MONTANA STATE UNIVERSITY

The chemical composition and utilization of greasewood and other browse species as related to some aspects of cattle nutrition on winter ranges in southeastern Montana

by Donald A Jameson

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Range Management
Montana State University
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Abstract:
A study was designed to explore the possibilities of a. correlation between blood level nutrients of cattle on winter ranges in southeastern Montana and the utilization and chemical composition of some of the major browse species of the area. The study was conducted near Miles City, Montana, and continued for two winter grazing seasons.

Previous work had indicated that browse plants were potentially valuable forage species, but little work had been done on their utilization in the Northern Great Plains.

Utilization was estimated by tagging twig's and measuring the length of these twigs at twenty-eight day intervals. The four browse species selected for the study were shadscale, big sagebrush, winterfat,, and greasewood.

After one season studies were discontinued on shadscale, winterfat, and big sagebrush, and a more intensive study of greasewood was initiated. Sampling was done on pastures under heavy, moderate, and light rates of stocking.

Browse and blood samples for chemical analyses were collected at about the same time that utilization was measured. Blood samples were analyzed for phosphorus, carotene, and vitamin A, and browse samples were analyzed for protein, phosphorus, and carotene.

Phosphorus levels in blood were lower than recommended all during the winter months, but vitamin A levels were adequate.

Utilization of greasewood, on the study plots, at a distance of about 600 yards from water was slightly over 50% under heavy stocking, and about 17% under light stocking. Utilization of greasewood under moderate stocking was about the same as under light stocking the first year, but was about 33% during the second year. About 10% use was made of greasewood in all pastures at a distance of about 1200 yards from water. Winterfat was used at least as much as greasewood. Most of the greasewood and winterfat use occurred during one sampling period in the early part of the season.

Utilization of shadscale was uneven and seems to be related to the amount of fruits left on the stems. Shadscale use may have some relationship to blood phosphorus levels.

Utilization of big sagebrush during one season's grazing was negligible.

Greasewood had an average crude protein content of 8.7%, winterfat and shadscale were about 1% lower, and big sagebrush more than 2% lower.

Phosphorus content of the species studied was too low for adequate nutrition of cattle.

Carotene in all species increased sharply during January of each year, and then dropped to the lowest point of the year just before growth began in the spring. Carotene content was adequate for proper cattle nutrition for most of the winter season.

During the second year, in addition to the analyses of protein, phosphorus, and carotene, greasewood was analyzed for moisture, ether extract, ash, crude fiber, calcium, magnesium, potassium, sodium, lignin, and chlorine. A high sodium content of the samples may have been partly responsible for the rather low salt consumption by the experimental cattle.

THE CHEMICAL COMPOSITION AND UTILIZATION OF GREASEWOOD AND OTHER BROWSE SPECIES AS RELATED TO SOME ASPECTS OF CATTLE NUTRITION ON WINTER RANGES IN SOUTHEASTERN MONTANA

by

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ABSTRACT

A study was designed to explore the possibilities of a correlation between blood level nutrients of cattle on winter ranges in southeastern Montana and the utilization and chemical composition of some of the major browse species of the area. The study was conducted near Miles City, Montana, and continued for two winter grazing seasons.

Previous work had indicated that browse plants were potentially valuable forage species, but little work had been done on their utilization in the Northern Great Plains.

Utilization was estimated by tagging twigs and measuring the length of these twigs at twenty-eight day intervals. The four browse species selected for the study were shadscale, big sagebrush, winterfat, and greasewood. After one season studies were discontinued on shadscale, winterfat, and big sagebrush, and a more intensive study of greasewood was initiated. Sampling was done on pastures under heavy, moderate, and light rates of stocking.

Browse and blood samples for chemical analyses were collected at about the same time that utilization was measured. Blood samples were analyzed for phosphorus, carotene, and vitamin A, and browse samples were analyzed for protein, phosphorus, and carotene.

Phosphorus levels in blood were lower than recommended all during the winter months, but vitamin A levels were adequate.

Utilization of greasewood, on the study plots, at a distance of about 600 yards from water was slightly over 50% under heavy stocking, and about 17% under light stocking. Utilization of greasewood under moderate stocking was about the same as under light stocking the first year, but was about 33% during the second year. About 10% use was made of greasewood in all pastures at a distance of about 1200 yards from water. Winterfat was used at least as much as greasewood. Most of the greasewood and winterfat use occurred during one sampling period in the early part of the season.

Utilization of shadscale was uneven and seems to be related to the amount of fruits left on the stems. Shadscale use may have some relationship to blood phosphorus levels.

Utilization of big sagebrush during one season's grazing was negligible.

Greasewood had an average crude protein content of 8.7%, winterfat and shadscale were about 1% lower, and big sagebrush more than 2% lower.

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Carotene in all species increased sharply during January of each year, and then dropped to the lowest point of the year just before growth began in the spring. Carotene content was adequate for proper cattle nutrition for most of the winter season.

During the second year, in addition to the analyses of protein, phosphorus, and carotene, greasewood was analyzed for moisture, ether extract, ash, crude fiber, calcium, magnesium, potassium, sodium, lignin, and chlorine. A high sodium content of the samples may have been partly responsible for the rather low salt consumption by the experimental cattle.

THE CHEMICAL COMPOSITION AND UTILIZATION OF GREASEWOOD AND OTHER BROWSE SPECIES AS RELATED TO SOME ASPECTS OF CATTLE NUTRITION ON WINTER RANGES IN SOUTHEASTERN MONTANA

INTRODUCTION

Objectives: This project was established as a part of a larger, year-long range nutrition study. It was designed as a preliminary survey to explore the possibility of a correlation between blood level nutrients of cattle on winter ranges in southeastern Montana and the utilization and chemical composition of some of the major browse species of the area. This sub-project was intended to provide some basis for more intensive research in the future. The ultimate purpose of the project was to help complete the yearlong picture of cattle nutrition as related to range forage. This information may be useful in planning ranches so more adequate winter forage can be obtained, and in determining the supplements needed on winter ranges.

In the words of Hurtt (1950):

> "Range use practices have developed with little or no knowledge of nutritional deficiencies, seasonal variation in nutrients, or of mineral, vitamin, and other obscure characteristics of range plants. Wasteful, inefficient management cannot be corrected until these characteristics are more fully known and used as a basis for supplemental feeding, seasonal grazing, and other range practices."

Although there has been much speculation of the value of browse as a winter feed for cattle in the Northern Great Plains region, there has been very little done in the way of a careful study of the problem.

The study area: This study was conducted at the Lone Pine winter pastures and adjacent areas of the U. S. Range Livestock Experiment Station at Miles City, Montana. Average annual precipitation is 13.2 inches. More than seventy percent of the precipitation comes during the six months period

starting April 1 (U. S. D. A., 1950). During normal winters the snowfall is slight and that which falls remains on the ground for only a short time.

The area is considered to be within the mixed prairie association of the grassland formation. On level and gently rolling portions the vegetation is typical of the grassland type commonly found in the mixed prairie, the dominant species being western wheatgrass (Agropyron smithii), needle-and-thread (Stipa comata), and blue grama (Bouteloua gracilis). On the rough, broken uplands, shadscale (Atriplex confertifolia), greasewood (Sarcobatus vermiculatus), big sagebrush (Artemisia tridentata), winterfat (Eurotia lanata), and silver sagebrush (Artemisia cana) are also important species. In addition to the species listed here there are many others which are present but which are less conspicuous. Figure 1 shows a general view of the area.

Other studies on the area: In 1932 the U. S. Forest Service began a study to determine the effect of light, moderate, and heavy grazing on Hereford breeding cows and range vegetation. The study was conducted on a portion of the U. S. Range Livestock Experiment Station (U. S. D. A., 1950).

Surface acre allowances per cow on a yearlong basis for the three rates of stocking were 38.8 for light, 30.5 for moderate, and 23.1 for heavy. Summer and winter grazing units were established and adjusted to the above rates of stocking. Each of the units was divided into six smaller pastures, two for each rate of grazing. The size of the pastures were varied and each pasture was stocked with ten animal units. The winter pastures were established in rough, broken country to provide protection from storms. The



Figure 1. A general view of the study area, pasture Q in the foreground. The larger browse plants can be seen protruding through the snow.

winter pastures were given the collective name of "Lone Pine", and were used from mid-November until mid-May (U. S. D. A., 1950).

The six pastures at both the winter and summer areas were arranged in a more or less circular pattern and watered by a central well. The winter pastures were designated by the letters Q through V. Pastures Q, R, and S (Figure 2) were used for this study. Pasture Q was heavily grazed, R lightly grazed, and S moderately grazed. The other pastures, T, U, and V were grazed in a similar manner. Weights of the breeding cows on these pastures were taken at twenty-eight day intervals (U. S. D. A., 1950).

In 1947 the Montana State Agricultural Experiment Station began a project on these same pastures to determine the nutritive value of Montana range plants and their influence on cattle nutrition. This project included sampling and chemical analyses of important range grasses and sampling and chemical analyses of the cattle blood. The project indicated within three years that the range grasses being sampled were deficient in some nutrients, especially phosphorus, during the fall and winter months, while at the same time the blood level counterparts of these same nutrients were not dangerously low, and in some cases even increased for a short time. This information indicated that the cattle were receiving nutrients from sources other than the grasses being sampled. The study reported here was launched to determine whether or not the source of some of the nutrients might be the shrubby plants which are abundant on the Lone Pine winter pastures.

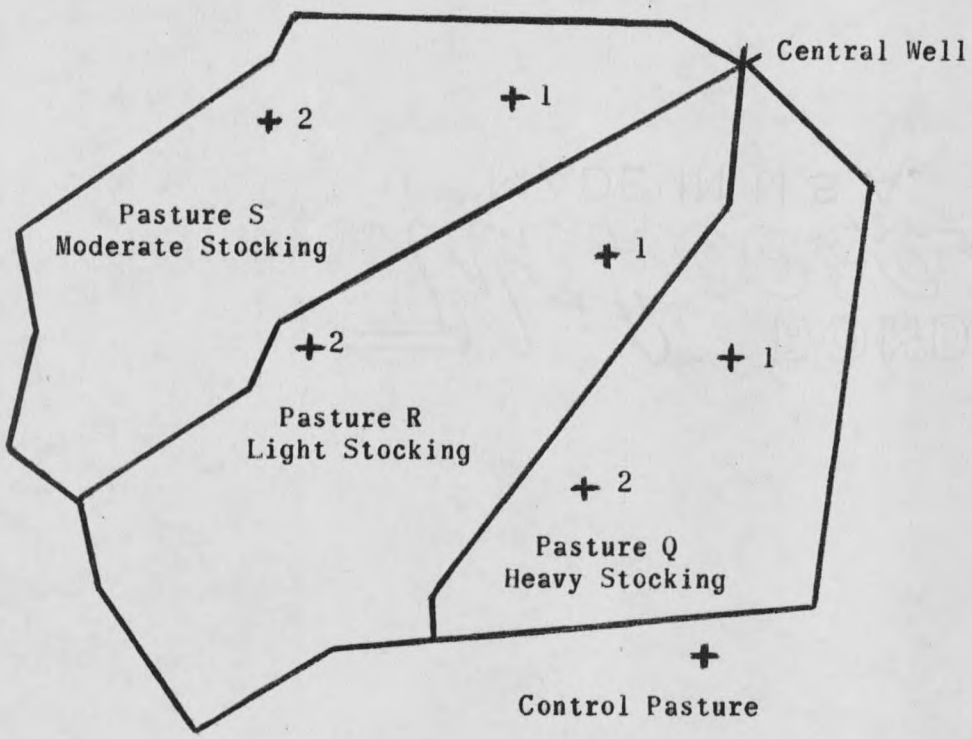


Figure 2. A map of the three Lone Pine winter pastures used in the study. Numbers 1 and 2 refer to the location of plots within the pastures.

REVIEW OF LITERATURE

Results of previous utilization studies: Clarke and Tisdale (1945) stated that:

> "Many of the broad-leaved herbs and shrubs are higher in nutritive value when in the cured stage than are the grasses. In addition such species as pasture sage (Artemisia frigida) and sagebrush (Artemisia cana) which are relatively unpalatable in the summer are utilized to a considerable extent in the winter.....Winterfat (Eurotia lanata), salt sage (Atriplex gardneri), willows (Salix spp.), pasture sage, and some sagebrush are highly desirable on a winter range."

This reference also gives relative palatibility of some browse species as follows: eaten readily - winterfat and salt sage; eaten slightly - pasture sage and sagebrush; eaten rarely or not at all - broom weed (Gutierrezia sarothrae). No other results of studies on the use of browse on cattle ranges of the Northern Great Plains area have come to the attention of the author. Observations of the use of browse species in this area have been made, but these observations have not been qualified by experimental evidence.

Nutritive value of browse species: Averages of chemical analyses of shadscale, big sagebrush, winterfat, and greasewood which have been published are shown in Table I.

Methods of sampling browse utilization: Five criteria were chosen for the selection of a method of sampling utilization of the four major browse species to be measured. The criteria of selection of the method were: 1) it should be applicable to the measurement of utilization of browse species; 2) it should provide an actual, quantitative measure of utilization of the browse species; 3) it would provide this measure of utilization at intervals

Table I. Average winter protein and phosphorus content of shadscale, big sagebrush, winterfat, and greasewood.[1/]

Species	Percent crude protein	Percent phosphorus
Shadscale (*Atriplex confertifolia*)	7.64	.080
Big sagebrush (*Artemisia tridentata*)	10.57	.300
Winterfat (*Eurotia lanata*)	9.46	.107
Greasewood (*Sarcobatus vermiculatus*)	----	.19[2/]

1/ The above figures are averages of analyses published by the following: Bidwell and Wooton (1925), Clarke and Tisdale (1945), Cook and Harris (1950), Esplin, *et al* (1937), Idaho Experiment Station (1937), McCreary (1927 and 1939), and Wasser (1945).

2/ One analysis.

to allow analysis of correlation of utilization of the browse species with blood level nutrients; 4) it should not require removal of a large amount of material from the pastures studied, since these pastures were a part of a rate of stocking study; and 5) it should allow sampling time to be held to a minimum.

Cassady (1941) developed a method of sampling utilization by clipping. Under this method, a given number of plant units of each of the species to be sampled were clipped by hand immediately before grazing by sheep and again immediately after grazing, the time between the two samplings being held to a minimum to reduce the influence of growth on the samples. The difference in the weight of each sample was taken as the amount of each species which was consumed by the grazing sheep.

Cook, Harris, and Stoddart (1948) later modified Cassady's method by adding to the sampling procedure the chemical analysis of both the before and after samples, the difference in the amounts of nutrients present in the two samples being taken as the amount of nutrients consumed by the sheep. This modification proved to give a more accurate measure of nutritive intake than determining the nutrient content of the forage by one sample, since the parts of the plants consumed by the sheep were more nutritious than the average nutrient content of the entire plant. The before and after method of Cook, Harris, and Stoddart has been used on both winter and summer ranges with apparent success (Cook, Cook, and Harris, 1948; Green, et al, 1951). Everson (1951) determined that using the before and after clipping method of determining utilization of individual species would require a minimum of 336

man hours work to reduce sampling error to 5%.

Many methods of estimating utilization have been developed by various workers. At least two of these methods have been developed especially for estimating utilization of browse species. Forsling and Storm (1929) estimated browse utilization and checked the estimates against actual measurements of ungrazed twigs. Hormay (1943) estimated utilization and measured actual diameters of browse plants to arrive at an estimate of utilization weighted by plant diameters.

Pickford and Reid (1948) divided the range into two areas, comparing clippings from ungrazed areas with clippings from grazed areas to determine utilization of the forage. Klingman and co-workers (1943) and others have protected small areas with cages, clipping both protected and unprotected areas after grazing to determine utilization.

Nelson (1930) determined utilization by placing a numbered tag on each of one to three large representative stems, and taking the measurements of all new growth on the larger tagged stems. Measurements could be repeated at intervals without damage to the plants. This method was used on long-time studies of utilization of browse plants, and included a non-grazed control plot to determine the change in length of twigs due to growth. The method was modified by Julander (1937). In the modified method each of four twigs on a plot were marked with numbered aluminum tags. The current growth on each twig was measured before use of the area by deer as winter range, and the same twigs were remeasured immediately after the deer departed for the summer range. The difference between the combined total lengths before and

after browsing represented the linear amount consumed. This modification needed no control plots if only one type of animal was grazing, since it was used in the winter months when no growth was taking place. In addition, if there obviously had been no utilization on a given plant during the winter, no new measurements needed to be taken, since the new measurements would have been the same as the measurements taken the previous autumn. This latter method has been used by Aldous (1945) and others with slight modifications.

McKinney (1951) studied the possibilities of determining species consumed by examination of the silica patterns in the feces of animals, and comparing those patterns with similar structures found in the plants. He concluded that there was some possibility of a qualitative determination of the species, but that there was little possibility of obtaining any quantitative measure of the various species consumed.

Methods of sampling for chemical analysis of browse nutrients: The chief criterion chosen for the selection of a method of collecting material for chemical analysis of nutrients was that of preservation of nutrients until the samples could be analyzed in the laboratory. This preservation was especially important in the case of carotene, because carotene does deteriorate very rapidly following clipping. A very satisfactory method of handling vegetation samples has been developed by Dr. Leon Johnson of the Montana Agricultural Experiment Station Chemistry Research Department.

EXPERIMENTAL PROCEDURE

The project was conducted on a winter cattle range in southeastern Montana during the 1950-1951 and the 1951-1952 winter grazing seasons. The study pastures were those of the U. S. Range Livestock Experiment Station as described earlier in this paper. Three of the six pastures (Q, R, and S; see figure 2) were used in the study. In addition an adjacent pasture, ungrazed during the winter, was used as a control.

Within each of the four pastures, sampling areas were located. Each of these areas were as nearly alike as possible with regard to site potential and grazing use.

The soil type of the sampling areas was kept relatively similar by locating all areas within two similar soil types which made up a major portion of the study area. These soil types are described as having a surface soil of brown to light brown friable clay loam underlain by a brown silty clay (Gieseker, 1948).

Each sampling area was located within a similar vegetative type. Three types were used, these three types making up 55% of the area of the study pastures. Vegetational composition of these types is shown in Table II.

Slope of each sampling area was less than 5%. Exposure was variable, but it is not believed that this variance greatly influenced plant growth or grazing action. Each sampling area, except for the control area, was at least 550 yards but not more than 720 yards from water, with a second area established between 1100 and 1240 yards from water during the second year.

Topography in each pasture was rough and broken with an interspersion of

Table II. Vegetational composition of the major types in the area embracing pastures Q, R, and S, according to reconnaissance survey. Types 1 and 2 were dominated by blue grama and western wheatgrass, type 3 was dominated by western wheatgrass, blue grama, and greasewood.[1]

Plants	Percent of total vegetation		
	Type 1	Type 2	Type 3
All forbs	15	5	10
All grasses	55	75	65
All shrubs	30	20	25
Shrubs by species:			
Greasewood (*Sarcobatus vermiculatus*)	15	6	8
Big sagebrush (*Artemisia tridentata*)	10	8	7
Winterfat (*Eurotia lanata*)	2	2	2
Fringed sagewort (*Artemisia frigida*)	Tr.	Tr.	2
Broom snakeweed (*Gutierrezia sarothrae*)	1	0	2
Shadscale (*Atriplex confertifolia*)	2	4	4
Soapweed (*Yucca glauca*)	0	0	Tr.
Rabbitbrush (*Chrysothamnus* spp.)	0	0	Tr.

[1] U. S. D. A., 1940

fairly level benches.

Vegetation sampling procedure: At each study area, including the pasture used as a control, shadscale (Atriplex confertifolia), big sagebrush (Artemisia tridentata), winterfat (Eurotia lanata), and greasewood (Sarcobatus vermiculatus) were measured for utilization during the first season. These species were selected as being the most abundant (Table III) and as being of possible forage value. Greasewood alone was studied during the second season. Two replications for each species were established, the boundaries of each replication being defined as a measured plot, or, where applicable, as a natural grouping of plants. The location of these replications were selected according to the previously discussed factors of soil type, vegetational type, slope, exposure, and distance from water, and were not selected at random. Each replication contained at least twenty plants of the species to be sampled in that replication.

After the first season, studies were discontinued on big sagebrush because of the very slight amount of use of this species by livestock. Studies were also discontinued on winterfat and shadscale because present methods did not seem to adequately measure the utilization of these species.

Utilization sampling procedure: Two methods of estimating utilization were used the first year, these being derivations of those described by Aldous (1945) and by Cook, Harris, and Stoddart (1948).

In applying the first named method five plants were selected at random within each replication during the first season, and ten plants were selected at random during the second year. The basic measurement unit of each

Table III. Relative amounts of browse species on the pastures studied. The figures were computed by multiplying density times percent composition times surface acres of each type.[1]

Species	Amount
Greasewood (Sarcobatus vermiculatus)	9.90
Big sagebrush (Artemisia tridentata)	9.68
Shadscale (Atriplex confertifolia)	4.82
Winterfat (Eurotia lanata)	1.82
Silver sagebrush (Artemisia cana)	1.35
Broom snakeweed (Gutierrezia sarothrae)	1.19
Rose (Rosa spp.)	0.48
Fringed sagewort (Artemisia frigida)	0.45
Snowberry (Symphoricarpos spp.)	0.32
Gardner saltbush (Atriplex gardneri)	0.27
Cudweed sagewort (Artemisia gnaphaloides)	0.16
Rabbitbrush (Chrysothamnus spp.)	Trace
Soapweed (Yucca glauca)	Trace
Others	0.09

[1] U. S. D. A., 1940

plant was called an observation. In the case of winterfat, an observation included the entire plant. In the cases of shadscale, big sagebrush, and greasewood, an observation was a group of at least five twigs on a major branch which was arbitrarily selected. Each twig on each observation was measured at the beginning of the grazing season and the length recorded. All the observations were marked for future reference. At twenty-eight day intervals these observations were remeasured to determine their utilization.

In applying the last named method (Cook, Harris, and Stoddart) five plants were selected at random in each replication except no plants were selected for winterfat because, due to its growth habit, the entire plant would have had to be taken for one observation of this species. At the beginning of the grazing season at least eight twigs from one major branch were clipped from each plant. These twigs were then air dried and weighed individually.

On February 22, 1951, the clipping procedure was repeated on the same plants as were sampled before. Because an inadequate sample had been clipped previously, the number of twigs clipped per plant was increased to ten or more, usually to about fifteen. These twigs were also dried and weighed individually, the difference between the two clippings giving the utilization on the sample plants.

The plan was to repeat the clippings on March 22, 1951, but since some growth had started on this date, this plan was abandoned. Because a very large amount of material would have been removed from pastures which are also used for grazing intensity studies, this method could not be used to

determine a month-by-month utilization measure, and so was not continued during the second year.

Collection of material for chemical analyses: From the plants chosen for the twig length method of measuring utilization, a twelve gram composite sample for each study area, except the control, was clipped at each twenty-eight day interval. In the case of winterfat, as the entire plant was measured for utilization, nearby plants were used for collection of the samples for chemical analyses. These samples were immediately packed in dry ice for preservation and shipped to the Chemistry Research Department of the Montana Agricultural Experiment Station for the determination of protein, phosphorus, and carotene of each sample. During the second season, sample size was increased to sixty grams of greasewood, and in addition to the individual analyses of protein, phosphorus, and carotene, a composite analysis was made to determine the amount of moisture, protein, ether extract, ash, crude fiber, phosphorus, calcium, carotene, magnesium, potassium, sodium, lignin, and chlorine. Through some mishap, no individual analyses were made at two dates for protein and phosphorus.

Grazing preference determination: At each sampling date that the cattle were actively grazing (ie., the dates when the cattle were not on feed) the cattle of pasture S (the pasture of moderate use) were observed in order to determine grazing preference. After a period of observation of about one-half hour, a sample was collected to represent the material being grazed, both as to the kind of plants grazed and the amount of each taken. These samples were usually collected twice during the day, but during severe

weather, when the cattle spent much of their time in sheltered locations, only one sample was collected each day. The samples were then packed in dry ice and shipped to Chemistry Research for analyses.

Sampling for blood nutrients: At each twenty-eight day interval the cattle from these study pastures were brought to the central corrals for weighing. At the same time, about 40 cc of blood were collected from the jugular vein of five animals from each pasture. The same five animals were bled each month. These samples were packed in wet ice and sawdust and shipped to the Veterinary Research Laboratory of the Montana Agricultural Experiment Station for analyses of phosphorus, carotene, vitamin A, magnesium, and calcium.

Methods of chemical analyses of browse nutrients: Association of Official Agricultural Chemists methods (1950) were used for determination of carotene, moisture, protein, ether extract, crude fiber, and ash. Protein determination was with mecuric oxide as a catalyst.

Phosphorus determination was by the method described by Allen (1940) and modified by Johnson and Giovanini (1949).

Magnesium determination was by the method described by Young and Gill (1951).

Lignin determination was by the methods described by Peterson, Walden, and Hixon (1932); Ritter, Seborg, and Mitchell (1932); and Shervard and Harris (1932).

Calcium, sodium, and potassium determinations were by a flame photometer method developed by Baker (1951).

Methods of chemical analyses of blood nutrients: Phosphorus determination

was done by a slightly modified version of the method published by Fiske and Subbarow (1925).

Carotene and vitamin A analyses were by the method described by Boyer, Phillips, and Smith (1944).

RESULTS AND DISCUSSION

Blood Nutrient Analyses

Phosphorus: Blood phosphorus levels (Tables IV and V) were in all cases below those observed by Thomas (1951) and most other workers, and were even as low as the deficient levels produced by Lewis (1951). In both years there was a highly significant variation between pastures (Appendix Tables I and II). Cows under heavy and light stocking had higher phosphorus than cows under moderate stocking. These differences may be influenced by vegetation of the pastures, as discussed later.

The variation of blood phosphorus levels between dates was highly significant for both seasons (Appendix Tables I and II). Each year as the winter grazing season began, phosphorus levels began to drop off, and in 1950-1951, continued to drop off until mid-season, and then began to slowly increase. In 1951-1952 the phosphorus levels rose in December and then began to drop and continued to drop until spring. Normally, the phosphorus levels were higher during the time hay was fed than during the immediately preceeding period. Analyses of the hay showed it to be higher in phosphorus than either the range grasses or browse. The phosphorus increase may be partly due to an increase in the total feed intake with the beginning of feeding, as well as an increase in the percentage of phosphorus in the feed. At no time were any of the usual external symptoms of a phosphorus deficiency observed.

Carotene: During the first season the blood carotene level (Table IV) on November 30 averaged 80 micrograms per 100 milliliters, and by February 22

Table IV. Phosphorus, carotene, and vitamin A blood levels in cattle on pastures Q (heavily stocked), R (lightly stocked), and S (moderately stocked) during the winter of 1950-1951.

Sampling Date	Pasture	Phosphorus mg/100 ml	Carotene mcg/100 ml	Vitamin A mcg/100 ml
11-30	Q	3.3	81	39
	R	3.2	63	39
	S	2.7	96	40
	Date mean	3.0	80	39
12-28	Q	3.3	57	34
	R	2.8	48	36
	S	2.3	46	33
	Date mean	2.8	50	34
1-24	Q	2.1	45	28
	R	2.2	42	33
	S	1.9	47	33
	Date mean	2.1	44	31
2-22	Q	3.0	44	23
	R	2.8	38	23
	S	2.2	40	27
	Date mean	2.7	41	25
3-22	Q	3.6	33	27
	R	3.0	29	24
	S	2.3	36	29
	Date mean	3.0	32	27
Season-long pasture means:				
	Q	3.0	52	30
	R	2.8	44	31
	S	2.3	53	32
Least significant differences between means:				
Pasture means:	5%	.24	8.0	2.9
	1%	.32	10.7	3.8
Date means:	5%	.32	8.4	3.7
	1%	.42	11.2	5.0

Table V. Phosphorus, carotene, and vitamin A blood levels in cattle on pastures Q (heavily stocked), R (lightly stocked), and S (moderately stocked) during the winter of 1951-1952.

Sampling Date	Pasture	Phosphorus mg/100 ml	Carotene mcg/100 ml	Vitamin A mcg/100 ml
11-1	Q	4.2	270	33
	R	4.1	307	34
	S	3.4	320	36
	Date mean	3.9	299	34
11-29	Q	2.7	125	36
	R	2.7	124	38
	S	2.7	160	40
	Date mean	2.7	137	38
12-27	Q	4.5	44	26
	R	4.0	36	26
	S	3.1	44	29
	Date mean	3.9	41	27
1-24	Q	3.6	20	20
	R	3.5	29	29
	S	3.6	37	33
	Date mean	3.6	29	27
2-21	Q	3.1	24	26
	R	3.6	29	25
	S	2.8	29	30
	Date mean	3.2	28	27
3-20	Q	3.0	52	19
	R	3.1	52	19
	S	2.2	58	23
	Date mean	2.8	54	20
Season-long pasture means:				
	Q	3.5	89	27
	R	3.5	96	29
	S	3.0	108	32
Least significant differences:				
Pasture means:	5%	.28	16.5	2.4
	1%	.38	21.9	3.2
Date means	5%	.40	23.3	3.4
	1%	.53	31.0	4.5

had dropped to 41 mcg/100 ml. During the second season blood level carotene was higher early in the season (Table V), averaging 137 mcg/100 ml on November 29, but by February 21 had dropped to 28 mcg/100 ml. The higher levels early in the second season were caused by green forage produced by late summer rains.

During both seasons there was a highly significant variation in blood carotene between sampling dates, but not between pastures (Appendix Tables I and II). After early December in both years, the blood carotene levels were lower than those found by Thomas (1951) and other workers, but this probably was not important because vitamin A levels were adequate at all dates. The continous drop may have been partly due to steadily decreasing body reserves which were built up during the summer months, and is not entirely indicative of current levels of carotene in the feed. Cattle with the lowest blood phosphorus tended to have the highest blood carotene levels, with some exceptions. This relationship between phosphorus and carotene agrees with the findings of Thomas (1951).

Vitamin A: The variation in vitamin A between sampling dates was highly significant in both years (Appendix Tables I and II). In general, vitamin A continued to drop throughout the winter, but did not become dangerously low (Thomas, 1951). No external symptoms of vitamin A deficiency were observed. The vitamin A decline, as that of carotene, was probably due to the dwindling body reserves.

In both years the vitamin A levels were heaviest in the order of moderate, light, and heavily stocked pastures. The variation between pastures

was highly significant during the second year, but not significant during the first year (Appendix Tables I and II). Even when highly significant, the variation between pastures was much less than the variation between sampling dates.

Utilization of Browse Plants, 1950-1951

Results of the before and after clipping method were extremely erratic because of inadequate sampling. The end of season clippings were in many cases heavier than those clipped at the beginning of the season. Results of the clipping method are not reported, and the following discussion is confined to results of the twig length method of determining utilization.

Table VI (a partial summary of Table VII) shows the season-long utilization of the four species measured. Utilization on the control pasture was subtracted from utilization on the study pastures to account for twig removal by factors other than grazing by domestic livestock.

Winterfat and greasewood showed heavier use under heavy stocking, with about equal use under light and moderate stocking. Appreciable use of shadscale occurred only under moderate stocking. These results would explain the highly significant interaction which was observed between species and pastures.

During the grazing preference observations, cattle were observed to utilize shadscale twigs which still held their fruits, but avoided those which had shed their fruits. The cattle also were seen to eat shadscale fruits which had fallen to the ground. The heavier use observed on shadscale under moderate stocking may have been due to a combination of inadequate sampling and utilization in relation to the amount of fruits on the plants, rather than to an overall difference in use between pastures.

Big sagebrush utilization was negligible, being no more than 1% in any of the pastures. For this reason studies were discontinued on this species

Table VI. Percentage twig length removed by cattle during the winter of 1950-1951 from pastures Q (heavy stocking), R (light stocking), and S (moderate stocking).

Pasture	Species			
	Winterfat	Greasewood	Shadscale	Big sagebrush
Q	63	52	0	0
R	13	16	3	1
S	15	17	22	1

after the first season.

The differences in utilization between species and between pastures were highly significant (Appendix Table III).

In an attempt to get a picture of differences in utilization of the species throughout the season, samples were taken at different dates during the winter. The length of sampling periods were not equal in all cases because inclement weather interfered with some measurements. To overcome the differences in length of sampling periods, each percentage was divided by the number of weeks in the sampling period (Table VII).

The winter grazing season began October 19. The first measurements were taken November 30, but observations on November 2 indicated that no utilization had occurred by that date. The greatest part of the average utilization occurred during the sampling period from November 2 to November 30, and tapered off rapidly for the rest of the season. These differences between sampling periods were highly significant (Appendix Table III). However, the greatest part of the utilization of greasewood and winterfat occurred during the sampling period from November 2 to November 30, while the major amount of shadscale utilization occurred from November 30 to February 22. These results would explain the highly significant interaction between dates and species (Appendix Table III), but the reason for greater use occurring during one particular period is not known.

Mention was made earlier that appreciable use of shadscale occurred only under moderate stocking, while winterfat and greasewood were utilized the most under heavy stocking. This difference, in connection with the difference

Table VII. Average weekly utilization of the browse plants studied on pastures Q (heavy stocking), R (light stocking), and S (heavy stocking) during the winter of 1950-1951.

Species	Sampling Date	Pasture				Species Means
		Control	Q	R	S	
Shadscale	11-30	0.0	0.0	0.0	0.5	
	1-3	0.0	0.0	0.0	1.7	
	2-22	0.0	0.0	0.0	1.6	
	3-22	0.0	0.0	0.8	0.1	0.3
Big sagebrush	11-30	0.0	0.0	0.2	0.5	
	1-3	0.0	0.0	0.0	0.0	
	2-22	0.0	0.0	0.0	0.0	
	3-22	0.0	0.0	0.0	0.0	0.1
Winterfat	11-30	0.0	7.8	1.2	9.0	
	1-3	0.0	5.3	0.2	2.4	
	2-22	1.8	4.8	3.2	0.3	
	3-22	0.9	1.1	1.0	0.0	2.4
Greasewood	11-30	0.8	8.5	2.8	5.2	
	1-3	0.0	4.7	1.5	1.0	
	2-22	0.0	1.9	0.2	0.2	
	3-22	0.0	0.0	0.8	0.2	1.7
Pasture means:		0.2	2.1	0.7	1.4	

Date means: 11-30, 2.3; 1-3, 1.0; 2-22, 0.9; 3-22, 0.3

Least significant differences for all means: at 5% .83, at 1% 1.10

in time of utilization of the different species, would explain the significant interaction between dates and pastures (Appendix Table III).

Although winterfat was considered to be an important forage species, studies on this species were discontinued after the first year because of difficulties with utilization measurements. A considerable amount of material was removed from three of the ten winterfat plants measured in the control pasture. The type of removal indicated utilization by small mammals or natural abscission. It is reasonable to suspect that some material was also removed by these causes from the other pastures as well. A more detailed study of winterfat is needed to develop more efficient methods of measuring utilization, fully accounting for the various agents of twig removal.

Although big sagebrush showed almost no use, it was observed that another species of sagebrush, silver sagebrush (Artemisia cana), which is abundant on the study area (Table III), was utilized to an appreciable extent. Unfortunately this species was not included in the study.

As a point of interest, considerable utilization of soapweed (Yucca glauca) was observed. After a period of heavy snowfall, when animal tracks could be readily distinguished, rabbit tracks were seen near recently eaten soapweed plants in areas where no cattle tracks were seen. Leaves as well as seed pods were eaten. The amount of utilization of soapweed did not seem to be greater in areas where cattle tracks were evident.

Chemical Composition of Browse Plants, 1950-1951

Protein: The average crude protein content of the greasewood samples (Table VIII) was comparable to the crude protein in good mixed hay as reported by Morrison (1949), indicating the potential protein value of greasewood. Morrison also gives a digestion coefficient for salt bush protein of 66%. If we assume a like digestion coefficient for greasewood protein, greasewood would have a digestible protein content of 5.8%, considerably above the 4.5% minimum recommended by the National Research Council (Guilbert, et al, 1950).

There was a highly significant variation in protein content of the browse between sampling periods (Appendix Table IV), the highest value occurring on January 3 and the lowest on February 22. There was also a highly significant difference between pastures, the shrubs in the lightly stocked pasture having the highest average protein, and the shrubs in the moderately stocked pasture having the lowest average protein. This suggests that the differences were not a result of grazing intensity.

There was a highly significant variation between species (Appendix Table IV). Greasewood had an average crude protein content of 8.4%, winterfat and shadscale about 1% less, and big sagebrush the lowest with 6.4% protein.

The first order interactions between species, pastures, and dates were significant (Appendix Table IV), indicating that these factors do not vary independently. The interaction between dates and pastures can be explained, at least in part, by the low protein content of the samples collected in Pasture S on February 22. The interaction between species and dates can be partly explained by the high protein content of the greasewood samples which

Table VIII. Percent protein in browse samples during 1950-1951.

Species	Sampling Date	Pasture Q	Pasture R	Pasture S	Species Means
Shadscale	11-30	7.4	7.5	7.7	
	1-3	8.5	8.0	7.0	
	2-22	8.1	7.8	5.9	
	3-22	8.1	7.5	6.6	7.5
Big sagebrush	11-30	6.4	6.7	7.4	
	1-3	6.4	6.5	7.1	
	2-22	6.1	6.3	5.4	
	3-22	5.7	6.6	6.0	6.4
Winterfat	11-30	6.5	8.8	7.6	
	1-3	6.8	8.7	7.1	
	2-22	6.6	8.7	6.1	
	3-22	---	8.3	7.5	7.4
Greasewood	11-30	8.0	7.4	8.1	
	1-3	9.2	9.1	9.5	
	2-22	8.2	7.7	8.1	
	3-22	8.4	8.7	8.7	8.4
Pasture means:		7.3	7.8	7.2	
Date means: 11-30, 7.5; 1-3, 7.8; 2-22, 7.1; 3-22, 7.4					

Least significant differences for date and species means: at 5% 0.29, at 1% 0.40. Least significant difference for pasture means: at 5% 0.25, at 1% 0.35.

were collected on January 3. The interaction between species and pastures is not too clear, but the lowest protein content of shadscale and winterfat occurred in the pastures where heaviest utilization of these species occurred, although the lowest protein content of greasewood occurred in the pasture of light use. The reasons for these results are not understood.

Phosphorus: Phosphorus content of the browse samples is shown in Table IX. In no case did the phosphorus content approach the .18% minimum recommended by the National Research Council (Guilbert, et al, 1950).

There was a highly significant variation of phosphorus content between sampling dates (Appendix Table IV), with the high value occurring January 3, and the low value occurring March 22.

There was a highly significant variation between species. Big sagebrush was the highest with an average phosphorus content of .104%, the other species having about .075% phosphorus. Although the phosphorus content of big sagebrush is considerably lower than the average winter phosphorus content of this species found by other workers (Table I), the relationship of phosphorus in big sagebrush to phosphorus in other species is the same as reported in other experiments.

The pastures of light and heavy stocking showed significantly more phosphorus in the browse samples than did the pasture of moderate stocking. These differences seem to be due mostly to the low phosphorus content of the shadscale samples from the pasture of moderate use.

The first order interactions of species, dates, and pastures were significant, indicating that these factors do not vary independently. The

Table IX. Percent phosphorus in browse samples during 1950-1951.

Species	Sampling Date	Pasture Q	Pasture R	Pasture S	Species Means
Shadscale	11-30	.08	.07	.07	
	1-3	.10	.07	.08	
	2-22	.09	.07	.05	
	3-22	.09	.06	.06	.074
Big sagebrush	11-30	.10	.12	.11	
	1-3	.12	.10	.10	
	2-22	.11	.11	.08	
	3-22	.09	.12	.09	.104
Winterfat	11-30	.06	.09	.08	
	1-3	.09	.11	.09	
	2-22	.07	.08	.07	
	3-22	---	.07	.06	.077
Greasewood	11-30	.07	.07	.07	
	1-3	.08	.08	.08	
	2-22	.09	.08	.08	
	3-22	.06	.07	.07	.075
Pasture means:		.084	.086	.078	

Date means: 11-30, .082; 1-3, .092; 2-22, .082; 3-22, .074

Least significant differences for date and species means: at 5% .006, at 1% .009. Least significant difference for pasture means: at 5% .005, at 1% .007.

importance of these interactions is not clear.

Carotene: Carotene content of the samples showed a highly significant variation between sampling dates (Appendix Table IV). Peak carotene content occurred in the January 3 samples, being about 20 micrograms per gram (Table X). This carotene content is comparable to U. S. no. 2 alfalfa (Morrison, 1949) and well above the 6.7 mcg/gm minimum recommended by the National Research Council (Guilbert, et al, 1950). On November 30, the carotene content was about half that of January 3, but still above the 6.7 mcg/gm minimum. On February 22 the carotene content had dropped to 5 mcg/gm.

Apparently there have been no previous studies on the amounts of carotene or other carotenoids in browse plants at different dates during the winter months. Rygg (1949) and earlier workers have made studies on the carotenoid content of stored carrots, and have reported an increase of carotenoids under certain conditions. Rygg did not have any information as to the source of the carotenoids formed, but suggested precursors which take considerable time to form carotenoids, the reaction beginning only when the plants become otherwise dormant. There seems to be great opportunity for work on the physiological reactions of plants during the "dormant" period of the winter months. It is of particular interest to note that no significant correlation was observed between temperature changes and carotene content of the browse.

Table X. Carotene in browse samples during 1950-1951. Carotene expressed in micrograms per gram.

Species	Sampling Date	Pasture			Species Means
		Q	R	S	
Shadscale	11-30	8.8	8.2	7.1	
	1-3	14.0	27.0	10.0	
	2-22	4.4	5.1	4.8	
	3-22	3.1	3.4	0.4	8.0
Big sagebrush	11-30	8.2	11.6	8.2	
	1-3	9.0	13.0	29.0	
	2-22	4.4	5.1	4.1	
	3-22	0.4	4.1	3.4	8.4
Winterfat	11-30	10.2	12.2	11.6	
	1-3	29.0	31.0	25.0	
	2-22	6.5	7.1	5.8	
	3-22	---	3.4	3.7	12.4
Greasewood	11-30	8.2	8.8	6.8	
	1-3	12.0	22.0	25.0	
	2-22	3.4	5.4	4.4	
	3-22	4.8	5.8	4.1	9.2
Pasture means:		8.1	10.8	9.6	

Date means: 11-30, 9.2; 1-3, 20.5; 2-22, 5.0; 3-22, 3.3

Least significant difference for date means: at 5% 3.6, at 1% 4.9. The other differences were not significant.

Relationships of Browse Utilization, Browse Nutrients, and Blood Nutrients, 1950-1951

The discussion in this section is drawn largely from the coefficients of correlation listed in Appendix Table V.

Vitamin A, and, to a lesser extent, its precursor carotene, can be stored in cattle for considerable lengths of time (Thomas, 1951). During the winter study period these blood levels had declined from those observed in the summer; this difference is probably due to the decreased supply of carotene in the feed source. The decline continued until new plant growth in the spring increased the supply of carotene.

The carotene content of the browse increased sharply in January. This rise in carotene may have had some tendency to reduce the rate of decline of blood carotene and vitamin A, but no significant correlations were observed between these data.

Utilization of greasewood and winterfat was highest at the beginning of the winter grazing season and declined as the season progressed. The carotene content of these species, being highest in mid-season, showed no significant correlation with their utilization.

The decline of utilization of greasewood and winterfat through the season was coincident with the decline of blood level carotene and vitamin A during the study period. There was a highly significant correlation of winterfat and greasewood utilization with blood carotene levels and a significant correlation of the utilization of these species with blood vitamin A levels. There were also highly significant multiple correlations among greasewood utilization, greasewood carotene, and blood carotene, and among winterfat

utilization, winterfat carotene, and blood carotene, and a significant multiple correlation among winterfat utilization, winterfat carotene, and blood vitamin A. However, it is felt that because carotene and vitamin A blood levels are not entirely dependent on immediate available supply of carotene, and because there was no significant correlation with greasewood or winterfat carotene content and the utilization of these species, the utilization of greasewood and winterfat did not necessarily influence the blood carotene and vitamin A levels.

Mention was made earlier of the fact that cattle made considerable use of shadscale fruits. Shadscale utilization showed a significant negative correlation with its protein content. Samples of the shadscale fruits showed a protein content of 5.4% on January 3, 1951, considerably less than the 7.8% protein of the composite samples of twigs, leaves, and fruits collected on the same date. The shadscale plants measured varied considerably in regard to the amount of fruit left on the stems. If we assume a carbohydrate content in inverse proportion to the protein content in the sample material, the evidence would seem to suggest a positive relationship of shadscale utilization with the carbohydrate content of the plants. Very recently Plice (1952) showed that plants with a higher sugar content were selected by livestock for grazing. It is probable that the stored carbohydrates in the shadscale seeds changed, at least in part, to sugars with the advent of cold winter weather.

Shadscale fruits collected on January 3 had an average phosphorus content of .075%, somewhat lower than the .083% average phosphorus content of the

composite samples collected on the same date. A negative correlation was observed between shadscale phosphorus and its utilization, but this value was not significant.

A significant negative correlation between shadscale utilization and blood level phosphorus was observed. The greatest amount of use of shadscale occurred in the pasture of moderate use. The cattle in this pasture showed lower phosphorus levels than the cattle in the other two pastures, the differences being highly significant.

In view of the negative correlations between shadscale phosphorus and its utilization and between blood phosphorus and shadscale utilization, a positive correlation between blood phosphorus and shadscale phosphorus is expected. Such a positive correlation was found to be present, the value being significant. There was also a significant multiple correlation among shadscale utilization, shadscale phosphorus, and blood phosphorus. The relationships of shadscale plants to blood nutrients as implied by these data are not understood.

There is a correlation (r = .773**, 10 d.f.) between the amount of protein and the amount of phosphorus in the shadscale samples. No measure of protein in the blood was available, but it is possible that phosphorus might indicate the relationships of protein between browse plants and blood nutrients, as well as the phosphorus relationships.

Studies were discontinued on shadscale because no methods were known to measure the amount of seeds eaten, and these seem to be the main attraction of the species to livestock. Work on methods of measuring utilization of

shadscale and more detailed analyses of the various edible parts of the shadscale plants, especially in regard to sugars and other carbohydrates, is suggested.

Utilization of Greasewood, 1951-1952

During the second year of study on greasewood, plots were established on the same locations as the greasewood plots of the first year (about 600 yards from water), and, in addition, plots were established at about 1200 yards from water (Figure 2).

There was a significant variation of greasewood utilization due to location of plots (Appendix Table VI). Average season-long utilization was 11% at location 2 and 36% at location 1 (Table XI). The difference between locations was probably not due so much to distance alone as it was to a combination of distance, cold, and snow. These last two factors encourage cattle to remain near hay, water, and shelter.

Table XI shows that in each pasture utilization was greater nearer water, but the relationship between locations was different for each pasture. An interaction between locations and pastures is indicated, but was not statistically significant (Appendix Table VI). However, the heaviest use was in the heavily stocked pasture on the plots nearest to water, and the least use occurred in the lightly stocked plots away from water, as would be expected.

There was no significant variation observed between pastures (Appendix Table VI). Although Table XI shows a considerable difference in utilization between pastures on the plots closest to water, these differences did not hold for the plots farther from water. Establishment of two sets of plots in each pasture apparently removed the significant variation between pastures observed the previous year. Apparently rate of stocking is less of a factor regarding amount of utilization at some distance from water than it is nearer

Table XI. Percentage twig length removed by cattle during the winter of 1951-1952 from pastures Q (heavy stocking), R (light stocking), and S (moderate stocking).

Location	Pasture			Location Means
	Q	R	S	
1	56	19	33	36
2	10	16	8	11
Pasture means:	33	18	21	

to water.

Some differences were observed between utilization on the plots nearest to water in relation to utilization on these same plots the previous year. The differences under heavy and light stocking probably were not important. Utilization under heavy stocking increased from 52% in 1950-1951 to 56% in 1951-1952. Utilization under light stocking increased from 16% to 19%. However, the utilization under moderate stocking increased from 17% in 1950-1951 to 33% in 1951-1952. The differences between years is probably largely due to uneven utilization within the pastures.

The variation between sampling dates was highly significant (Appendix Table VI). The cattle went on the winter range October 18. Some utilization was observed at the first two sampling dates, but the greatest amount of utilization was measured on December 27 (Table XII). The period from December 27 to January 24 was marked by severe cold and deep snows which limited cattle movement. The only greasewood utilization observed during this month was under the heavy rate of stocking at the location nearest to water.

There was a significant interaction between pastures and dates, indicating that pastures were utilized differently during the different sampling periods. Greasewood in heavily and moderately stocked pastures was utilized the most during the sampling period ending December 27, but the greasewood in the lightly stocked pastures showed the greatest utilization during the sampling period ending February 21, with considerable use also occurring in the moderately stocked pasture on that date.

Table XII. Monthly greasewood utilization on pastures Q (heavy stocking), R (light stocking), and S (moderate stocking) during the winter of 1951-1952.

Sampling Date	Location	Pasture			Date Means
		Q	R	S	
11-1	1	0.4	0.0	0.0	
	2	0.0	0.0	0.6	0.18
11-29	1	5.8	8.2	2.3	
	2	3.2	0.3	3.3	3.86
12-27	1	46.7	5.6	20.0	
	2	6.3	0.0	4.6	13.87
1-24	1	1.3	0.0	0.0	
	2	0.0	0.0	0.0	0.22
2-21	1	1.5	5.0	10.4	
	2	0.0	14.4	0.0	5.23
3-20	1	0.0	0.0	0.2	
	2	0.0	1.5	0.0	0.27
Pasture means:		5.45	2.92	3.45	

Location means: 1, 5.98; 2, 1.90

Least significant differences for pasture means: at 5% 4.48, at 1% 6.01
Least significant differences for location means: at 5% 3.66, at 1% 4.91
Least significant differences for date means: at 5% 6.34, at 1% 8.50

There was also a significant interaction between locations and dates, indicating that the relationship between sampling locations was not the same during the different sampling periods. During the sampling period ending December 27, utilization nearer water was about seven times as great as that occurring away from water, but during the other sampling periods the differences between sampling locations were much smaller. During the sampling period ending March 20 utilization was slightly greater on the plots farther from water than on those nearer water.

Many hypotheses could be formulated explaining the reasons for the differences in utilization which were observed. The meager data presented here should provide leads to further research, but in themselves are not sufficient to provide a basis for sound reasoning.

Chemical Composition of Greasewood, 1951-1952

Protein: There was a significant variation in protein content between pastures (Appendix Table VII). The greasewood in the heavily stocked pasture had the highest percent protein and the greasewood in the lightly stocked pasture had the lowest percent protein (Table XIII). Reference is again made to Table VIII which shows that in 1950-1951 greasewood protein was highest in the moderately stocked and lowest in the lightly stocked pasture. The discrepencies in these data suggest that insufficient sampling, rather than rate of stocking, accounted for the apparent differences in protein content of greasewood due to rate of grazing.

Other than between pastures no significant variation of protein in greasewood was observed. The highly significant variation between sampling dates observed during 1950-1951 was not supported by a similar variation during 1951-1952. Protein content of the samples was somewhat higher than the greasewood samples of the previous year, being 9.0 as compared to 8.4.

Phosphorus: A variation in phosphorus content between pastures was noted but it was not significant (Appendix Table VII). The relationship between pastures was the same as for protein, being highest under heavy stocking and lowest under light stocking (Table XIV). Phosphorus, as was true of protein, was considerably higher than during the previous season, being .087 as compared to .075. The reason for these differences between pastures and between years is not known.

Carotene: There was a significant variation of carotene between sampling dates (Appendix Table VII). In general carotene content was about 12

Table XIII. Percent protein in greasewood samples during 1951-1952.

Sampling Date	Location	Pasture Q	Pasture R	Pasture S	Date Means
11-1	1	10.2	8.4	9.2	
	2	9.3	9.3	8.5	9.2
11-29		Composite sample - 9.4% protein[1/]			
12-27		Composite sample - 8.6% protein[1/]			
1-24	1	9.0	8.1	9.2	
	2	9.5	8.6	8.3	8.8
2-21	1	8.6	8.6	8.5	
	2	9.5	8.8	8.3	8.7
3-20	1	9.7	8.4	9.3	
	2	9.9	9.2	9.7	9.4
Pasture means:		9.5	8.7	8.9	
Location means:	1, 8.9; 2, 9.1				

Least significant difference pasture means: at 5% 0.52, at 1% 0.79

[1/] Only composite analyses for protein were run on these dates.

Table XIV. Percent phosphorus in greasewood samples during 1951-1952.

Sampling Date	Location	Pasture Q	Pasture R	Pasture S	Date Means
11-1		Composite sample - .08% phosphorus[1]			
11-29		Composite sample - .08% phosphorus[1]			
12-27	1	.09	.09	.09	
	2	.12	.08	.09	.093
1-24	1	.09	.08	.08	
	2	.07	.08	.08	.080
2-21	1	.10	.08	.07	
	2	.10	.08	.08	.085
3-20	1	.10	.08	.08	
	2	.10	.09	.10	.092
Pasture means:		.096	.082	.084	
Location means:	1, .086; 2, .089				

[1] Only composite analyses for phosphorus were run on these dates.

micrograms per gram from November 1 to December 27, rising sharply to 21 mcg/gm by January 24, and dropping to 2.5 mcg/gm by February 21 (Table XV). The trend of carotene content of greasewood through the season was very similar to that observed the previous season. Repetition of this rise in carotene is of special interest. The original thought that temperature change was a factor seems unlikely as weather records show no appreciable rise in temperatures during the month of January. There has been no plausible explanation of this phenomenon suggested from the data available.

Table XV. Carotene in greasewood samples during 1951-1952. Carotene expressed in micrograms per gram.

Sampling Date	Location	Pasture			Date Means
		Q	R	S	
11-1	1	18.0	5.1	8.2	
	2	11.0	28.0	6.1	12.7
11-29	1	10.0	9.7	16.0	
	2	12.0	12.0	13.0	12.1
12-27	1	8.7	9.2	13.0	
	2	9.7	10.0	14.0	10.8
1-24	1	29.0	29.0	14.0	
	2	13.0	13.0	28.0	21.0
2-21	1	1.5	2.0	3.5	
	2	3.5	3.0	1.5	2.5
3-20	1	4.0	3.0	4.0	
	2	3.5	3.5	4.0	3.7
Pasture means:		10.3	10.6	10.4	

Location means: 1, 10.4; 2, 10.5

Least significant difference between date means: at 5% 9.33, at 1% 13.27

Relationships of Greasewood to Blood Nutrients, 1951-1952

Blood carotene and vitamin A showed a gradual decline through the winter season as was the case the previous winter season (Table V), but in contrast to the previous season there was very little utilization of greasewood at the beginning of the season during 1951-1952 (Table XII). There was an increase in utilization during the third sampling period, followed by a decrease during later periods. The apparent correlations observed between greasewood and blood carotene and vitamin A levels during the first year were not supported by similar correlations during the second year (Appendix Table VIII). However, it is quite possible that utilization of greasewood, and other browse species, was a factor in determining the winter levels of blood carotene and vitamin A.

No other correlations among greasewood utilization, greasewood nutrients, and blood nutrients were observed.

Miscelleaneous Data

Analyses which were run on the composite samples of greasewood, although actually not a part of this study, are presented in Appendix Table IX for any interest value they may have to the reader. One item of interest in this table is the high sodium content of greasewood (.648% average), which may have been a factor in the rather low salt (sodium chloride plus iodine) consumption by the experimental cattle (.02 pounds per head per day, Appendix Table X). Chlorine content of greasewood was no greater than that commonly found in livestock feeds.

Another factor influencing salt consumption might have been the high sodium content of the water supply. The water, from which all lots were watered, contained about 3350 ppm of soluble salts. About 97% of the cations were sodium. The anions were mostly sulfates and bicarbonates with a trace of chlorides. This salt content is near the upper limit for water which is considered fit for livestock consumption.

Pounds of hay fed cows in each pasture each day are shown in Appendix Tables XI and XII. Each lot of cows was fed as much hay as was needed during the first season, but during the second season each lot was fed the same amount regardless of needs. Hay was fed when the cattle under the heavy rate of stocking required feeding. This feeding continued as long as the ground was so covered with snow that the cattle were not able to reach grass.

CONCLUSIONS

1. Blood phosphorus levels were lower during the winter months than those reported as adequate levels by other workers, but none of the usual external symptoms usually attributed to phosphorus deficiency were observed. The minimum blood phosphorus levels at which external symptoms of deficiency occur apparently have not been established well enough to cover all situations.

2. On the study area phosphorus content of the browse plants was lower than average levels previously reported for these species. This variation in phosphorus indicates the necessity of analysis of browse plants on a particular area before assuming their value as a source of phosphorus.

3. Blood carotene and vitamin A levels of cows in all pastures declined throughout the winter grazing season. This decline was attributed to the decreased intake of carotene and to the steadily decreasing body reserves of carotene and vitamin A which were built up during the summer.

4. Carotene content of the browse species increased greatly in the January samples of each year. The reason for this rise in not known, but it is not believed to be due to a change in temperature.

5. It is believed that carotene content and utilization of the browse plants was high enough during the early part of the grazing season to have an effect on blood carotene and vitamin A levels.

6. Winterfat, greasewood, and shadscale were important as winter feed on the study pastures, whereas big sagebrush had very little use.

Use of browse on the study pastures was heavier in the areas nearest water

and shelter. In these areas utilization of winterfat and greasewood was heaviest under heavy stocking. On sampling areas more distant from shelter and water, utilization of greasewood was not greatly different for the three rates of stocking.

Shadscale fruits are eaten more readily by cattle than are other portions of these plants. The amount of fruit left on the stems is more of a factor governing utilization of shadscale than is rate of stocking. Shadscale fruits are probably preferred by livestock because of their sugar content.

7. Although protein, unlike phosphorus, was above the minimum recommended levels, the variations in protein and phosphorus were correlated. Abundant palatable browse plants on winter ranges would reduce the need for protein supplements.

8. The many interrelationships among browse utilization, browse nutrients, and blood nutrients are complicated and only a few of them are understood. Further studies on these relationships are greatly needed.

SUMMARY

A study was designed to explore the possibilities of a correlation between blood level nutrients of cattle on winter ranges in southeastern Montana and the utilization and chemical composition of some of the major browse species of the area. The study was conducted near Miles City, Montana, and continued for two winter grazing seasons.

Previous work had indicated that browse plants were potentially valuable forage species, but little work had been done on their utilization in the Northern Great Plains.

Utilization was estimated by tagging twigs and measuring the length of these twigs at twenty-eight day intervals. The four browse species selected for the study were shadscale, big sagebrush, winterfat, and greasewood. After one season studies were discontinued on shadscale, winterfat, and big sagebrush, and a more intensive study of greasewood was initiated. Sampling was done on pastures under heavy, moderate, and light rates of stocking.

Browse and blood samples for chemical analyses were collected at about the same time that utilization was measured. Blood samples were analyzed for phosphorus, carotene, and vitamin A, and browse samples were analyzed for protein, phosphorus, and carotene.

Phosphorus levels in blood were lower than recommended all during the winter months, but vitamin A levels were adequate.

Utilization of greasewood, on the study plots, at a distance of about 600 yards from water was slightly over 50% under heavy stocking, and about 17% under light stocking. Utilization of greasewood under moderate stocking

was about the same as under light stocking the first year, but was about 33% during the second year. About 10% use was made of greasewood in all pastures at a distance of about 1200 yards from water. Winterfat was used at least as much as greasewood. Most of the greasewood and winterfat use occurred during one sampling period in the early part of the season.

Utilization of shadscale was uneven and seems to be related to the amount of fruits left on the stems. Shadscale use may have some relationship to blood phosphorus levels.

Utilization of big sagebrush during one season's grazing was negligible.

Greasewood had an average crude protein content of 8.7%, winterfat and shadscale were about 1% lower, and big sagebrush more than 2% lower.

Phosphorus content of the species studied was too low for adequate nutrition of cattle.

Carotene in all species increased sharply during January of each year, and then dropped to the lowest point of the year just before growth began in the spring. Carotene content was adequate for proper cattle nutrition for most of the winter season.

During the second year, in addition to the analyses of protein, phosphorus, and carotene, greasewood was analyzed for moisture, ether extract, ash, crude fiber, calcium, magnesium, potassium, sodium, lignin, and chlorine. A high sodium content of the samples may have been partly responsible for the rather low salt consumption by the experimental cattle.

LITERATURE CITED

Aldous, C. M. 1945. A winter study of mule deer in Nevada. Jour. of Wildlife Management 9:145-151.

Allen, R. J. L. 1940. The estimation of phosphorus. Biochemical Journal 34:858-865.

Association of Official Agricultural Chemists. 1950. Official and Tentative methods of analysis. Association of Official Agricultural Chemists, Washington, D. C.

Baker, G. 1951. Unpublished chemical analysis methods. Montana State College, Bozeman, Montana.

Bidwell, G. L. and E. O. Wooton. 1925. Salt bushes and their allies in the United States. U. S. D. A. Bull. 1345.

Boyer, P. D., P. H. Phillips, and J. K. Smith. 1944. The separation of carotene from vitamin A for the determination of vitamin A in blood plasma. Jour. of Biological Chemistry 152:445-452.

Cassady, J. T. 1941. A method of determining range forage utilization by sheep. Jour. of Forestry 39:667-671.

Clarke, S. E. and E. W. Tisdale. 1945. The chemical composition of native forage plants of southern Alberta and Saskatchewan in relation to grazing practices. Dominion of Canada, Department of Agriculture Tech. Bull. 54.

Cook, C. J., C. W. Cook, and L. E. Harris. 1948. Utilization of Utah summer range plants by sheep. Jour. of Forestry 46:416-425.

Cook, C. W., L. E. Harris, and L. A. Stoddart. 1948. Measuring the nutritive content of a foraging sheep's diet under range conditions. Jour. of Animal Science 7:170-180.

Cook, C. W. and L. E. Harris. 1950. The nutritive content of the grazing sheep's diet on summer and winter ranges of Utah. Utah Agr. Expt. Sta. Bull. 342.

Esplin, A. C., J. E. Greaves, and L. A. Stoddart. 1937. A study of Utah's winter range, composition of forage plants, and use of supplements. Utah Agr. Expt. Sta. Bull. 277.

Everson, A. G. 1951. Analysis of a forage utilization method based on the weight of plant units. (Abstract of a Master's thesis submitted to the Utah State Agricultural College in 1949). Jour of Forestry 49:92.

Fiske, C. H. and Y. Subbarow. 1925. The colorimetric determination of phosphorus. Jour. of Biological Chemistry 66:375-400.

Forsling, C. L. and E. V. Storm. 1929. The utilization of browse forage as summer range for cattle in southwestern Utah. U. S. D. A. Circ. 62.

Gieseker, L. F. 1948. Detailed soil survey, Hogback summer and Lone Pine winter range pastures, U. S. Range Livestock Experiment Station, Miles City, Montana. Montana Agr. Expt. Sta. mimeo.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Jour. of Range Management 4:233-241.

Guilbert, H. R., P. Gerlaugh, and L. L. Madsen. 1950. Recommended nutrient allowances for domestic animals. Number IV. Recommended nutrient allowances for beef cattle. National Research Council, Washington, D. C.

Hormay, A. L. 1943. A method of estimating the grazing use of bitterbrush. Calif. Forest and Range Expt. Sta. Research note no. 35.

Hurtt, L. C. 1950. Northern Great Plains range problems. Northwest Science 24:126-131.

Idaho Agricultural Experiment Station. 1937. Preliminary report on the composition of range forage plants as related to animal nutrition. Idaho Agr. Expt. Sta. mimeo leaflet no. 13.

Johnson, L. H. and I. Giovanini. 1949. Unpublished chemical analysis methods. Montana State College, Bozeman, Montana.

Julander, O. 1937. Utilization of browse by wildlife. Trans. Second North Americal Wildlife Conf., 276-287.

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

Lewis, J. K. 1950. The effect of excess calcium with borderline and deficient phosphorus in the rations of steer calves. Thesis submitted to the Graduate Faculty at Montana State College, Bozeman, Montana.

McCreary, O. C. 1927. Wyoming forage plants and their chemical composition - Studies no. 8. Wyo. Agr. Expt. Sta. Bull. 157.

McCreary, O. C. 1939. Phosphorus in Wyoming pasture, hay, and other foods. Wyo. Agr. Expt. Sta. Bull. 233.

McKinney, A. M. 1951. Studies on fecal analysis for determining forage species and protein in the diet of range ewes. Thesis submitted to the Graduate Faculty at Montana State College, Bozeman, Montana.

Morrison, F. B. 1949. Feeds and Feeding. The Morrison Publishing Co., Ithaca, New York.

Nelson, E. W. 1930. Methods of studying shrubby plants in relation to grazing. Ecology 11:764-769.

Peterson, C. J., A. W. Walden and R. M. Hixon. 1932. Effect of temperature on sulfuric acid method for lignin. Industrial and Engineering Chemistry, Analytical Edition 4:216-217.

Pickford, G. D. and E. H. Reid. 1948. Forage utilization on summer cattle ranges in eastern Oregon. U. S. D. A. Circ. 796.

Plice, M. J. 1952. Sugar versus the intuitive choice of foods by livestock. Jour. Range Management 5:69-75.

Ritter, G. J., R. M. Seborg, and R. L. Mitchell. 1932. Factors affecting quantitative determination of lignin by 72 percent sulfuric acid method. Industrial and Engineering Chemistry, Analytical Edition 4:202-204.

Rygg, G. L. 1949. Changes in carotenoid content of harvested carrots. Proceedings of the American Society for Horticultural Science 54:307-310.

Shervard, E. C. and E. E. Harris. 1932. Factors influencing properties of isolated wood lignin. Industrial and Engineering Chemistry, Industrial Edition 24:103-106.

Snedecor, G. W. 1946. Statistical Methods. Iowa State College Press, Ames, Iowa.

Thomas, O. O. 1951. I. Relation of nutrition and age at first calving to lifetime performance of beef cows. III. The effect of low phosphorus rations upon carotene metabolism in ruminants. Thesis submitted to the Graduate Faculty of the Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma.

U. S. Department of Agriculture. 1940. Unpublished data of the U. S. Forest Service. The Northern Great Plains Research Center, Miles City, Montana.

U. S. Department of Agriculture. 1950. The Northern Great Plains Research Center, its work and aims. Northern Rocky Mountain Forest and Range Expt. Sta. Misc. Pub. 1.

U. S. Department of Agriculture. 1951. Unpublished data of the Bureau of Animal Industry. U. S. Range Livestock Experiment Station, Miles City, Montana.

U. S. Department of Agriculture. 1952. Unpublished data of the Bureau of Animal Industry. U. S. Range Livestock Experiment Station, Miles City, Montana.

U. S. Department of Agriculture. 1952. Unpublished data of the U. S. Forest Service. The Northern Great Plains Research Center, Miles City, Montana.

Wasser, C. H. 1945. High protein content makes winterfat valuable forage for Colorado ranges. Colo. Farm Bull. 7:6, 7, 13.

Young, H. Y. and R. F. Gill. 1951. Determination of magnesium in plant tissue with thiazole yellow. Analytical Chemistry 23:751-754.

APPENDIX

Appendix Table I. Analysis of variance of phosphorus, carotene, and vitamin A cattle blood levels during the winter season of 1950-1951.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Phosphorus						
Total	74	29.26				
Dates	4	9.05	2.26	12.16**	2.52	3.65
Pastures	2	7.57	3.78	20.35**	3.15	4.98
Dates X Pastures	8	1.45	0.18	0.97	2.10	2.82
Error	60	11.19	0.19			
Carotene						
Total	74	35742				
Dates	4	20273	5068	25.01**	2.52	3.65
Pastures	2	1185	592	2.92	3.15	4.98
Dates X Pastures	8	2127	266	1.31	2.10	2.82
Error	60	12157	203			
Vitamin A						
Total	73	3868				
Dates	4	2078	519.4	19.99**	2.52	3.66
Pastures	2	66	33.2	1.28	3.15	4.99
Dates X Pastures	8	192	24.0	0.92	2.10	2.83
Error	59	1533	26.0			

Appendix Table II. Analysis of variance of phosphorus, carotene, and vitamin A cattle blood levels during the winter season of 1951-1952.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Phosphorus						
Total	88	52.97				
Dates	5	20.17	4.03	13.36**	2.35	3.29
Pastures	2	5.98	2.99	9.90**	3.13	4.92
Dates X Pastures	10	5.35	0.54	1.77	1.97	2.59
Error	71	21.48	0.30			
Carotene						
Total	88	940247				
Dates	5	855034	171007	166.51**	2.35	3.29
Pastures	2	5592	2796	2.72	3.13	4.92
Dates X Pastures	10	6703	670	0.65	1.97	2.59
Error	71	72918	1027			
Vitamin A						
Total	88	5042				
Dates	5	2844	568.7	26.08**	2.35	3.29
Pastures	2	384	192.0	8.80**	3.13	4.92
Dates X Pastures	10	266	26.6	1.22	1.97	2.59
Error	71	1548	21.8			

Appendix Table III. Analysis of variance of average weekly utilization of browse plants during 1950-1951.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Total	127	73.24				
Dates	3	7.26	2.420	8.85**	2.75	4.11
Pastures	3	6.60	2.198	8.04**	2.75	4.11
Species	3	12.63	4.210	15.41**	2.75	4.11
Dates X Pastures	9	5.68	0.631	2.31*	2.02	2.70
Dates X Species	9	6.83	0.759	2.78**	2.02	2.70
Species X Pastures	9	7.01	0.779	2.85**	2.02	2.70
Dates X Species X Pastures	27	9.74	0.361	1.32	1.65	2.05
Error	64	17.49	0.273			

Appendix Table IV. Analysis of variance of protein, phosphorus, and carotene in browse samples during 1950-1951.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Protein						
Total	46	48.84				
Dates	3	3.33	1.110	9.49**	3.20	5.18
Pastures	2	2.62	1.310	11.20**	3.59	6.11
Species	3	25.10	8.367	71.51**	3.20	5.18
Dates X Pastures	6	2.80	0.467	3.99*	2.70	4.10
Dates X Species	9	3.14	0.349	2.98*	2.50	3.68
Species X Pastures	6	9.86	1.643	14.04**	2.70	4.10
Error	17	1.99	0.117			
Phosphorus						
Total	46	.01550				
Dates	3	.00185	.000617	11.77**	3.20	5.18
Pastures	2	.00061	.000305	5.82*	3.59	6.11
Species	3	.00755	.002517	48.03**	3.20	5.18
Dates X Pastures	6	.00089	.000148	2.83*	2.70	4.10
Dates X Species	9	.00137	.000152	2.90*	2.50	3.68
Species X Pastures	6	.00234	.000390	7.44**	2.70	4.10
Error	17	.00089	.000052			
Carotene						
Total	46	2977.2				
Dates	3	2149.5	716.5	42.07**	3.20	5.18
Pastures	2	59.3	29.6	1.74	3.59	6.11
Species	3	143.1	47.7	2.80	3.20	5.18
Dates X Pastures	6	77.8	13.0	0.76	2.70	4.10
Dates X Species	9	159.5	17.7	1.04	2.50	3.68
Species X Pastures	6	98.4	16.4	0.96	2.70	4.10
Error	17	289.5	17.0			

Appendix Table V. Coefficients of correlation among browse utilization, browse nutrients, and blood nutrients during 1950-1951.

Browse nutrient	Blood nutrient	Species		
		Winterfat	Greasewood	Shadscale
1. Correlation of browse utilization with browse nutrients:				
Protein		-.283	-.087	-.685*
Phosphorus		-.021	-.046	-.430
Carotene		+.237	+.062	-.151
2. Correlation of browse utilization with blood nutrients:				
	Phosphorus	+.271	+.036	-.686*
	Carotene	+.881**	+.829**	-.151
	Vitamin A	+.585*	+.669*	-.119
3. Correlation of browse nutrients with blood nutrients:				
Phosphorus	Phosphorus	-.008	-.401	+.629*
Carotene	Carotene	+.246	+.082	+.229
Carotene	Vitamin A	+.524	+.140	+.508
4. Correlation of browse nutrients and utilization with blood nutrients:				
Phosphorus	Phosphorus	+.271	+.401	+.779*
Carotene	Carotene	+.882**	+.830**	+.258
Carotene	Vitamin A	+.707*	+.676	+.510

Levels of significance for 1, 2, and 3 (simple correlation): 5%, .576; 1%, .708

Levels of significance for 4 (multiple correlation): 5%, 697; 1%, .800

Appendix Table VI. Analysis of variance of monthly greasewood utilization during 1951-1952.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Total	71	7294.8				
Dates	5	1700.4	340.1	5.81**	2.48	3.58
Pastures	2	85.6	42.8	0.73	3.26	5.25
Locations	1	298.7	298.7	5.10*	4.11	7.39
Dates X Pastures	10	1227.3	122.7	2.10*	2.10	2.86
Dates X Locations	5	989.6	197.9	3.38*	2.48	3.58
Locations X Pastures	2	159.7	79.8	1.36	3.26	5.25
Dates X Pastures X Locations	10	725.2	72.5	1.24	2.10	2.86
Error	36	2108.1	58.6			

Appendix Table VII. Analysis of variance of protein, phosphorus, and carotene in greasewood samples during 1951-1952.

Source of variation	d.f.	S.S.	M.S.	F ratios		
				Observed	5%	1%
Protein						
Total	23	7.6				
Dates	3	1.7	0.57	3.17	4.76	9.78
Pastures	2	2.7	1.35	7.50*	5.14	10.92
Locations	1	0.1	0.10	0.56	5.99	13.74
Dates X Pastures	6	0.7	0.01	0.06	4.28	8.47
Dates X Locations	3	0.4	0.01	0.06	4.76	9.78
Locations X Pastures	2	0.9	0.04	0.22	5.14	10.92
Error	6	1.1	0.18			
Phosphorus						
Total	23	.00305				
Dates	3	.00068	.000227	2.10	4.76	9.78
Pastures	2	.00093	.000465	4.31	5.14	10.92
Locations	1	.00008	.000080	0.74	5.99	13.74
Dates X Pastures	6	.00044	.000073	0.68	4.28	8.47
Dates X Locations	3	.00022	.000073	0.68	4.76	9.78
Locations X Pastures	2	.00005	.000025	0.23	5.14	10.92
Error	6	.00065	.000108			
Carotene						
Total	35	2167.72				
Dates	5	1371.65	274.33	5.22*	3.33	5.64
Pastures	2	0.55	0.28	0.01	4.10	7.56
Locations	1	0.02	0.02	0.00	4.96	10.04
Dates X Pastures	10	137.39	13.74	0.26	2.95	4.85
Dates X Locations	5	87.48	17.50	0.33	3.33	5.64
Locations X Pastures	2	44.72	22.36	0.43	4.10	7.56
Error	10	525.91	52.59			

Appendix Table VIII. Coefficients of correlation among greasewood utilization, greasewood nutrients, and blood nutrients during 1951-1952.

Browse nutrients	Blood nutrients	Coefficients of correlation		
		Observed	5%	1%
1. Correlation of browse utilization with browse nutrients:				
Protein		-.219	.330	.424
Phosphorus		+.090	.330	.424
Carotene		+.097	.330	.424
2. Correlation of browse utilization with blood nutrients:				
	Phosphorus	+.331	.468	.590
	Carotene	-.256	.468	.590
	Vitamin A	-.025	.468	.590
3. Correlation of browse nutrients with blood nutrients:				
Phosphorus	Phosphorus	+.105	.468	.590
Carotene	Carotene	+.016	.468	.590
Carotene	Vitamin A	+.335	.468	.590
4. Correlation of browse nutrients and utilization with blood nutrients:				
Phosphorus	Phosphorus	+.340	.574	.677
Carotene	Carotene	+.260	.574	.677
Carotene	Vitamin A	+.345	.574	.677

Appendix Table IX. Miscelleaneous chemical analyses of greasewood during the winter of 1951-1952.

Analysis[1]	11-1	11-29	12-27	1-24	2-21	3-20	Mean
Moisture	3.8	4.6	4.1	3.0	3.7	2.1	3.6
Protein	9.4	9.4	8.6	8.7	9.1	9.1	9.0
Ether Extract	1.7	1.9	1.7	1.5	1.6	1.6	1.7
Ash	6.0	5.8	5.5	5.0	4.7	5.3	5.4
Crude Fiber	39.2	39.0	37.9	40.1	41.7	40.9	39.8
Phosphorus	.08	.08	.10	.08	.10	.09	.09
Calcium	.76	.80	.69	.74	.72	.70	.74
Carotene	12.7	13.1	10.8	17.7	2.5	3.7	10.1
Magnesium	.15	.17	.16	.15	.15	.16	.16
Potassium	1.02	0.90	1.18	0.91	0.90	0.95	0.98
Sodium	.87	.67	.66	.58	.49	.62	.65
Lignin	21.6	20.9	22.1	22.7	22.6	22.8	22.1
Chlorine	.29	.24	.30	.21	.26	.21	.25

[1] Carotene expressed in micrograms per gram, others in percent.

Appendix Table X. Periodical salt consumption of experimental cattle during 1951-1952 expressed in pounds per cow per period.[1/]

Period	Days	Pasture			Mean
		Q	R	S	
Oct. 18 - Nov. 29	42	.60	.60	.50	.57
Nov. 29 - Jan. 10	42	.60	.95[2/]	1.20[2/]	.92
Jan. 10 - Feb. 20	41	.70	1.20[2/]	1.30[3/]	1.07
Feb. 20 - Apr. 3	43	1.20	.40	.90	.83
Total	168	3.10	3.15	.390	3.34

[1/] U. S. D. A. 1952. Forest Service.

[2/] These salt boxes contained about three quarts of saturated salt solution which was not weighed. Each box salted ten cows.

[3/] This salt box contained about four quarts of saturated salt solution which was not weighed. Each box salted ten cows.

Appendix Table XI. Pounds of hay fed per pasture per day during the winter of 1950-1951. Each pasture contained ten mature cows.[1/]

Date	Pasture			Date	Pasture		
	Q	R	S		Q	R	S
Jan. 15	0	0	0	Feb. 19	80	80	80
16	115	0	0	20	150	150	150
17	115	0	0	21	100	100	100
18	120	0	0	22	150	150	150
19	118	0	0	23	150	116	127
20	121	0	0	24	80	80	80
21	124	0	0	25	80	80	80
22	124	0	0	26	140	140	140
23	118	0	0	27	140	140	140
24	126	0	0	28	84	82	80
25	119	0	0	Mar. 1	150	150	145
26	127	0	0	2	147	150	150
27	150	150	150	3	150	145	150
28	150	150	150	4	150	140	140
29	150	150	150	5	150	150	147
30	150	150	150	6	150	112	100
31	150	150	150	7	150	150	150
Feb. 1	150	150	150	8	150	150	148
2	150	150	150	9	150	146	148
3	150	80	80	10	150	140	140
4	100	100	100	11	135	150	150
5	150	150	150	12	150	150	150
6	150	150	150	13	147	143	148
7	150	150	150	14	140	140	140
8	80	80	80	15	140	140	140
9	150	150	150	16	140	140	140
10	100	100	100	17	140	140	140
11	150	80	80	18	80	80	80
12	150	0	150	19	152	0	0
13	150	150	150	20	140	140	140
14	100	100	100	21	80	80	80
15	150	150	150	22	150	150	150
16	80	80	80	23	150	150	150
17	150	150	150	24	90	80	82
18	150	150	150	25	80	0	0

[1/] U. S. D. A., 1951. Bureau of Animal Industry.

Appendix Table XII. Pounds of hay fed per pasture per day during the winter of 1951-1952. Each pasture contained ten mature cows.[1/]

Period	Pasture		
	Q	R	S
Dec. 21 - Dec. 22	140	140	140
Dec. 23	0	0	0
Dec. 24	200	200	200
Dec. 25	0	0	0
Dec. 26 - Dec. 28	200	200	200
Dec. 29 - Jan. 1	185	185	185
Jan. 2	200	200	200
Jan. 3	0	0	0
Jan. 4	180	180	180
Jan. 5 - Feb. 12	200	200	200
Feb. 13 - Feb. 18	160	160	160
Feb. 19 - Feb. 26	200	200	200
Feb. 27	160	160	160
Feb. 28 - Mar. 18	200	200	200
Mar. 19 - Mar. 26	160	160	160
Mar. 27 - Mar. 28	160	0	160

[1/] U. S. D. A. 1952. Bureau of Animal Industry.

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