T H E S I S

METHODS OF DETERMINING RANGE CAPACITY

Submitted by

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COLORADO AGRICULTURAL COLLEGE

- - -

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BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science - Major in Botany

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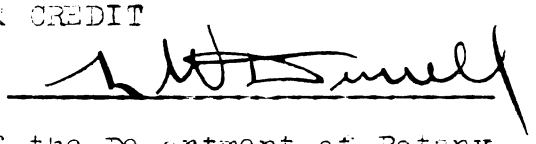

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May 1, 1932

This is to certify that Mr. Laurence A. Stoddart has translated for me assigned passages of technical French bearing upon his graduate Botanical work.

Sarah D. Kittle
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of Modern Language.

The writer wishes here to express appreciation to Dr. L. W. Durrell and other members of the Botany Department who have given helpful criticism in this work.

TABLE OF CONTENTS

INTRODUCTION - 1

LITERATURE REVIEW - - - - - - - - - - - - - - - - - 2

EXPERIMENTAL METHODS AND DATA - - - - - - - - - - 9

Plant Value Determinations - - - - - - - - - - 9

1. Preference of animals for different species - - - - - - - - - - - - - - - - - 11

2. Yield of forage per unit area - - - - - - 38

3. Chemical constituents and digestibility- - - - - - - - - - - - - - - 58

4. Characteristics affecting grazing value - - - - - - - - - - - - - - - - - - 78

5. Palatability or percentage consumed - - - 95

Range Capacity by Quadrat Measurement - - - - 112

CONCLUSIONS - - - - - - - - - - - - - - - - - - - 117

SUMMARY - 122

REFERENCES - 125

METHODS OF DETERMINING RANGE CAPACITY

Laurence A. Stoddart

INTRODUCTION

The commercial value of our Colorado range is primarily determined by the number of livestock which it is capable of supporting. This value depends upon several factors that influence the forage. The information on these factors, however, is fragmentary and scattered and there exists a wide diversity of opinion as to the proper method of determining forage value and range capacity.

Such factors as the preference displayed by the animal for certain plant species, the amount of forage production, the chemical constituents of the plants and the digestibility all enter into consideration. Moreover the physical features of the plant such as structure, accessibility, method of reproduction, and ability to withstand grazing play a part in determining the value of range plants.

It is the purpose of this thesis to discuss these factors on which the value of range plants is dependent and to present data indicating forage values of important range plants of Colorado.

LITERATURE REVIEW

The methods of estimating forage values now in use are chiefly estimation methods, based solely on the palatability of the plant or the actual percentage of an individual stalk which is grazed. This, however, does not give a true index to the usefulness of range plants.

Previous work on determining the value of range grasses has been limited. The forest service has assembled lists of the palatability of all important range plants within certain forests (Table XV). Such lists are found for the following forests and stations:

Ashley - Utah

Boise - Idaho

Cache - Utah

Caribou - Idaho

Coconino - Arizona

Coronado - Arizona

Datil - New Mexico

Lincoln - New Mexico

Madison - Montana

Malheur - Oregon

Nezperce - Idaho

Plumas - California

Powell - Utah

Prescott - Arizona

Uinta - Utah

Weiser - Idaho

Region two - Colorado, Wyoming, South Dakota, Nebraska, and western Oklahoma

Great Basin Exp. Sta. - Utah

Jornada Exp. Sta. - New Mexico

These lists have not been summarized, and have not been published except for the information of the local foresters. They are used only in the regions where they were assembled and are not applicable elsewhere unless they are adjusted for the new area.

These lists are based on the actual percentage of the plant which is eaten. Thus an eight inch plant grazed to a height of two inches would unconditionally receive a palatability rating of 75 per cent.

A method of procedure for determining these percentages has been briefly outlined by V. L. Cory (7). He states that the actual time the animal spends on each plant is the determining factor. This time is obtained by following the animal in the field for a period of 24 hours, and the time for all activity is recorded. Corey also recommends, in this paper, fencing a small area which is not to be grazed. Then, with this area as a check plot, the plants which are eaten outside the area can be determined and any resultant vegetational changes

may also be noted. Further data and measurements are given in another paper by Cory (6). This paper gives the detail of an average day's routine of Texas cattle. The time spent on various activities and the time of grazing on four different types of vegetation is recorded. Rather than listing the plants grazed, only the grazing time spent on four major classes is given. These classes include short grass, bunch grass, weeds and annuals.

J. H. Shepperd (27) records a method whereby stock was watched by means of field glasses, and the time spent on various quadrats previously located was recorded. The distance traveled by the cattle in various sized areas was also noted.

Recently some contributions on the methods of determining range values have been made by A. R. Standing (28) who has done valuable work on the importance of volume as a factor influencing plant value. This work was done in the national forests of Utah and has not been published. Standing measured the basal diameter of the individual plants and from this figure the basal area was computed for all important range plants. After the plant was so measured it was clipped and air dried. The figures obtained from this process were used to compute the volume per unit area. This figure, representing the volume, was then multiplied by the percentage eaten to give the

volume eaten.

In Colorado, J. H. Hatton (14) has studied the relationship between height of forage and the volume. According to this work the volume should vary directly with the height variation, allowing for ground cover density to take care of all lateral differences. All plants are grouped according to heights, with 1.0 as an average and others rated proportionally. The number obtained is then multiplied by the percentage eaten to give the volume allowance.

A. W. Sampson (26) has summed up the various factors to be considered in determining the value of a plant, but has given no key as to what effect each has or how to determine and measure this effect. He states, "Although the number of forage species grazed is very large, those devoured somewhat closely in a given region, or in a vegetative type, are not very numerous. The potential grazing value of the different species, in general, varies widely in accordance with a number of considerations. The more important of these may be grouped as follows:"

"A. Growth Habits and Growth Requirements

1. Growth period and growth form
   (a) Annual, biennial, perennial
   (b) Woody or herbaceous
   (c) Tufted or turf-forming
   (d) Root system fibrous or tap-shaped, deep, spreading, etc.
   (e) Ability to withstand grazing

2. Distribution
   (a) Elevational or vertical range
   (b) Soil:
      (1) Moist, medium moist, or dry
      (2) Acid, saline, or neutral
      (3) Well or poorly disintegrated

3. Adaptation
   (a) Ability to occupy various soils and suitability or diversified climatic conditions
   (b) Occurrence in shaded, partially shaded, or sunny, exposed habitats.

B. Life History Performances
1. Production of flower stalks abundant or limited
2. Seed habits strong or weak
3. Establishment of seedling plants abundant or limited
4. Extent of vegetative reproduction

C. Feeding Value
1. Character of herbage
   (a) Harsh or tender when green and when mature
   (b) Abundant, especially in proportion to number of seed stalks
   (c) Deciduous or evergreen

2. Yielding qualities
   (a) In favorable and unfavorable seasons
   (b) When grazed in varying degrees of intensity
   (c) When grazed in the green and in the mature state

3. Palatability and nutritive qualities
   (a) Season when most relished
   (b) Gusto with which eaten before and after seed maturity
   (c) Class of stock to which best suited
   (d) Absence of poisonous or mechanically injurious properties
   (e) Good curing qualities
   (f) Nutritive value of different parts of the plant

4. Accessibility.*

With this outline as a guide for determining value, Sampson has proceeded to classify the important forage plants. No attempt was made to give specific ratings and the plants are classified throughout only as belonging to one of three groups as, excellent, good, or fair. Plants are rated as follows: (1) for cattle, sheep and horses according to forage value, dependent upon the relish displayed by the animal; (2) according to abundance and distribution advantages, (3) according to general value as forage, all factors concerned.

This classification is, of course, very general within itself and also is necessarily very general in comparison in that it covers no special region and gives no qualification as to conditions existing where the data were taken. It is, doubtless, an excellent guide for making more complete studies within a region and is surely a pioneer in this field.

Analytical work on range grasses has been carried on by the University of Wyoming (10, 16, 17, 18, 20, 21). In these bulletins all important range grasses were chemically analyzed and the comparative feeding constituents noted. This has not been used, however, to compare the actual value of the plant in relation to other factors. The plants were analyzed for water, ash, ether extract, crude fiber, crude protein, and nitrogen-free extract.

Some analytical work was done as early as 1889 on Colorado grasses (3). In this study the plants were analyzed for ash, fat, albuminoid nitrogen, fiber and nitrogen-free extract. It compares the cultural values of different species but it shows no seasonal variation and the feeding value or range usefulness was not determined.

EXPERIMENTAL METHODS AND DATA

Plant Value Determinations

The studies on which this thesis is based were carried on in the College pasture. This pasture is made up largely of grass, including short grasses as grama grass and buffalo grass and taller grasses such as wheat grass and needle grass. It is located at the base of the foothills as is shown in Figure 1.

In figuring capacity of pastures the value determination may be made on each species and this value multiplied by the ground cover of that species as is the present practice, or by actual quadrat measurement of the percentage eaten during a certain time. These two methods will be covered in detail in the following consideration.

In determining the value of range plants palatability or per cent eaten is now most generally used as the measuring unit. The range management handbook defines palatability as "the proportion of the aggregate bulk of foliage of that plant which is grazed, considering the forage type as a unit". In actual practice palatability is usually considered to be the height percentage of the individual plant that is eaten upon maximum utilization. This, however, does not seem to be an accurate basis for the determination of forage plant value because of the many influencing factors that it does not consider.

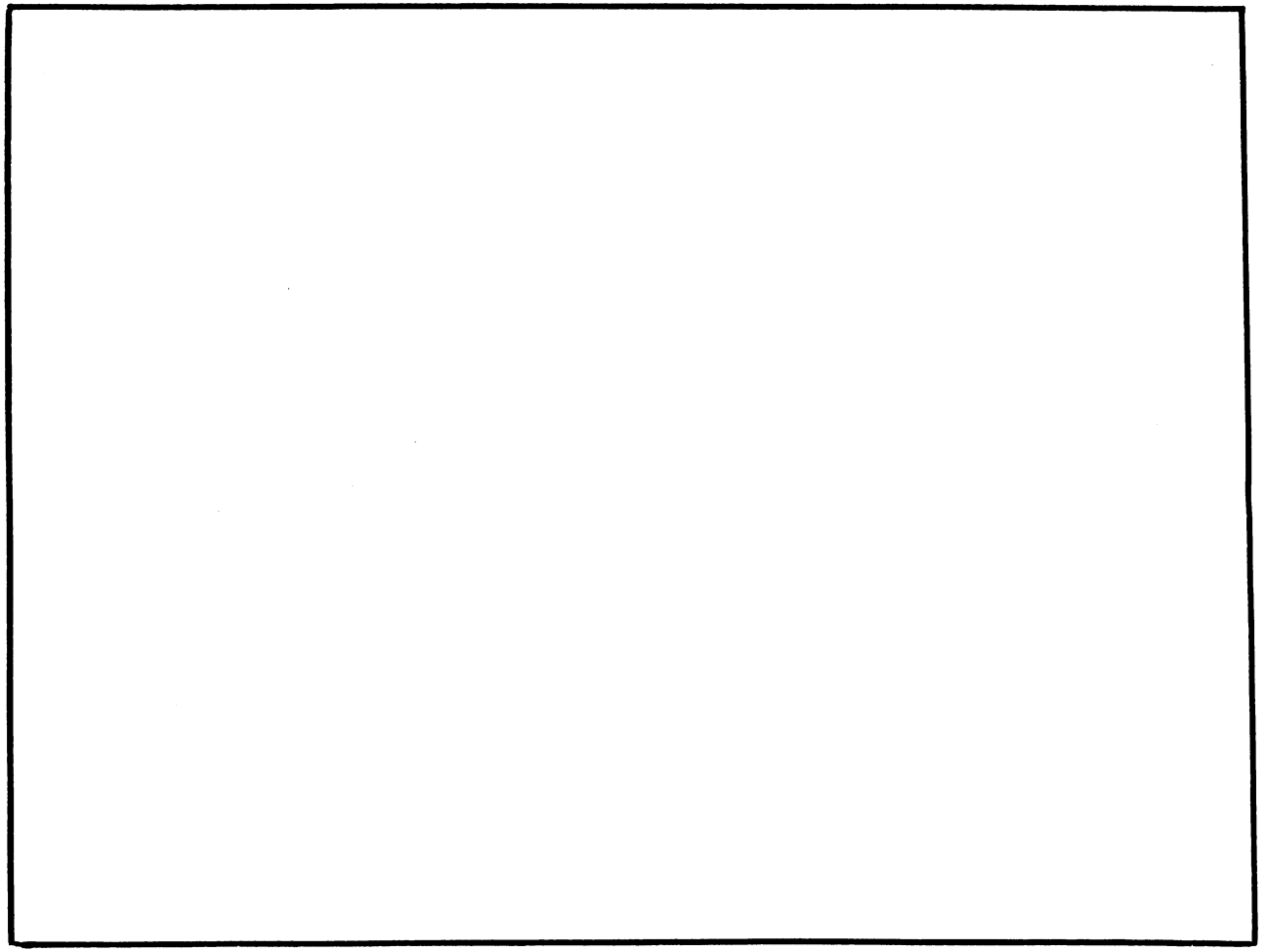


Figure 1.-Photograph showing the College pasture upon which the grazing experiments of this work were carried out.

The following factors may influence the value of a plant on the range.

1. Preference of animals for different species
2. Yield of forage per unit area
3. Chemical constituents and digestibilities
4. Characteristics affecting grazing value
5. Palatability or percentage consumed

In the following discussion these factors will be considered in their bearing on the determination of capacity through range plant values.

1. Preference of animals for different species

Preference is perhaps one of the most important considerations in determining the value of range plants. Preference will be used to indicate the desire an animal displays for a plant. Thus the plant upon which an animal spends most of its time will have the highest preference figure. The importance of this figure is clear. A plant can have no value if a range needs to be overgrazed in order to force the animal to eat that plant. One of the greatest weaknesses of the present palatability figure is that it does not consider preference. In this way two plants eaten off at the same height receive the same value rating regardless of the fact that 10 times as many more stalks are eaten in one case as in the other.

Range workers are just beginning to consider this factor. Both Corey (6), (7) and Shepperd (27) have given some consideration to preference by observing the time the animals spend on certain species. Corey has perhaps done the most extensive work, and as a result he concludes that time grazed is the determining factor for each plant. Corey did his observations by following a selected animal for a 24 hour period, keeping track of all time spent on each plant. The feed of range stock is divided into four classes, namely grazing, browsing, supplementary, and miscellaneous. Grazing, which may be divided into short grass, weed, bunch grass, and winter annuals, comprises more than three-fourths of an animal's feeding. The study of cattle preference led Corey to conclude that cattle have a decided preference for grass, weeds being taken only incidentally. Of the 56 per cent of the day which is spent in feeding Corey found the following times and percentages to hold true for cattle:

Kind of Grazing	Minutes spent daily	Per cent of grazing
Short grass	273.7	78.15
Weeds	31.8	9.08
Bunch grass	33.1	10.89
Annuals	6.6	1.88

Corey reported no further division of his groups and gave no individual species figures. It is evident, however, from his work that most grasses are considerably

higher in preference than weeds, and that short grasses are higher than are tall grasses.

Shepperd made his observations from a shed top by the use of field glasses, taking the time spent on each plant. The time spent on previously located quadrats was also recorded. Shepperd outlined a good method of procedure here but he did not publish any report on the individual species, his report being more on the action of the animal than on the value of the species.

The most accurate method of determining forage preference is by quadrat measurement. To do this a representative number of quadrats should be set up in early spring prior to grazing and these quadrats completely gone over for location and height of each plant within the area. Then by going over these quadrats and checking the number and height of each species grazed the actual percentage can be determined and preference determinations made. The figure obtained will, of course, vary almost directly with variation of the site or accompanying species, so is applicable only to similar areas. Variation also occurs with different seasons so each area should be studied during the season it is to be grazed. A second method may be applied with greater ease but somewhat less accurate results. This method consists in fencing a smaller but representative plot and confining

stock on that area. In this way the time involved is cut to a minimum and observations to accompany data are easily made. If the area selected can be grazed to capacity within a few days the experiment can be concluded in that time and thus allow for much more extensive work. If an animal is confined, however, and thus forced to remain under abnormal conditions, it is doubtful if the results would be quite so accurate as those obtained from more stock and under more normal conditions as outlined by the first method.

The second of the above described methods was used in this work because no ungrazed pasture was obtainable. An experimental plot which had not been grazed for several years was located on the college pasture west of Fort Collins. This plot was about one hundred by fifty feet in size and was covered by a typical mixed prairie vegetation with about four-tenths density cover. The cover was determined by ocular estimate to be somewhat as follows:

Aristida longiseta	45%
Bulbilis dactyloides	20
Agropyron Smithii	9
Aster hebecladus	6
Yucca glauca	4
Stipa comata	4
Stipa viridula	4

Helianthus pumilus.....2%

Stipa vaseyi 1

Bouteloua gracilis.....1

The remaining four per cent was composed largely of Eurotia lanata, Comandra pallida, Iva axillaris, Psoralea tenuiflora, Opuntia humifusa, Oryzopsis juncea, Gutierrezia longifolia, Astragalus albiflorus, Artemisia gnaphaloides, Argemone intermedia, Liatris ligulistylis, and Lygodesmia juncea. (See Figure 2.)

Within this enclosure were located seven quadrats each one-meter square, the corners of which were marked to enable a return to the exact spot. Each quadrat was mapped and the plants on each located as to position. Each plant was measured and its centimeter height recorded. These quadrats were located so as to show the greatest variety of plants possible, rather than to show an average sampling of the area. Some areas gave only one species while in others as high as 10 species were included.

An attempt was first made to graze this area by leaving it open to the stock in the adjacent pasture. These cattle grazed the area slightly but it was too small to offer attraction enough to offset a fear of the unnatural surroundings, so they did not return. Since it was desired to have the area grazed closer than the pasture area a single hereford cow was next confined on the spot.

Figure 2.--Photograph showing grazing plot used in preference studies prior to grazing. Compare to Figure 3, which is the same plot after grazing. This vegetation is largely Agropyron Smithii and Aristida longiseta.

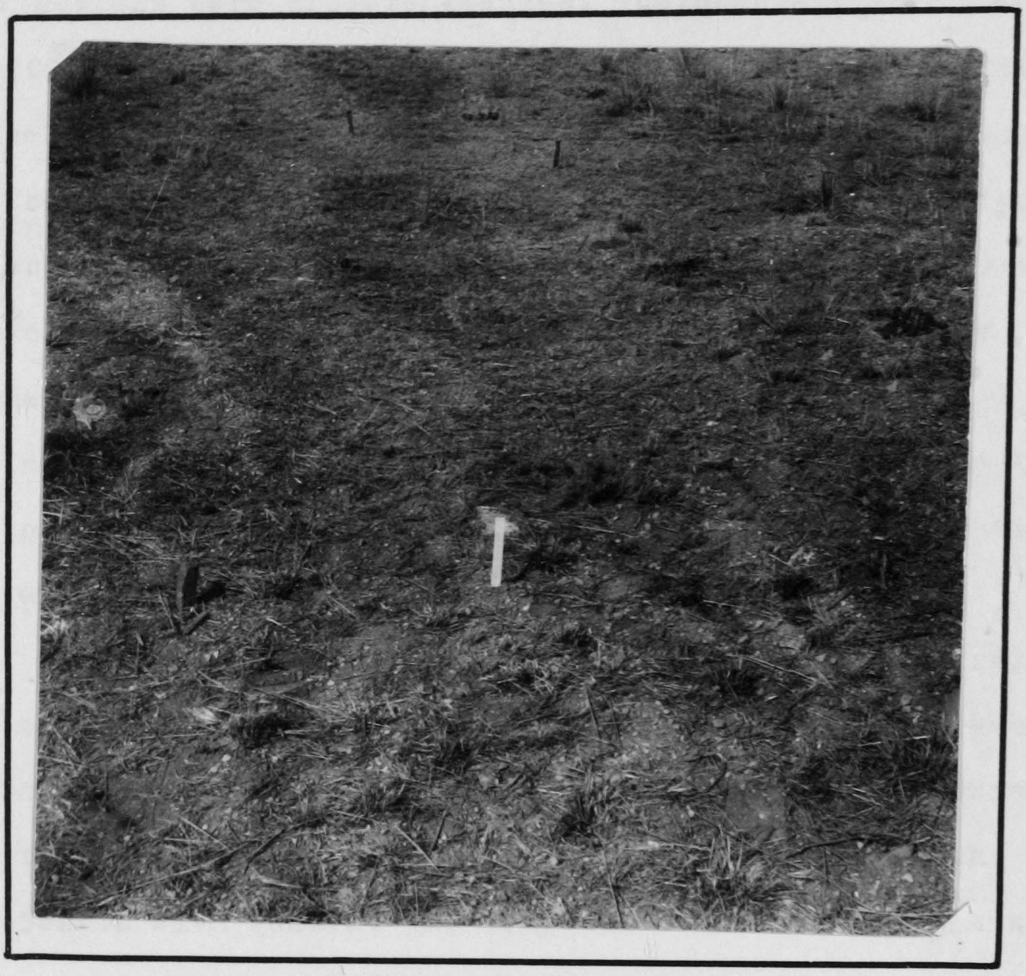


Figure 3.--Photograph of a section of the grazing enclosure used in preference tests after it had been grazed for a one-week period. Note the extreme overgrazing and the eroded areas where fresh soil can be seen between the dried stalks of previous years growth.

Her actions were closely studied. The quadrats were re-charted after each day and during the most active period, twice daily. This animal, having come from a better pasture and being somewhat excited, ate very little for a period of about two days. After this time her activities correlated closely with those of stock outside the plot. The animal was left on this area for a period of seven days during which time all desirable plants were eaten almost to the ground but certain undesirable plants were still standing untouched.

The data obtained from the quadrat work were correlated as follows: Average height of all bunch grasses such as wheat grasses, Stipas, etc., was obtained. Forbs were treated in the same manner. The average height of each species in each quadrat was computed for each day. Thus the amount of the species eaten was obtained rather than the amount of the individual plant as is done in palatability determination. This might be compared to adding the heights of all stalks of a species together each day and finding the percentage decrease as they are grazed.

Short grasses such as buffalo and grama were measured by determining the average height within a square decimeter by the use of a quadrat frame divided into decimeter squares. Thus in sod forming grasses the average height of a square decimeter was measured rather than the height of an individual plant. The percentage decrease each day

was computed as in bunch grasses and forbs.

Day 1- The plot had been grazed at will by range herefords which remained on the area only during one day. The grazing was not intense but showed marked preferences. Bulbilis dactyloides was grazed in some spots to a height of two centimeters and was in great demand. Close to 70 per cent of the stalks were grazed somewhat. Bouteloua gracilis was taken with somewhat less relish but seemed to be very favored. Eurotia lanata was grazed more than any other forb, every stalk having been grazed on the tender trips. The leaves of Helianthus pumilus were grazed almost completely leaving only woody stalks. Two awned grasses namely Aristida longiseta and Stipa comata were grazed somewhat where no fruits were present on the plant. Some Stipa viridula plants were grazed, about 80 per cent but the species had no marked preference. About 40 per cent of the leaves had been grazed over in spite of the fruit stalks.

Buffalo grass was the most highly preferred, but was closely followed by grama grass.

Day 2 - A single hereford range cow was confined on the area. No activity was noticed during the following 24 hours.

Day 3 - A very little grazing could be noticed, the preference still being markedly for Bulbilis dactyloides and Bouteloua gracilis. Agropyron Smithii was grazed for

the first time but did not have a high preference. Aristida longiseta was grazed somewhat; about 10 per cent of the plants had fruit stalks and leaves grazed off. Stipa comata was grazed considerably and was closely followed by Stipa viridula. About 50 per cent of the Stipa viridula leaves had been grazed. Oryzopsis juncea was grazed to 20 per cent and showed a high preference.

Day 4 - Relatively little feeding was taking place. Activity showed marked evidence of scarcity of desirable feed. Practically no Bulbilis dactyloides and but little Bouteloua gracilis was available. All the plants of these two grasses were grazed over by this time. Stipa comata was also grazed almost to capacity. Grazing began on the Aristida longiseta which constituted the majority of the bulk of the forage. This grass was grazed to about 70 per cent in places, and at least a fourth of the total volume was eaten. This does not mean that the preference for this grass was high, because all desirable forage was scarce. Its preference, however, was higher than that of western wheat grass which seemed to be almost totally ignored at this time. The Aristida constituted the bulk of the day's feed.

Day 5 - Aristida longiseta was intensely grazed during this period. About 80 per cent of the stalks had been grazed down to 10 centimeters height. It

constituted far the majority of the feed and seemed to be preferred above all that remained.

Oryzopsis juncea was grazed down to 50 per cent and displayed only a fair preference. Agropyron Smithii was also grazed down to about 50 per cent volume. The Bulbilis dactyloides was again gone over and was grazed this time extremely low, its height being close to one centimeter. Bouteloua gracilis was also regrazed and still was very desirable. It was grazed about 80 per cent.

Stipa comata displayed a very high preference and was grazed about 80 per cent. Stipa viridula, with a somewhat lower preference was grazed to 50 per cent of its volume.

Day 6 - The Aristida longiseta was all eaten somewhat and was being regrazed. Agropyron Smithii seemed to be taken with about equal choice, half of the stalks being grazed 75 per cent. Almost all grama and buffalo grass was entirely eaten. Eurotia lanata had been grazed again until nothing but woody stalks remained. Stipa viridula had been heavily grazed but its preference was only fair. The plot was decidedly overgrazed at this time, all desirable plants being grazed too closely for normal recovery. Certain plants such as Stipa vaseyi, Yucca glauca and Astragalus albiflorus, however, were untouched.

Day 7 - Agropyron Smithii was grazed closely being eaten to 80 per cent volume. Grama and buffalo grass were literally grazed to the ground. Three-awn grass was re-grazed somewhat closely. It was grazed to three centimeters in some places and showed decided effects of trampling. It was plainly grazed too closely. Feed was becoming very scarce.

Day 8 - The animal was removed from the plot after seven days of grazing. The area was grazed to capacity. All plants not protected by yucca or cactus were grazed, with the following exceptions: Yucca glauca, Stipa vaseyi, Argemone intermedia, Liatris ligulistylis, Psoralea tenuiflora, Opuntia camanchica, Gutierrezia longifolia, and Astragalus albiflorus. These plants obviously have a preference of zero for this time of the year and consequently are of no value to the range. They would therefore receive a rating of zero as would any plant ungrazed when the desirable plants are grazed to capacity. It is evident from these observations that keeping stock on an area after desirable plants have been grazed to capacity results in overgrazing and resultant destruction of the valuable plants. The range within this grazed area was ruined and will take years to recover. The ground was badly trampled and many plants were uprooted.

The general observations which were made daily revealed the facts shown in Table 1. Whereas these data are brief it is suggestive of considerable preference variation among different species as is shown in Table 1.

Table 1.--Daily preference percentage on seven quadrats

Quadrat 1
(1) Bulbilis dactyloides
5,500 sq. centimeters area

Day	Average Height	Per cent grazed
1	7.2 cm.	--
2	4.1 "	43
3	4.1 "	43
4	3.8 "	47
5	3.8 "	47
6	2.8 "	61
7	2.5 "	65
8	1.7 "	76

Quadrat 2
(1) Stipa comata
785 sq. cm. area

Day	Average Height	Per cent grazed
1	23 cm.	--
2	20 "	13
3	17 "	26
4	17 "	26
5	14 "	39
6	11 "	53
7	10 "	57
8	7 "	70

Table 1.-- Daily preference percentage on seven quadrats (continued)

Quadrat 3.
(1) Agropyron Smithii
13 plants

Day	Ave. Height	Per cent Grazed
1	24.2 cm.	--
2	24.2 "	0
3	24.2 "	0
4	24.2 "	0
5	24.2 "	0
6	12.1 "	50.0
7	12.1 "	50.0
8	11.6 "	52.1

Quadrat 3.
(2) Stipa viridula
942.5 sq. cm.

Day	Ave. Height	Per cent Grazed
1	24.8 cm.	--
2	24.8 "	0
3	24.8 "	0
4	24.8 "	0
5	21.9 "	11.7
6	11.1 "	55.3
7	9.5 "	61.7
8	6.0 "	75.8

Quadrat 4.
(1) Helianthus pumilus
3 plants

Day	Ave. Height	Per cent Grazed
1	25 cm.	--
2	17 "	32.0
3	17 "	32
4	17 "	32
5	17 "	32
6	17 "	32
7	17 "	32
8	16 "	36

Quadrat 4.
(2) Agropyron Smithii
21 plants

Day	Ave. Height	Per cent Grazed
1	22.3 cm.	--
2	22.3 "	0
3	22.3 "	0
4	22.3 "	0
5	19.5 "	12.6
6	14.2 "	36.4
7	10.8 "	51.6
8	10.0 "	55.2

Quadrat 4.
(3) Aristida longiseta
500 sq. cm. area

Day	Ave. Height	Per cent Grazed
1	26.5 cm.	---
2	24.0 "	9.5
3	24.0 "	9.5
4	24.0 "	9.5
5	9.0 "	66.1
6	7.0 "	73.6
7	5.5 "	79.3
8	5.5 "	79.3

Quadrat 4.
(4) Bouteloua gracilis
1073 sq. cm. area

Day	Ave. Height	Per cent Grazed
1	13.5 cm.	--
2	5.0 "	63
3	5.0 "	63
4	5.0 "	63
5	4.1 "	70
6	4.1 "	70
7	3.9 "	71
8	3.9	71

(5) Stipa Vaseyi - one plant not grazed

(6) Petalostemon oligophyllus - one plant not grazed.

Table 1.--Daily preference percentage on seven quadrats (continued)

Quadrat 5.
(1) Bulbilis dactyloides
925 sq. cm.

Day	Ave. Height	Per cent Grazed
1	7.5 cm.	--
2	5.0 "	33.3
3	5.0 "	33.3
4	5.0 "	33.3
5	3.1 "	58.7
6	2.0 "	73.4
7	2.0 "	73.4
8	1.5 "	80.0

Quadrat 5.
(2) Aristida longiseta
300 sq. cm. area

Day	Ave. Height	Per cent Grazed
1	29.0 cm.	--
2	29.0 "	0
3	29.0 "	0
4	29.0 "	0
5	19.1 "	34.1
6	9.5 "	67.3
7	9.5 "	67.3
8	5.9"	76.6

Quadrat 5.
(3) Agropyron Smithii
3 plants

Day	Ave. Height	Per cent Grazed
1	28.6 cm.	--
2	28.6 "	0
3	28.6 "	0
4	28.6 "	0
5	22.3 "	22.1
6	22.3 "	22.1
7	11.3 "	60.1
8	11.3 "	60.1

Quadrat 5.
(4) Helianthus pumilus
3 plants

Day	Ave. Height	Per cent Grazed
1	32.3 cm.	--
2	32.3 "	0
3	32.3 "	0
4	32.3 "	0
5	15.6 "	51.7
6	15.6 "	51.7
7	15.6 "	51.7
8	15.6 "	51.7

(5) Stipa Vaseyi
3 plants ungrazed
(6) Senecio perplexus
1 plant ungrazed
(7) Yucca glauca
2 plants ungrazed

Table 1.--Daily preference percentage on seven quadrats (continued)

Quadrat 6 (1) Agropyron Smithii 36 plants			Quadrat 6 (2) Bouteloua gracilis 2513 sq. cm. area		
Day	Ave. Height	Per cent grazed	Day	Ave. Height	Per cent grazed
1	26.1 cm	--	1	6.5 cm.	--
2	25.7 "	1.5	2	3.7 "	43.1
3	24.9 "	4.6	3	3.5 "	42.6
4	24.9 "	4.6	4	3.5 "	46.2
5	20.1 "	23.1	5	2.7 "	58.5
6	11.9 "	54.4	6	1.9 "	70.8
7	9.9 "	62.1	7	1.7 "	73.9
8	8.6 "	67.1	8	1.3 "	80.0

Quadrat 6 (3) Aristida longiseta 437.5 sq. cm. area		
Day	Ave. Height	Per cent grazed
1	28.6 cm	--
2	28.6 "	0
3	28.6 "	17.5
4	23.6 "	17.5
5	18.8 "	34.3
6	9.2 "	67.9
7	8.2 "	71.4
8	6.6 "	77.3

(4) Commandra pallida - ungrazed

(5) Artemisia gnaphaloides - ungrazed

(6) Petalostemon oligophyllus - ungrazed

(7) Antennaria aprica - ungrazed

(8) Psoralea tenuiflora - ungrazed

Table 1.--Daily preference percentage on seven quadrats (continued)

Quadrat 7
(1) Bulbilis dactyloides
3462.5 sq. cm. area

Day	Ave. Height	Per cent grazed
1	12.0 cm.	--
2	4.1 "	65.9
3	4.1 "	65.9
4	4.1 "	65.9
5	4.1 "	65.9
6	3.0 "	75
7	2.5 "	79
8	1.6 "	86.7

Quadrat 7
(2) Eurotia lanata
375 sq. cm. area

Day	Ave. Height	Per cent grazed
1	31 cm.	--
2	23 "	25.8
3	23 "	25.8
4	23 "	25.8
5	23 "	25.8
6	19 "	39.7
7	18.5"	40.1
8	9.5 "	69.4

Quadrat 7
(3) Aristida longiseta
50 sq. cm. area

1	25 cm.	--
2	25 "	0
3	25 "	0
4	25 "	0
5	20 "	20
6	8 "	64
7	8 "	64
8	7 "	78

Quadrat 7
(4) Sporobolus cryptandrus
48 sq. cm. area

1	39.0 cm.	57.4
2	16.6 "	57.4
3	16.6 "	57.4
4	16.6"	57.4
5	16.6 "	57.4
6	16.6 "	57.4
7	16.6 "	57.4
8	7.1 "	81.8

Quadrat 7
(5) Helianthus pumilus
2 plants

Day	Ave. Height	Per cent grazed
1	32 cm.	--
2	24.8 "	22.4
3	24.8 "	22.4
4	24.8 "	22.4
5	24.8 "	22.4
6	21.5 "	32.8
7	21.5 "	32.8
8	21.5 "	32.8

Quadrat 7
(6) Agropyron Smithii
6 stems

Day	Ave. Height	Per cent grazed
1	20.3 cm.	--
2	20.3 "	0
3	20.3 "	0
4	20.3 "	0
5	20.3 "	0
6	13.3 "	34.5
7	13.1 "	35.0
8	8.7 "	57.2

(7) Argemone intermedia - ungrazed
(8) Liatris ligulistylis - ungrazed
(9) Yucca glauca - ungrazed
(10) Artemisia gnaphaloides - ungrazed

Figure 4.--Photograph showing the pasture just outside the enclosure used in preference tests. The grazing here is seen to be similar but not as intense as that shown in Figure 3.

Figure 5.--This photograph shows one end of the preference test enclosure. Note the severe grazing on parts of the area and the untouched stalks of *Stipa vaseyi* and *Yucca glauca*.

This table (Table 1) gives the average heights and the volume percentage which was eaten for each species on each quadrat used in the preference studies.

When the grazing percentages for each individual species from the various quadrats as seen in Table 1 are assembled the figures found in Table 2 will be obtained. These show the actual volume percentages eaten on each quadrat.

Table 2.--Daily preference averages for all species studied

Day	2	3	4	5	6	7	8
1. Agropyron Smithii							
	0	0	0	0	50.0	50.0	52.1
	0	0	0	12.6	36.0	51.6	55.2
	0	0	0	22.1	22.1	60.1	60.1
	1.5	4.6	4.6	23.1	54.4	62.1	67.1
	0	0	0	0	34.5	35.0	57.2
2. Stipa comata							
	13.	26.	26.	39	53	57	70
3. Stipa viridula							
	0	0	0	11.7	55.3	61.7	75.8
4. Eurotia lanata							
	25.8	25.8	25.8	25.8	39.7	40.1	69.4
5. Bouteloua gracilis							
	63	63	63	70	70	71	71
	43	46	46	58	71	74	80
6. Bulbilis dactyloides							
	65.9	65.9	65.9	65.9	75	79	87
	33.3	33.3	33.3	58.7	73	73	80
	43	43	47	47	61	65	76

Table 2.--Daily preference averages for all species studied (continued)

7. Helianthus pumilus						
Day 2	3	4	5	6	7	8
32	32	32	32	32	32	36
0	0	0	52	52	52	52
22	22	22	22	33	33	33
8. Aristida longiseta						
0	0	0	20	64	64	78
0	17	17	34	68	71	77
0	0	0	34	67	67	77
9	9	9	66	73	79	79
9. Sporobolus cryptandrus						
57	57	57	57	57	57	82

10. Argemone intermedia - 0
11. Liatris ligulistylis - 0
12. Yucca glauca - 0
13. Stipa vaseyi - 0
14. Petalostemon oligophyllus - 0
15. Senecio perplexus - 0
16. Artemisia gnaphaloides - 0
17. Psoralea tenuiflora - 0
18. Antennaria aprica - 0
19. Commandra pallida - 0

Table 2, showing the percentage eaten on each quadrat, indicates a very definite trend and shows a decided variation in preference for various species.

The data from these tables were next averaged together to obtain a specific figure. In view of the fact that some quadrats contained many times more plants than others it is advisable to use a weighted average. This average was obtained by considering the area in the short grasses and the stalk number in the bunch grasses and forbs. Thus if one grama grass patch contains three times

Fig. 6.--Photograph showing the contrast between the grazing enclosure used in the preference tests, and the pasture outside. The area between the first two fences is the grazing plot. Note the untouched Yucca glauca and Stipa vaseyi in the grazing plot.

as much as another it is given three times as much weight in the average.

The weighted averages for all species may be found in Table 3 and the graph in Figure 7.

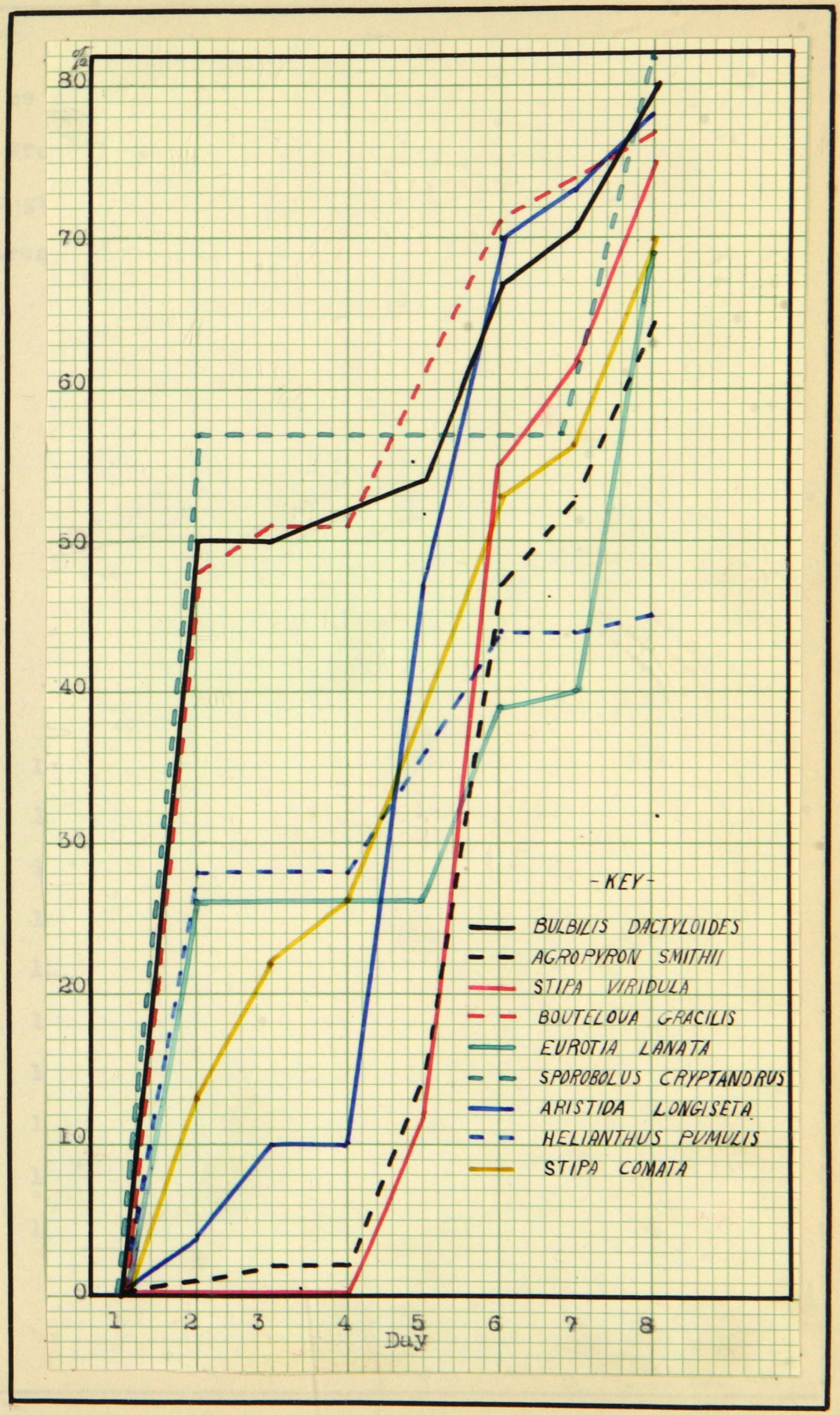
This table and graph shows the percentage preference for the common range plants of a mixed prairie pasture.

Table 3.--Average preferences for each day

Day	2	3	4	5	6	7	8
Agropyron Smithii	1	2	2	15	47	53	64
Stipa comata	13	26	26	39	53	57	70
Stipa viridula	0	0	0	12	55	62	76
Eurotia lanata	26	26	26	26	39	40	69
Bouteloua gracilis	48	51	51	61	71	73	77
Bulbilis dactyloides	50	50	52	54	67	71	80
Helianthus pumilus	28	28	28	37	44	44	45
Aristida longiseta	4	10	10	47	70	73	78
Sporobolus cryptandrus	57	57	57	57	57	57	82
Stipa vaseyi	0	0	0	0	0	0	0
Argemone intermedia	0	0	0	0	0	0	0
Liatris ligulistylis	0	0	0	0	0	0	0
Yucca glauca	0	0	0	0	0	0	0
Petalostemon oligophyllus	0	0	0	0	0	0	0
Senecio perplexus	0	0	0	0	0	0	0
Artemisia gnaphaloides	0	0	0	0	0	0	0

Table 3 gives the final preference figures of the volume eaten. It is the purpose in figuring preference to segregate those plants which normally are not eaten unless the range is overgrazed. The percentages obtained on the eighth day are, obviously, too high since the range was, at that time, overgrazed. The overgrazing was first markedly evident on the sixth day so in good range management grazing would be stopped on the sixth day. For this reason the preference figures obtained on the sixth day

Figure 7.--This graph shows the percentage preference for the most important plants of a mixed prairie pasture. The pasture was considered to be properly grazed at the end of the sixth day. Note the marked preference cattle display for grass species.


% of 12
80
70
60
50
40
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1
2
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Day
-KEY-
BULBILIS DACTYLOIDES
AGROPYRON SMITHII
STIPA VIRIDULA
BOUTELOUA GRACILIS
EUROTIA LANATA
SPOROBOLUS CRYPTANDRUS
ARISTIDA LONGISETA
HELIANTHUS PUMULIS
STIPA COMATA

will be used as a comparative basis.

From column six (Table 3) the following figures, which give the relative preference rating of all plants on the area may be obtained.

1.	Bouteloua gracilis	71
2.	Aristida longiseta	70
3.	Bulbilis dactyloides	67
4.	Sporobolus cryptandrus	57
5.	Stipa viridula	55
6.	Stipa comata	53
7.	Agropyron Smithii	47
8.	Helianthus pumilus	44
9.	Eurotia lanata	39
10.	Stipa vaseyi	0
11.	Argemone intermedia	0
12.	Liatris ligulistylis	0
13.	Yucca glauca	0
14.	Petalostemon oligophyllus	0
15.	Senecio perplexus	0
16.	Artemisia gnaphaloides	0
17.	Psoralea tenuiflora	0
18.	Antennaria aprica	0
19.	Commandra pallida	0

It must be remembered that such a rating is strictly limited to the season in which the test was made. The striking feature is the rating of 70 given Aristida longiseta and the rating of 47 given Agropyron Smithii. The season selected was immediately after three-awn grass dropped its seed and obviously before that time its rating would have been considerably lower. Western wheat grass, on the other hand, becomes tough and dry during late season and so loses considerable value. In early season its rating must have been much higher. Again the accompanying species are important considerations. It is evident that a patch of dry wheat grass would be practically ignored in a blue grass meadow because the blue grass is so much more desirable. Such a test, however gives a very definite relative rating for the season and range in which it is carried out.

It is apparent from this work that there exists a wide variation in the preference animals display for range grasses of different species. Exactly similar work has not been recorded, all previous measurements being limited to the percentage of individual plants giving no consideration to the percentage of the species. Preference has been very much under-rated in the past. It is, in reality, a very important figure, in that it gives the volume per-

centage eaten during a season of proper management. It is therefore much more valuable in itself than is the palatability figure used heretofore. It adds accuracy to previous methods in that it is actual measurement and not estimation. Since quadrat measurement gives an accurate figure for relative preference, and since preference figures are highly valuable for correct range management this system seems to be highly practical.

2. Yield of forage per unit area

Though the preference figure is an important factor in determining the value of range plants, the volume of forage produced by different plants is also an important consideration. Volume studies give the yield of forage per unit area whereas preference studies give the percentage of this yield which is normally eaten.

The forage or volume production is considered to be the weight of plant materials produced by each plant species per unit area and may be expressed in pounds per square foot or in grams per square meter.

Volume yield has not as yet received adequate attention though it is very important. Experiments have shown that some plants furnish as much as 10 times the forage per unit area as is furnished by shorter or sparser plants. The only method whereby volume can be accurately measured is by clipping plant samples from a measured unit area,

and weighing these samples.

It would be desirable to use a method whereby volume production can be obtained for various types of forage plants. This method would also show that volume may vary during different seasons of the year.

A. R. Standing (28), inspector of grazing for the United States Forest Service, has, during the past four years, worked on volume production on the ranges of Region four of the Forest Service (Utah, southern Idaho, western Wyoming, Nevada, and northwestern Arizona). His report covering two hundred separate studies in the region mentioned above, gives the data for all major species that were clipped, dried, and weighed.

Grazing survey work done by the forest service consists of an estimate of the density of forage on the area or the actual percentage of the ground which is covered by living plants. This is multiplied by a palatability estimate in order to obtain a relative capacity figure. It was with a view of allowing for a volume factor that Standing's work was done. For this purpose the volume for each species on a given area was computed and a corresponding volume rating given. These ratings were used to determine a weighted average palatability for the type, and were thus used in calculating the capacity of the area.

The total number of square inches of ground completely covered by a plant was obtained by measuring the average diameter of the plant and squaring the figure so obtained. The plants were then clipped, weighed, air dried, and reweighed. Only plants which completely covered the ground within their boundaries were selected, that is, plants which show no ground when looked at from above. Forage normally not eaten was discarded. Such forage included all woody stems and all browse above the reach of an animal. Plants normally somewhat spreading were bunched up or pulled together until their stems formed a 60 degree angle with the ground level, prior to diameter measurement.

Standing also considered the influence of site upon volume. Site may be defined as the condition of the area with reference to factors influencing growth. Plants were measured and weighed on sites considered poor, average, and better than average. The plants grew taller and more luxuriantly on better sites, and lower and less luxuriantly on poorer sites. Concerning his results on this study, Standing says, "Considering that the so-called 'better sites' or 'poorer sites' for any given species are few, small and scattered, that a site that is average for one species will very probably be better or poorer than

average for another species, and that sites that are actually better than average usually support high volume producing species which give the type a high volume rating without a site classification,as such, it seems unnecessary, for all practical purposes to classify sites in grazing survey work.*

Standing further studied regrowth as a factor influencing volume. Plants were studied to determine whether or not the production of forage after it had been repeatedly grazed was sufficient to give a plant an increased volume rating.

Seven typical plots, in meadows, were selected for the regrowth studies. One plot was clipped in September only, three in early August and again in September, three in late May, early August, and again in September. The yields from these seven plots were weighed. It was found that practically the same total amount of forage volume was taken from each, regardless of the time and number of clippings. This work shows that grasses, having a low point of growth, are not materially effected by grazing so far as volume production is concerned. The results of this study indicate that accounting for regrowth in meadows seems unnecessary.

Standing's work shows that "volume-palatability" may be obtained as follows: the average volume obtained is

given a rating of 1.0 for its volume. Other plants are then given comparative volume ratings by averaging their volumes between the figures 0.1 and 2.0, thus giving an equal variation on each side of the average. The local palatability figure for each species is then multiplied by its volume ratio to give "volume-palatability". Standing's volume figures in ounces per 10 square feet, range between 5.0 for Medicago lupulina and 86.2 for Elymus condensatus, with an average figure of about 38.0 as in Phleum pratense. Other figures are rated according to relative volumes between 0.1 for Medicago lupulina and and 2.2 for Elymus condensatus with Phleum pratense taking a value of 1.0 as an average. These are based entirely on relative percentages.

Test experiments were carried out upon areas with dominants of browse, grass, and weeds in which capacity computations were made by using the figures for volume production and other computations not allowing for volume production. These tests show that browse and weed types receive a very much lower capacity rating when volume is considered, while grass types are not seriously affected. Standing concludes from these experiments that "if the volume method is the correct one then the method now in use is in error," and "from the studies made to date, it appears that the volume method is feasible and

practical."

John H.Hatton, (14) assistant regional forester of Region two, has also worked out a system in which allowance is made for volume. This work was based on the assumption that all volume variation is in direct proportion to the height of the plants because the lateral differences, or differences due to area or ground cover, were taken care of by the density estimate. Kentucky blue grass was used as the base and was given a relative volume unit of 1.0. All other plants were rated in proportion to height, i. e., a plant twice as high as Kentucky blue grass would have a unit of 2.0, a plant half as high, a unit of 0.5, etc. It is assumed that volume will not vary to any great degree with the difference in locality. Thus a relative "volume palatability" may be obtained by multiplying the volume by the local palatability factor. The method outlined above is now being used in Region two.

The methods worked out and put into use by Standing and Hatton show striking differences since within the species the results are not constant. Standing gives June grass a volume of 0.5 and Hatton gives it a volume of 1.0. Forbs differ even more, for example, Standing gives lupine a volume of 0.6 while Hatton gives it a volume of 3.0. It is evident that the volume figure for browse will vary even more than the two examples cited above. Standing's method

gives almost every browse species a volume below 1.0 and by Hatton's method it is evident that browse species would, because of their relative height, receive volumes of 3 to 4 times as much as grasses.

To more definitely compare these methods of forage estimation the results of Standing's and Hatton's work were averaged individually, i. e., the grasses, weeds and browse of each were averaged together to obtain a comparative average figure for each method. Table 4 gives the average volume figures obtained by Hatton's height volume methods and Standing's measured volume methods.

Table 4.--Standing's and Hatton's methods compared.

Type	Hatton's height volume	Standing's measured volume
Grass	1.42	0.98
Browse	No figures	0.525
Weed	2.14	0.700

It is quite evident from the averages shown in Table 4, that the two methods do not correspond, in that weed volume increases over grass volume in Hatton's method, while in Standing's method it decreases. It is evident that browse is, as a rule, higher than forb growth and that browse volume would, as a result, be higher than the volume 2.14 listed for forbs, by Hatton's method. This will give even more difference in browse comparison by the two

methods, for by Standing's method browse produces but a 0.525 volume.

It is evident therefore that one of these two methods is in error. In view of the fact that Standing's work is an actual measurement of weight production, and that Hatton's work is based on an assumption, it seems reasonable to suppose that Standing's method is the more accurate. For this reason the height method will not be used in the following experiments on volume production. Standing's methods will be followed with slight variation.

The methods for determining volume must be limited to actual volume measurements by weight. The volume of all plants on the range may be determined in this way, although the methods for different types , i. e., browse, forbs, and grass, vary slightly. Two methods of collecting the plants and assembling the data may be used.

In the first method the palatability, or percentage eaten, is taken from local lists and only that percentage of the plant is clipped for weighing. In the second method the plant may be clipped at the ground and the entire plant weighed. This weight is then multiplied by the local palatability figure. The former of these two methods seems to be more accurate and can be handled with greater ease. It is more accurate in that it considers nothing except what the animal normally eats and it is the actual edible

part which is weighed. Therefore, by this method it is not necessary to assume that the stalk is homogeneous throughout with regards to weight, i. e., that a unit length of the coarse stem below weighs the same as a similar length of the finer leaf above. It offers greater ease of handling because it facilitates clipping. Clipping a plant flush with the ground is often difficult, especially with the shorter grasses.

The disadvantages of clipping at the height which the plant is grazed are first, that a height must be either measured or estimated at the time of clipping, and, secondly, the volume and palatability are considered as a unit and not as separate factors; consequently the palatability cannot be changed in different sites without making new clippings for the new palatability. The advantages of the method, however, seem to outweigh the disadvantages. The method of clipping at the height grazed will be used (5).

Basal areas or ground covered should be the actual area which is covered one hundred per cent by the plant in the normal state. Thus in determining the area of a shrub two cross diameters will be measured and multiplied together to obtain an area figure. If only half this area is shut off from vision - looking down from above - only half that area is covered and the above area figure should

be divided by two. This method allows for grass or forbs that grow below a shrub where sunlight is available to them. Grasses and forbs should be treated in the same manner and should be given an area equivalent to the area of ground which they cover. This might be compared to the ground area which is shaded by the plant at noon.

Two plants have been completely treated for volume production on the mixed grass prairie. The range used is located four miles west of Fort Collins, Colorado. The vegetation is largely grass and is covered by two dominant species, grama grass (Bouteloua gracilis) (see Figure 9) and buffalo grass (Bulbilis dactyloides) which are typical short grass species. Western wheat grass (see Figure 8) (Agropyron Smithii) is the third most abundant plant and the Stipas are also quite numerous. The two plants selected for this experiment were grama grass and western wheat grass which offer two extremes of grass types. The clipping work was carried out at two-week intervals from the beginning of the grazing season, about June 1, 1931, to August 15, 1931. This time was sufficient to allow for seasonal volume variation.

Plots of pure grama grass which offered an area of 4,000 sq. cm. were chosen at random over the range. A frame was placed over this area, enabling the clipping of exactly 4,000 sq. cm. All the grass from the area was then

Figure 8.--Figure showing a plant of western wheat grass (Agropyron Smithii). Note the tall leaf growth and the creeping underground stems or rhizomes.

Figure 9.--Figure showing a plant of grama grass (Bouteloua gracilis). Note the short leaf growth but relatively high inflorescence, and the short root growth.

removed by the use of strong shears, and was clipped at a height of one centimeter. It was found that an average grama grass height was ten centimeters and local grama grass has a palatability of about 90 per cent. This means that grama grass is eaten, usually, to a height of one centimeter.

A large cloth helped in gathering this material and kept losses at a minimum. All material clipped was placed in an individual air-tight container and a number given to it. These samples were taken into the laboratory and oven dried at a temperature of 100°C. for 24 hours, before they were weighed. Ten such samples were taken at each interval of time.

The wheat grass samples were taken by the number of stalks rather than by the area, because stands of a measurable density are not to be found. Fifty stalks clipped at five centimeter height constituted a sample. It was found by 1,500 random measurements that wheat grass has an average height of 17.0 centimeters. The observed palatability of this grass is 70 per cent, which means that 70 per cent of the 17.0 centimeters height would be eaten and 30 per cent would remain. Thirty per cent of 17.0 gives a height of 5 centimeters which is normally not eaten. Hence the samples were clipped at 5 cm. These samples were chosen at random, clipped, dried, and weighed

in the same manner as the grama grass samples. The results are shown in Table 5 and 6.

Using the above methods yield data were accumulated as presented below. Table 5 gives the grams weight of oven dry samples of grama grass (Bouteloua gracilis) which were clipped from a 4,000 square centimeter area at a one centimeter height.

Table 5.--Seasonal yield of grama grass in grams

Sample Number	June 3	June 18	July 2	July 31	August 20
1	10.5	16.7	9.8	10.1	9.8
2	11.5	21.3	11.8	15.8	8.9
3	12.5	18.1	11.8	15.3	11.1
4	11.4	20.1	13.0	13.4	11.1
5	10.8	17.1	16.8	17.6	10.6
6	11.5	23.0	12.8	13.4	9.8
7	14.0	17.1	8.2	13.5	10.5
8	14.7	14.5	13.7	14.1	9.2
9	11.5	21.8	13.2	13.4	10.5
10	12.7	19.3	16.1	10.0	9.0
Average	12.11	18.90	12.72	13.66	10.10
Standard Deviation	1.24	2.43	2.45	2.22	0.78

It will be noted in this table that grama grass volume yields increase in early season and, after June, they make a steady decline, except at the end of July at which time some good rains caused a renewed growth and consequently a slight volume increase.

Table 6 gives the grams weight of oven dry samples of western wheat grass (Agropyron Smithii) of which 50 stalks were clipped for each sample at a height of five centi-

meters.

Table 6.--Seasonal yield of western wheat grass in grams.

Sample Number	June 2	June 17	July 1	July 15	July 29	Aug. 17
1	1.4	4.2	4.9	4.8	4.4	3.7
2	2.2	3.9	5.6	4.9	4.5	3.2
3	3.4	4.4	6.3	7.0	4.1	3.1
4	3.3	5.1	8.4	[illegible].7	3.0	4.6
5	2.3	4.5	7.3	6.5	3.6	4.8
6	4.1	5.6	7.2	8.7	5.1	3.0
7	2.5	5.2	8.2	9.3	4.0	3.0
8	2.8	6.4	8.6	7.1	4.1	3.8
9	2.8	6.1	7.5	6.4	5.0	3.6
10	2.0	5.0	7.5	7.6	4.2	4.0
Average	2.68	5.04	7.15	6.8	4.2	3.68
Standard Deviation	.80	.76	1.14	1.42	.59	.60

In the above table it will be noted that western wheat grass production follows the same curve as does that of grama grass except that no increase is noted during the late rain period.

The next step in the method of yield determination used is to put these two grasses into equivalent figures, namely into gram volumes produced per square meter.

Grama grass may be converted as follows: the figures listed in Table 5 are volume per 4,000 square centimeters, which is only two-fifths of one square meter. The figure should, therefore, be multiplied by 2.5 to convert it into terms of one square meter. The density estimates of grama grass show it to give approximately a 70 per cent covering within the area measured. The production from one meter

should, therefore, be divided by 0.70 to give the production from 100 per cent ground cover on one square meter.

It is not so easy to convert the wheat grass because of its different growth habit. The problem is to find out how many stalks are necessary on a meter square to form a one hundred per cent ground cover. Fortunately an experiment plot which had been protected for several years was found to contain a maximum stand of wheat grass which measured up to all the requirements of a perfect covering. Countings were made on this area of the number of stalks in some 20 meter squares. These were averaged together and found to consist of 1,374 stalks per square meter. This number divided by 50 stalks gives 27.48 as the number of samples needed to make up one meter of ground cover. The figures listed in Table 6 should, then be multiplied by 27.48 to give the weight produced on one meter of ground with a 100 per cent cover.

The results given in Tables 5 and 6 when treated as explained above become equivalents, namely grams yielded per square meter with 100 per cent ground cover. These results are given in Table 7. The average for the group is given for each date clipped.

Table 7 and Figure 10 show the dry weight yield of grama grass (Bouteloua gracilis) and of western wheat grass (Agropyron Smithii) from a meter square with one

hundred per cent density.

Table 7.---Average yield of grama grass and western wheat grass in grams

	Grama Grass				
	June 3	June 18	July 2	July 31	August 20
Grams	42.2	67.5	45.4	48.8	36.1

	Western wheat grass					
	June 2	June 17	July 1	July 15	July 29	Aug. 17
Grams	73.65	138.5	196.5	186.9	115.4	101.1

Table 7 shows western wheat grass to produce a much greater volume per unit area than is produced by grama grass. It also shows that grama grass reaches its maximum volume earlier than does wheat grass and consequently that wheat grass is better late season grazing and grama grass better early season grazing so far as volume is concerned. For comparative purposes the results shown in Table 7 and Figure 10 give a definite, measured value for the volume relationship between these two species. It will be noted that volume increases steadily during the growing season and decreases correspondingly as the plant dries out after maturity. Weight losses were probably due largely to the action of grasshoppers which became exceptionally numerous during the latter part of the season when these studies were made.

The use of these data depends upon the season grazed, because they are not proportional during different seasons.

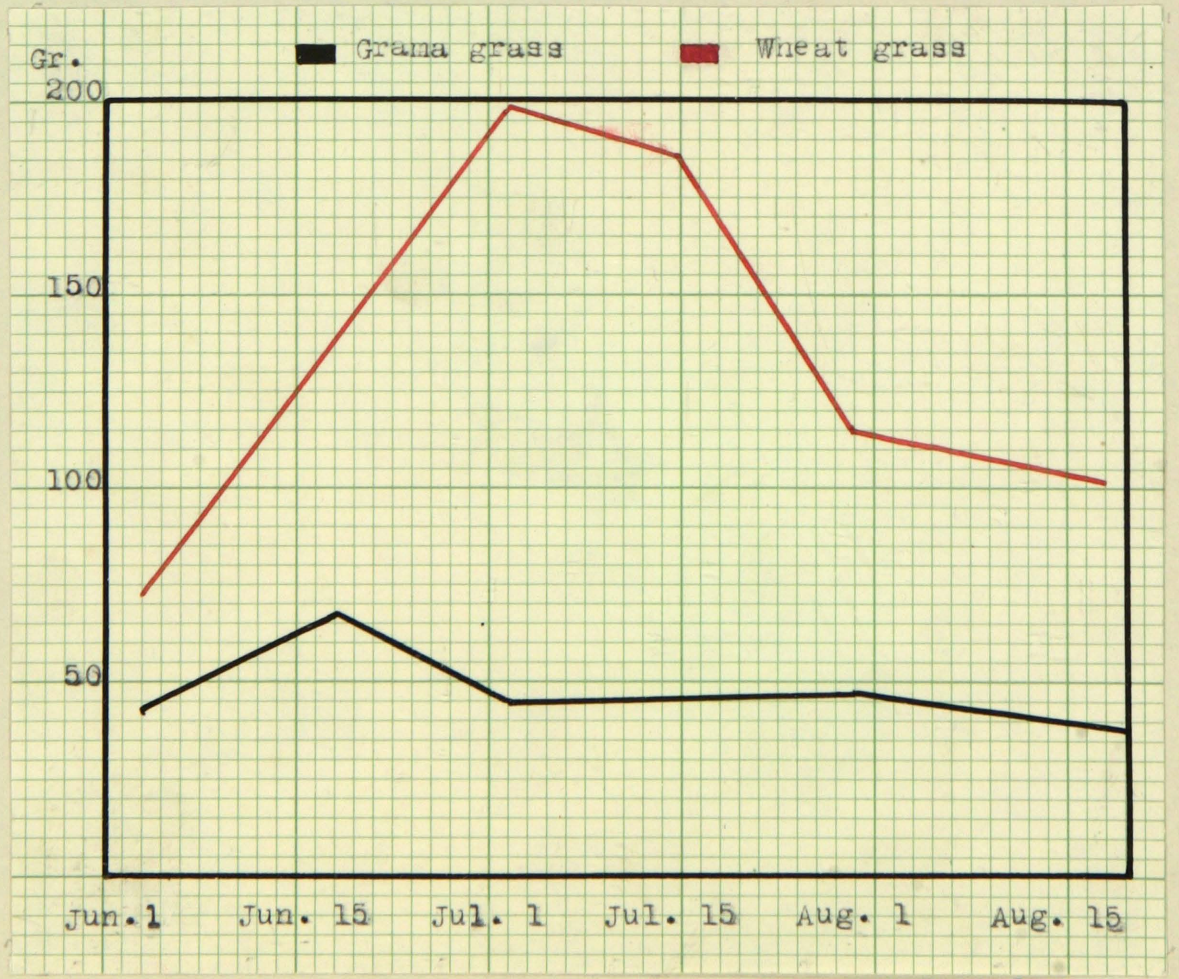


Figure 10.---Graph showing the volume of Bouteloua gracilis and Agropyron Smithii which was produced during various periods of the summer of 1931. This measurement was made in grams per square meter.

Thus grama grass will offer almost as much volume as wheat grass during the early season while later in the season it offers only about one-third as much volume. Since Standing's method does not consider the seasonal variation the method used in the above studies seems to be a more accurate measurement.

The weights for each plant during the season grazed may be averaged and the resultant figure be used for comparison. Thus if the area studied were grazed from June 1 to August 20 the figures for each grass would be averaged together to obtain the average volume exhibited during that period. If the pasture studied were grazed from June 1 to August 20 the figures presented in Table 7 would all be averaged together and the resultant figure be used for comparison.

When the weights shown in Table 7 are averaged together the following figures are obtained: 48 grams--average volume for grama grass; 135 grams -- average volume for western wheat grass.

From this it is evident that during this season western wheat grass had a volume approximately 2.81 times as great as that of grama grass. Therefore, all other factors being equal, western wheat grass would have a value 2.81 times as great as grama grass, despite the fact that grama grass has a 20 per cent higher palatability.

It will be remembered that in these calculations the plants were clipped at a height which allowed for their respective palatabilities and hence the palatability need no longer be considered as a factor. Using no volume measure these two grasses were rated as to value according to palatability, namely grama grass 90 and wheat grass 70. From the volume studies discussed above it becomes evident that these palatability ratings are inadequate because, other factors being equal, wheat grass is 2.81 times as valuable as grama grass.

In conclusion it may be stated that inasmuch as some plant produces more than 10 times as much volume per unit area as other plants, volume must be considered in rating plants as to value. The method of determining this volume is a method of measuring the yield from a unit area which has been clipped at a proportional height equivalent to its palatability. That such a method would be practical is shown by the fact that western wheat grass, previously rated as having a lower value than grama grass, has in reality, a value 2.81 times as great as grama grass due to its excessive volume production.

3. Chemical constituents and digestibility

It is evident that the volume produced, or the volume eaten by stock is not the sole deciding factor for determining the value of a plant. It is no more reasonable to assume that one range plant is equivalent to another, volume for volume, than to assume that pound for pound of alfalfa is equal to oat straw. Every plant has its own value as a feed, which value depends upon its constituents, namely, crude protein; ether extracts or fats; crude fiber, and nitrogen-free extracts, which together make up the carbohydrates; and the mineral content referred to as ash. The amounts of the above constituents can be only a relative comparing standard, for actual feed value depends upon digestibility, or the actual percentage of the constituent that is utilized by the animal.

"The analysis is used to give an idea of the feed value of the forage and is often used to confirm work on stock feeding. The analysis must not be considered final before feeding tests have been made with the forage. Chemical analysis can be used in comparing different kinds of forage. If one plant contains more protein and ether extract than the others it is considered of higher feeding value." (10)

Chemical analysis of forage has been worked on quite extensively by several experimenters. All the important cultivated crops and many of the range plants have been analyzed.

Almost all work on range plants is deficient, however, in that it does not cover any special season, the type of growth, site, and habitat are not given, and no attention is given to digestibility.

Perhaps the most extensive work is that of Henry and Morrison (21). Their work covers the most species and is the only workwhich adequately covers digestibility.

The most extensive work on western range plants is that of the Wyoming Experiment Station (10), (16), (17), (18), (20), (21). Work was begun as early as 1905 but includes only the general analysis and not digestibility. The seasonal variation mentioned in this work was as follows: a definite drop in the percentage of protein toward the end of the season; variations in the percentage of carbohydrates. These variations show no definite trend as related to season, however. Considerable irregularity was found in the fiber content with a general tendency toward increase as season progresses and a decided variation in both ash and fats with a slight tendency toward increase of fat with maturity. This work indicates that forage plants are less valuable as feed

when harvested unduly late.

Extensive analysis made by the Colorado experiment station on range and pasture grasses (3) gives a general figure for many range plants but lacks date and location figures and so can be used for comparison only.

The publications listed all offer material for comparative information but do not show the variation from season to season and do not rate the plants according to value from an analytical viewpoint, or according to digestibility.

While chemical analysis in itself offers no definite figure of value, it may be interpreted for some indication as follows (4)

1. Water - Water is of no feeding value but influences the palatability of the feed. Limited amounts of water are, then, of some value and are desirable.

2. Ash - The ash substances present in feed play an important part in the physiological processes of digestion but possess no value as an energy source. Ash furnishes lime and phosphorus for bone building, sulfur and phosphorus for cell constituents, etc. Most feeds furnish sufficient ashand any increase is not necessarily to advantage.

3. Crude protein - Crude protein is made up of nitrogenous material from which the animal derives its

muscle tissue, ligaments, hair, and replacement material. The more protein a given feed contains, the better is its quality as compared with other similar feeds.

4. Crude fiber - The most indigestible part of the feed, including cell walls and woody material, comes under this head. It is not digested in any considerable amounts, but has a value somewhat similar to that of sugar and starches. The fact that a grass cures well and retains its nutritive qualities is said to be due to the large amounts of crude fiber present. It cannot, therefore, be said that fiber is objectionable but it is the least valuable of the constituents.

5. Fat - Fat furnishes heat and energy to the animal and next to protein, is the most valuable part of the feed.

6. Nitrogen-free extract - The sugars, starches and non-nitrogenous organic acids, together with soluble cellulose make up the nitrogen-free extract. It is more soluble and hence more digestible than fiber, and thus has a higher nutritive value.

The work presented below gives the seasonal analysis of range plants, and a method whereby comparable values may be obtained, by the use of nutritive ratio. In this way it is possible to show which of two species is the more valuable feed and also to show what season is the best for grazing each species, since chemical make-up

varies with season.

The analysis method used in this work is that outlined by the Association of Official Agricultural Chemists (2). Nitrogen-free extract was found by subtraction. All analyses was based on oven-dry weight. Figures for digestibility were taken from Henry and Morrison(15).

The samples analyzed were collected during the summer of 1931, at intervals approximating two weeks. The grasses were clipped at the height normally eaten by stock. Analyses weremade on grama grass (Bouteloua gracilis) and on western wheat grass (Agropyron Smithii), which were considered the two most important grasses on the college pasture and which offered two extremes in type. Ten separate samples were taken for each grass at each time interval, each sample being clipped at random over the pasture. The samples were inclosed in air tight cans, taken to the laboratory, and weighed immediately. They were then oven dried and the loss of water recorded. The samples were next stored in covered cans until analysis was made. All samples were ground to a two millimeter texture and those of the same date were thoroughly mixed. Analysis was made in duplicate on all samples, and where doubt occurred, triplicates were run. When any appreciative variation which was not sufficient to cause a recheck

occurred between duplicate samples, the two readings were averaged, to obtain the accepted figure.

The results of the analyses are given in Table 8 and the accompanying graph (Figure 11). Table 8 shows the chemical analysis of two important range grasses collected at two-week intervals during the grazing season of 1931. The analysis included crude protein, ether extract, crude fiber, nitrogen-free extract, and ash. All figures are based on oven-dry weights, and are listed in percentage.

Table 8.--The chemical analysis of grama and wheat grass (dry weight)

1931 Date	Grama grass June 3	June 18	July 2	July 25	July 31	Aug. 20	Season Average
Crude protein	12.65	11.06	10.43	9.30	8.13	7.24	9.8
Ether extract	3.15	2.1	2.37	1.45	1.78	3.2	2.3
Crude fiber	26.0	25.2	27.1	27.3	22.0	25.35	25.8
Ash	7.55	10.9	9.56	9.2	11.65	12.5	10.2
Nitrogen-free extract	50.65	50.74	50.54	52.75	57.44	51.71	52.1

1931 Date	Western wheat grass June 2	June 17	July 1	July 25	July 29	Aug. 17	Season Average
Crude protein	17.49	16.21	10.4	7.08	7.65	6.68	10.9
Ether extract	4.11	4.1	2.8	2.35	3.10	4.65	3.5
Crude fiber	27.6	28.0	30.1	30.45	29.05	32.3	29.7
Ash	7.35	8.65	7.15	8.2	8.8	7.85	8.0
Nitrogen-free extract	43.45	43.04	49.55	51.92	51.40	48.52	48.0

It will be noted in Table 8 that there is a very regular drop in the crude protein content as the season progresses. In view of the fact that crude protein is the

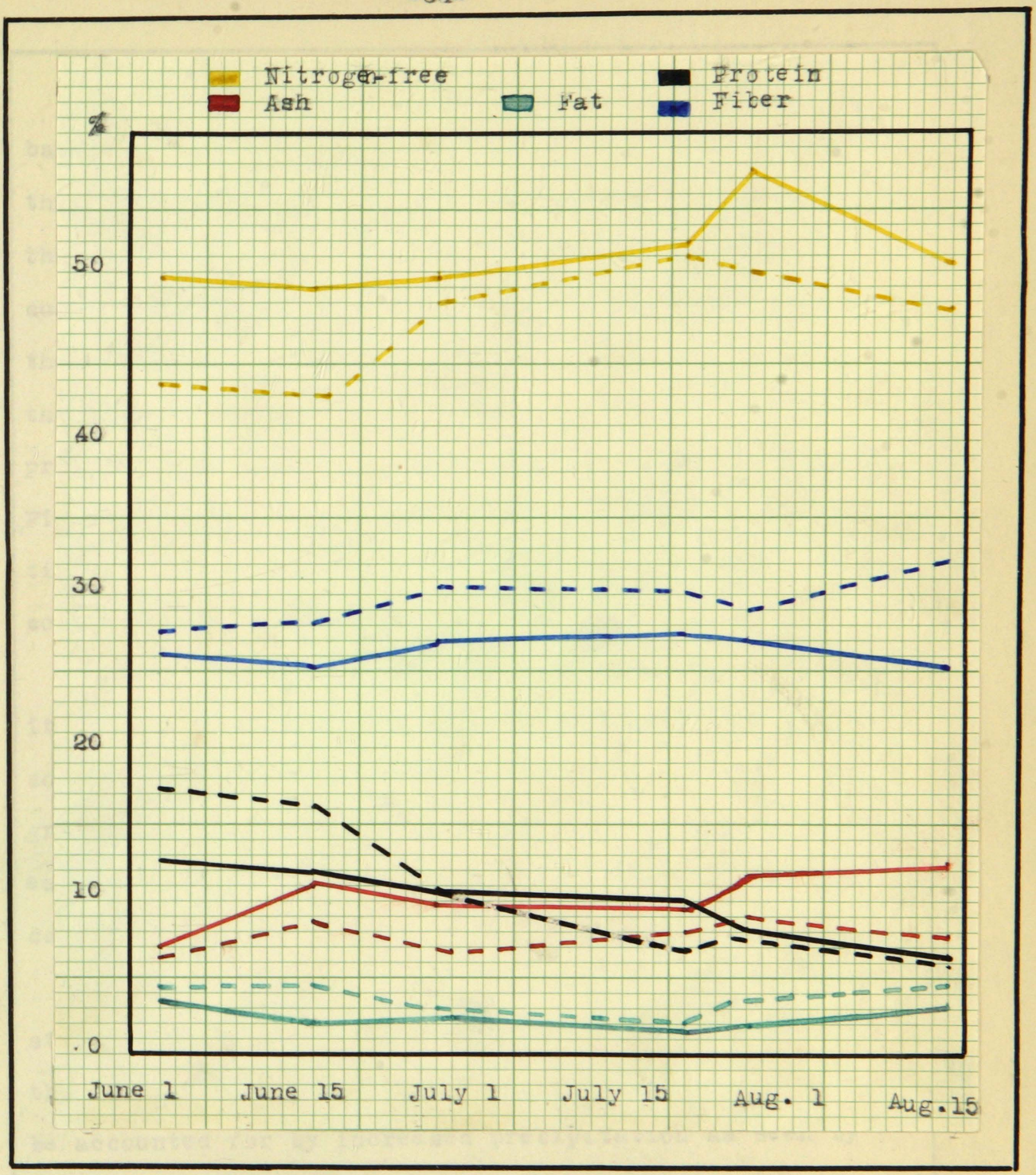


Figure 11.--Graph showing the chemical analysis of Agropyron Smithii and Bouteloua gracilis for various seasons of the year of 1931. Solid lines represent Bouteloua gracilis and dotted lines represent Agropyron Smithii. These percentages are based on oven dry weight.

basis of computing the forage value of a feed, it shows that the grasses have a definite decrease in value during the summer season. This drop is probably closely connected with the drop in precipitation. Figure 12 shows the rainfall wnich occurred during the summer of 1931 at the time the samples were taken. Figure 13 shows that the protein drops to a level after August first. Since Figure 12 shows late summer rains to occur also at this time it indicates a relationship existing between protein content and rainfall.

While grama grass is lower in crude protein content, it will be noted that the drop is much less than that shown in western wheat grass, and, for this reason, grama grass is a better late season feed and wheat grass a better early season feed, as far as chemical constituents are concerned.

Ether extract is high during early summer but drops steadily until midsummer. This probably is the result of the grass drying out. The reverse, during late summer may be accounted for by increased precipitation as seen by comparing Figures 11 and 12 or by the development of seed which is known to have a high fat content. Both grasses show a decided fat increase during the latter part of the season.

Both fiber and ash seem to have variation within the

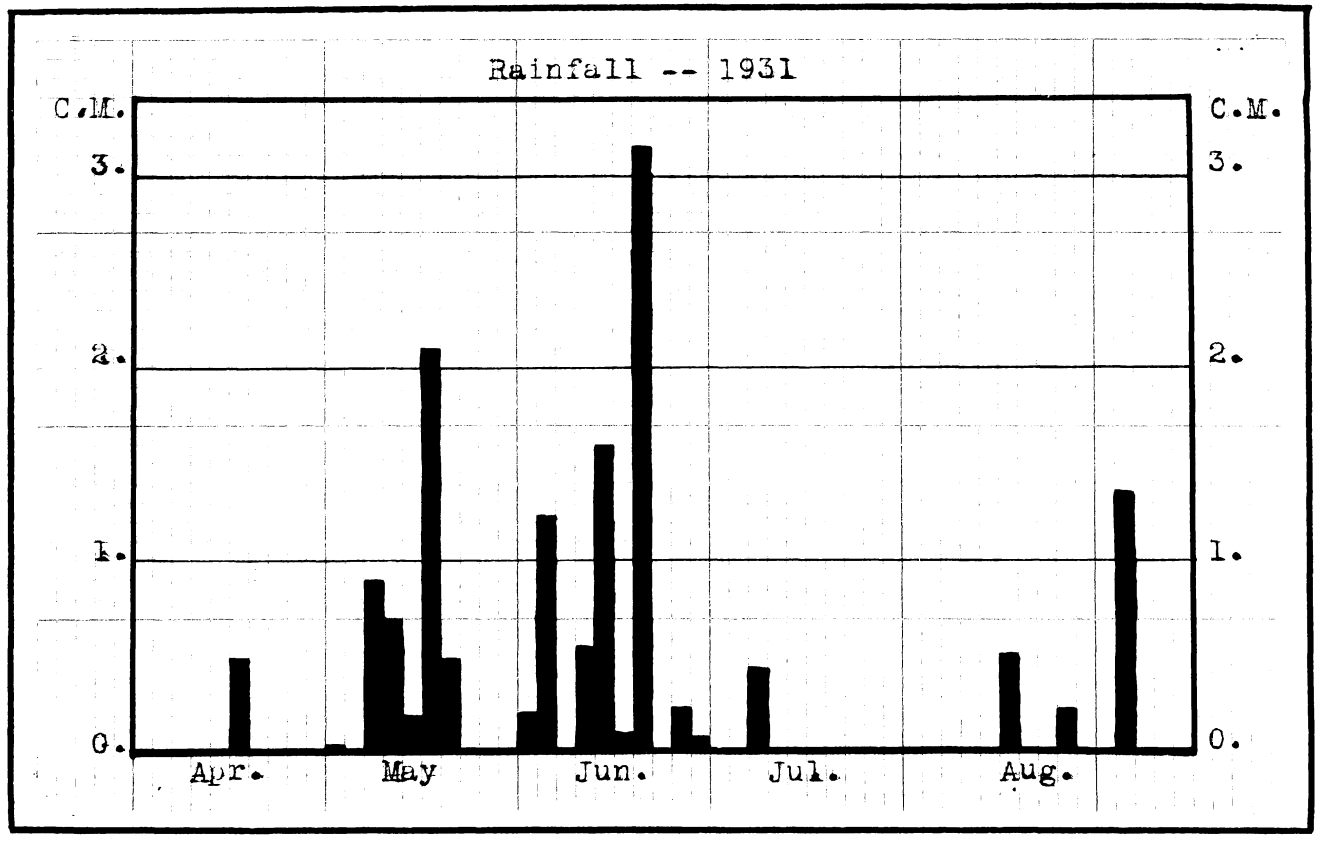
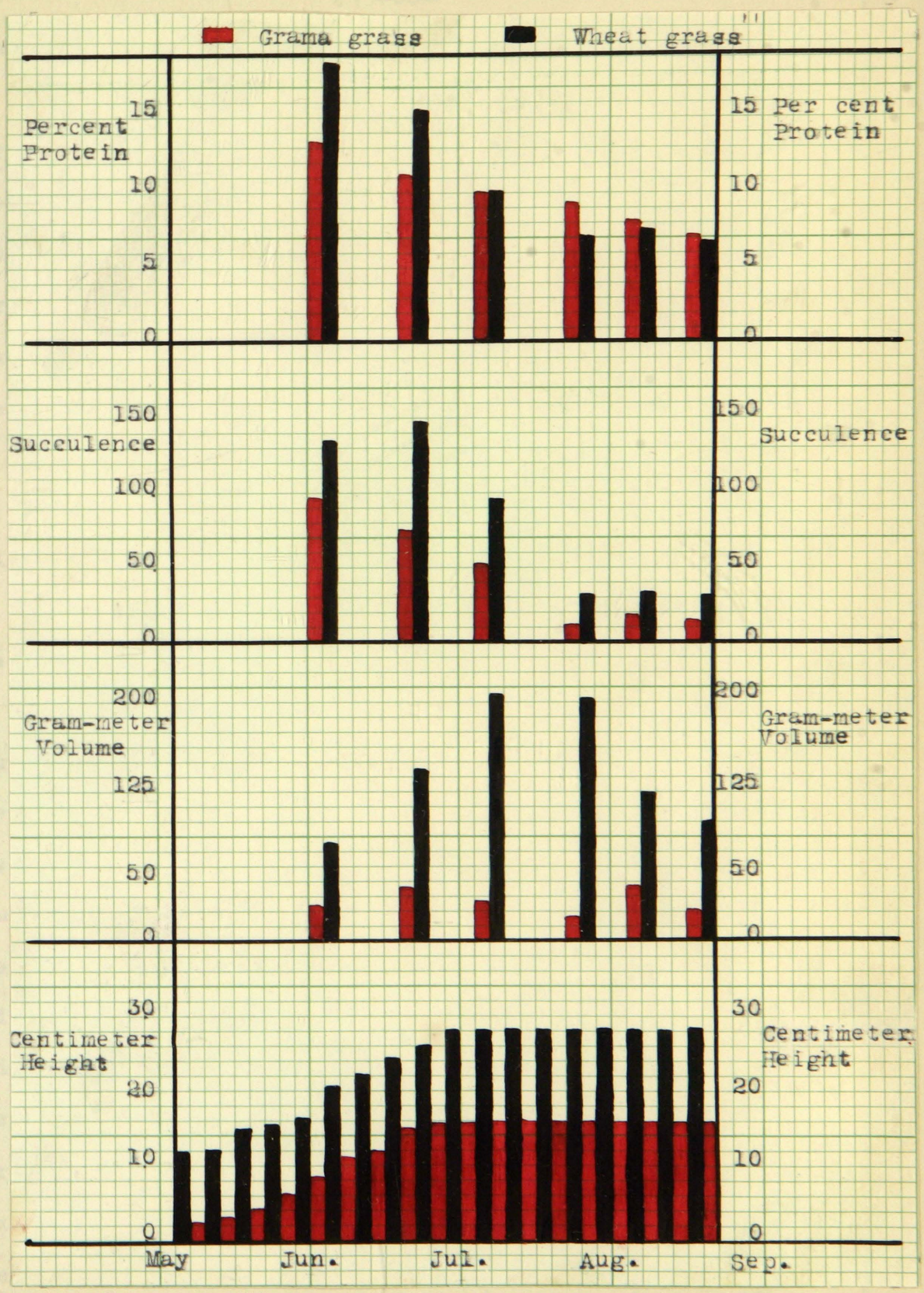


Figure 12.--Graph showing the centimeters rainfall at Fort Collins, Colorado during the summer of 1931. (Data from Colo. Agric. College Weather Bureau).

Figure 13.--Graph showing the comparison of grama grass and western wheat grass as to height, volume, succulence, and protein content during the summer of 1931.


Grama grass
Wheat grass
Percent Protein
15
10
5
0
15 Per cent Protein
10
5
0
Succulence
150
100
50
0
150
Succulence
100
50
0
Gram-meter Volume
200
125
50
0
200
Gram-meter Volume
125
50
0
Centimeter Height
30
20
10
0
30
Centimeter Height
20
10
0
May
Jun.
Jul.
Aug.
Sep.

samples only. No consistant tendency is shown except for a fiber increase in western wheat grass, as the season progresses. This fiber increase is known to characterize very dry weather conditions. The slight rains in early August probably account for the fiber drop found in grama grass during the latter part of the season. Grama grass due to its lack of height, reacts very readily to slight moisture changes. This drop was not noted in wheat grass.

Nitrogen-free extracts show a tendency to increase as the season progresses but again a decided drop takes place in both grasses as the late rains appear.

The effect of late rains or late season maturity can be noted in all five constituents as Figure 11 shows.

To summarize these changes during the season the nutritive ratio can be applied. The nutritive ratio is merely a relative figure which shows the ratio existing between crude protein and all other digestible constituents, offering a simple means of comparing feeding value. All figures used in computing this value are digestible percentages and not total values. The digestible figures used are those of Henry and Morrison(15) and may be enumerated as follows: Western wheat grass - crude protein 55 per cent; fiber, 69 per cent; nitrogen-free extract, 63 per cent; fat, 41 per cent. These digestible percentage figures are known to vary somewhat in different

regions due to high altitude, moisture, etc., which affect somewhat the solubility and hence digestibility. The listed figures are approximately correct and may be used as a working basis, since digestibility experiments are too detailed to attempt in every region.

To obtain the nutritive ratio of wheat grass the figures listed in Table 8 are multiplied by these digestible percentages and substituted in the following formula:

$$\text{Nutritive ratio} = \frac{(\text{Digestible fat} \times 2.25) + \text{digestible carbohydrates}}{\text{Digestible crude protein}}$$

Grama grass has, as yet, never been tested for digestion percentages, but it has been approximated by Henry and Morrison (15) to obtain some comparative figures. These figures may be listed as follows: Crude protein, 50.0 per cent; fat, 41.2 per cent, and carbohydrates (fiber and nitrogen-free extract combined), 54.9 per cent.

By substituting these figures and those found in Table 8 in the nutritive ratio formula a fairly exact figure can be obtained, but it must be remembered that all available digestion figures are for grass hays cut at the end of the season and may not give a wholly accurate figure for digestible percentage during other seasons.

The nutritive ratios obtained for grama grass and western wheat grass by this method are given in Table 9

and Figure 14. This table shows the change in ratio as the season progresses and also offers a means of comparing feeding value of the two grasses.

Table 9.--Nutritive ratios of grama and wheat grasses.

Wheat grass	Date	June 2	June 17	July 1	July 25	July 29	Aug. 17
	Ratio	1:5.2	1:5.6	1:9.5	1:14.3	1:13.1	1:15.5
Grama grass	Date	June 3	June 18	July 2	July 25	July 31	Aug. 20
	Ratio	1:7.1	1:7.9	1:8.5	1:9.7	1:11.1	1:12.5

A very decided increase as the season progresses may be noted in these figures. The ratio, then, may be said to become wider as the grass matures. Both grasses have a relative narrow nutritive ratio and grama grass one that is very constant. In general a feed with the narrow ratio is the more valuable. A ratio 1:6.3 is said to be about average for feed. Thus during June wheat grass is a very valuable feed, being far above average and better than some of our common grains. During the last of July and August, however, the ratio has become so wide that the grass is of little value unless supplemented by nitrogenous feeds. It may be said that wheat grass is a very valuable feed during the early season but losses value rapidly as it matures. Its value depends upon the stock. Thus a young animal will make best gains at a ratio of 1:4, while a mature animal will thrive best at a 1:10 ratio. A ratio of 1:6 is generally spoken of as a balanced ratio (26).

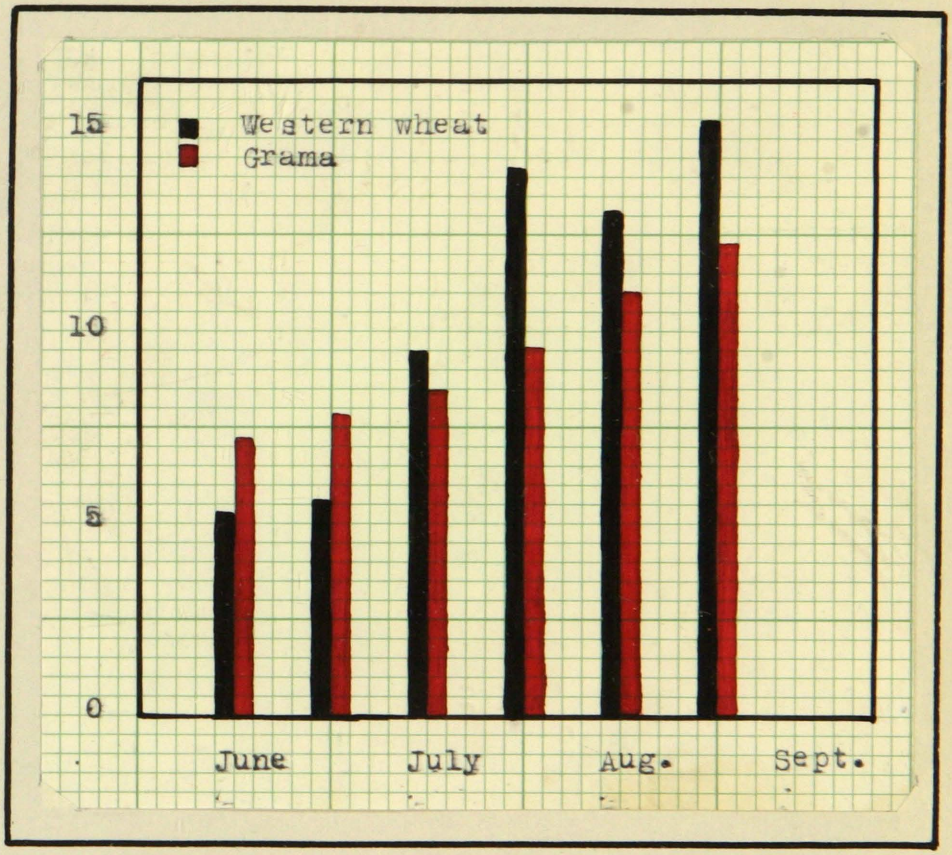


Figure 14.--Graph showing width of the nutritive ratio exhibited by Agropyron Smithii and Bouteloua gracilis during the grazing season of 1931.

The correct time to graze a wheat grass pasture, therefore depends on the class and age of stock. For young stock it offers the best feeding value during June, however, for mature animals July will give the best results. After the first of August, without supplementary feeds, the wheat grass pasture is of little value except as maintainance feed.

Grama grass offers a good feed, unsupplemented, until August. It compares very favorably with wheat grass, for, though wheat grass offers the narrower ratio during June, the grama grass gives a considerably narrower ratio for July and August. The wheat grass ratio widens much more rapidly and much more variation is shown. For an average figure during the grazing season grama grass offers a 1:9.4 ratio while wheat grass offers a 1:10.5 ratio.

Either figure is very good as a 1:10 ratio is suggested for mature animals. From the standpoint of nutritive ratio, however, grama grass offers the better feed for the season as a whole.

The water lost between green and oven dry grasses may be considered as a constituent of the grass and on analysis shown based upon green, rather than oven dry weight. When so figured the percentages show what is actually consumed by the animal when the grass is eaten.

These figures can be found in Table 10. The figures may be looked upon as the actual pounds of various constituents found in 100 pounds of green grass for different times during the season.

Table 10.--The chemical analysis of grama and wheat grass (green weight)

	Grama grass					
Date	June 3	June 18	July 2	July 25	July 31	Aug. 20
Crude protein	6.4	6.31	6.79	8.24	6.9	6.23
Ether extract	1.6	1.19	1.54	1.28	1.5	2.75
Crude fiber	13.1	14.36	17.60	24.22	18.7	21.81
Ash	3.8	6.21	6.23	8.15	9.9	10.75
Nitrogen-free extract	25.6	28.93	32.95	46.76	48.8	44.5
Water	49.5	42.99	34.81	11.34	15.22	13.94

	Western wheat grass					
Date	June 2	June 17	July 1	July 25	July 29	Aug. 17
Crude protein	7.86	6.67	5.26	5.30	5.67	4.96
Ether extract	1.84	1.69	1.41	1.76	2.30	3.45
Crude fiber	12.40	11.53	15.23	22.82	21.56	24.00
Ash	3.30	3.56	3.62	6.14	6.53	5.83
Nitrogen-free extract	19.57	17.73	25.13	38.92	38.15	36.05
Water	55.07	58.86	49.39	25.03	25.75	25.7

It may be seen from table 10 that the wheat grass protein still shows the consistent drop which characterized oven dry material. Fiber shows a decided increase, as the season progresses, in both grasses. Fiber cannot be classed as a desirable constituent and again it becomes evident that the value of the plants decreases with maturity. Ash and nitrogen-free extracts both show steady

increase as maturity is approached.

Since rain was very scarce during the entire season of 1931 the water content or succulence is also seen to take a steady drop throughout the summer. Water may be considered as a valuable constituent in that it adds to the succulence and palatability of the grass. The rainfall during the 1931 season is shown in Figure 12.

A very important feature can be brought out by combining the results of volume experiments listed in Table 7 with the analysis experiments listed in Table 8. When the two listed figures, i. e., volume and per cent composition, are multiplied together the actual amount of each constituent per unit area may be obtained. In Table 11 may be found figures representing the pounds yielded per acre of one hundred per cent cover. These data, because they present the actual obtainable nutrient per unit area, give the best means of comparison.

In Table 11 the various constituent percentages based on dry weight are combined with the dry weight volume yield to give the actual pounds per acre yield of all constituents during the season.

Table II.--The volume constituents yielded by grama grass and wheat grass

Grama grass

Date	June 3	June 18	July 2	July 31	Aug. 20	Season average
Crude protein	47.6	66.6	42.4	35.4	23.3	43.02
Ether extract	11.9	12.6	9.6	7.7	10.3	10.42
Crude fiber	97.9	151.7	109.7	95.8	81.6	107.54
Ash	28.4	65.6	38.7	50.7	40.3	44.54
Nitrogen-free extract	190.6	305.5	204.6	245.7	166.5	222.58
Total	376.4	602.1	404.9	435.3	322.0	428.14

Wheat grass

Date	June 3	June 17	July 1	July 25	July 29	Aug. 17	Season average
Crude protein	114.9	200.3	182.3	117.8	78.8	60.2	125.7
Ether extract	27.0	50.6	49.1	39.1	31.9	41.9	39.9
Crude fiber	181.3	345.9	527.6	506.6	299.0	291.3	358.6
Ash	48.3	106.9	125.3	136.4	90.6	70.8	96.4
Nitrogen-free extract	285.4	531.7	868.5	863.9	529.1	437.6	568.0
Total	656.9	1235.4	1752.8	1663.8	1029.4	901.8	1206.7

It will be noted in Table II that both grasses give greatest protein production in the middle of June. That, therefore is the ideal time for grazing such pasture so far as volume and constituents are concerned.

The average of production throughout the season gives a definite means of comparison to determine the relative seasonal value of the two plants with regard to production. Crude protein, which, it will be remembered, is the basis of feeding value, is found to have only 34.2 per cent as much volume in grama grass as that produced in wheat grass. It may, then, be stated that for actual feeding constituent production, wheat grass is approximately three times as valuable as grama grass.

Chemical analysis indicates that plants vary in composition to a considerable degree even within relatively similar areas. Table 12 shows the variation obtained by three different workers in the analysis of wheat grass samples from regions relatively close together. All figures are given in average percentages.

Table 12.--Wheat grass analyses

	Local average for 1931 season	Average of all analysis by Wyoming Station	Colorado Experiment Station 1889
Ash	8.0	7.04	5.74
Ether extract	3.52	2.36	2.24
Crude fiber	29.7	35.63	21.14
Crude protein	10.92	7.68	7.10
Nitrogen-free extract	47.98	47.27	63.78

There are very decided fluctuations among these figures listed in Table 12, with seemingly no consistency. There are several factors which must be considered. The nitrates in the soil, for example, have been proved to be almost a controlling factor for protein content. It is known that drouth causes increase in fiber and decrease in protein (21). The Wyoming station has shown definite variation in protein content due to altitude, plants of higher elevation having a higher protein content (17), (18). Shading was also found to be influential in protein production (20).

In conclusion, therefore, it is evident that analyses can be only relative unless they are performed for each region in which readings are desired. Strict attention must be given to the season in which the area is to be grazed.

Without chemical analysis it is difficult to determine the actual value of a plant for feed. Digestion percentages should accompany the analysis figures.

Chemical analysis in itself gives only comparison between grasses. With digestibility figures a nutritive ratio can be obtained which gives the most usable figure for determining the feeding value of a plant and for a comparison between different species. Seasonal variation can be clearly demonstrated both by the use of nutritive ratio and by the use of volume production of each constituent. Volume protein production during the season shows wheat grass to yield three times as much protein per unit area as is produced by grama grass.

Chemical analysis serves an important part in the determination of plant value since it indicates the most nutritious species and the most productive season. Despite the difficulties involved in chemical analysis its importance more than justifies its consideration.

4. Characteristics affecting grazing value

There are certain physical factors characteristic of some plants which make them unfit for stock to eat, either during a certain season or perhaps during all seasons. It is evident that the value of a plant on the range may be seriously lowered by the presence of objectionable features such as sharp awns, stipes, leaf blades, thorns, etc. Plants may be avoided because of their toughness during late seasons, due to fiber development, or due to drying out of the tissues. Habitat of the plant may be objectionable because of an inaccessible location. Such are the plants characteristic only of rocky hillsides. The plant may have roots so short that the animal cannot graze without pulling the entire plant. Some plants may never attain a height which can be grazed. These and many other factors may decrease the value of a plant on the range.

Practically no work has been done in rating plants on the basis of their physical factors. Workers such as Pammel (23), (24), (25), Long (19), Nelson (22), Durrell and Glover (11), (12), and Harshberger (13) have mentioned mechanical injury attributed to various plants but this has not been correlated with grazing value.

Plants thus referred to are injurious because of spines, awns, sharp leaves, excess fiber, etc. These include the following:

1. Hordeum jubatum
2. Stipa vaseyi
3. Stipa viridula
4. Stipa comata
5. Stipa spartea
6. Stipa capellata
7. Stipa setigera
8. Bromus tectorum
9. Cenchrus tribuloides
10. Aristida longiseta
11. Trifolium incarnatum
12. Opuntia Engelmanii
13. Avena fatua
14. Xanthium canadense
15. Heteropogon contortus
16. Stellaria media
17. Spartina cynosuroides
18. Aira caespitosa
19. Capsella bursa-pastoris
20. Polygonum aviculare
21. Aristida hygrometrica
22. Erodium cicutarium
23. Rosa fendleri
24. Tribulus terrestris
25. Yucca glauca
26. Urtica gracilis
27. Polygonum convolvulus
28. Sarcobatus vermiculatus
29. Equisetum arvense
30. Lappula major
31. Bidens frondosa

Some of these plants are very valuable range plants; others are worthless. Plants such as the Stipas have very high value for seasons in which their sharp awns are not present. It can readily be seen that the value of such plants is not seriously lowered if the animal does not eat them during the awn-bearing season. The seriousness comes when the plants are eaten in spite of these features. Some plants not eaten directly may be taken along with other feed. Such are the long awns and dissected racheae which are blown by the wind and distributed among palatable feeds where they can be taken up by the animal, causing serious injury and sometimes death. Such plants also are dangerous to the eyes, nose, and even to the body of an

animal. Grasses such as Stipas (See Figures 15 and 16) may be brushed up against by the grazing animal, and a stray fruit with its long jagged awn be lodged in the wool of the face. By means of the long barbed awn it may work into the animal's eye. Serious inflamation and even blindness may result. A section of the racnis of Hordeum (See Figure 21) which has become lodged in the blades of a palatable grass may enter the nostril of a grazing animal. Here it may work into the nasal chambers and cause considerable damage. Stipa awns may become lodged in the wool of sheep and, as the awn absorbs moisture it will twist and turn, sometimes pushing the sharp bristled callus of the fruit into the animal's flesh causing great discomfort to the stock and often ruining the pelt.

Plants which have a high fiber content may produce balls similar to hair balls in the animal's intestine. This formation may result in a mechanical obstruction causing death. The most common and serious disease resulting from mechanical injury onour ranges is the common actinomycosis or lumpy jaw. This disease is a swelling or tumerous growth on the head of the animal. Actinomycosis is a disease of the bone of the jaw, caused by a ray bacterium which grows on the plants (9). It has been definitely shown that this disease is transmitted to the

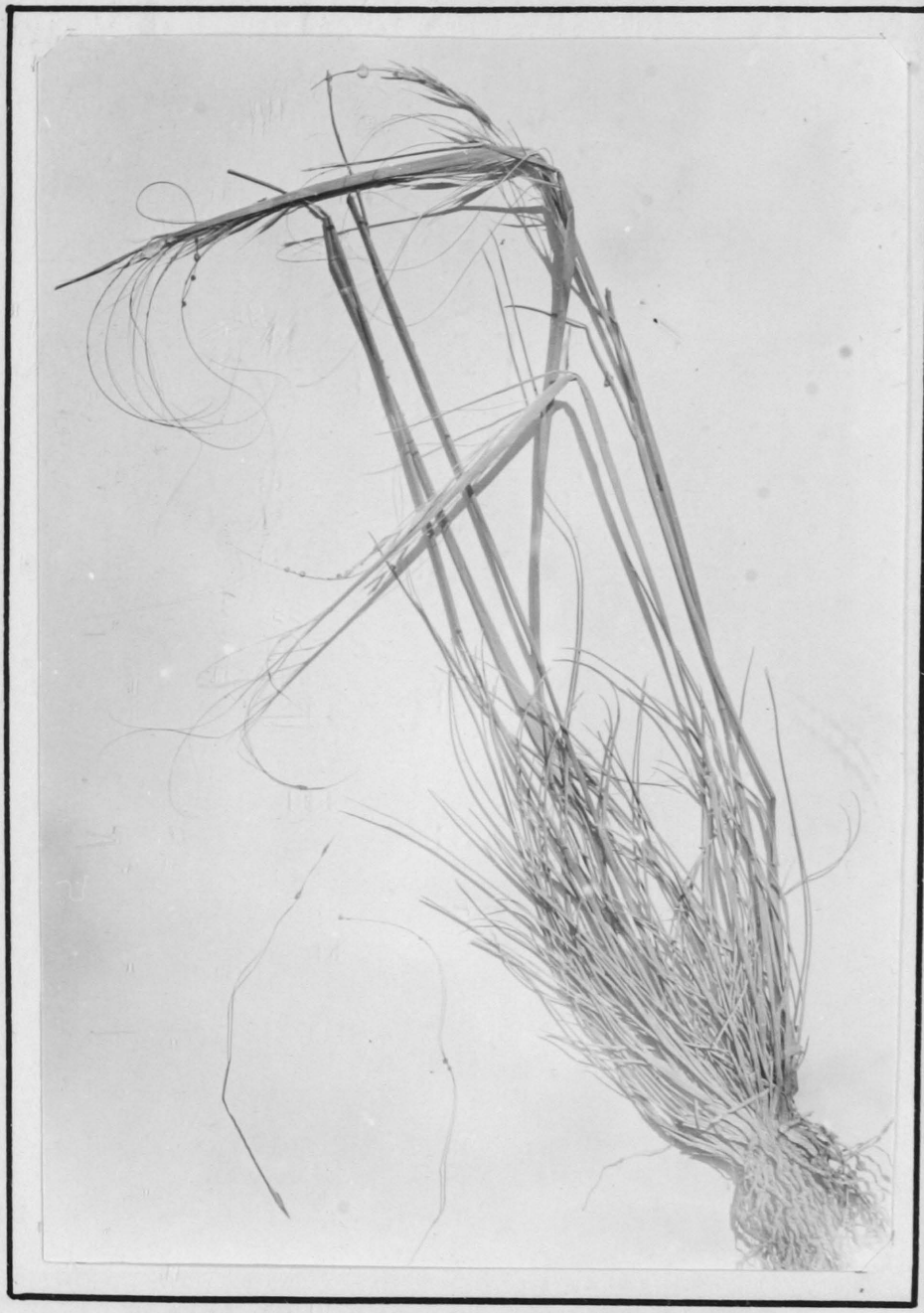


Figure 15.--A plant of Stipa comata showing the long awns and sharp stipes which characterize it. See also Figure 16.

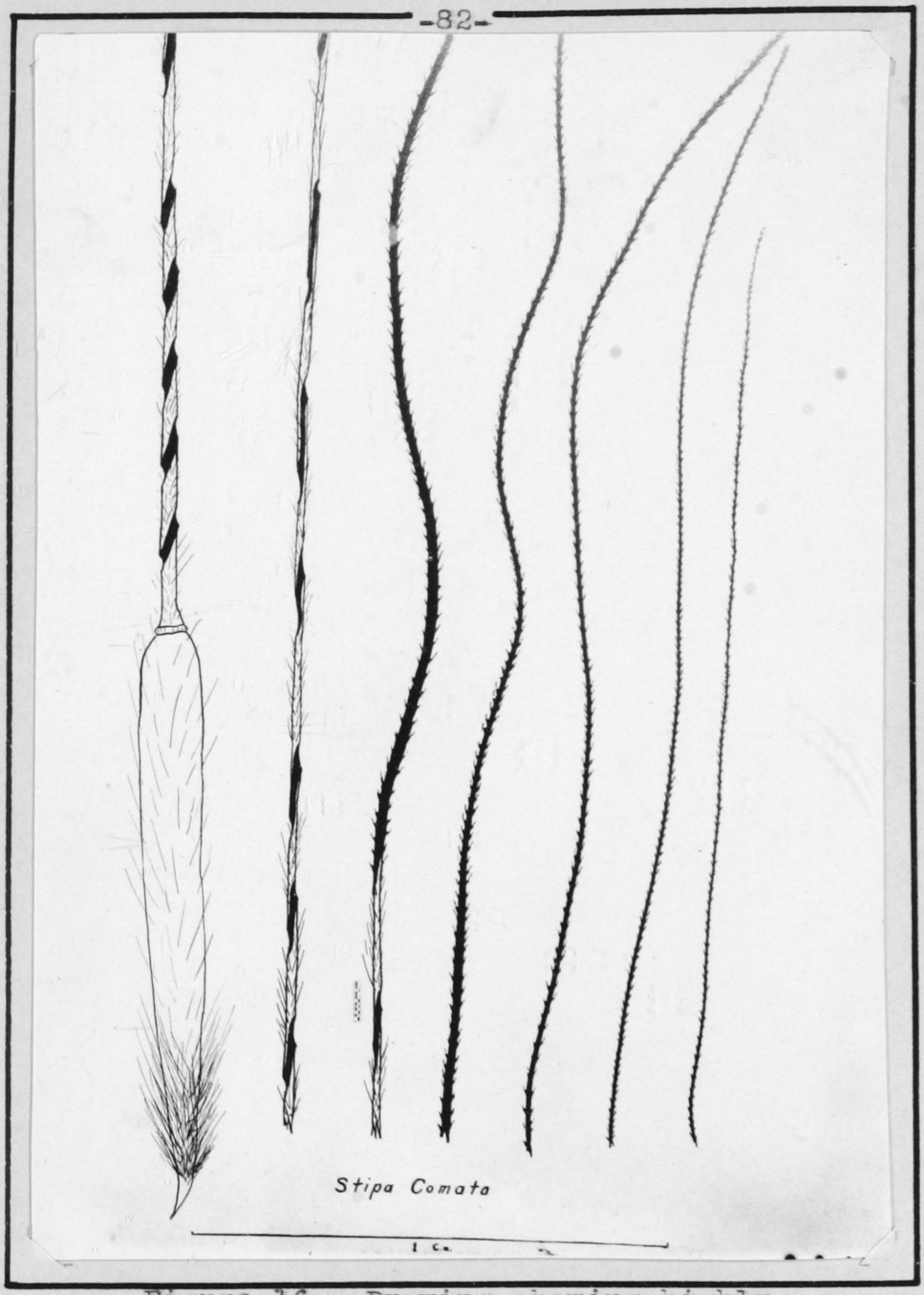


Figure 16.--Drawing showing highly magnified seed of Stipa comata with its abnormally long awn bearing barbs and stiff hairs. Note the twist of the awn and the sharp horny stipe at the base.

Figure 17.--Figure showing the shorter fruits and awns which are produced by Stipa vaseyi. This plant is not palatable and has no value.

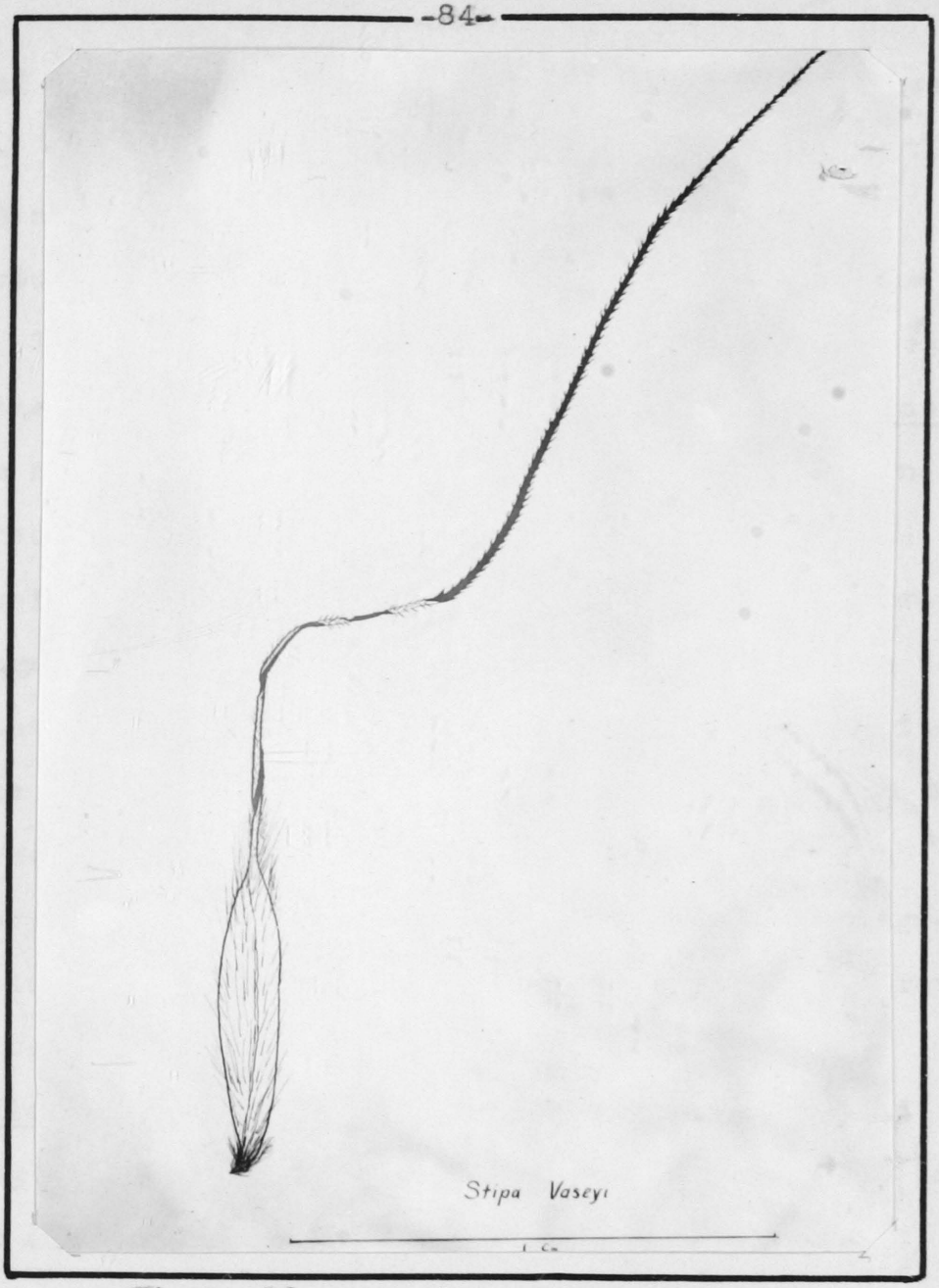


Figure 18.--Drawing showing a highly magnified seed of Stipa vaseyi with its long barbed awn. Note the sharp hairy stipe at the base.

animal through open wounds caused by injury from grass awns. These awns penetrate the mucous membranes of the mouth and carry with them the organism which causes tumerous growths.

The value of some plants is more than enough to offset their objectionable features. Such are the Stipas which have relatively high palatabilities and are considered valuable plants. They act only by seasons so can be avoided during the dangerous period. The high preference value of the Stipas, however, causes animals to eat them at all seasons, regardless of the discomfort that may be encountered. For this reason the plants must only be grazed early, (prior to awn development), or late (after awn dissemination), so a method of range management is necessary and fences should be employed to prevent grazing at other times. Other awned grasses, the Aristidas for example, (See figure 19) are not grazed during the period in which their fruit is dangerous, because of a lower preference. Since the plant is not eaten during dangerous seasons and is grazed extensively after the awns drop, it is evident that the value of the plant is not cut down by the production of awns, since it can be utilized during a late season when it will cause no trouble. Thus the higher the preference and palatability of a plant the more its value is decreased by the

presence of objectionable features.

The value of some plants is not high enough to offset the objectionable features. Hordeum jubatum (See Figure 21) receives an average of about 35 for palatability, but the great damage caused by its awns makes it a highly undesirable plant on a range. Hence it has no value to the range even though it produces good feed during early season.

There are plants whose spines, which are retained throughout the year, make it highly undesirable on a range rather than desirable. Such a plant as the common cacuts has a palatability of zero because stock cannot eat it, whereas it would doubtless be a valuable feed otherwise. Plants which retain their objectionable features throughout the grazable season will always be valueless and so receive a zero rating.

Plants which have a certain palatability, therefore, may be valueless, and so not an asset to the range. Any plant which possesses disadvantages in excess of its advantages would be so rated.

Factors which lower the value of the plant because of mechanical injury are the most important among the physical factors influencing value. There are, however, numerous other factors which may lower the palatability or preference and so be rated as indirect factors.

Figure 19.--Figure showing a plant of Aristida longiseta. Note the three awns which characterize the fruit.

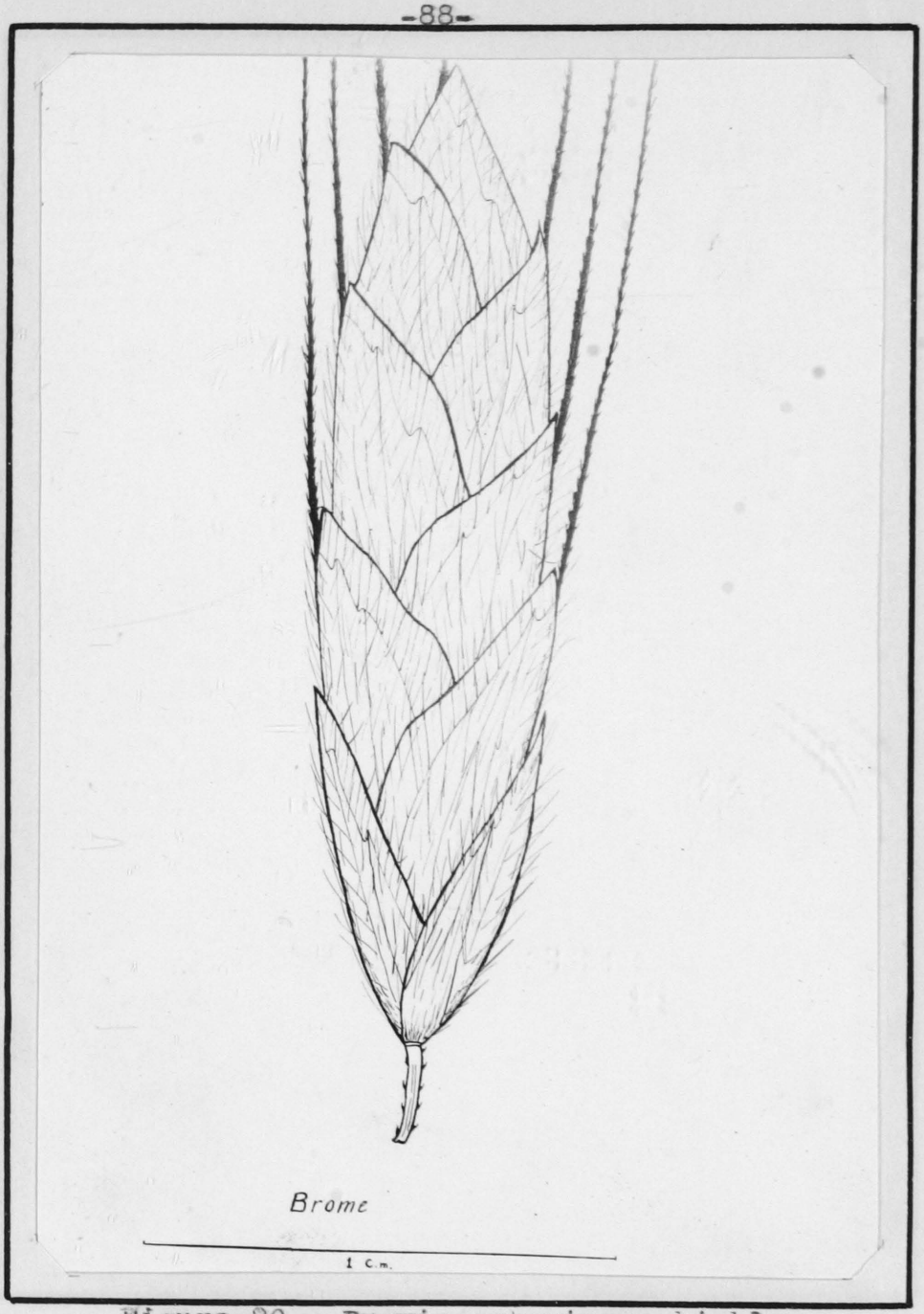


Figure 20.--Drawing showing a highly magnified spikelet of Bromus tectorum. Note the barbed awns and hairy florets.

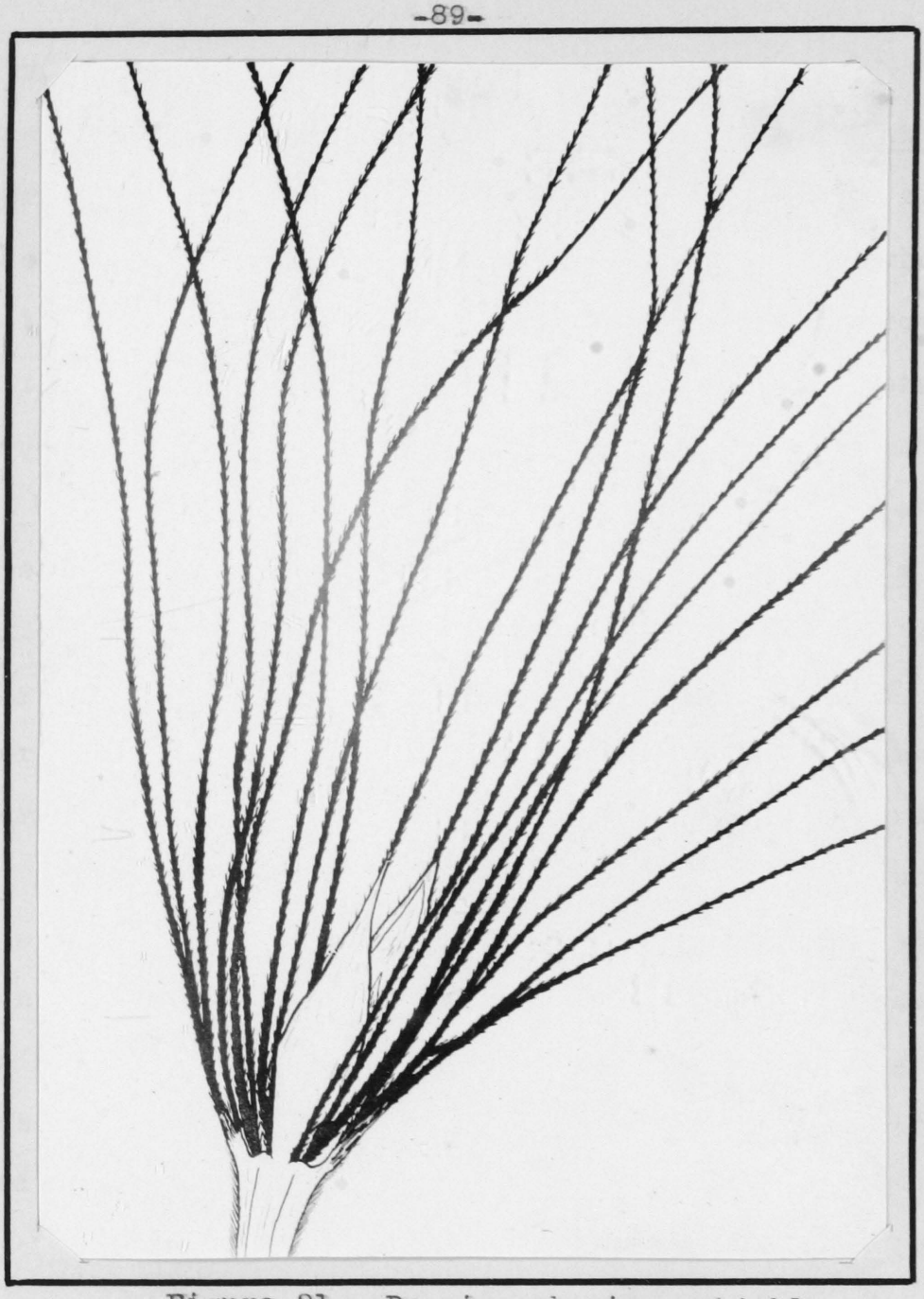


Figure 21.--Drawing showing a highly magnified spikelet of Hordeum jubatum. Note the many stiff barbed awns which characterize the plant.

Numerous annual grasses whose root systems are not developed enough to withstand grazing would be so rated. Bromus tectorum (See Figure 20) offers a good feed prior to fruit development except for the fact that the plant is uprooted with the slightest pull. The animal cannot eat the roots with their sandy mass of soil, and consequently the plant is rejected and so the palatability is practically zero.

Other plants are seriously handicapped because of lack of height growth. Short grasses such as Bulbilis dactyloides (See Figure 22) are very highly preferred and highly relished but the animal cannot graze the plant closer than 50 to 60 per cent and then there is serious danger of too close grazing and a resulting growth handicap. A plant so grazed is also subject to severe injury due to root exposure. Excess height may also effect the grazing value of a plant. Such shrubs as oak grow above an animal's reach and consequently a part of the forage is useless. Generally nothing above a 52-inch height is regarded as accessible.

The palatability in plants may be low, especially for sheep, due to excess toughness. The value of some Agropyrons such as western wheat grass is materially lessened by a wiry texture which makes grazing difficult. This is probably the factor which causes palatability for sheep to be lower in grasses than in forbs. There is a

Figure 22.---Figure showing a plant of Buffalo grass (Bulbilis dactyloides) with its characteristic creeping stolons. Its low form of growth is a serious handicap to its accessibility.

distinct seasonal action here and plants which are too fibrous to be grazed in late seasons may offer excellent early spring forage. Other plants are low in value because of woodiness in the stem or stalk. Plants such as our foothill shrubs necessarily cannot be eaten as completely as fleshy plants because of the toughness of their woody stems. Some rank growing forbs such as the taller butterweeds (Senecio), the stem is left standing after the leaves are grazed off.

The habit of growth may have a direct bearing on the plant's value. Certain plants, usually annuals, dry up and disappear by the first of July in normal years. Though such plants had a palatability which would rate them very high theywould, obviously, be of no value to a fall pasture. Few annual plants have sufficient root system to withstand any severe grazing. No annual gives the stability and protection from erosion that is offered by perennial plants. In short, it might well be said that annual plants are lower in value than perennial plants, and, though palatability may indicate equality between two such plants the perennial must be given a higher rating than the annual.

The abundance of growth is an important item in rating plants. Some relatively rare plants have an extremely high palatability but due to their scarcity can

never become an important part of a range. In protected areas around Fort Collins winter fat (Eurotia lanata) attains a good growth and is a fairly dominant plant. It has a palatability of about 90 per cent and is usually taken before almost any other plant when the area is subjected to grazing. On areas which are commonly grazed this plant is very rarely, if ever, found. This may be due to its high preference figure, or to its inability to withstand grazing. At any rate it can never become an appreciable part of the range though it is an excellent feed.

The ability of plants to reproduce under adverse conditions is also a very important feature. This includes ability to withstand grazing and to withstand severe weather conditions. Grasses, as a rule, can withstand grazing better than forbs due to their low center of growth. Forbs grow from a bud at the tip of the stalk and, when this bud is nipped off, growth necessarily stops until lateral buds are formed. Grasses grow from below, hence when the leaf tips are bitten off the growth is seldom retarded; indeed, it may even be stimulated.

A plant's ability to produce seed is important. Grama grass (Bouteloua gracilis) is a short range grass which produces seed only during wet seasons but which retains its ability to seed, throughout the season. Even

in late August after a very dry season this grass will seed with amazing vigor after a single good wetting. For this reason there is seldom a season in which grama grass fails to produce a seed crop. Such a feature must be considered in rating this plant. Western wheat grass (Agropyron Smithii) is a good example of an adapted reproductive system. The seed of this grass has a very low fertility but the plant is endowed with an underground stem which enables it not only to spread but to be one of the earliest invaders of an eroded area. These underground stems can withstand very severe conditions. The plant itself may be entirely destroyed, but shoots from the buried stems will grow abundantly. It is, therefore, difficult to destroy this grass by misuse of the range.

There are plants which are not grazed because of the presence of objectionable oils, excess bitterness, etc. Such is probably the case in Rhus trilobata which has been aptly termed "skunk brush" because of the rank volatile oil found in its stems and twigs. The palatability of this species is practically zero as a result.

To summarize the study of objectionable features of a plant it might be said that any inherent physical factor which cuts down the value of a plant may be rated as an objectionable feature. They must be studied and worked out on each individual plant, and no general rules can be

set down whereby their relative importance can be determined. In the majority of cases such factors are taken care of by palatability figures. Such is the case in plants having volatile oils, short roots, spines prohibiting grazing, etc.

These, then need not be considered as separate items in rating the plants according to value. Other cases, those in which plants are eaten in spite of objectionable features, must be considered. The relative damage done must be compared to the value of the plant as forage. If objection exceeds value then the plant is rated as zero. If value exceeds objection then their relative importance must be compared and correct deductions made on a percentage basis for each individual plant.

5. Palatability or percentage consumed

It is obvious that palatability is a factor in plant value, for though a plant be chemically perfect and high in volume, it can be of no use if the animal will not eat it. "You can lead a horse to water but you cannot make him drink" might well be applied also to feed. Though one grass has a 20 per cent higher volume than a second grass the second grass will be more valuable if its palatability is 90 per cent as compared to 50 per cent for

first grass.

Through past usage palatability has come to mean the percentage of the individual plant which is consumed by an animal during the grazing season. Thus a plant, half of which is nipped off, will receive a palatability of 50 per cent. Palatability will be used here to denote the percentage eaten and will not refer to the flavor and quality as it does in general usage.

It is difficult to say just what factors enter in to determine palatability, i. e., just why an animal should graze one plant close but not extensively, while it grazes another extensively but not close. The short grasses such as buffalo grass and grama grass are usually grazed closer to the ground than are other species but their shortness prohibits the animal from obtaining as great a percentage as could be obtained from a taller plant.

Certain classes of stock can graze plants closer than can others. For example sheep can graze a grama grass range much closer than cattle. The class of stock is also concerned with toughness of the plant. Cattle for example can graze a woody shrub much more completely than can sheep because they are more capable of breaking the tough stems. This probably accounts for the noted decrease in figures listed for sheep on the tougher grasses

in Table 13. Time of year also influences palatability because of the toughness some grasses assume during late season. Thus a plant such as western wheat grass may be highly palatable in the spring but in late season it becomes so tough that stock will seldom graze more than a few inches at the tip of the plant.

There are certain physical factors inherent in some parts of a plant which cause that part to be refused though other parts are eaten. A plant which has a thorny stem as that of roses is often of lower palatability because the animal eats only the leaf. Other plants are too high to graze completely. A plant such as sage or skunk brush is eaten only in small amounts because of volatile oils which are apparently displeasing to the animal.

There may be any number of such factors having many different effects upon palatability.

In the past, palatability has been used almost exclusively as the measurement of plant value. Experimental work has been carried out largely by Forest Service workers. The grazing examiners, with the help of local rangers have compiled palatability lists including almost all plants occurring on national forests. These forest service lists are largely the result of the estimation method. This method is merely a comparison of heights between grazed and ungrazed plants of the same species. The per-

centage eaten is then estimated. There have recently been a few methods advanced for determining palatability which seem to be somewhat more accurate than the estimation method.

J. H.Sheppard (27) devised a system whereby cattle were branded with a serial number and were then observed from a shed top, by the use of field glasses. The time spent on each species was also considered here to allow for preference. Quadrat measurements were also taken in Shepperd's work, where the height grazedwas actually measured to obtain figures for palatability.

A second worker on systems is V. L. Cory (6), (7) who devised a system somewhat similar to that advanced by Shepperd. This method regards time grazed on each plant as the determining factor. This was obtained by following an individual animal for a 24-hour period to determine the actual time spent on each species. Cory also fenced a section of the area studied and, by comparing the grazed and ungrazed areas, was able to determine what plants were eaten.

These newer systems tend to overcome the greatest disadvantages of the old system by allowing for the stock preference and by introducing measurement rather than relying upon approximation.

Because of their great local importance the

palatability tables from all forest regions doing grazing work were correlated and placed together in one table. This table gives an excellent means of comparing the value of grasses in different regions and under different conditions. The lists offer the only means of comparing plant value on a large scale, with the exception of the lists offered by A. W. Sampson (26). Each list is typical only of its own locality as can be seen by comparing the listed figures for the same species.

All the palatability lists referred to on page 2 have been collected and the figures for grasses compiled. The result is given in Table 13.

Separate lists were included for class of stock, namely sheep, cattle, horses, etc., and for various grazing seasons when such were available. These classifications included under the column "use" are cattle (C), horses (H), goats (G), sheep (S), common use (C.U.), spring (Sp), winter (W).

Where no species was given under the genera the figure used was placed under all species of that genera which were listed in this table. This table is complete for all range grasses listed on the national forests contributing lists.

Table 13 gives the palatability figures listed by the Forest Service in all sections of the United States.

The figure listed is percentage palatable or percentage of the stalk which is grazed by an animal.

The inconsistency of these figures clearly demonstrates the inaccuracy of the estimation method of determining palatability. Thus in Bromus tectorum figures are presented from 0 to 85 per cent with every gradation between these figures. Similar variation is found throughout the chart, a certain amount of this variation is doubtlessly due to variation in the site and stock in different regions. It is, however, almost inconceivable that stock on one correctly managed range would ignore a grass which stock on a similar pasture graze to 85 per cent. The palatability estimate, therefore, can at best, give little more than a relative value.

The figures for all species have been averaged to obtain a relative figure for value comparison. This is, of course, a very general figure and cannot be used directly. Local variations and conditions must be considered and corresponding allowances made before considering the average figure. A good method of making comparisons between plants is that of grouping according to the average palatability. All the grasses appearing in Colorado were placed in such a chart.

They were divided into 10 groups, the highest consisting of all plants having a palatability average of 90

Table 13.

PALATABILITY TABLES OF RANGE GRASSES OF UNITED STATES 1931

No.	Region	Forest	Use	Species: Genus	Agropyron bakeri	Agropyron caninum	Agropyron cristatum	Agropyron dasystachyum	Agropyron inerme	Agropyron riparium	Agropyron scribneri	Agropyron smithii	Agropyron spicatum	Agropyron tenerum	Agropyron violaceum	Agrostis alba	Agrostis exarata
1.	R-1	Madison	C		80	80	80	80	80	80	80	80	80	80	80	80	80
2.	R-1	Madison	S		50	50	50	50	50	50	50	50	50	50	50	50	50
3.	R-1	Nezperce	C-Sp		80	80	80	80	80	80	80	80	80	80	80	60	60
4.	R-1	Nezperce	C-W		80	80	80	80	80	80	80	80	80	80	80	80	80
5.	R-1	Nezperce	S-Sp		40	40	40	40	40	40	40	40	40	40	40	10	10
6.	R-1	Nezperce	S-W		80	80	80	80	80	80	80	80	80	80	80	80	80
7.	R-2	All	C		70	80		80			70			80	80	70	70
8.	R-2	All	S		50	50		50			50			50	50	50	50
9.	R-3	Coconino	C.U.									65		70			
10.	R-3	Coronado	C.U.									75		75			
11.	R-3	Datil	H-C									90		90			
12.	R-3	Datil	G-S									90		90			
13.	R-3	Lincoln	C									75		75	75		
14.	R-3	Lincoln	S									75		75	75		
15.	R-3	Prescot	C.U.		75	75	75	75	75	75	75	75	75	75	75		
16.	R-4	Ashley	C.U.			80		75				80	80	85	85	80	80
17.	R-4	Boise	C			80			15					80		80	80
18.	R-4	Boise	S			50			10					50		80	80
19.	R-4	Caribou	C					70					90	90			
20.	R-4	Caribou	S					30					70	80			
21.	R-4	Powell	C.U.					50				60	70	80	85	80	80
22.	R-4	Uinta	C.U.			80		75				80	80	90	85	80	80
23.	R-4	Weiser	C			80							80	80			
24.	R-4	Weiser	C.U.			80							80	80			
25.	R-4	Weiser	S			40							40	40			
26.	R-5	Plumas	C											70		80	80
27.	R-5	Plumas	S											40		60	60
28.	R-6	Malheur	C		80	80	80	80	80	80	80	80	80	80	80		
29.	R-6	Malheur	S		30	30	30	30	30	30	30	30	30	30	30		
30.	R-4	Cache	C.U.			75						70	70	75	75	65	65
31.	Jornada Exp. Sta.		C.U.														
32.	Great Basin Exp. Sta.		C				85	80		80		70	80	85	85		
33.	Great Basin Exp. Sta.		S.				80	60						80	80		
	Average				65	68	76	65	56	67	65	67	70	72	72	67	67

Agrostis idahoensis			60	80	10	30	70	50								80	80	80			80	80			80	60			65						68
Agrostis hiemalis	80	50	60	80	10	80	70	40	20		50	50	40	40	40	80	80	80	90	80	80	80			80	60	50	20	65			85		90	62
Agrostis palustris			60	80	10	80			70				75	75		80	80	80			80	80			80	60			65						70
Agrostis rossae			60	30	10	30										30	80	30			30	30			30	60			65						69
Agrostis verticillata			60	80	10	80				40			40	40		80	80	80			80	80			80	60			65						64
Aira caespitosa	80	20	80	80	60	80	60	60								70	70	40	80	70	50	70					90	50				70		50	65
Aira danthonioides			80	80	60	80										70	70	40			50	70			80	50	90	50							67
Aira elongata			80	80	60	80										70	70	40			50	70					90	50							68
Alopecuris aristulatus							80	60								80						80													75
Andropogon chrysocomus							50	40	60	30	30	30	20	20	30																				34
Andropogon hallii							50	40	60	30	30	30	20	20	30																				34
Andropogon neomexicana							50	40		30	30	30	20	20	30																				31
Andropogon saccharoides							50	40		35	30	30	20	20	30															30					31
Aristida arizonica			10	50	10	20	60	50	25	45	30	30	30	30	45															60					35
Aristida bromoides			10	50	10	20	60	50		45	5	5	20	20	45															60					31
Aristida californica			10	50	10	20	60	50		75	0	0	20	20	45															60					32
Aristida divaricata			10	50	10	20	60	50	15	45	5	5	20	20	45															60					30
Aristida fasciculata			10	50	10	20	60	50	0	45	0	0	20	20	45															60					28
Aristida fendleriana			10	50	10	20	60	50	25	45	10	10	20	20	45															60					31
Aristida longiseta			10	50	10	20	60	50	70	45	30	30	20	20	45	50						50								60					39
Aristida oligantha			10	50	10	20	60	50	0	45	0	0	20	20	45															60					28
Aristida ternipes			10	50	10	20	60	50		20	0	0	20	20	45															60					28
Arundo donax									0																										0
Avena fatua							70	60																	45	30	80	70							59
Avena barbata							70	60																	45	30									51
Beckmannia erucaeformis	50	20					50	10																											32
Blepharoneuron tricholepis							70	60	50	40	40	40	40	40	40						70														49
Bouteloua aristidoides										0					0																				0
Bouteloua barbata															0																				0
Bouteloua chondrosioides										85																									85
Bouteloua curtipendula							80	50	70	75	75	75	85	85	80																				75
Bouteloua eriopoda									85	80	80	80			75																80					80
Bouteloua filiformis										85																									85
Bouteloua gracilis							80	80	85	85	85	85	85	85	85	60					75														81
Bouteloua hirsuta							80	80		85	85	85			85																				83
Bouteloua procumbens											10	10	0	0	0																				5
Bouteloua radicosa										85																									85
Bouteloua rothrockii										85					85																				85
Bouteloua trifida										75					75																				75
Bromus brizaeformis			10	80	10	80	60	40		70	60	60	85	85	70		80	50												50					59
Bromus commutatus			80	80	70	80	60	40		70	60	60	85	85	70																				70
Bromus hordeaceus			80	80	70	80	60	40		70	60	60	85	85	70											40	30								65
Bromus inermis	80	50	80	80	70	80	60	40		70	60	60	85	85	70	85			90	80		85										90	90		74
Bromus marginatus	70	40	80	80	70	80	80	60	75	70	60	60	85	85	70		80	50	90	80			80		30	70	40					85	85		70
Bromus pallidus			80	80	70	80	60	40	75	70	60	60	85	85	70																				70
Bromus polyanthus			80	80	70	80	60	40		70	60	60	85	85	70	85					85	85								75		85	85		74
Bromus porteri	80	50	80	80	70	80	80	60	75	70	60	60	85	85	70	85	80	50	90	80	85	85								75		85	85		75
Bromus richardsoni			80	80	70	80	80	60	75	70	60	60	85	85	70																				73
Bromus rigidus			80	80	70	80	60	40		70	60	60	85	85	70											10	0								61
Bromus secalinus			80	80	70	80	60	40		70	60	60	85	85	70								80		30										68
Bromus subvelutinus			80	80	70	80	60	40		70	60	60	85	85	70																	85			71
Bromus tectorum	40	20	10	80	10	80	70	50		70	60	60	85	85	70	80	5	5	40	20		45	70		0	10	0	0	0	45		80	75		45
Calamagrostis canadensis	70	60	50	50	20	50	10	0								75	50	50	90	80								60	70	20					50
Calamagrostis langsdorfii			30	50	10	50	20	10																											28
Calamagrostis rubescens	30	20	30	50	10	50	10	0								10	5	5	15	10			30	40	10			50	20	20					22
Calamovilfa longifolia							10	0																											5
Catabrosa aquatica							50	0									80	50														20	10		35
Cenchrus caroliniamus							50	30																											40
Chaetochloa composita							50	10		30			20	20	30																				27
Chaetochloa grisebachii							50	10		10	10	10	20	20	10																				17
Chaetochloa elegans							50	10					20	20																					25
Chaetochloa viridis							50	10	25	0			20	20																					21
Cinna sp.			80	80	70	30																													73
Dactylis glomerata			30	80	60	80											60	50								90	50								67
Danthonia intermedia	70	50	80	80	60	80	50	20											75	50	60					50	40								59
Danthonia parryi	70	50	80	80	60	80	30	0													60														56
Danthonia unispicata	70	50	80	80	60	80	50	20													60														61
Distichlis spicata									80												25														52
Echinochloa crus-galli							50	20	10	25	10	10			25																				21
Elymus canadensis	40	20	10	80	0	80	70	40	15	30	15	15	20	20	30													70	40						35
Elymus condensatus	30	10	10	80	0	80	70	40	15	30	15	15	20	20	30	30	25	25	40	30		30						80	10	25					32
Elymus glaucus	40	10	10	80	0	80	70	40	15	30	15	15	20	20	30	75	80	50	75	60		75	30		20	30	10	70	40	70					41
Elymus salinus			10	80	0	80	70	40	15	30	15	15	20	20	30													70	40			50			36
Elymus simplex			10	80	0	80	70	40	15	30	15	15	20	20	30						50							70	40						36
Epicampes ligulata									30	20	10	5	30	30	20																				21
Epicampes rigens									85	40	20	10	30	30	30																				35
Eragrostis caroliniana							30	10	60				20	20	30																				30
Eragrostis ciliianensis							30	10		40			20	20	30																				25
Eragrostis lugens							30	10		40			20	20	65																				31
Eragrostis lutensis							30	10	60				20	20	30																				30
Eragrostis major							30	10	60				20	20	30																				30
Eragrostis mexicana							30	10	20		30	30	20	20	30																				24
Eragrostis pectinacea							30	10	0				20	20	30																				18
Eragrostis pilosa							30	10	5				20	20	30																				19
Festuca arizonica			80	80	70	80	40	20	30	40	40	40	20	20	30	80					40	80													50
Festuca brachyphylla			80	80	70	80				40	30	30	60	60	40	80					40	30										70	60		60
Festuca calligera			80	80	70	80	60	50		40	30	30	60	60	40	80					40	80													58
Festuca capellata			80	80	70	80	60	50		40	30	30	60	60	40	80					40	80													58
Festuca confinis			80	80	70	80				40	30	30	60	60	40	80	40	40	80	65	40	80								60					58
Festuca elatior			80	80	70	80				40	30	30	20	20	40	80					40	80													53
Festuca evina			80	80	70	80				40	30	30	60	60	60	80					40	80													67
Festuca idahoensis	80	60	80	80	70	80				40	30	30	20	20	40	80	40	30	90	90	40	80	80	80	40	80	60	75	40	75					77
Festuca megalura			80	80	80	80				40	30	30	60	60	40	80					40	80													68
Festuca minutiflora			80	80	70	80	60	50		40	30	30	60	60	40	80					40	80													58
Festuca octoflora			80	80	70	80				40	30	30	60	60	40	30					40	80				30	0			40		55	55		49
Festuca ovina			80	80	70	80	60	50		40	60	60	60	60	40	80					40	80													58
Festuca pseudovina			80	80	70	80	60	50		40	30	30	60	60	40	80					40	80													58
Festuca scabrella	80	50	80	80	70	80				40	30	30	60	60	40	80					40	80													60
Festuca sororia			80	80	70	80				40	30	30	60	60	40	80					40	80													58
Festuca supina			80	80	70	80	60	50		40	30	30	20	20	40	80					40	80													53
Festuca thurberi			80	80	70	80	40	20		40	30	30	60	60	40	80					40	80													55
Festuca viridula	80	40	80	80	70	80				40	30	30	60	60	40	80					40	80													60
Heteropogon contortus										70					10																				40
Hilaria belangeri										85			25	25	85																				55
Hilaria cenchroides									90																										90
Hilaria jamesii									0				60	60							30														38
Hilaria mutica									60	40			50	50	40																60				50
Holcus halpensis									400																										40
Hordeum jubatum	40	10	40	80	20	80	40	20		30	20	20	50	50	30	40					40	40				40	20			60					38
Hordeum nodosum	40	10	40	80	20	80	40	20	20	30	20	20	50	50	30	40			80	75		40				70	40			60		65	60		45
Koeleria cristata	60	40	70	80	30	80	60	50	30	75	60	60	75	75	75	85	50	40	80	70	85	85	80	80	40			80	60	70		60	40		64
Leptochloa dubia										50			20	20	50																				35
Leptochloa filiformis									45	50			20	20	50																				37
Lolium sp.			80	80	60	80																													75
Lycurus phleoides									70	75	45	45	60	60	50																				58
Melica bella	80	60	80	80	60	80	70	50								75	15	5				75	80	80	40			60	60			85	75		64
Melica bulbosa	80	60	80	80	60	80	70	50								75	15	5				75				80	50			75		85	75		65
Melica spectabilis	80	60	80	80	60	80	70	50								75	15	5	80	70		75								75					64
Melica subulata	80	60	80	80	60	80	70	50								75	15	5				75	80	80	40										63
Muhlenbergia depauperata			80	80	60	80	60	50		40	0	0			45		50	40			40					50	40								48
Muhlenbergia dubia			80	80	60	80	60	50		40	30	30	40	40	40		50	40			40					50	40								50
Muhlenbergia emersleyi			80	80	60	80	60	50		40	50	50	40	40	45		50	40			40					50	40								53
Muhlenbergia filiculmis			80	80	60	80	60	50		40	55	55			45	60	50	40			40	60			60	50	40			65					55
Muhlenbergia gracilis			80	80	60	80	60	50		40	50	50			45		50	40			40					50	40								51
Muhlenbergia gracillima			80	80	60	80	60	50	0	40	0	0	0	0	0		50	40			40					50	40								37
Muhlenbergia microsperma			80	80	60	80	60	50		40	50	50			65		50	40			40					50	40								52
Muhlenbergia montana			80	80	60	80	20	10	50	40	50	50	40	40	45		50	40			40					50	40								48
Mylenbergia pauciflora			80	80	60	80	60	50	60	40	50	50	40	40	45		50	40			40					50	40								53
Muhlenbergia porteri			80	80	60	80	60	50	85	75	50	50			75		50	40			40					50	40				80				66
Muhlenbergia racemosa			80	80	60	80	60	50	85	40	50	50	40	40	45		50	40			40					50	40								54
Muhlenbergia repens			80	80	60	80	60	50		40	50	50	0	0	45		50	40			40					50	40								48
Muhlenbergia rigidia			80	80	60	80	60	50		40	50	50	40	40	45		50	40			40					50	40								52
Muhlenbergia sitifolia			80	80	60	80	60	50		40	50	50	40	40	45		50	40			40					50	40								52
Muhlenbergia squarrosa			80	80	60	80	60	50		40	60	60			60		50	40	50	40	40					50	40								55
Muhlenbergia virescens			80	80	60	80	60	50	30	40	50	50			40		50	40			40					50	40								52
Muhlenbergia wrightii			80	80	60	80	60	50		40	60	60	0	0	45		50	40			40					50	40								49
Munroa squarrosa							0	0					0	0																					0
Notholcus lanatus			80	80	30	80																													68
Oryzopsis fimbriata	80	60					50	10		60	70	70	50	50	60																				50
Oryzopsis hymenoides	80	60					50	10	70				50	50		75					75	75								70		75	70		62
Oryzopsis micrantha	80	60					50	10	60		70	70	50	50	60																				56
Panicularia borealis			80	80	60	80	60	30													60														55
Panicularia nervata			80	80	60	80	60	30	80							85	80	50			85	85	90		40					75					71
Panicum barbipulvinatum							40	20	50	20	20	20	20	20	20																				25
Panicum bulbosum							40	20	35	20	20	20	20	20	20																				23
Panicum hirticaule							40	20		20	20	20	20	20	20																				22
Panicum obtusum							40	20	50	20	20	20	20	20	20																		30		26
Panicum virgatum							40	20	70	20	20	20	20	20	20																				27
Pappophorum wrightii										20																									20
Phleum alpinum	90	70					80	70								70	80	80	90	80	80	70	90		40					75		85	85		77
Phleum pratense	90	70					80	70					85	85		80	80	80				80				70	50			75		85	85		78
Poa ampla	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85	80		40	80	60	90	60	75					76
Poa bigelovii	90	70	80	80	80	80	80	70		60	60	60	85	85	60	85	80	50			85	85				80	60	90	60	75					75
Poa bolanderi	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85	80		40	80	60	90	60	75					76
Poa brevipaniculata	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85	80		40	80	60	90	60	75					76
Poa buckleyana	90	70	80	80	80	80	80	70					85	85		85	80	50	90	75	85	85				80	60	90	60	75					78
Poa compressa	90	70	80	80	80	80	80	70	90				85	85	85	85	80	50			85	85				80	60	90	60	75					78
Poa epilis	90	70	80	80	80	80	80	70					85	85		85	80	50	90	80	85	85	80		40	80	60	90	60	75					78
Poa fendleriana	90	70	80	80	80	80	80	70	90	80	60	60	85	85	85	85	80	50			85	85				80	60	90	60	75		90	90		78
Poa gracillima	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85	80		40	80	60	90	60	75					76
Poa longiligula	90	70	80	80	80	80	80	70	80				85	85		85	80	50	90	80	85	85				80	60	90	60	75		85	85		79
Poa nevadensis	90	70	80	80	80	80	80	70					85	85		85	80	50	90	85	85	85				80	60	90	60	75		85	85		79
Poa occidentalis	90	70	80	80	80	80	80	70			60	60	85	85	85	85	80	50			85	85				80	60	90	60	75					76
Poa pratensis	90	70	80	80	80	80	80	70	90		100	100	85	85		85	80	50	90	90	85	85				100	70	90	60	75		90	90		90
Poa pratericola	90	70	80	80	80	80	80	70	90				85	85		85	80	50			85	85				80	60	90	60	75					77
Poa relfexa	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85				80	60	90	60	75		80	80		77
Poa rupicola	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85				80	60	90	60	75		85	85		78
Poa sandbergi	90	70	80	80	80	80	80	70					85	85		85	10	50	90	90	85	85				80	60	90	60	75		85	85		76
Poa wheeleri	90	70	80	80	80	80	80	70					85	85		85	80	50			85	85	80		40	80	60	90	60	75					76
Polypogon sp.							50	30																											40
Redfieldia flexuosa							10	10																											10
Savastana odorata							20	0																											10
Schedonnardus paniculatus							10	10	0				10	10																					8
Scleropogon brevifolius									30																					20					25
Scolochloa sp.							40	10																											25
Sitanion glabrum	40	10	40	80	20	80	50	40	20				50	50			0	0																	37
Sitanion hystrix	40	10	40	80	20	80	50	40		40	50	50	50	50	40	60	0	0	80	65	50	40	40		40	40	0			40		50	40		42
Sitanion jubatum	40	10	40	80	20	80	50	40					50	50			0	0					40		40										36
Sitanion molle	40	10	40	80	20	80	50	40	20				50	50			0	0																	37
Sitanion putiflorum	40	10	40	80	20	80	50	40	30				50	50																					44
Sorghastrum nutans							40	10	25				30	30																					27
Sporobolus airoides			60	80	40	80	60	50	50	50			50	50	50	60					50	60								60	50				56
Sporobolus confusus							60	50	0		60	60	50	50		60					50	60								60					51
Sporobolus cryptandrus							60	50	70	30	60	60	50	50	35	60					50	60								60	60				54
Sporobolus interruptus							60	50	90				85	85	80	60					50	60								60					68
Sporobolus neglectus							60	50	10				50	50		60					50	60								60					50
Sporobolus utilis							60	50					50	50		60					50	60								60					55
Stipa columbiana	70	60	60	80	20	80	50	40		40			40	40	40		60	30	85	75	70					60	60			70		75	65		58
Stipa comata	40	20	60	80	20	80	50	40	5	40			40	40	40	80	0	0			50	60				60	60			40		75	65		45
Stipa lettermani	70	60	60	80	20	80	50	40		40			40	40	40	70	60	30	90	80	70	70				60	60			65		85	75		60
Stipa minor	80	60	60	80	20	80	50	40		40			40	40	40		60	30			70					60	60								53
Stipa neomexicana	70	60	60	80	20	80	50	40	10	40			40	40	40		60	30			70					60	60								51
Stipa spartea	70	60	60	80	20	80	50	40	50	40			40	40	40		60	30			70					60	60								53
Stipa speciosa	70	60	60	80	20	80	50	40		60			40	40	60		60	30			70					60	60								54
Stipa vaseyi	70	60	60	80	20	80	60	20		40			0	0	40		60	30			70					60	60								49
Stipa williamsii	70	60	60	80	20	80	50	40		40			40	40	40		60	30			70		80		40	60	60								54
Triodia avenaceus										60			10	10																					27
Triodia elongata									20				10	10																					13
Triodia pilosa													10	10	60																				27
Triodia pulchella									70	0			10	10	0																				18
Triplasis purpurea							10	0																											5
Trisetum canescens	60	40	60	80	40	80	50	20																						60					54
Trisetum spicatum	60	40	60	80	40	80	50	20	75							65	50	40	70	70	65	65								60		80	65		60
Valota saccharata										70					65																				67

or better, the second of 80 to 89, the third of 70 to 79, etc. The plants in any community can be so grouped by reference to Table 13 and a good idea of their relative value obtained. All grasses listed for Colorado can be found in Table 14. This table shows the palatability groupings for plants appearing in Colorado as obtained from average figures found in Table 13.

Table 14.-- Palatability of Colorado grasses

Poa pratensis	90-100%
Bouteloua gracilis	80-89 %
Bouteloua hirsuta	80-89 %
Agropyron tenerum	70-79 %
Agropyron violaceum	70-79 %
Alopecurus sp.	70-79 %
Bouteloua curtipendula	70-79 %
Bromus porteri	70-79 %
Bromus marginatus	70-79 %
Bromus richardsonii	70-79 %
Panicularia nervata	70-79 %
Phleum sp.	70-79 %
Poa sp.	70-79 %
Agropyron caninum	60-69 %
Agropyron dasystachyum	60-69 %
Agropyron Smithii	60-69 %
Agropyron Bakeri	60-69 %
Agropyron Scribneri	60-69 %
Agrostis hiemalis	60-69 %
Agrostis alba	60-69 %
Agrostis exarata	60-69 %
Agrostis idahoensis	60-69 %
Aira caespitosa	60-69 %
Koeleria cristata	60-69 %
Melica sp.	60-69 %
Oryzopsis hymenoides	60-69 %
Trisetum spicatum	60-69 %
Avena sp.	50-59 %
Calamagrostis canadensis	50-59 %

Table 14.--Palatability of Colorado grasses (continued)

Danthonia intermedia	50-59%
Danthonia parryi	50-59%
Festuca ovina	50-59%
Festuca calligera	50-59%
Festuca capillata	50-59%
Festuca minutiflora	50-59%
Festuca pseudovina	50-59%
Festuca supina	50-59%
Festuca Thurberi	50-59%
Festuca arizonica	50-59%
Panicularia borealis	50-59%
Sporobolus sp.	50-59%
Trisetum canescens	50-59%
Blepharoneuron sp.	40-49%
Bromus tectorum	40-49%
Cenchrus sp.	40-49%
Muhlenbergia montana	40-49%
Hordeum nodosum	40-49%
Polypogon sp.	40-49%
Sitanion hystrix	40-49%
Stipa sp.	40-49%
Andropogon sp.	30-39%
Aristida longiseta	30-39%
Beckmannia sp.	30-39%
Catabrosa sp.	30-39%
Elymus sp.	30-39%
Hordeum jubatum	30-39%
Calamagrostis langsdorfii	20-29%
Chaetochloa sp.	20-29%
Echinochloa sp.	20-29%
Eragrostis sp.	20-29%
Panicum sp.	20-29%
Scolochloa sp.	20-29%
Sorghastrum sp.	20-29%
Redfieldia sp.	10-19%
Savastana sp.	10-19%
Calamovilfa sp.	0-9 %
Munroa sp.	0-9%
Schedonnardus sp.	0-9%
Triplasis sp.	0-9%

Table 14 shows a great variation in palatability to exist among different species within the Colorado region. From this table it can be seen that Poa pratensis has the highest palatability average of all plants listed by the Forest Service. A great many workers, for this reason, give Poa pratensis a value of 100 and base the palatability of all other plants upon their relative comparison with Poa pratensis. Poa pratensis can, therefore, be considered as a standard and having this plant as an objective or ideal facilitates estimation.

The only practical method of determining the percentage figure for any plant is by actual field measurement for that plant. In this way the weight of influencing factors need not be considered. Table 13 will give a figure which can be used only as a reference or an approximation since it is not possible to have a general figure because of local variations.

The method of measuring palatability by estimation is not practical, so an attempt was made to devise an accurate measuring system which could be of some practical value. For this purpose an area west of Fort Collins which had been grazed during the summer months was selected as a location to be studied. It was desirable to have an area which was fairly well utilized but not overgrazed. The selected area (See Figure 23) had a covering

of grama grass and buffalo grass with a sub-dominant of western wheat grass constituting the main forage plant. Since western wheat grass is the most important forage plant on the area and constitutes the bulk of the forage it was chosen as an example for determining palatability.

During the latter part of September a series of 12-meter quadrats were laid out at regular intervals across the pasture. In this way an unprejudiced sampling was made. The method of procedure was as follows: the 12 quadrats were carefully gone over and the actual number of wheat grass stalks in each was determined. Records were made of the number of these stalks which had been grazed, and the number which had not been grazed. The height of each stalk was measured by the use of a centimeter rule and the average height of the grazed plants and of the ungrazed plants was determined. These were, in turn, averaged together for all 12 quadrats to obtain the results given in Table 15.

This table shows the results obtained from averaging together the figures obtained by measuring and counting all wheat grass plants on 12 meter quadrats.

Table 15.--Palatability figures

Ave. no. of stalks	Ave. no. ungrazed	Ave. no. grazed	Ave. height of ungrazed plant	Ave. height of grazed plant
119	31	88	17.0 cm.	5.9 cm.

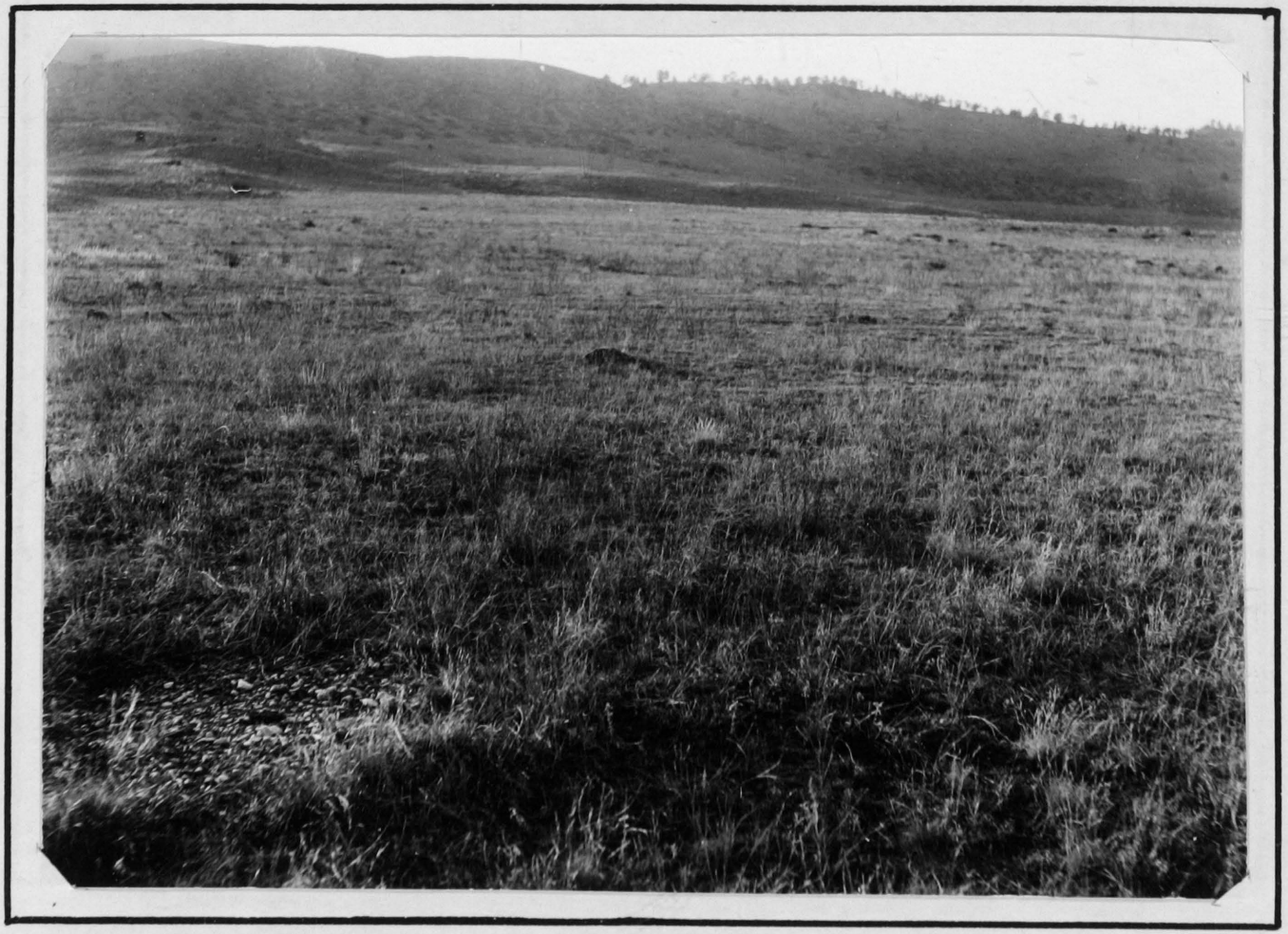


Figure 23.--Photograph showing the pasture upon which palatability measurements were made. This pasture is chiefly western wheat grass as a sub-dominant to grama grass and buffalo grass.

Figure 24.--Photograph showing a closeup of the pasture shown in Figure 23. Stalks of grazed and ungrazed Agropyron Smithii can be seen in the foreground.

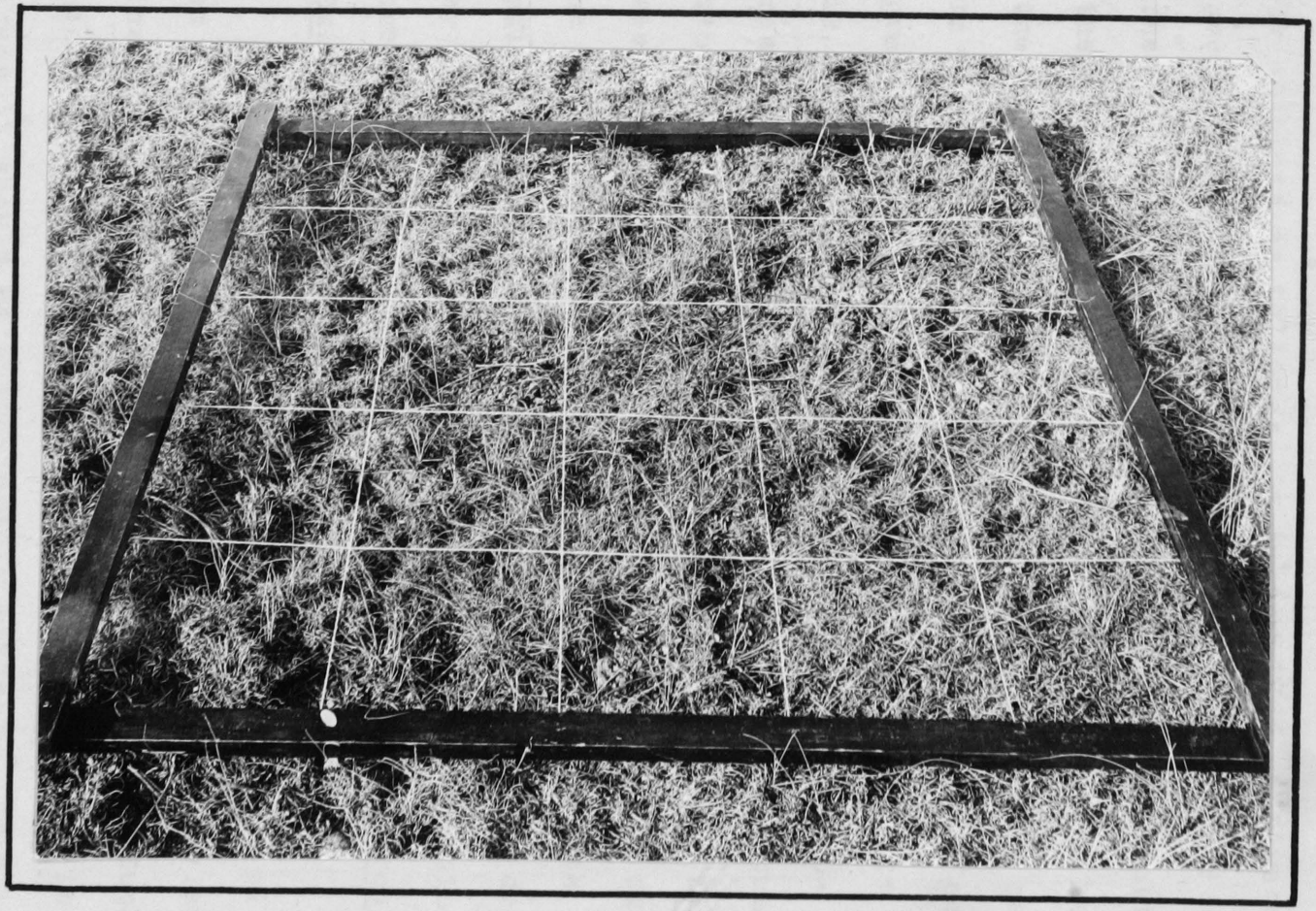


Figure 25.--Photograph showing one of the quadrats upon which palatability measurements were made. The stalks of Agropyron Smithii can be seen in the foreground.

From this table the palatability can easily be computed. The aggregate bulk of the plant which is eaten may be obtained as follows: By taking 17.0 centimeters as an average height for all plants on the area prior to grazing, the centimeters eaten off may be obtained by subtracting the height of the grazed plants (5.9) from the height of the ungrazed plants (17.0). This figure (11.1 centimeters) is the average amount bitten off. To find the percentage grazed off each plant (palatability) this figure (11.1) is divided by the ungrazed height figure (17.0). The result of this division (65 per cent) is an actual measurement and thus is a fairly accurate palatability figure for western wheat grass in the area studied. This figure may be compared to 80 per cent which is the accepted palatability for wheat grass in this region as determined by estimations. It does, however, agree very nicely with the group figure, 60-69 per cent, given for Agropyron Smithii in Table 14.

Measurement of grazed and ungrazed plants will not be so easy for the shorter bunch grasses, but in view of its increased accuracy it seems quite practical. Such a measurement is purely local in application but in similar areas it should be approximately correct. Thus in mixed prairie type pasture with few or no weedy plants, having dominants of grama grass, buffalo grass, wheat

Figure 26.--Photograph showing stalks of Agropyron Smithii which have been grazed by stock such as were used in the determination of palatability. This illustrates the ease with which grazed and ungrazed stalk height can be measured.

grass and Stipas, palatability should vary little from this figure, 65 per cent, provided the stocking is similar. Care must be taken to make measurements toward the end of the grazing season in order to allow for variations which may prevail throughout the season.

Palatability has received more attention than has any other factor influencing plant value; indeed, it has been the very basis of all previous value determinations. These determinations are only personal estimates and are of no scientific value andof but little practical value, especially outside the region in which the estimate was made. For approximate results the average figures for the western states can be taken from Table 13, and altered to fit local conditions. For more accurate results a quadrat measurement of grazed and ungrazed plants should be used. The figures so obtained will be accurate and should be applicable to other similar types of pasture.

Range Capacity by Quadrat Measurement

The work covered above gives some idea of the complexity involved in making value determinations for each individual species on a range. It is by such an analysis that an accurate figure for value comparison can be obtained and without such detailed work it is impossible to arrive at accurate conclusions.

The ultimate aim of value determinations is comparison with other species to determine which plants are most desirable on the range. From such figures it is possible to decide upon what species to use in reseeding, what species to graze in various seasons, what stock class to use on various ranges, whether a range composed of one species is more valuable than a range composed of another species, how to tell whether the range is improving or deteriorating, etc.

The greatest use made of plant value at present is in the determination of range value as shown by capacity. This work has been done by the use of palatability estimates and density, or ground cover estimates. The inaccuracy of such determination is made evident by the fact that it is obtained through the use of two estimated figures and by the fact that one of these figures, palatability, is indicative of neither plant value nor range capacity. For this reason a new and improved method has

been devised whereby the capacity of a range can be determined with both greater accuracy and greater ease than the palatability method now extensively employed. Knowing this capacity, it is possible to avoid overgrazing the range rather than finding out too late that it has been overstocked, and that restoration is necessary. To ruin a range is easy, but to improve a range is difficult.

To demonstrate how capacity may be accurately determined a range west of Fort Collins was selected. This area, which had been previously grazed somewhat, was essentially a wheat grass pasture with extensive coverings of both grama grass and buffalo grass. The wheat grass, since it makes up the bulk of the forage on the area, was selected as a basis upon which to make calculations. Since this plant is the dominant and most important plant it should not be overgrazed, and hence when it is grazed to capacity the range will be fully utilized. Having made these conclusions, it is evident that no attention need be given as to how much any other plant is grazed, why any other plant is grazed, nor indeed the volume and chemical constituents of the wheat grass. Nothing concerns the investigator except how many stalks of western wheat grass are now grazed and how many will be grazed when the range is properly utilized. Obviously

a certain per cent of the plants should remain each season to furnish seed and early feed for the following season. Various workers place this percentage at 15 to 25, which means that 75 to 85 per cent of the plants can safely be grazed. An average figure of 80 per cent seems to be a wise choice, and will be the accepted figure for capacity grazing. The second figure needed is present percentage grazed. To obtain this 12 quadrats were placed at regular intervals across the pasture previously described. These quadrats were carefully gone over and the actual number of stalks of wheat grass on each was determined. A record was also made of the number of these stalks which had been grazed. Averages were made of the 12 quadrats to obtain the following figures.

Average number of stalks per meter - 119

Average number of stalks grazed ---- 88

Average number of stalks ungrazed--- 31

The per cent of the plants which had been grazed was next obtained by dividing the number of plants grazed by the total number of plants on the area. The figure so obtained was 74 per cent. Seventy-four is 92.5 per cent of the 80 per cent which can be grazed. The utilization then was 92.5 per cent.

The capacity of this range then may be obtained as follows: There have been 15 head of cows on the area of

145 acres for 5.5 months. The cow months per acre, or the number of months which one acre will support one cow is desired. The cow months used to date is obtained by multiplying the number of cows by the number of months grazed. This figure is divided by the acres on the area and .57 is obtained as the months each acre has supported one cow. This is only 92.5 per cent of the possible use on this range. Multiplying the remaining 7.5 per cent by .57 already used we get a figure .04 cow months remaining. Those used (.57) plus those remaining (.04) gives .61 cow months per acre. This means that on such a range one cow can be grazed on one acre for .61 months.

The analysis of the range studied would be as follows: 145 acres x .61 cows gives 88 cow months on this area. The number of stock to graze is 15 so the 88 cow months divided among 15 cows gives 5.9 months possible to graze without overgrazing the range. There have been 5.5 months used and so only 0.4 months remain. These computations and the figures used may be found in Table 16.

Table 16.--Computations involved in a quadrat measurement of range capacity

Subject	How figured	Result
Average stalks on each meter quadrat	Count	119
Average number of stalks grazed	Count	88
Average number of stalks ungrazed	Count	31
Per cent of total number of stalks grazed	$\frac{88}{119}$	74
Per cent allowed for grazing (20 per cent for seed)	100-20 per cent	80
Per cent of this allowance ungrazed	$100-\left\{\frac{74}{80} \times 100\right\}$	7.5
Per cent of allowance grazed (utilization)	100 - 7.5	92.5
Head of stock on the area		15
Acres area of plot		145
Months it has been grazed		5.5
Months one acre supported one cow	$\frac{15 \times 5.5}{145}$	0.57
Cow months remaining on each acre	.57 x 7.5 %	0.04
Total cow months on such a type	.04 + .57	0.61
Months possible to graze 15 cows on 145 acres	$\frac{145 \times .61}{15}$	5.9
Months yet to graze on this area	5.9 - 5.5	0.4

This method is somewhat laborious to use in analysis of an individual plot but it can, with allowance for density variation, be applied to any foothill range of this type with a reasonable accuracy. The density on this area will approximate 70 per cent. Other areas of similar type should vary in capacity, in direct proportion to their densities.

Such an analysis gives the following advantages:

1. A calculated capacity and consequently a knowledge before depletion.

2. An elimination of the guess element.

3. A greater ease of measurement.

This method seems to offer much more usability for capacity determination than does the method of determining the value of the individual plants, which is, at best, quite involved and detailed. Thus the value of a range, measured directly by carrying capacity, is much easier to arrive at by measurement as a unit rather than by measurement of the factors involved.

CONCLUSIONS

The measurement of factors controlling plant value is of great importance for scientific determinations of relative comparisons and ecological relationships. In the study of these factors the determinations were concentrated on Bouteloua gracilis (grama grass) and Agropyron Smithii (western wheat grass). To arrive at the relative value of these two plants, consideration must be given to (1) their preference figure, (2) their volume, (3) their chemical constituents, and (4) any physical factors which may materially decrease their use.

The first, and most important of these, the preference figure, is an actual measurement of the amount of the species eaten and includes palatability variation. The primary consideration of plant value determinations is, "will the stock eat this species and if so, how much of it?"

In Table 3 the preference figures given for these two grasses at maximum usage are grama grass 71 and western wheat grass 47.

The second consideration of the plant value is volume production per unit area. Averages from Table 7 show an average volume production of 48 grams for grama grass and 135 grams for western wheat grass, or a ratio of 1.0 for grama grass to 2.81 for western wheat grass.

If the percentage eaten (preference) is multiplied by the production ratio (volume) the result gives an actual volume eaten figure. Thus there is a 2.81 greater production in wheat grass but only 47 per cent of this is eaten so 47 per cent is multiplied by 2.81 to obtain a figure 1.32 for wheat grass value as compared to 71 per cent multiplied by 1.0 or 0.71 for grama grass value. The ratio 1.32 to 0.71 is a final volume eaten figure, and represents the actual amount of each species that an animal will remove from the pasture.

The third consideration, the chemical constituents, determines plant value largely through the amount of digestable crude protein present in the species. This protein content is expressed in relationship to carbohydrate content in the nutritive ratio. Table 9 shows an average seasonal nutritive ratio of 1:9.4 for grama grass and 1:10.5 for western wheat grass. The wider the ratio

the less valuable the feed hence grama grass pound for pound is a better feed than wheat grass. Thus, considering 9.4 and 10.5 as pounds of digestible protein, 9.4 is divided by 10.5 to obtain .895, which means that a pound of western wheat grass is equivalent to .895 pounds of grama grass as feed. Thus the volume eaten for wheat grass, 1.32, is multiplied by .895 to obtain a figure 1.18 as compared with a value of 0.71 for grama grass.

Neither of these two grasses produces awns, nor has any poisonous qualities. They both grow in accessable locations, are able reproducers, and withstand grazing as well as could be expected. Consequently the fourth consideration, physical factors affecting palatability, does not influence their values. The final figures upon which to base comparison of the grasses are these: grama grass, .71; wheat grass, 1.18.

It is evident from these computations that for comparisonof a great number of grasses, one must be considered as an average and its value called one, in all four considerations. Thus in these figures grama grass was chosen as the average plant. Its volume and its nutritive ratio were therefore called one, as an average. Plants with above average volume and ratio were correspondingly above one, likewise plants with below average volume and ratio were correspondingly lower than one. It is apparent

that this individual figure carries no special significance other than as a means of comparison with similarly treated plants unless some standardization is agreed upon for method and a species agreed upon for basis of comparison.

Though this determination is difficult and somewhat involved the resultant figures seem to fill a need of exact means of evaluating plants and are therefore of recognized scientific value.

The present method of determining range capacity is to estimate the percentage of the vegetation that each species makes up. This figure is multiplied by the palatability rating. This figure, which is percentage of palatable forage, is multiplied by the percentage of the ground which is covered by forage to obtain a forage acre factor, which may be defined as the acre area having a perfect cover of one hundred per cent palatable forage.

This same procedure may be followed in determining "forage acre factor" under the new method except that each species is multiplied by its value rating also. Thus grama grass would be multiplied by .71 and wheat grass by 1.18.

Forest service tests have shown 0.8 forage acres to support one cow for one month, thus range capacity can easily be figured from the above data.

For practical use determining the range capacity is the ultimate aim, not evaluating species. This capacity determination can be made by use of a method which is far more simple than the detailed procedure of rating individual species. This method consists of a quadrat measurement of the pasture dominants as to location and heighth before the grazing season. Another measurement of the same individuals after the grazing season is designed to give the percentage which has been grazed by stock. Figuring from a desired percentage of 80 enables the worker to determine percentage utilization at any time desired and capacity during the season.

This method is much more simple and consequently of much greater practical value to the ranch man. A test on mixed prairie pasture showed an acre to support one cow for a period of 0.57 months.

From the data assembled in this paper and from the methods experimented upon, it seems highly probable that quadrat capacity measurement has an unlimited practical value and that the method of determining capacity from the value of individual species is too laborious for anything other than range management and ecological studies.

SUMMARY

The present methods of determining range capacity are not accurate. Greater accuracy can be obtained by either of two methods, a system in which the value of each species is obtained, or a system in which quadrat measurement is made to determine the percentage of utilization in a unit time.

The value tests under the first of these two methods involve animal preference, volume yield, chemical analysis, physical characteristics and palatability.

An animal preference is best determined by quadrat measurement both before and after grazing to obtain the percentage of the volume of each species which is eaten. The results obtained from such tests on two type plants showed grama grass (Bouteloua gracilis) to have a value of 0.71, while western wheat grass (Agropyron Smithii) had a value of 0.47.

Volume yield is best determined by clipping and weighing the yield from a unit area. Such tests showed western wheat grass, a typical tall grass, to produce 2.81 times as much volume per unit area as is produced by grama grass, a typical short grass.

Chemical analysis is most effective when coupled with digestion percentages. Analysis experiments showed a decided value drop in range grasses as the season

progresses. Nutrition ratio obtained from this analysis coupled with digestion percentages showed 0.895 pounds of grama grass to be equivalent to 1.0 pounds of western wheat grass as a feed.

Physical characteristics and their effect on plant value can best be determined by relative comparison of their advantages and disadvantages to the range. Factors such as awns, poisonous qualities, inaccessibility, etc., were found to have direct influence upon plant value.

Palatability or percentage eaten can best be obtained by quadrat measurement of grazed and ungrazed plants. An average of all forest service palatability lists in the western states is given. This list offers a simple but inaccurate means of determining the value of any western range grass. The palatability figure, at best is of little practical use.

The value factors used in the first method of determining range capacity show western wheat grass to have a value of 1.18 and grama grass a value of 0.71 as compared to a factor 1.0 which is considered average for range grasses. Wheat grass range will therefore support 1.66 times as much stock as grama grass range.

The system of capacity determination by quadrat measurement involves a count of the number of grazed

and ungrazed plants of one dominant species to determine the per cent that have been grazed within a unit time by a unit number of stock. From this utilization per cent the stocking which will result in the desired utilization is computed. Such a test shows one acre of a typical mixed grass prairie range to support one cow for a period of 0.57 months.

The species value determination seems to have the greater scientific value in determining range capacity while the quadrat measurement determination has the greater practical value. Either method is more accurate than the present method, and the quadrat measurement is more simple.

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