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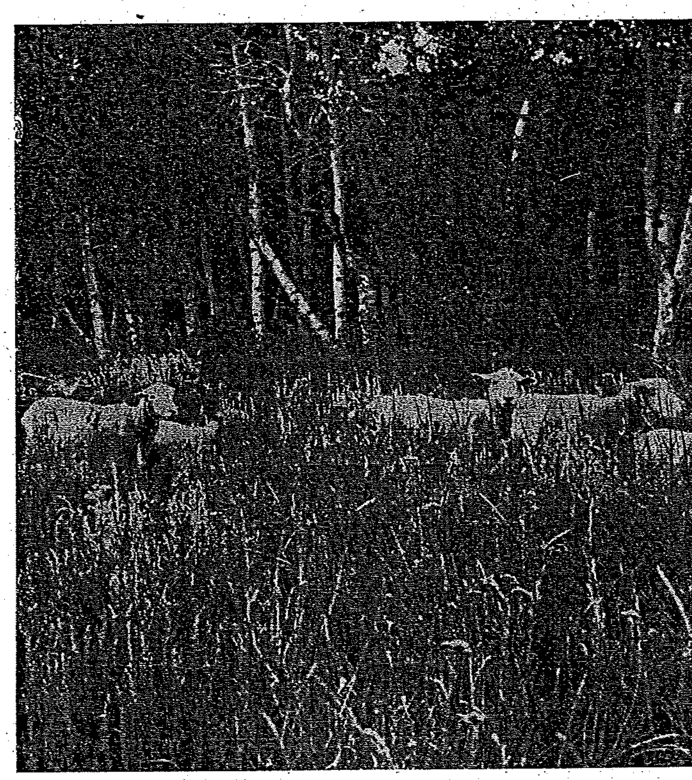

The Nutritive Value of Range Forage As Affected By Vegetation Type, Site, And Stage of Maturity

By C. Wayne Cook
Lorin E. Harris

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SUMMARY

DURING the summer grazing season of 1946, a sheep range in northern Utah mountains was studied to determine the effect of vegetation type, site, and stage of growth upon the nutritive value of range forage.

From these studies it was found that site conditions and stage of growth were important factors affecting the nutritive content of range forage. Sites indirectly affected the chemical content of plants and plant parts through soil and plant development, water runoff, intensity of shade, and other environmental factors.

Aspen types produced a higher content of ether extract in some species, whereas, sagebrush types produced a higher content in others. The effect of seasonal change or stage of maturity on ether extract was not pronounced and shows no directional trend.

Plants growing on aspen areas had a higher protein content than those on sagebrush areas. This could not be explained on the basis of nitrogen in the soil since some areas lowest in nitrogen sometimes produced the highest content of protein in the plants. Shade and increased soil moisture were thought to be responsible for the higher protein content in plants on aspen types. Protein content of all species and all plant parts showed an orderly decrease as the plants matured.

Aspen areas generally produced a higher ash content than sagebrush areas. There was a general decrease in ash content as the season advanced. This seasonal decrease was more pronounced on aspen areas than on sagebrush areas.

Aspen types generally produced a higher phosphorus content in all plants and in all plant parts than sagebrush types. However, the content of available phosphorus in sagebrush soils was higher than aspen soils. Increased shade and greater soil moisture were believed responsible for increased phosphorus content in plants produced on aspen types. There was a significant decrease in percent phosphorus as the season advanced for all species and for all plant parts except for the last period when some plant parts showed a slight increase.

There was little difference in the calcium content of plants or plant parts on aspen types compared to sagebrush types. In some cases, the calcium content of the forage was significantly higher on unfavorable sites than on favorable sites, yet, available calcium in the soil was generally higher on favorable sites.

Sagebrush types produced higher lignin, cellulose, and cellulose to lignin ratios in some plants and in some plant parts, whereas, aspen types were higher in these respects in other cases. Cellulose and lignin content increased with increased plant maturity. The cellulose to lignin ratio generally decreased with increased plant growth, thus, it is shown that lignin increases at a more rapid rate than cellulose. Unfavorable sites generally produced a higher cellulose to lignin ratio than favorable sites, and likewise aspen types favored a higher cellulose to lignin ratio compared to sagebrush types. Thus, it is indicated that vegetation type and site influenced the content of cellulose and lignin differently in various species and various plant parts.

Vegetation type did not appear to influence crude fiber content to any marked degree. However, aspen types favored a more rapid seasonal increase in crude fiber than sagebrush types.

Nitrogen-free-extract fraction and other carbohydrates were rather closely associated with respect to seasonal changes and differences between vegetation types and sites. There was no decided seasonal change in some plant parts but in others there was a slight decrease.

Significant interactions showed that vegetation types and sites affected various chemical constituents in the plant parts differently and likewise influenced the variation of these constituents at various stages of growth. For example, ether extract, lignin, and cellulose in stems and leaves of some species were higher on aspen types than on sagebrush types; but in other species the reverse was true. Nitrogen-free-extract, cellulose, and calcium in the stems and leaves of some species showed orderly increases or decreases as the season advanced, but the amount and rate of change were dependent upon site and vegetation type.

It was concluded that environmental factors and soil moisture are more important in determining the nutrient content of range forage plants under various site conditions than the chemical content of the soil as determined by standard methods.

All species became more stemmy as the season advanced and this was more pronounced in some sites than others. The relative amounts of stem and leaf produced accounted for some of the differences in chemical composition between species, and likewise, for some of the seasonal changes in composition of the various plants.

The composition of the two parts differed rather markedly. The leaves were higher in ether extract, protein, ash, calcium, phosphorus, and nitrogen-free-extract, whereas, the stems were higher only in lignin, crude fiber, and cellulose.

The stem-leaf ratios on aspen areas suggested a more leafy browse, and a more stemmy forb and grass compared to sagebrush areas. Site conditions within vegetation types, likewise, affected the stem-leaf ratio for individual species differently.

From these studies it can be concluded that the nutrient content of the forage is influenced by many interdependent factors, and the result is the additive or mass effect of all factors operating simultaneously.

ACKNOWLEDGMENTS

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The authors also wish to express their appreciation to Swift and Company for financial support in carrying out this experiment.

THE NUTRITIVE VALUE OF FORAGE AS AFFECTED BY VEGETATION TYPE, SITE, AND STAGE OF MATURITY[1]

C. Wayne Cook and Lorin E. Harris[2]

INTRODUCTION

NATIVE ranges of Utah are extremely heterogeneous. Pronounced variations exist in soil, seasonal rainfall, temperatures, and altitude on most grazing areas. Rough topography and micro-climates on even individual grazing allotments present variable vegetation types and site conditions. Such variations account for the comparatively large number of species and variable nutritive content found in range forage.

At present there is a growing interest in the value and importance of the nutritive content of range forage as it affects the productive efficiency of range animals.

For many years stockmen have recognized the value of range forage plants by the general avidity with which animals consumed various species. However, of equal importance in the evaluation of range plants is the amount of specific nutrients contained in them.

The quality of forage is of great practical and economic importance. Such information provides a fundamental basis for managing ranges to assure high productivity and continued survival of desirable plants.

The value of a feed depends upon the specific chemical substances contained in it and minimum requirements of various constituents should be met for efficient livestock production. Therefore, for balanced nutritional requirements, suplementary feed must often be supplied in addition to the basal range diet.

There is no easy method of determining the chemical composition of the herbage actually being consumed by the grazing animal, since various classes of livestock display a preference for certain plants and for certain portions of these plants. However, with care-

[1]Experimental results reported herein were used as part of the senior author's thesis in partial fulfillment of the requirements of the degree of Doctor of Philosophy at A. and M. College of Texas. The work was done on project 260—Purnell, State.

[2]Associate professor of range management and professor of animal husbandry, respectively.

fully planned technique it is possible to collect and analyze bits of herbage comparable to those being eaten by the grazing animal.

In addition to animal selectivity, the appraisal of the nutritive value of range forage may be further complicated by the many physical factors that affect the chemical composition of native forage plants, such as composition of the forage species present, soil type, site, stage of growth, weathering, and shattering of seed.

Thus chemical analyses of range forage present only limited information unless all influencing factors have been recognized and properly evaluated.

REVIEW OF LITERATURE

The wide variability of botanical composition of the range, stage of growth as it affects the value of separate parts of the plants, available soil moisture, temperature, soil type, site, and general climatic conditions have all been shown to contribute to the variable chemical composition of plants and nutritive content of the animal's diet.

Drought may lower both phosphorus and protein, whereas, calcium and crude fiber may increase (1, 34)[3]. Harper and Daniel (7) in Oklahoma, reported that a season of heavy rainfall produced a hay of low calcium and high phosphorus content and a season of light rainfall produced a hay high in calcium and low in phosphorus. However, Scott (26) in Montana, found no marked effect of precipitation on either the phosphorus or calcium content of native forage species.

It has long been recognized that intermittent periods of rain and sunshine greatly change the chemical composition of forage, especially when the plants have matured and partially dried. Guilbert and Mead (14) in California, observed that exposure to rain resulted in a loss of nutrients which was accounted for by leaching of soluble constituents. Hart *et al.* (15) reported that calcium was not appreciably affected by leaching, but phosphorus was decidedly lowered, which widened the calcium-phosphorus ratio. Nitrogen-free-extract and crude protein were likewise reduced by leaching. Buckner *et al.* (4) in Kentucky, concluded that the higher protein content in fall growth as compared to spring growth was caused by differences in rainfall and temperature during these seasons.

The effect of soil differences upon nutritive composition of plants is difficult to determine because of the many interacting and interdependent factors involved. These include: soil acidity, soil

[3]Numbers in parentheses are to Literature citations, page 42.

moisture, structure, texture, organic-matter content, soil organisms, and chemical composition of the soil solution. Most studies of this nature have included not only soil differences, but also environmental influences. Nevertheless, it is indicated that soils developed under various site conditions do affect the chemical composition of plants (8, 10, 11, 22, 28, 32, 33).

Soil acidity, within certain limits, is an important factor in rendering nutrients available to plants. Phosphorus, calcium, and potassium content of plants have been observed to increase with increased soil acidity (17, 31). The relationship of mineral and organic content of the soil may influence acidity, and thereby, favor the absorption of certain constituents by plants. However, a change in acidity may depress the availability of some soil constituents depending upon the degree of acidity and the constituents involved. A high content of calcium may inhibit the availability of phosphorus and other minerals which may be partially attributed to acidity, chemical combinations of the minerals themselves, or both (2).

Increased soil moisture, to a limited degree, has been found to increase the mineral content of forage plants (3, 22). Increased intensity of sunlight has been shown to increase carbohydrate content and decrease protein content of plants when compared to plants grown in the shade (32).

Soil and site factors all contribute to the complexity of plant chemistry, explaining why various investigators encounter so many controversial problems.

Thus, it is quite understandable that various observations (2, 3, 6) have shown that plants do not absorb mineral constituents in the same proportions in which they occur in the soil.

Stoddart (28), in Utah, found that favorable and less favorable sites had no significant influence upon chemical content of plants, but plants grown on various soil types showed a marked difference in total ash, protein, and phosphorus content. Edwards and Goff (8), in Hawaii, reported that location or variable site conditions had a marked influence upon the mineral composition of pasture grasses.

Generally, it has been found that soils high in calcium and phosphorus produce plants relatively high in these minerals. However, this has been true only for certain species and the correlation significant only while the forage plants were in the early growth stages (10, 11, 32). Tuninger and Grunigen (31), in Germany, studied the response of plant composition to soil constituents and found no correlation in either calcium or phosphorus.

Fig. 1. A typical summer range area in northern Utah showing the rough topography and variable sagebrush and aspen types

Thus the complex relationships between plants, soil, and environment are not fully understood because of the large number of variables that operate to modify the physiological responses of plants.

METHOD AND PROCEDURE

This study was made during the summer grazing season of 1946 on mountainous range east of Logan, Utah, on the Cache National Forest. The area has an average precipitation of approximately 30 inches annually, about 60 percent of which is received as snow and the remainder as rain during the spring and summer. The region is characterized by steep slopes and heterogeneous soils derived from limestone and dolomite formations. The chief vegetation types are aspen (*Populus tremuloides*), which occupies the less exposed north, northwest, and northeast slopes, and sagebrush (*Artemisia tridentata*), which occupies the more exposed south and west slopes and ridges (fig. 1).

Three typical summer range areas, each approximately 700 acres, were chosen for study, one on the Blacksmith Fork watershed, one on the Ephraim canyon watershed, and one on the Mudflat canyon watershed. All of these areas were adjacent to each other. Four sites, approximately five acres in area, were selected on each of the three watersheds for detailed study and sample collections. These were: favorable sagebrush, unfavorable sagebrush, favorable aspen, and unfavorable aspen. Slope, exposure, and vegetation cover were criteria for separating favorable and less favorable

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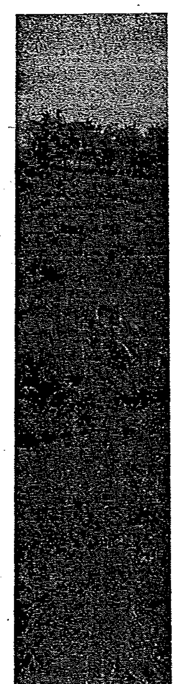

sites in each of the vegetation types. Favorable sagebrush sites were found on all broad ridges compared to unfavorable sagebrush sites which were confined to the south facing slopes (fig. 2 and 3). Favorable aspen sites were located on north facing slopes and unfavorable aspen on the northwest slopes (fig. 4 and 5).

Forage samples from three important range plants, a browse (*Symphoricarpos vaccinioides*), a forb (*Achillea lanulosa*), and a grass (*Bromus carinatus*) were collected from the date animals were allowed to enter the forest reserve, July 8, and continued at 3- to 4-week intervals until the close of the grazing season, September 27, making a total of four collection periods. These collections were made on both favorable and unfavorable sites in both sagebrush and aspen areas. These species were selected because they were not restricted in their habitat requirements and were found in relative abundance on all sites.

Sampling on these areas was done by collecting plant units consisting of current years growth, which were selected by randomized pacing on transect lines through the sampling areas. The units collected were: snowberry (*Symphoricarpos vaccinioides*), only the current year's growth, yarrow (*Achillea lanulosa*), and mountain bromegrass (*Bromus carinatus*), the entire plant at ground level. The samples were separated into stems, leaves, and seed heads, as soon as collected. Each sample was air-dried, ground through a

Fig. 2. A favorable sagebrush site located on a broad ridge with sparsely scattered aspen stands intermixed

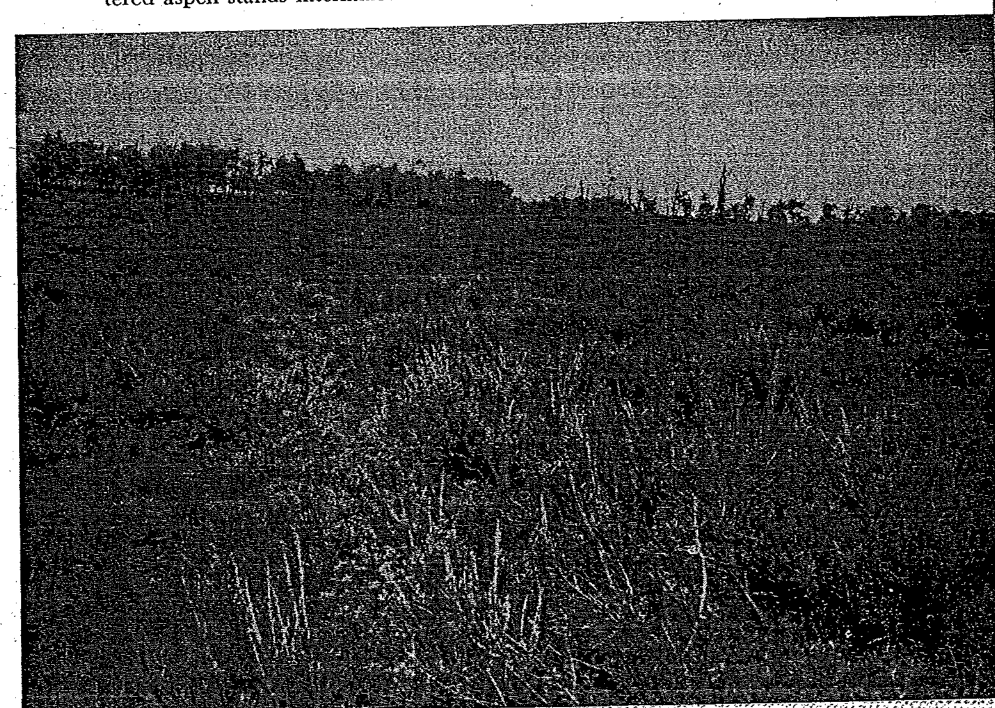

Fig. 3. Unfavorable sagebrush site located on a south facing slope showing scattered sagebrush and associated species. Vegetation cover appears dense but bare, rocky areas are common

Wiley mill to pass a 1 mm. screen, and stored in air-tight containers. Later this material was oven-dried, and chemically analyzed by both the conventional method of proximate analysis and the modified method of proximate analysis in order to compare the variability of analytical fractions determined by the two methods.

The soils in each site were sampled along eight transects radiating from the center of the area. Two sampling stations were located on each radius, one at twenty paces, and the other forty paces from the center. The samples taken at these stations were labeled with either Arabic or Roman numbers. The stations on the radius running north from the center were labeled 1 (Arabic) at twenty paces and I (Roman) at forty paces. The location of the Arabic and Roman numbers was exchanged on alternating radii. Thus, the stations on the second radius, running northeast from the center were labeled II (Roman) at twenty paces and 2 (Arabic) at forty paces. At each location the soil profile was exposed into the C horizon and samples were taken from each horizon, A, B, and C. These mountainous soils are not fully developed; therefore, the A and B horizons, as identified in this study, do not display all of the characteristics of a mature soil profile. The Arabic numbered samples and likewise the Roman numbered samples for each horizon within each site were composited for each of the 12 site areas. These two duplicated samples, each composed of 8 collections, from each of 3 profiles, were obtained for each of the 12 sites. The 72 composite

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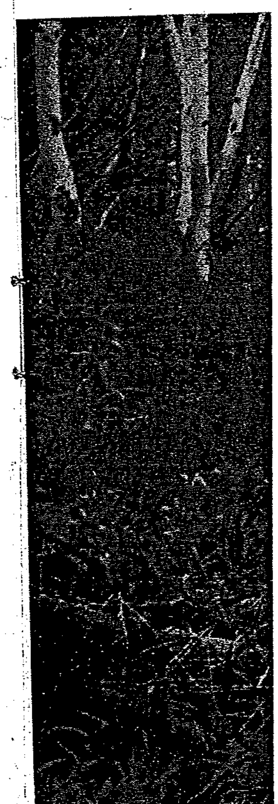

samples were analyzed for acidity (pH), nitrogen, organic matter, available phosphorus, and available calcium.

RESULTS AND DISCUSSION

Soil Analysis

CHEMICAL analyses for the soil profiles on each vegetation type and site are shown in table 1. The pH was measured on all soil samples and most of them were found to be slightly acid. In general, the organic matter content was high and, as would be expected, the A horizon contained considerably more than the B or C horizons. Available phosphorus was determined by measuring the amount of CO_2 soluble phosphorus. Nitrate nitrogen is considered a rather variable substance in the soil and frequently changes in concentration over a short period of time. The amount present at the time of sampling depends upon rate of release from decomposing organic matter, the amount being removed by growing plants and micro-organisms, and the removal by leaching. In most cases the values for nitrate nitrogen appeared to be low; however, all samples

Fig. 4. A favorable aspen site located on a north facing slope. Vegetation cover is very dense

Table 1. *Chemical analyses of soils from mountainous summer ranges of northern Utah collected from favorable and unfavorable sites of sagebrush and aspen types*

Vegetation type and site	Horizons	Soil description	Nitrogen as NO_3	Organic matter	pH* (soil-paste)	Available PO_4	Available Ca	Carbonates as $CaCO_3$
			ppm	*percent*		*ppm*	*ppm*	*percent*
Sagebrush								
Favorable site	A	Sand loam-sandy clay loam	2.17	5.25	6.14	4.17	1470	
	B	Clay loam-silty clay loam	1.67	2.68	6.28	2.03	1645	
	C	Clay loam	2.00	0.97	7.10	0.07	....	3.33
	Average		1.95	2.97	6.41	2.09	1557	
Unfavorable site	A	Sandy loam-loam	3.00	5.63	6.92	10.00	1550	
	B	Clay loam-silty clay loam	1.83	3.08	6.73	4.00	1195	
	C	Clay loam-silty clay loam	2.00	1.57	7.30	0.30	....	9.00
	Average		2.28	3.43	6.98	4.77	1373	
Sagebrush average			2.11	3.20	6.60	3.43	1465	
Aspen								
Favorable site	A	Loam-clay loam	4.17	6.28	6.35	4.17	1900	
	B	Clay loam-silty clay loam	1.67	1.80	6.17	1.73	1403	
	C	Clay loam-silty clay loam	2.00	0.47	6.97	0.03	....	4.00
	Average		2.61	2.85	6.43	1.98	1652	
Unfavorable site	A	Sandy loam-loam	2.67	7.83	6.27	8.50	1667	
	B	Clay loam-clay	2.00	2.27	6.40	3.30	1357	
	C	Sandy loam-clay loam	1.63	0.47	6.93	0.13	....	2.33
	Average		2.10	3.52	6.48	3.98	1512	
Aspen average			2.36	3.19	6.45	2.98	1582	

* pH averages were calculated from arithmetic equivalents of the logarithmic expressions of pH values.

Fig. 5. Unfavorable aspen site located on a northwest facing slope. Vegetation only moderately dense with scattered sagebrush plants in the background

showed the presence of some nitrate. Available calcium was determined by using the acetate extraction method with subsequent precipitation of calcium as oxalate and titration with permanganate. All values obtained for available calcium on all sites were high.

An analysis of variance of soil constituents is presented in table 2. The data for horizon C were not included because they did not appear to account for any of the differences found in the chemical composition of plants, and roots did not penetrate this zone of the soil profile to any appreciable extent. The differences between horizons A and B were highly significant for all constituents except for degree of acidity (pH) which showed no difference. Horizon A contained more of all constituents in each case except for available calcium which was higher in the B horizon on favorable sagebrush sites (table 1). This accounts for the significant interaction between horizons and types in the case of calcium content (table 2).

The differences in available phosphorus content in horizons A and B between sites within vegetation types were highly significant (table 2). The A horizon in unfavorable sites in both sagebrush and aspen was considerably higher in available phosphorus than the B horizon, whereas, the favorable sites in both sagebrush and aspen did not show this wide difference between the A and B horizons (table 1).

If one chose to limit the application of these data only to the areas included in the experiment, horizons x samples and between samples (table 2) could be used as error terms, whereby, a multitude of significant differences would appear. However, since these data are being applied to broad range areas it is desirable to use the more appropriate error terms as indicated in table 2.

Table 2. *Analysis of variance of composition of soil from A and B horizons from 2 sites and 2 vegetation types*

Source	D.F.	Nitrogen as NO_3	Organic matter	pH	Available PO_4	Available Ca
			Mean squares			
Vegetation types	1	2.52	1.76	0.65	4.69	105,128
Sites within types	2	1.77	3.62	1.18	71.74	140,940
Areas within types and sites. Error (a)	8	1.52	11.13	0.35	28.07	833,676
Between samples	12	0.31	0.11	0.02	1.44	31,557
Horizons (A and B)	1	17.52**	172.52**	0.0	186.44**	616,911**
Horizons x types	1	1.69	18.26	0.01	0.18	366,000*
Horizons x site within types	2	2.86	0.78	0.11	16.96**	194,674
Areas x horizons within types and sites. Error (b)	8	1.04	4.45	0.04	2.08	51,638
Horizons x samples	12	0.19	0.19	0.02	0.73	14,793
			Coefficient of variability			
Error (a)		25.80	36.78	4.50	55.69	32.39
Error (b)		29.75	34.48	3.10	21.52	11.43

* Indicates significance at the 0.05 level.
** Indicates significance at the 0.01 level.

Available phosphorus was somewhat higher in the unfavorable sites than in favorable sites (table 1). This might be accounted for by the higher calcium content in favorable sites in both sagebrush and aspen, which would tend to reduce the content of available phosphorus.

Hoagland (16) suggests that available phosphate is affected by the capacity of the soil to neutralize acids as they are formed. Thus, if a soil is high in calcium the plant may be prevented from acquiring potentially acid-soluble phosphate.

There were no significant differences in soil constituents (table 2) between sagebrush and aspen types. However, available phosphorus was generally higher in sagebrush types, whereas, available calcium was generally higher in aspen types (table 1). As mentioned previously the higher calcium content may account for lower available phosphorus in these soils.

Aspen had a greater density of forage cover on both favorable and unfavorable sites, and supported a higher percentage of grass and a lower percentage of browse compared to sagebrush sites (table 3). There was little difference in the average depth of horizon A among the various sites and vegetation types. Horizon B was developed to a deeper depth in aspen types compared to sagebrush types, and likewise, in the favorable sites as compared to unfavorable sites within each type.

The zone of root concentration had a tendency to extend only slightly into the B horizon. The extent of penetration was more pronounced in favorable than in unfavorable sites. A similar relationship existed between depth of horizon B and the root feeding zone (table 3). Most of the fibrous roots did not extend below the B horizon in unfavorable sites, whereas, an increased number was found in the C horizon in favorable sites in both sagebrush and aspen types.

Plant Analysis

The complex relationship between the chemical composition of plants and soils has never been fully understood. There is no general agreement on how most environmental factors operate to modify either the influence of plants upon the soil composition or conversely, the influence of soil upon plant composition. There are many interdependent and interacting factors working simultaneously. One factor may influence another and the degree of influence may be dependent upon still another factor. For example, climatic conditions influence the development of plants, and in turn, plants influence soil development. Yet, at the same time soil development may be influenced directly by climate, and through the soil, climate may influence plants. Thus, soils and plants develop together and are mutually dependent, one upon the other.

The effects of vegetation types and sites upon percent dry matter and chemical composition of the three representative species, a browse (snowberry), a forb (yarrow), and a grass (mountain bromegrass) are shown in tables 4, 5, and 6, respectively. It is recognized that these values do not represent the effect of vegetation

Table 3. *Total plant cover, composition, horizon depths, and root penetration as found on two sites within mountain sagebrush and aspen types*

Vegetation type and site	Total density	Grass	Forbs	Browse	Exposure	Slope	Horizon depth: Horizon A	Horizon B	Horizon C*	Root feeding zone†	Root concentration zone†
	percent	*percent*	*percent*	*percent*		*percent*	*inches*	*inches*	*inches*	*inches depth*	
Sagebrush											
Favorable	20.8	39.0	12.8	48.2	S66°E	9.0	12.8	26.1	42.3	31.3	19.3
Unfavorable	15.8	26.5	25.2	48.3	S57°W	32.0	9.2	20.9	35.1	18.3	11.3
Average	18.3	32.8	19.0	48.2	....	20.5	11.0	23.5	38.7	24.8	15.3
Aspen											
Favorable	28.3	59.7	14.2	26.1	N3°W	11.7	11.9	29.4	63.1	32.0	17.3
Unfavorable	17.3	54.0	17.8	28.2	N85°W	15.3	12.6	27.7	55.0	22.7	14.7
Average	22.8	56.8	16.0	27.2	....	13.5	12.3	28.6	59.1	27.4	16.0

* The C horizon was not sampled below the point at which calcium carbonate gave a vigorous effervescence with dilute hydrochloric acid.

† The figures in these columns are presented in inches depth; root feeding zone represents a depth below which only a few fibrous roots were found.

Table 4. *Percent dry matter and chemical composition of snowberry (Symphoricarpos vaccinioides) a browse common on summer range areas showing variability in nutritive value of plant parts as affected by vegetation types and site*[*]

Other ... Cellulose Stem-

Table 4. *Percent dry matter and chemical composition of snowberry (Symphoricarpos vaccinioides) a browse common on summer range areas showing variability in nutritive value of plant parts as affected by vegetation types and site**

Type and site	Plant part	Dry† matter	Ether extract	Protein	Cellulose	Lignin	Other carbohydrates	Total ash	Phosphorus	Calcium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
SAGEBRUSH														
Favorable	Stem	55.6	2.18	3.92	35.68	19.70	34.39	4.13	.145	0.77	50.98	38.79	1.84	
	Leaf	43.7	5.87	10.13	14.10	6.84	56.29	6.77	.333	1.54	63.63	13.60	2.10	
	Avg.	48.1	4.50	7.82	22.11	11.61	48.16	5.79	.264	1.25	58.94	22.95	2.01	0.59
Unfavorable	Stem	58.2	1.88	4.14	34.61	20.55	34.39	4.43	.160	0.87	51.62	37.93	1.69	
	Leaf	47.3	5.73	9.29	13.69	7.05	56.51	7.73	.405	1.82	65.55	11.70	1.96	
	Avg.	51.2	4.36	7.46	21.12	11.84	48.66	6.56	.318	1.48	60.61	21.01	1.86	0.55
Average sagebrush	Stem	56.9	2.03	4.03	34.73	20.12	34.81	4.28	.153	0.82	51.30	38.36	1.76	
	Leaf	45.5	5.80	9.71	13.90	6.94	56.40	7.25	.369	1.68	64.59	12.65	2.03	
	Avg.	49.6	4.43	7.65	21.46	11.73	48.38	6.35	.290	1.37	59.59	21.98	1.93	0.57
ASPEN														
Favorable	Stem	53.2	2.11	4.33	37.66	19.67	31.64	4.59	.155	0.76	48.49	40.48	1.93	
	Leaf	39.0	6.13	12.09	14.60	7.19	52.45	7.54	.357	1.57	61.29	12.95	2.06	
	Avg.	43.1	4.96	9.84	21.30	10.82	46.40	6.68	.299	1.33	57.57	20.96	2.02	0.41
Unfavorable	Stem	52.9	2.20	4.23	36.28	19.89	32.94	4.46	.164	0.78	45.84	43.27	1.84	
	Leaf	39.3	6.33	11.34	14.72	7.24	52.49	7.88	.444	1.69	62.05	12.40	2.05	
	Avg.	43.5	5.05	9.13	21.41	11.17	46.42	6.82	.357	1.41	57.02	21.98	1.98	0.45
Average aspen	Stem	53.1	2.15	4.28	36.97	19.78	32.29	4.53	.159	0.77	47.17	41.87	1.87	
	Leaf	39.1	6.23	11.71	14.66	7.21	52.48	7.71	.401	1.63	61.67	12.68	2.06	
	Avg.	43.3	5.00	9.48	21.37	10.99	46.40	6.76	.328	1.37	57.31	21.45	2.00	0.43

* These figures represent seasonal averages from July 8 to September 27, 1946, on three comparable areas in each case, and all whole plant averages are weighted by dry weight of each part of the plant.

† Represents percent dry matter of green weight.

Table 5. *Percent dry matter and chemical composition of yarrow (Achillea lanulosa) a forb common on summer range areas showing variability in nutritive value of plant parts as affected by vegetation types and site**

Type and site	Plant part	Dry† matter	Ether extract	Pro-tein	Cellu-lose	Lignin	Other carbo-hydrates	Total ash	Phos-phorus	Cal-cium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
SAGEBRUSH														
Favorable	Stem	51.9	1.59	2.89	42.96	13.34	34.92	4.30	.144	0.60	39.60	51.62	3.28	
	Leaf	37.4	6.11	10.99	21.73	7.91	42.98	10.28	.287	1.28	51.54	21.08	2.87	
	Head	55.5	5.58	9.19	30.75	13.47	34.66	6.35	.292	0.71	43.71	35.17	2.33	
	Avg.	48.9	3.91	6.81	33.81	11.86	37.10	6.51	.223	0.82	44.01	38.76	2.91	1.65
Unfavorable	Stem	53.7	1.04	3.36	44.30	13.30	33.67	4.33	.161	0.63	38.82	52.45	3.38	
	Leaf	38.5	6.08	11.02	22.25	7.92	42.20	10.53	.328	1.37	51.11	21.26	2.90	
	Head	58.2	5.66	9.14	30.95	13.78	33.94	6.53	.308	0.87	43.64	35.03	2.28	
	Avg.	49.2	3.92	7.45	33.27	11.46	36.83	7.08	.255	0.95	44.37	37.18	2.96	1.13
Average sagebrush	Stem	52.8	1.31	3.13	43.63	13.32	34.29	4.32	.153	0.61	39.21	52.03	3.33	
	Leaf	38.0	6.10	11.00	21.99	7.92	42.58	10.41	.308	1.32	51.32	21.17	2.88	
	Head	56.8	5.62	9.17	30.85	13.63	34.29	6.44	.300	0.79	43.67	35.10	2.30	
	Avg.	49.1	3.91	7.11	33.64	11.69	36.90	6.76	.238	0.88	44.13	38.09	2.93	1.39
ASPEN														
Favorable	Stem	40.5	1.27	3.44	43.89	12.83	32.89	5.68	.186	0.65	37.13	52.48	3.58	
	Leaf	31.4	5.53	13.17	22.07	8.43	39.35	11.45	.325	1.37	48.56	21.29	2.72	
	Head	46.3	5.61	11.62	29.29	12.38	33.63	7.47	.363	0.87	41.88	33.42	2.43	
	Avg.	38.8	3.26	7.70	34.95	11.44	34.94	7.70	.257	0.89	41.33	39.99	3.09	1.79
Unfavorable	Stem	43.6	1.13	3.13	43.78	13.29	33.69	4.98	.189	0.63	37.63	53.13	3.40	
	Leaf	31.3	5.83	12.36	22.35	8.69	39.21	11.56	.347	1.31	47.51	22.74	2.66	
	Head	51.6	5.68	10.76	29.31	13.03	33.95	7.27	.350	0.85	42.76	33.53	2.29	
	Avg.	41.5	3.50	7.52	34.26	11.83	35.43	7.46	.270	0.88	41.70	39.81	2.94	1.60
Average aspen	Stem	42.0	1.20	3.28	43.83	13.06	33.30	5.33	.187	0.64	37.38	52.81	3.49	
	Leaf	31.4	5.68	12.76	22.21	8.56	39.29	11.50	.336	1.34	48.04	22.02	2.69	
	Head	48.9	5.66	11.19	29.30	12.71	33.77	7.37	.356	0.86	42.18	33.60	2.36	
	Avg.	40.1	3.38	7.61	34.62	11.63	35.20	7.57	.263	0.89	41.54	39.90	3.04	1.70

* These figures represent seasonal averages from July 8 to September 27, 1946, on three comparable areas in each case, and all whole-plant averages are weighed by dry weight of each part of the plant concerned.
† Represents percent dry matter of green weight.

Table 6. *Percent dry matter and chemical composition of mountain bromegrass (Bromus carinatus) common on summer range areas showing variability in nutritive value of plant parts as affected by vegetation types and sites**

Type and site	Plant part	Dry† matter	Ether extract	Pro-tein	Cellu-lose	Lignin	Other carbo-hydrates	Total ash	Phos-phorus	Cal-cium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio

* These figures represent seasonal averages from July 8 to September 27, 1946, on three comparable areas in each case, and all whole-plant averages are weighed by dry weight of each part of the plant concerned.
† Represents percent dry matter of green weight.

Table 6. *Percent dry matter and chemical composition of mountain bromegrass (Bromus carinatus) common on summer range areas showing variability in nutritive value of plant parts as affected by vegetation types and sites**

Type and site	Plant part	Dry† matter	Ether extract	Protein	Cellulose	Lignin	Other carbohydrates	Total ash	Phosphorus	Calcium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
SAGEBRUSH														
Favorable	Stem	60.3	1.07	3.04	50.23	9.52	32.48	3.66	.148	0.21	45.58	46.65	5.34	
	Leaf	58.5	5.97	9.53	35.16	6.31	34.74	8.29	.197	0.87	45.59	30.62	5.72	
	Head	58.1	2.01	9.09	32.59	6.73	45.50	4.08	.276	0.30	56.71	28.11	4.93	
	Avg.	59.6	2.12	5.17	44.75	8.50	34.89	5.23	.176	0.35	47.28	40.85	5.34	3.51
Unfavorable	Stem	63.5	1.08	2.80	51.29	9.52	31.23	4.08	.152	0.20	44.42	47.62	5.42	
	Leaf	61.8	5.56	8.46	36.08	6.15	34.81	8.94	.206	0.88	45.94	31.10	6.60	
	Head	57.8	1.63	8.26	34.07	6.69	43.25	4.10	.278	0.27	57.88	28.13	5.11	
	Avg.	62.7	2.00	4.33	47.01	8.65	32.81	4.45	.173	0.34	45.70	42.94	5.63	3.67
Average sagebrush	Stem	61.9	1.07	2.92	50.76	9.52	31.87	3.86	.150	0.21	45.02	47.13	5.38	
	Leaf	60.2	5.76	8.99	35.62	6.23	34.78	8.62	.201	0.87	45.17	30.86	5.89	
	Head	58.0	1.82	8.67	33.33	6.71	45.38	4.09	.277	0.28	57.30	28.12	5.02	
	Avg.	61.2	2.07	4.68	46.06	8.59	33.79	4.82	.174	0.34	45.94	41.76	5.41	3.59
ASPEN														
Favorable	Stem	47.8	0.87	3.18	51.38	10.90	28.94	4.73	.185	0.27	41.56	49.76	4.82	
	Leaf	46.1	5.49	11.80	33.83	6.83	32.40	9.65	.232	1.04	43.33	29.83	5.13	
	Head	50.6	1.77	10.35	34.12	6.99	41.86	4.91	.329	0.29	52.44	30.53	4.95	
	Avg.	48.0	1.87	5.42	46.35	9.75	30.44	5.71	.204	0.42	42.51	44.12	4.88	3.53
Unfavorable	Stem	54.6	0.89	2.81	52.47	10.33	33.50	4.32	.198	0.21	42.44	49.54	5.14	
	Leaf	53.6	5.58	9.32	35.27	6.97	33.62	9.24	.245	0.95	43.62	33.24	5.25	
	Head	54.5	2.08	10.77	32.76	6.84	42.86	4.69	.336	0.25	53.59	28.87	4.78	
	Avg.	54.3	1.80	4.92	46.91	9.29	34.67	5.15	.223	0.33	44.00	44.14	5.10	4.31
Average aspen	Stem	51.2	0.88	3.00	51.93	10.61	29.06	4.52	.192	0.24	41.95	49.65	4.98	
	Leaf	49.8	5.53	10.56	34.55	6.90	37.64	9.45	.239	1.00	41.12	31.54	5.19	
	Head	52.6	1.92	10.56	33.44	6.92	42.36	4.80	.332	0.27	53.02	29.70	4.87	
	Avg.	51 1	1.84	5.12	46.63	9.57	31.91	5.47	.214	0.38	42.83	44.13	4.97	3.92

* These figures represent seasonal averages from July 8 to September 27, 1946, on three comparable areas in each case, and all whole-plant averages are weighed by dry weight of each part of the plant concerned.
† Represents percent dry matter of green weight.

Table 7. *Percent dry matter and chemical composition of snowberry (Symphoricarpos vaccinioides) common on summer range areas showing affect of season from July 8 to September 27, 1946**

Periods	Plant part	Dry† matter	Ether extract	Protein	Cellulose	Lignin	Other carbohydrates	Total ash	Phosphorus	Calcium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
Period I (July 8)	Stem	44.3	2.40	4.25	36.86	17.95	33.76	4.78	.190	0.77	48.96	39.61	2.07	
	Leaf	37.2	5.72	13.43	14.42	7.33	51.71	7.39	.431	1.21	62.86	10.60	2.03	
	Avg.	39.0	4.86	11.05	20.24	10.08	47.06	6.71	.369	1.10	59.26	18.12	2.04	0.35
Period II (July 31)	Stem	52.3	2.43	3.86	35.41	21.35	32.88	4.07	.140	0.87	49.20	40.44	1.67	
	Leaf	39.2	5.88	11.68	15.09	6.71	53.67	6.97	.351	1.43	60.58	14.89	2.26	
	Avg.	43.2	4.83	9.29	21.30	11.18	47.32	6.08	.287	1.26	57.11	22.69	2.08	0.44
Period III (Aug. 28)	Stem	59.7	2.24	4.08	35.71	20.63	32.93	4.41	.141	0.79	49.96	39.31	1.74	
	Leaf	44.3	6.30	10.09	13.42	7.05	56.42	6.72	.333	1.83	64.28	12.61	1.91	
	Avg.	49.5	4.93	8.06	20.95	11.64	48.48	5.94	.268	1.48	59.44	21.63	1.85	0.51
Period IV (Sept. 27)	Stem	63.8	1.29	4.44	36.25	19.89	33.77	4.36	.153	0.76	49.80	40.11	1.83	
	Leaf	48.6	6.15	7.64	14.18	7.22	55.97	8.84	.425	2.14	64.82	12.55	1.98	
	Avg.	54.9	4.15	6.32	23.27	12.44	46.83	6.99	.313	1.57	58.64	23.90	1.92	0.70
Average	Stem	55.0	2.09	4.16	36.06	19.98	33.34	4.41	.156	0.80	49.48	39.87	1.83	
	Leaf	42.3	6.01	10.71	14.25	7.08	54.44	7.48	.385	1.65	63.13	12.66	2.05	
	Avg.	46.7	4.69	8.68	21.44	11.34	47.42	6.43	.309	1.35	58.61	21.59	1.97	0.50

* These figures represent averages from three favorable areas and three unfavorable areas in each of two vegetation types, sagebrush and aspen, making a total of twelve figures constituting the average in each case.

† Represents percent dry matter of green weight.

type and site independently, but also the influence of climate and other habitat factors, as well as differences in soil composition, and stage and character of growth.

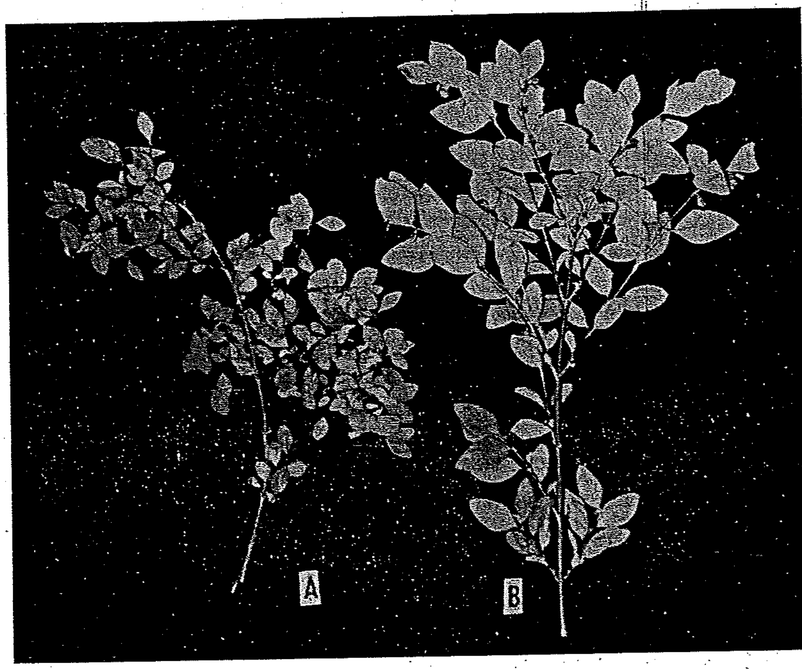

Fig. 6. A summer-range browse, snowberry (*Symphoricarpos vaccinioides*), (A) showing characteristic growth on unfavorable sagebrush sites and (B) characteristic growth on favorable aspen sites

The character of growth was markedly different on the various sites. The greatest contrasts were found in favorable aspen sites compared to unfavorable sagebrush sites (fig. 6, 7, and 8).

Seasonal trends in chemical composition for the three representative plant species are shown in tables 7, 8, and 9. Seasonal variation in chemical content between vegetation types and sites includes a slight difference in developmental stage of plant material. The greatest difference was between favorable aspen sites and unfavorable sagebrush sites. The sampled species on the latter sites were about one week further advanced in growth stages than the former. On other sites, differences were considered negligible. The stages of growth for the three species of plants studied are shown in table 10.

Table 8. *Percent dry matter and chemical composition of yarrow (Achillea lanulosa) common on summer range areas showing affect of season from July 8 to September 27, 1946**

Periods	Plant part	Dry† matter	Ether extract	Protein	Cellulose	Lignin	Other carbohydrates	Total ash	Phosphorus	Calcium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
Period I (July 8)	Stem	30.4	1.49	4.28	41.60	10.05	37.05	5.53	.241	0.57	41.35	47.35	4.18	
	Leaf	25.4	5.10	14.29	21.39	6.01	42.45	10.76	.410	1.14	50.10	19.75	3.58	
	Head	28.0	5.14	14.03	26.46	10.07	36.37	7.93	.442	0.73	44.05	28.85	2.63	
	Avg.	28.0	3.53	9.87	31.10	8.48	39.04	7.98	.342	0.82	45.23	33.39	3.68	1.12
Period II (July 31)	Stem	40.2	1.33	2.94	42.88	13.71	33.99	5.15	.185	0.64	38.24	52.34	3.21	
	Leaf	32.2	5.75	11.90	21.70	8.03	41.33	11.29	.339	1.30	50.01	21.05	2.72	
	Head	34.9	6.24	11.10	27.01	11.83	36.02	7.80	.403	0.77	43.75	31.11	2.91	
	Avg.	36.4	4.01	7.87	32.18	11.50	36.73	7.71	.291	0.87	43.26	37.15	2.98	1.42
Period III (Aug. 28)	Stem	49.6	1.05	2.63	44.59	14.24	32.89	4.60	.130	0.65	37.28	54.44	3.14	
	Leaf	37.2	6.60	10.52	22.77	8.89	40.14	11.08	.257	1.43	49.23	22.57	2.59	
	Head	59.4	7.29	9.44	31.69	14.71	29.92	6.95	.299	0.81	39.34	36.98	2.21	
	Avg.	48.2	4.18	6.59	35.03	12.76	34.36	7.08	.207	0.92	41.34	40.81	2.76	1.56
Period IV (Sept. 27)	Stem	69.5	1.16	2.97	45.84	14.76	31.25	4.02	.124	0.64	36.30	55.55	3.12	
	Leaf	44.0	6.10	10.82	22.54	10.02	39.82	10.70	.282	1.45	49.37	23.01	2.27	
	Head	89.4	3.86	6.13	35.15	16.05	32.87	5.94	.170	0.99	43.62	40.45	2.20	
	Avg.	66.5	2.93	5.57	37.90	13.77	33.74	6.09	.173	0.92	40.99	44.42	2.73	2.18
Average	Stem	47.4	1.26	3.20	43.73	13.19	33.79	4.83	.170	0.63	38.29	52.42	3.41	
	Leaf	34.7	5.89	11.88	22.10	8.24	40.94	10.96	.322	1.33	49.68	21.59	2.79	
	Head	52.9	5.63	10.18	30.08	13.16	33.79	7.16	.329	0.82	42.69	34.35	2.49	
	Avg.	44.8	3.66	7.46	34.05	11.63	35.98	7.22	.253	0.88	42.72	38.94	3.04	1.57

* These figures represent averages from three favorable areas and three unfavorable areas in each of two vegetation types, sagebrush and aspen, making a total of twelve figures constituting the average in each case.

† Represents percent dry matter of green weight.

Table 9. *Percent dry matter and chemical composition of mountain bromegrass (Bromus carinatus) common on summer range areas showing affect of season from July 8 to September 27, 1946**

* These figures represent averages from three favorable areas and three unfavorable areas in each of two vegetation types, sagebrush and aspen, making a total of twelve figures constituting the average in each case.

† Represents percent dry matter of green weight.

Table 9. *Percent dry matter and chemical composition of mountain bromegrass (Bromus carinatus) common on summer range areas showing affect of season from July 8 to September 27, 1946**

Periods	Plant part	Dry† matter	Ether extract	Protein	Cellulose	Lignin	Other carbohydrates	Total ash	Phosphorus	Calcium	N.F.E.	Crude fiber	Cellulose lignin ratio	Stem-leaf ratio
Period I (July 8)	Stem	36.6	1.28	4.87	48.37	8.63	32.28	4.57	.262	0.16	44.81	44.47	5.67	
	Leaf	35.1	6.45	14.69	30.94	4.88	32.96	10.08	.299	0.82	42.75	26.03	6.51	
	Head	36.9	1.96	11.07	40.28	6.87	35.09	4.73	.347	0.24	47.45	34.79	5.96	
	Avg.	36.4	2.44	8.23	43.09	7.49	33.07	5.68	.289	0.31	45.03	38.62	5.90	2.97
Period II (July 31)	Stem	48.1	0.66	2.93	50.58	11.13	30.01	4.69	.174	0.21	45.11	46.61	4.60	
	Leaf	47.2	5.17	9.12	33.38	5.84	36.81	9.68	.209	0.99	44.27	31.76	5.78	
	Head	47.9	1.43	8.99	30.45	7.01	47.57	4.55	.306	0.29	58.82	26.21	4.39	
	Avg.	49.9	1.52	5.45	42.72	9.26	35.66	5.39	.214	0.35	48.62	39.02	4.72	3.95
Period III (Aug. 28)	Stem	61.1	0.94	2.07	53.07	10.31	29.73	3.88	.121	0.22	42.09	51.02	5.18	
	Leaf	67.2	6.32	7.55	38.67	7.48	31.83	8.15	.159	1.00	44.18	33.80	5.22	
	Head	81.0	2.23	8.79	29.42	6.56	48.95	4.05	.261	0.30	59.20	25.73	4.48	
	Avg.	63.08	1.92	3.33	49.49	9.65	30.99	4.62	.134	0.36	43.25	46.88	5.16	4.49
Period IV (Sept. 27)	Stem	80.3	1.03	1.97	53.36	10.19	29.81	3.64	.125	0.30	41.87	51.49	5.27	
	Leaf	70.5	4.65	7.75	37.37	8.07	33.94	8.22	.213	0.93	46.17	33.21	4.66	
	Head	—	—	—	—	—	—	—	—	—	—	—	—	
	Avg.	78.2	1.82	3.23	49.88	9.73	30.71	4.63	.144	0.44	42.80	47.52	5.14	3.60
Average	Stem	56.5	0.98	2.96	51.34	10.06	30.46	4.19	.171	0.22	43.47	48.40	5.18	
	Leaf	55.0	5.65	9.78	35.09	6.57	33.88	9.03	.220	0.94	44.34	31.20	5.54	
	Head	55.3	1.87	9.62	33.38	6.81	43.87	4.44	.305	0.28	55.16	28.91	4.94	
	Avg.	56.9	1.93	5.06	46.30	9.03	32.60	5.08	.195	0.37	44.92	43.01	5.23	3.75

* These figures represent averages from three favorable areas and three unfavorable areas in each of two vegetation types, sagebrush and aspen, making a total of twelve figures constituting the average in each case.

† Represents percent dry matter of green weight.

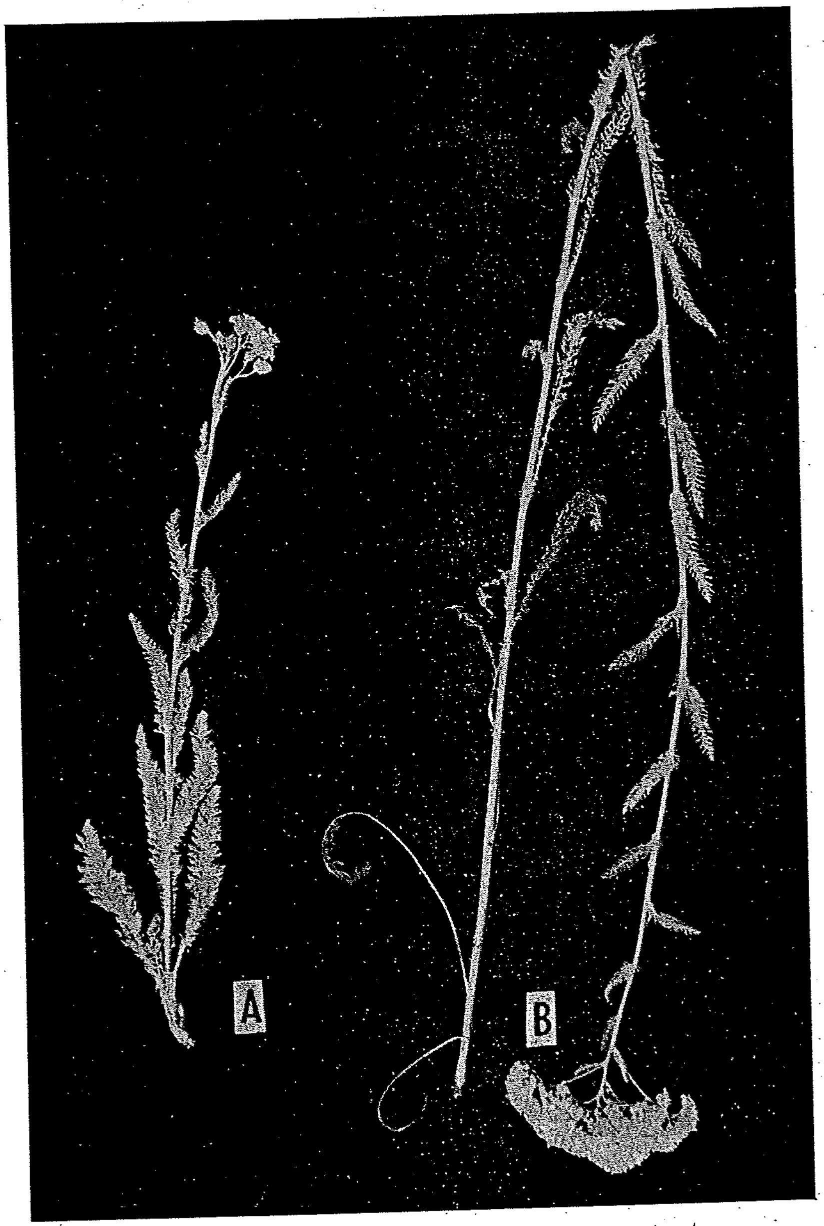

Fig. 7. A summer-range forb, yarrow (*Achillea lanulosa*), (A) showing characteristic growth on unfavorable sagebrush sites and (B) showing characteristic growth on favorable aspen sites

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Plants growing on aspen types in both favorable and unfavorable sites contained more field moisture as compared to sagebrush types. This was true for all plants and all plant parts (tables 4, 5, and 6). As would be expected, the percent moisture in all three species and in all parts of plants decreased as the season advanced (tables 7, 8, and 9).

Table 10. *Stage of growth for the three plants as related to period of study*

Plant	Period*	Stage of growth
Symphoricarpos vaccinioides	Period I	Late bud to full flower stage
	Period II	Late flower to medium fruiting stage
	Period III	Full to late fruiting stage
	Period IV	Very late fruiting stage, fruits mostly dry
Achillea lanulosa	Period I	Late bud to full flower stage
	Period II	Full to late flower stage
	Period III	Early to late seed disseminating stage
	Period IV	Very late seed dissemination stage
Bromus carinatus	Period I	Full head to early dough stage
	Period II	Medium dough to early seed shattering stage
	Period III	Late seed stage, most seeds disseminated
	Period IV	Very late seed dissemination stage

* These periods represent the same dates and periods presented in tables 7, 8 and 9.

The analysis of variance for the chemical constituents found in the plant parts for each of the species is presented in tables 10, 11, and 12.

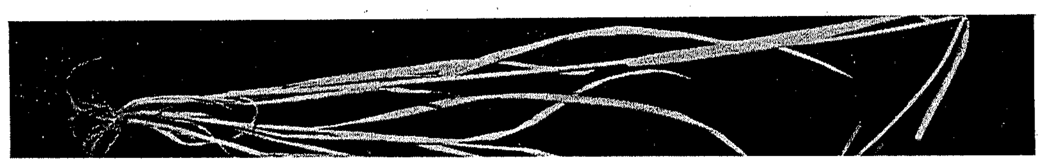
Ether Extract: All fats and fat-like substances that are soluble in ether are included in the ether-extract fraction and are commonly classified as lipids. Snowberry contained the greatest amount of ether extract and mountain bromegrass the least, with yarrow in an intermediate position (tables 7, 8, and 9). Leaves of all three species contained considerably more ether extract than stems. This was most pronounced in mountain bromegrass.

The differences in ether-extract content of plants growing on aspen areas as compared to sagebrush areas were not significant as shown by an analysis of variance (tables 11, 12, and 13). However, interactions between vegetation type and plants were significant and show that vegetation types affect the ether-extract content of various parts of the plants differently. For example, aspen types produced a

Table 11. *Analyses of variance of the chemical composition of snowberry (Symphoricarpos vaccinioides) collected during four periods of the summer grazing season from favorable and unfavorable sites within sagebrush and aspen types*

Source and part of plant	D. F.	Ether extract	Protein	Nitrogen-free extract	Crude fiber	Total ash	Phosphorus	Calcium	Cellulose	Lignin	Cellulose-lignin ratio
							Mean squares				
STEM											
Vegetation types	1	.1850	.768	181.35	147.70	.73	.00051	.0331	39.79*	1.428	.179**
Sites within types	2	.2891	.173	25.04	25.60	.34	.00094	.0315	9.20	2.304	.094*
Areas within types and sites. Error (a)	8	.5646	.308	37.41	35.39	.37	.00056	.0162	3.70	.722	.014
Periods	3	3.4936*	.726**	6.36	8.00	1.01**	.00672**	.0292*	4.89	25.738**	.379**
Periods x types	3	.5868	.030	37.98	57.74	.08	.00031	.0047	6.57	.693	.032
Periods x sites within types	6	.8052	.115	20.82	22.70	.08	.00017	.0096	5.19	2.518*	.057*
Areas x periods within types and sites. Error (b)	24	.8736	.089	23.16	23.16	.06	.00024	.0090	2.86	.691	.012
							Coefficient of variability				
Error (a)		17.98	6.67	6.21	7.46	21.80	7.50	7.92	2.67	2.13	3.24
Error (b)		44.72	6.94	9.60	3.30	5.57	9.94	11.89	4.69	4.17	5.97
							Mean squares				
LEAF											
Vegetation types	1	2.2017	48.260**	107.10	.01	2.61	.01203	.0295	6.97	.905	.011
Sites within types	2	.1786	3.824	12.52	11.74	3.10	.03823	.2726*	.54	.129	.056
Areas within types and sites. Error (a)	8	1.2217	1.944	24.05	17.24	1.09	.01213	.0594	1.96	.494	.077
Periods	3	.8386	72.715**	45.97	36.95	10.83**	.03060**	2.0654**	5.73**	.882	.274**
Periods x types	3	.6120	.451	10.13	8.14	.00	.00121	.0067	1.95	2.272**	.186**
Periods x sites within types	6	.8148	.319	21.71	15.88	.15	.00105	.0347*	.67	.535	.081
Areas x periods within types and sites. (Error (b)	24	.5736	.198	17.94	15.16	.18	.00167	.0131	1.02	.305	.036
							Coefficient of variability				
Error (a)		9.19	6.51	38.86	16.35	6.84	14.02	7.37	4.90	4.82	6.76
Error (b)		12.6	4.12	65.55	30.72	5.57	10.59	6.93	7.07	7.65	9.22

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



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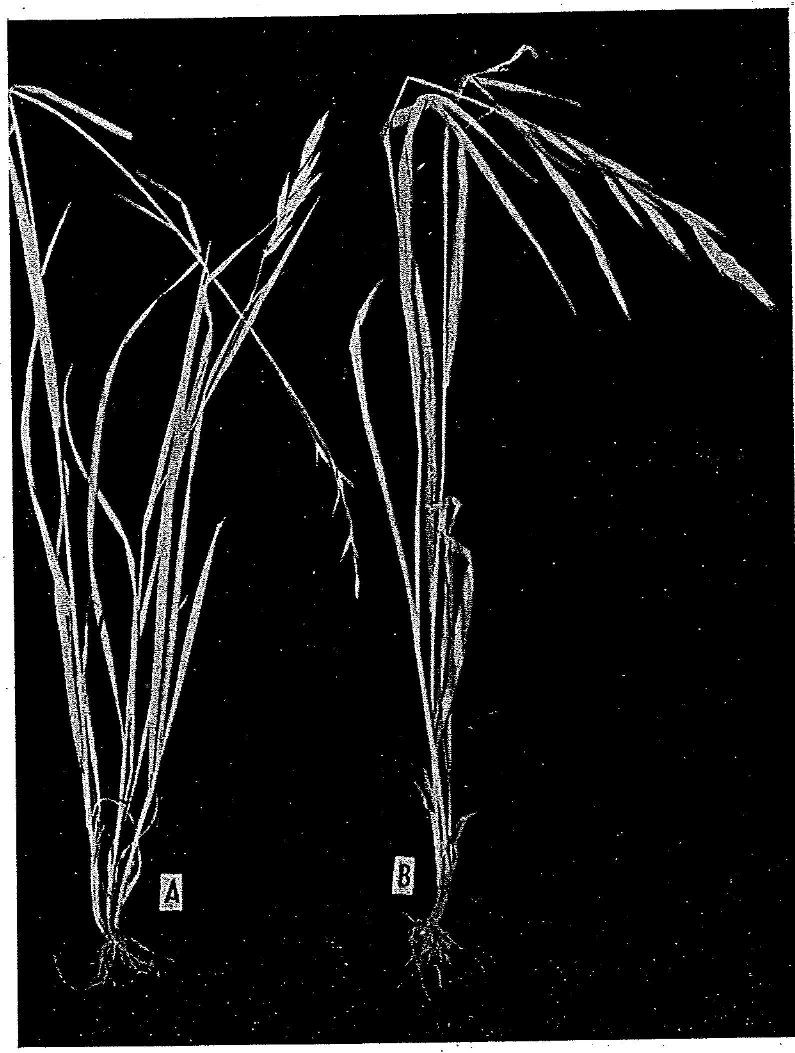

Fig. 8. A summer-range grass, mountain bromegrass (*Bromus carniatus*), (A) showing characteristic growth on unfavorable sagebrush sites and (B) showing characteristic growth on favorable aspen sites

higher content of ether extract in the leaves of snowberry on both favorable and unfavorable sites, whereas, sagebrush areas produced a higher content of ether extract in the leaves of yarrow on both sites (tables 4 and 5).

Table 12. *Analyses of variance of the chemical composition of yarrow (Achillea lanulosa) collected during four periods of the summer grazing season from favorable and unfavorable sites within sagebrush and aspen areas*

Source and part of plant	D. F.	Ether extract	Pro-tein	Nitrogen-free extract	Crude fiber	Total ash	Phos-phorus	Cal-cium	Cellu-lose	Lignin	Cellulose-lignin ratio
							Mean squares				
STEM											
Vegetation types	1	.1496	.298	29.92**	7.21	12.40**	.01463*	.0082	.46	.816	.304
Sites within types	2	.9656	.948	1.19	3.35	1.48	.00088	.0047	5.45	.632	.138
Areas within types and sites. Error (a)	8	.8548	1.289	2.44	2.63	.46	.00159	.0027	1.30	1.544	.092
Periods	3	.4410	6.460**	73.64**	158.38**	5.25**	.03552**	.0150**	41.88**	54.699**	3.183**
Periods x types	3	.6385	1.916	3.42	4.24	1.32**	.00129**	.0086	5.47*	.822	.279
Periods x sites within types	6	1.6646	1.214	5.25	.96	.33	.00039	.0036	2.35	1.095	.044
Areas x periods within types and sites. Error (b)	24	.7244	1.057	5.44	3.02	.19	.00019	.0029	1.33	1.998	.147
							Coefficient of variability				
Error (a)		35.90	17.66	2.04	1.53	7.02	11.69	4.19	1.30	4.71	4.44
Error (b)		66.75	32.02	6.09	3.32	9.00	8.05	8.54	2.64	10.70	11.23
							Mean squares				
LEAF											
Vegetation types	1	2.0875	37.031**	85.87**	8.59	14.41**	.00969	.0027	.61	4.954*	.445*
Sites within types	2	.2725	1.982	8.56	6.40	.22	.00645	.0314	1.06	.198	.014
Areas within types and sites. Error (a)	8	.9092	2.666	4.41	2.33	1.01	.00393	.0226	1.10	.560	.052
Periods	3	4.7814**	35.169**	2.15	26.57**	.93	.05548**	.2458**	5.21**	34.580**	3.758**
Periods x types	3	.1988	.872	6.34	2.28	1.55	.00570**	.0183	.49	.778	.036
Periods x sites within types	6	.2447	.089	5.35	1.51	.81	.00023	.0071	.35	.459	.025
Areas x periods within types and sites. Error (b)	24	.3037	2.340	2.89	1.53	.55	.00075	.0092	.85	.509	.032
							Coefficient of variability				
Error (a)		8.10	6.87	2.12	3.54	4.58	9.73	5.62	2.37	4.44	4.09
Error (b)		9.17	12.84	3.43	5.72	6.77	8.51	7.21	4.17	8.66	6.38

Source and part of plant	D. F.	Ether extract	Pro-tein	Nitrogen-free extract	Crude fiber	Total ash	Phos-phorus	Cal-cium	Cellu-lose	Lignin	Cellulose-lignin ratio
and sites. Error (b)	24	.3037	2.340	2.89	1.53	.55	.00075	.0092	.85	.509	.032
					Coefficient of variability						
Error (a)		8.10	6.87	2.12	3.54	4.58	9.73	5.62	2.37	4.44	4.09
Error (b)		9.17	12.84	3.43	5.72	6.77	8.51	7.21	4.17	8.66	6.38

Table 12. *Analyses of variance of the chemical composition of yarrow (Achillea lanulosa) colected during four periods of the summer grazing season from favorable and unfavorable sites within sagebrush and aspen areas* (continued)

Source and part of plant	D. F.	Ether extract	Pro-tein	Nitrogen-free extract	Crude fiber	Total ash	Phos-phorus	Cal-cium	Cellu-lose	Lignin	Cellulose-lignin ratio
						Mean squares					
HEAD											
Vegetation types	1	.0111	48.965**	5.67	26.85	10.55*	.03814*	.0567	28.67*	10.083*	.039
Sites within types	2	.0342	2.235	2.72	.13	.21	.00133	.0766	.12	1.552	.072
Areas within types and sites Error (a)	8	.6801	2.242	7.65	6.00	1.15	.00577	.0207	4.50	1.866	.044
Periods	3	26.0336**	130.348**	77.82**	339.61**	6.93**	.17785**	.1645**	203.42**	88.360**	.511**
Period x types	3	1.9704*	.910	2.09	4.42	.70	.00161	.0093	4.70	2.631	.062
Periods x sites within types	6	.1627	.228	7.50*	.96	.32	.00118	.0016	.57	.708	.047
Areas x periods within types and sites. Error (b)	24	.4390	.985	2.56	3.18	.33	.00144	.0086	2.13	1.131	.055
					Coefficient of variability						
Error (a)		7.32	7.45	3.23	3.57	7.76	11.56	8.79	3.52	5.18	4.52
Error (b)		11.59	9.23	3.74	5.19	8.31	11.56	11.30	4.85	8.07	10.11

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

Table 13. *Analyses of variance of the chemical composition of a mountain bromegrass (Bromus carinatus) collected during four periods of the summer grazing season from favorable and unfavorable sites within sagebrush and aspen areas*

Source and part of plant	D. F.	Ether extract	Pro-tein	Nitrogen-free extract	Crude fiber	Total ash	Phos-phorus	Cal-cium	Cellu-lose	Lignin	Cellulose-lignin ratio
						Mean squares					
STEM											
Vegetation types	1	.4275	.071	93.52**	76.01*	5.14	.02083**	.0102	16.45*	14.432**	1.948*
Sites within types	2	.0016	.579	4.57	2.94	1.02	.00055	.0108	6.99	.949	.316
Areas within types and sites. Error (a)	8	.1162	.986	6.96	14.66	1.37	.00065	.0063	2.74	.935	.337
Periods	3	.7708*	21.681**	34.57*	140.87**	3.17**	.05155**	.0444*	65.87**	13.027**	2.338**
Periods x types	3	.2717	.063	35.72*	23.18	.38	.00002	.0109	2.80	.821	.255
Periods x sites within types	6	.0415	.114	.66	1.97	.21	.00025	.0129	1.55	.176	.078
Areas x periods within types and sites. Error (b)	24	.1764	.081	10.97	10.85	.14	.00029	.0104	1.61	.617	.179
						Coefficient of variability					
Error (a)		17.41	16.65	3.04	3.95	13.97	7.50	18.20	1.44	4.70	5.60
Error (b)		42.94	9.59	7.40	6.81	8.93	9.96	46.36	2.47	7.79	7.97
						Mean squares					
LEAF											
Vegetation types	1	.6394	29.359	46.61**	5.54	8.25	.01661*	.1789*	13.65	5.333*	5.845**
Sites within types	2	.5360	21.904	7.04	35.55	1.76	.00072	.0220	8.80	.134	.385
Areas within types and sites. Error (a)	8	.4150	11.763	3.76	15.13	1.79	.00237	.0179	7.26	.521	.500
Periods	3	9.2690**	134.543**	34.07**	151.54**	11.84**	.04030**	.0787**	152.50**	25.912**	7.466**
Periods x types	3	1.0403	8.061*	9.43*	8.34	.20	.00096	.0475**	2.43	.322	.049
Periods x sites within types	6	.1953	.366	2.15	11.32	.37	.00064	.0035	2.47	.287	.270
Areas x periods within types and sites. Error (b)	24	.3685	2.090	2.44	10.81	.26	.00066	.0056	3.85	.376	.478
						Coefficient of variability					
Error (a)		5.52	17.48	2.16	6.23	7.41	10.54	7.14	3.82	4.58	6.20
Error (b)		10.74	14.72	3.49	10.54	5.64	11.68	7.96	5.59	7.88	12.35

				Coefficient of variability						
Error (a)	5.52	17.48	2.16	6.23	7.41	10.54	7.14	3.82	4.58	6.20
Error (b)	10.74	14.72	3.49	10.54	5.64	11.68	7.96	5.59	7.88	12.35

Table 13. *Analyses of variance of the chemical composition of a mountain bromegrass (Bromus corinatus) collected during four periods of the summer grazing season from favorable and unfavorable sites within sagebrush and aspen areas* (continued)

Source and part of plant	D. F.	Ether extract	Pro-tein	Nitrogen-free extract	Crude fiber	Total ash	Phos-phorus	Cal-cium	Cellu-lose	Lignin	Cellulose-lignin ratio
					Mean squares						
HEAD											
Vegetation types	1	.0992	31.941**	181.80*	22.41	4.55*	.02789**	.0013	.11	.395	.213
Sites within types	2	.5330	1.955	7.82	6.25	.12	.00012	.0044	9.12	.050	.133
Areas within types and sites. Error (a)	8	.7182	1.565	19.25	12.33	.56	.00163	.0048	8.68	.247	.189
Periods	2	2.0107**	19.265**	529.18**	311.91**	1.50**	.02212**	.0106	431.70**	.650	9.245**
Periods x types	2	.0221	.634	60.10*	23.67	.40*	.00014	.0006	38.75	.492	.849
Periods x sites within types	4	.5132	1.240	11.64	14.96	.04	.00068	.0043	28.10	1.093	.169
Areas x periods within types and sites. Error (b)	16	.2142	1.786	14.98	21.98	.10	.00115	.0063	14.00	.758	.672
					Coefficient of variability						
Error (a)		22.13	6.44	3.97	6.07	8.42	6.60	16.48	4.43	3.65	4.40
Error (b)		24.21	13.82	7.01	16.22	7.12	11.13	37.81	11.20	12.63	16.59

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

The effect of stage of maturity upon ether-extract content was variable and shows no orderly increase or decrease among periods (tables 7, 8, and 9). Nevertheless, the differences between periods for the various parts of the plants were significant except for the leaves of snowberry and the stems of yarrow (tables 11, 12, and 13). The seasonal trend of ether extract for the heads of yarrow on sagebrush areas was downward, whereas, on aspen areas it was upward, which explains the significant interaction between periods and types (table 12).

Protein: Fudge and Fraps (11) working in the gulf-coast prairie of southeast Texas, found that the protein content of young immature forage generally increased with increased nitrogen content in the soil. However, intermediate and mature stages of plant growth did not show this difference to any significant degree. Daniel and Harper (6) concluded that such relationships were highly variable and the study of a single nutrient element in the soil would not give a reliable indication of the amount of that element to be found in the plant since many soil factors are involved and plant species vary in their ability to utilize soil nutrients.

Mountain bromegrass contained the lowest percentage of protein, and snowberry the highest, with the forb yarrow only moderately high (tables 7, 8, and 9). However, when the protein content of the leaves only was compared forbs were highest and browse second. The differences in protein content of the three species were largely attributable to the stem-leaf ratios which showed that grass had a higher percentage of stemmy material than the browse or forb (tables 7, 8, and 9).

Aspen areas produced plants with a higher protein content than did sagebrush areas (tables 4, 5, and 6). This cannot be explained entirely by the higher content of nitrogen in the soil (table 1) since on some sites plant protein was relatively high, whereas, soil nitrogen was low. The greater shade may explain, in part, the higher protein content of forage in aspen areas since it has been found that plants growing in the sun generally have a lower percentage of protein than plants under shade (32). In spite of the consistently higher protein content on aspen areas, this difference between vegetation types was significant only in the case of the leaves of snowberry, the leaves and heads of yarrow, and the heads of bromegrass (tables 11, 12, and 13).

All three species showed an orderly decrease in percentage protein with advancement of season (tables 7, 8, and 9). However, when the parts of the plants were considered separately it was found, in some cases, that protein increased as the growth stages advanced. In general, the trend was downward for all plants and all plant parts, and the difference in content between periods was highly significant in all cases (tables 11, 12, and 13). Inconsistencies in seasonal trends were reported by Archibald *et al.* (1) who found that protein content of pasture grasses was high in the early season and later displayed a temporary drop after which it increased slightly depending upon moisture conditions and soil fertility.

The general decrease in protein with advanced maturity of plants is best explained by Murneek (20) and Richardson *et al.* (24) who reported that during the time of reproduction or at maturity nitrogen normally descends from the stems and leaves to the basal portion of the plant and into the roots.

The stem-leaf ratio increased for all three species and accounted for part of the decrease in protein content as the season advanced (tables 7, 8, and 9). However, individual parts of the plants displayed a seasonal decrease, independent of stem-leaf ratio, and accounted for a large portion of the seasonal decrease for the total plant.

A lack of orderly trends with advancement of season is not surprising when data are expressed in percent of dry matter. For instance, an increase or decrease in percent of any constituent as the season advances does not necessarily mean that a plant has added or lost that amount, but rather, may indicate that this constituent has not increased in the same proportion as the increase in dry matter brought about by increased growth. An increase in growth may be accompanied by a rapid increase in one or more nutrients; hence, others which have increased little may actually show a decrease in percent composition. This, of course, does not detract from chemical analysis as an index to the nutrient content, but it does indicate that the analysis is not an accurate expression of the actual physiological activities of the plant.

Phosphorus and Calcium: Availability of minerals in the soil is determined not only by the chemistry of the soil but also by the many biological factors involved. For this reason it is difficult to explain the many differences in the mineral content of plants produced on different sites.

Beeson (2) reports that plants do not assimilate mineral constituents in the same proportion in which they occur in the soil because vegetation has a marked selective power. However, some soils have a profound influence upon the quantity of the mineral constituents in the forage growing upon them.

Truninger and Grunigen (31) studied the assimilation of minerals by plants and found no correlation between either calcium or phosphorus in the forage as compared to the supply of these elements in the soil solution. Fraps and Fudge (10) found a correlation between calcium and phosphorus in the soil and plants only for certain species. Watkins (33) reported that soils high in phosphorus generally produced plants high in phosphorus, but some species were more efficient than others in obtaining phosphorus from the soil and showed a high content even on soils low in available phosphorus.

Kauter (17) found that the pH of the soil was an important factor in rendering nutrients available to plants. The percentage of phosphorus and calcium in hay increased with higher pH soil values. Truninger and Grunigen (31) observed that differences in pH values ranging from 4.5 to 8.0 had no effect on either the calcium or phosphorus content in forage plants. Hoagland (16) suggested that the activities of micro-organisms on organic matter and excretion of carbonic acid by roots brought about increased acidity, thereby, increasing the availability of phosphorus. Conversely, lime in soils tends to buffer against acidity, and to make phosphorus less available to plants.

Thus, the availability of soil phosphate and its influence upon phosphorus content of plants is dependent upon many variable factors.

The average phosphorus content for the three species shown in tables 7, 8, and 9, was highest in snowberry, lowest in mountain bromegrass, and only moderate for yarrow.

Differences in phosphorus content among the three species were greater when only leaves were compared, whereas, there was little difference in the phosphorus content of stems (tables 7, 8, and 9). The leaves contained considerably more phosphorus than did stems and the difference among species was largely the result of the difference in phosphorus content of the leaves.

There was a significant decrease in percent phosphorus as the season advanced in all species and in all plant parts except during the last period when some parts showed slight increases. This might be explained by the increase in soil moisture brought about by fall rains after a rather dry summer. This was true even when plants displayed no apparent signs of regrowth. Greenhill and Page (13) found comparable trends and reported that phosphorus in grass underwent a definite downward trend as the season progressed, especially during drought, after which it recovered.

All three species and their individual parts showed a close parallel seasonal change between phosphorus and protein content (tables 7, 8, and 9). However, direct relationships between phosphorus and protein among the individual species and parts of the plant were not evident. In addition, sites influenced these constituents differently (tables 4, 5, and 6).

All plants and plant parts were considerably higher in phosphorus on aspen areas compared to sagebrush areas, and unfavorable sites generally produced plants higher in phosphorus than favorable sites (tables 4, 5, and 6). The higher content of phosphorus in the forage on unfavorable sites agrees with the higher phosphorus content in the soils on these sites. However, the content of phosphorus in sagebrush soils was considerably higher than in aspen soils (table 1) yet, the forage on aspen soils was decidedly higher in phosphorus (tables 4, 5, and 6). Aspen soils had a higher content of moisture, and since Orr (22) and Daniel and Harper (6) found a direct relationship between soil moisture and phosphorus content of the forage, this would favor a higher phosphorus content in plants found growing on aspen areas. This fact, however, does not favor the increased phosphorus content of forage produced upon unfavorable sites. There is some indication that decreased light favors an increase in phosphorus (19) which may explain increased phosphorus under aspen. The differences in phosphorus content of forage between sites were not significant by an analysis of variance even though unfavorable sites consistently produced more phosphorus in plants. However, vegetation type did show a significant influence upon phosphorus content of plants (tables 11 and 12). This agrees with Stoddart (28) who found that good and poor sagebrush sites did not significantly influence phosphorus content in snowberry (*Symphoricarpos vaccinioides*) but soil types displayed a significant effect.

Available soil phosphorus tests have been interpreted for farm crops as follows: Zero to 5 parts per million of PO_4 in the surface 6 inches indicates that the soils are deficient, 5 to 10 parts per million indicates that soils are probably deficient, and 10 parts per million indicates that the available phosphorus in the soil is adequate for normal production (18).

Hoagland (16) suggests that unless a critically low level of phosphate in the soil is reached plants may not show lowered phosphorus content. Thus, since the average phosphorus content for A horizons on neither aspen nor sagebrush areas was critically low or essentially different (6.33 and 6.71 parts per million, respectively) it might be concluded that environmental factors and soil moisture may be more influential in determining the phosphorus content of forage than the available phosphorus in the soil.

Calcium content in both stems and leaves was decidedly highest in snowberry and lowest in mountain bromegrass, whereas, yarrow, which had the highest average content of total ash, was only intermediate in calcium content (tables 7, 8, and 9). Leaves of snowberry and yarrow contained more than twice as much calcium as stems, and bromegrass leaves contained more than four times as much as stems.

There was little difference in the calcium content of plants or plant parts on aspen types compared to sagebrush types except in the case of mountain bromegrass leaves which were significantly higher on aspen types (tables 6 and 13). Site significantly influenced the calcium content of plants only in the case of snowberry leaves which were higher on unfavorable sites than on favorable sites (tables 4 and 11).

Generally, all plant parts (stems, leaves, and heads) in all species increased in percent calcium as the season advanced (tables 7, 8, and 9). This trend was more pronounced in leaves than in stems and seasonal changes were significant in all cases except in heads of mountain bromegrass (tables 11, 12, and 13). The fact that percentage calcium increases with age of tissue may be explained by the increased cellular material of which calcium is a constituent (30).

Sullivan and Garber (30) stated that the calcium content of forage plants generally increased with age, whereas, Hart *et al.* (15) reported that there was no general trend in the percentage of calcium in forages with respect to growth stages. Several investigators (13, 25, 27, 29) reported that there was no general trend in the calcium content of grasses as the growth stage advanced. However, some of these studies and others (12, 25, 28, 29) suggest that browse and forbs have a tendency to increase in calcium content with increased growth.

Thus, the seasonal trend of calcium is not well understood and reveals the fact that a number of factors may operate to modify the mineral content of the forage. This was indicated in tables 11 and 13 showing the significant interaction between periods and sites within types for the calcium content of snowberry leaves, and between periods and vegetation types for mountain bromegrass leaves. In the first case there was a decided increase in calcium content as the season advanced but the amount of increase was dependent upon site. The interaction between periods and vegetation type for mountain bromegrass leaves was caused by the orderly increase in percentage calcium on aspen areas, whereas, on sagebrush areas there was little or no change.

Thus, it can be concluded that the content of phosphorus and calcium, and the seasonal variation of these minerals in the various species and parts of plants are influenced differently by vegetation type and site factors.

Total Ash: The total ash content was almost twice as high in leaves as stems (tables 7, 8, and 9). This difference was greatest for yarrow and least for snowberry. Yarrow contained the highest percentage ash and there was little difference between snowberry and mountain bromegrass.

There was a general decrease in ash content for all three species as the season advanced. The seasonal variability was significant for all species and for all plant parts with the exception of yarrow leaves which displayed no seasonal trend. The ash content in all parts of yarrow and in mountain bromegrass heads was significantly higher on aspen areas than on sagebrush areas (tables 5 and 6). The seasonal decrease in percent ash was decidely more pronounced on aspen areas than on sagebrush areas which accounts for the significant interaction between vegetation types and periods (tables 12 and 13).

Cellulose, Lignin, and Cellulose-Lignin Ratio: Cellulose and lignin content among the species was highly variable (tables 7, 8, and 9). Snowberry was highest in lignin and lowest in cellulose in both stems and leaves, whereas, mountain bromegrass was decidely high in cellulose and low in lignin in both stems and leaves.

Stems of all species contained more cellulose and lignin than leaves. However, the proportion of each of these constituents in leaves and stems varied among species (tables 7, 8, and 9). Leaves of snowberry and yarrow contained only about 50 percent as much cellulose as stems, whereas, mountain bromegrass leaves contained almost 70 percent as much as stems. A similar relationship existed in lignin content.

The cellulose to lignin ratio, likewise, varied rather decidely among the three species and among the various plant parts. Snowberry contained only about twice as much cellulose as lignin, whereas, yarrow contained about three times as much, and mountain bromegrass about five times as much (tables 7, 8, and 9). The leaves of snowberry had a higher cellulose to lignin ratio than stems, whereas, the stems of yarrow had a higher ratio than leaves. In mountain bromegrass there was little difference between stems and leaves in this respect.

There were significant seasonal increases in both lignin and cellulose content for all plant parts except for cellulose in stems of snowberry and lignin in mountain bromegrass heads and snowberry leaves (tables 11, 12, and 13).

The plants displayed no appreciable differences in percentages of either cellulose or lignin between aspen and sagebrush types except for mountain bromegrass which had higher lignin content on aspen areas and snowberry which had a higher lignin content on sagebrush areas (tables 4, 5, and 6). However, when various plant parts were analyzed separately, vegetation type had a profound influence upon both lignin and cellulose content. Cellulose content in the stems of snowberry and mountain bromegrass was significantly higher on aspen areas, whereas, sagebrush areas produced a significantly higher cellulose content only in the heads of yarrow. Cellulose in the stems of yarrow increased decidedly more rapidly on sagebrush areas as the season advanced than on aspen areas. This accounts for the significant interaction between periods and vegetation types in table 12. Vegetation type significantly influenced the lignin content in the stems and leaves of mountain bromegrass, and the leaves and heads of yarrow (tables 12 and 13). Aspen types favored higher lignin content than sagebrush types in each case.

The ratio of cellulose to lignin generally decreased with increased plant maturity. This indicates that lignin increased more rapidly than cellulose (tables 7, 8, and 9). However, the ratios for various periods of the season were variable and showed that lignin and cellulose did not increase consistently as the season advanced. This variability between periods was significant for all plant parts and all species (tables 11, 12, and 13).

Cellulose to lignin ratios were higher on aspen areas in both snowberry and yarrow and in both stems and leaves, whereas, the ratios in both stems and leaves of mountain bromegrass were higher in sagebrush areas. This indicates that vegetation type influenced the content of cellulose and lignin differently in various species. These differences among species may be partially explained by the stem-leaf ratios which were lower in aspen areas in the case of snowberry and higher in sagebrush areas in the case of mountain bromegrass. The differences in cellulose to lignin ratios, caused by the influence of vegetation type, were of significant magnitude only in the stems of snowberry, the leaves of yarrow, and the leaves and stems of mountain bromegrass as shown in tables 11, 12, and 13.

Sites influenced the cellulose to lignin ratio differently in the various species. Favorable sites generally produced higher cellulose to lignin ratios in snowberry and yarrow, whereas, unfavorable sites produced higher ratios in bromegrass (tables 4, 5, and 6).

Some investigators (21, 23) have suggested that lignin or the cellulose to lignin ratio might be used as an index to the nutrient content of forage plants. This, however, can be interpreted only in light of chemical changes that take place with advanced growth stage of individual species. As indicated in tables 7, 8, and 9, there were a number of chemical changes in plants that were related or correlated with increased age of plant tissue. These changes were relatively consistent and could be applied with a reasonable degree of accuracy as an index to the nutrient content and digestibility which are, likewise, associated with plant development.

For certain species it could be supposed that the stem-leaf ratio might even be a better index to nutritive value than any single chemical constituent, since this ratio is an important factor affecting all nutrients and displays a characteristic seasonal trend.

However, since vegetation type and site significantly affect the various chemical constituents of the plant differently it would seem that any single determination would be only an index to the content of that nutrient in the forage.

Crude Fiber and Nitrogen-Free-Extract: Crude-fiber content was lowest in snowberry and differences between yarrow and mountain bromegrass were only slight (tables 7, 8, and 9). There appears to be no relationship between crude fiber and lignin content among the three species since the lignin content of snowberry was decidedly high and bromegrass showed a low percentage. However, both lignin and crude fiber showed the same general trend toward increased amount as the season advanced. Increases in crude fiber were significant for all plant parts of yarrow and mountain bromegrass but not for snowberry (tables 11, 12, and 13). Vegetation types appeared to influence crude-fiber content only slightly since a significant difference in crude-fiber content was found only in the case of mountain bromegrass stems which were higher in fiber on aspen areas than on sagebrush areas (tables 6 and 13).

Nitrogen-free-extract content was highest in snowberry and lowest in yarrow with mountain bromegrass intermediate. This agrees with the other carbohydrate fraction found by difference in the modified method of proximate analysis except there was no appreciable difference between yarrow and mountain bromegrass. Leaves contained more nitrogen-free-extract than stems and this was most pronounced in snowberry and only moderately so in the other two species.

There was a significant seasonal decrease in nitrogen-free-extract in all plant parts except the stems and leaves of snowberry (tables 11, 12, and 13), and this decrease was more evident in aspen areas in all plant parts of mountain bromegrass, which accounted for the significant interaction between vegetation types and periods (table 13).

The nitrogen-free-extract fraction closely paralleled the other carbohydrate fraction in seasonal trends in the individual species and their respective plant parts. This was also true for differences between vegetation types and sites which would be expected since they were both calculated by difference and contain a large portion of the same constituents.

Stem to Leaf Ratio: It has been suggested by various investigators (5, 9, 30) that the relative amounts of stem and leaf produced by plants may account for some of the differences in chemical composition between species and, likewise, for some of the seasonal changes in chemical content of certain species.

The chemical composition of the two parts differed rather markedly in all plants. The leaves were higher in ether extract, protein, ash, calcium, phosphorus, and nitrogen-free-extract, whereas, the stems were higher only in lignin, crude fiber, and cellulose. Consequently, any change in the stem to leaf ratio affected the average composition of the entire plant.

The stem-leaf ratio was decidedly different for each species as shown in tables 7, 8, and 9. Snowberry possessed twice the amount of leaves as stems, whereas, mountain bromegrass had only about 25 percent as much leaf as stem and yarrow only about 60 percent as much.

The stem-leaf ratios on aspen areas indicated a more leafy browse, and a more stemmy forb and grass compared to sagebrush areas (tables 4, 5, and 6). Site appeared to affect individual species differently. Mountain bromegrass was more stemmy on unfavorable sites, whereas yarrow was more stemmy on favorable sites.

All species became more stemmy as the season advanced (tables 7, 8, and 9). The influence of changes in the stem-leaf ratios upon chemical content was dependent upon the relative difference in chemical composition of the respective plant parts. It was possible to determine the effect of stem-leaf ratio upon seasonal change in chemical composition by assuming no change in the chemical content of the stem or leaf from period one to period four and calculating the result at the end of the season from changes in the dry-weight production of relative amounts of the two parts. This was compared to the change in chemical composition for respective plant parts when assuming no change in stem-leaf ratio. The effect of stem-leaf ratio upon seasonal changes was variable for different species and for the individual constituents considered. Some interesting comparisons showing the percent influence brought about by seasonal changes in stem-leaf ratio alone are as follows: for snowberry, protein 25 percent, lignin 79 percent, cellulose 88 percent, and phosphorus 73 percent; for yarrow, protein 40 percent, lignin 12 percent, cellulose 53 percent, and phosphorus 17 percent; and for mountain bromegrass, protein 8 percent, lignin 6 percent, cellulose 53 percent, and phosphorus 17 percent. The percent influence caused by seasonal changes in the plant parts themselves is represented by the difference from 100 percent in each of the above cases. Thus, seasonal changes in chemical content are affected by both the changes in stem-leaf ratio and actual changes in composition within each part.

Since vegetation type and site influence the stem-leaf ratios, chemical content of the various plant parts and the response of these constituents to seasonal trends, it is quite evident that many interrelated factors are exerting an influence upon the nutrient content of range forage.

CONCLUSIONS

FROM these studies it was concluded that site conditions and stage of growth were important factors affecting the nutritive value of range forage. Sites indirectly affected the chemical content of plants and plant parts through soil and plant development, water runoff, intensity of shade, and other environmental factors. Individual chemical constituents of the plants were affected differently by various sites. In addition, the effects of site presented marked differences in the stem-leaf ratio in various species, thereby affecting the palatability of forage and nutrient content of the diet since leaves are more preferred than stems and are decidedly different in chemical composition.

These studies indicate that environmental factors and soil moisture are more important in determining the nutrient content of range forage plants under various site conditions than the chemical content of the soil as determined by standard methods.

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