The procedure used in determining the per cent utilization with the regression method is to measure 20 Stipa comata plants, grazed or ungrazed, along a pace transect and record stubble height, or ungrazed leaf height, to the nearest one-half inch. This procedure is repeated on 10 or more sites representative of the field to be sampled. The measuring rule should rest firmly on the cushioned and central portion of the plant. The stubble heights recorded are then converted to per cent of use by reference to the chart of height-per cent use table. The utilization values at each site are totalled and averaged. The average values from each site are again totalled and averaged. The mean utilization value thus obtained is the utilization percentage of the field sampled.

LITERATURE CITED

Caird, R. W. 1945. Influence of site and grazing intensity on yields of grass forage in the Texas Panhandle. Jour. For. 43:45-49.

Campbell, R. S. 1937. Problems of measuring forage utilization on western ranges. Ecology. 18:528-532.

Campbell, J. B., R. W. Lodge and A. C. Budd. 1956. Poisonous plants of the Canadian prairies. Can. Dept. Agr. Pub. No. 900. 31 pp.

Clark, I. 1945. Variability in growth characteristics of forage plants on summer range in central Utah. Jour. For. 43:273-283.

Clarke, S. E., J. A. Campbell and J. B. Campbell. 1942. An ecological and grazing capacity study of the native grass pastures in southern Alberta, Saskatchewan and Manitoba. Can. Dept. Agr. Tech. Bul. 44. 31 pp.

Clarke, S. E., E. W. Tisdale and N. A. Skoglund. 1943. The effects of climate and grazing practices on shortgrass prairie vegetation. Can. Dept. Agr. Tech. Bul. 46. 54 pp.

Collins, R. W. and L. C. Hurtt. 1943. A method for measuring utilization of bluestem wheatgrass on experimental range pastures. Ecology. 24:122-125.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecol. Mono. 20:271-315.

Crafts, E. C. 1938. Height-volume distribution in range grasses. Jour. For. 36:1182-1185.

Goulden, C. H. 1939. Methods of statistical analysis. John Wiley and Sons, Inc., New York, New York.

Goulden, C. H. 1952. Methods of statistical analysis. 2nd. Ed. John Wiley and Sons, New York, New York.

Heady, H. F. 1949. Methods of determining utilization of range forage. Jour. Range Mangt. 2:53-63.

Heady, H. F. 1950. Studies on bluebunch wheatgrass in Montana and height-weight relationships of certain range grasses. Ecol. Mono. 20:55-81.

Holscher, C. E. and E. J. Woolfolk. 1953. Forage utilization by cattle on Northern Great Plains ranges. U. S. D. A. Circ. 918. 27 pp.

Hubbard, W. A. 1950. The climate, soils and soil-plant relationships of an area in southwestern Saskatchewan. Sci. Agr. 30:327-342.

Klingman, D. L., S. R. Miles and G. O. Mott. 1943. The cage method for determining consumption and yield of pasture herbage. Jour. Amer. Soc. Agron. 35:739-746.

Levy, E. B. and E. A. Madden. 1933. The point method of pasture analysis. New Zealand Jour. Agr. 46:267-279.

Lommasson, T. and C. Jensen. 1938. Grass volume tables for determining range utilization. Science. 87:444.

Lommasson, T. and C. Jensen. 1942. Determining the utilization of range grasses from height-weight tables. U. S. Forest Service. Unnumbered publication. 15 pp.

Lommasson, T. and C. Jensen. 1943. Determining utilization of range grasses from height-weight tables. Jour. For. 41:589-593.

Mattox, J. E. 1955. A study of per cent of plants grazed method of utilization determination and its application. (M. S. thesis). Mont. Agr. Exp. Sta. Mimeo. Circ. 88. 140 pp.

McArthur, J. A. B. 1951. The use of regression equations to determine utilization of little bluestem. Ph.D. Dissertation. Agr. Mech. Col. of Texas (Unpublished).

Mitchell, J., H. C. Moss and J. S. Clayton. 1944. Soil survey of southern Saskatchewan. Univ. Sask., Soil Survey Report 12.

Moss, E. H. 1955. The vegetation of Alberta. Bot. Rev. 21:493-567.

Pechanec, J. F. and G. D. Pickford. 1937. A comparison of some methods used in determining percentage utilization of range grasses. Jour. Agr. Res. 54:733-765.

Peters, H. F., et al. 1953. Progress Report, 1948-1953. Can. Dept. Agr. Pub. 45 pp.

Reid, E. H. and G. D. Pickford. 1941. A comparison of the ocular-estimate-by-plot and the subble-height methods of determining percentage utilization of range grasses. Jour. For. 39:935-941.

Roach, M. E. 1950. Estimating perennial grass utilization on semi-desert cattle ranges by percentages of ungrazed plants. Jour. Range Mangt. 3:182-185.

Russel, L. S. and R. W. Landes. 1940. Geology of the southern Alberta plains. Geo. Survey Memoir 221. Can. Dept. Mines and Resources. 219 pp.

Sampson, A. W. 1952. Range management principles and practices. 1st Ed. John Wiley and Sons, Inc., New York, New York. 570 pp.

Shultz, A. M. 1956. The use of regression in range research. Jour. Range Mangt. 9:41-46.

Smoliak, S. 1956. Influence of climatic conditions on forage production of shortgrass rangeland. Jour. Range Mangt. 9:89-91.

Snedecor, G. W. 1946. Statistical methods. 4th Ed. The Iowa State College Press. Ames, Iowa.

Snedecor, G. W. 1956. Statistical methods. 5th Ed. The Iowa State College Press. Ames, Iowa.

Stoddart, L. A. and A. D. Smith. 1955. Range management. 2nd Ed. McGraw-Hill Book Co., Inc. New York, New York.

Valentine, K. A. 1946. Determining the grazing use of grasses by scaling. Jour. For. 44:528-530.

Woolfolk, E. J. 1949. Stocking Northern Great Plains sheep range for sustained high production. U. S. D. A. Circ. 804. 39 pp.

Wyatt, E. A., et al. 1937, 1941. Soil survey reports. Univ. Alta., Col. Agr. Buls. 28, 36. Edmonton, Alta.