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THESIS

NUTRITIVE VALUE OF COLORADO RANGE PLANTS

Submitted by

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In partial fulfillment of the requirements for

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY John Taylor ENTITLED "NUTRITIVE VALUE OF COLORADO RANGE PLANTS" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT OF THESIS

NUTRITIVE VALUE OF COLORADO RANGE PLANTS

This study was undertaken to investigate the nutritive value of some of the more important forage species grazed by livestock in various areas of Colorado. The samples were analyzed for energy, protein, cellulose, vitamin A, calcium, phosphorus and magnesium. The digestibility coefficients of the plants, protein, energy and cellulose were also determined by the *in vivo* nylon bag technique.

All species studied were deficient in at least one of the elements analyzed at some phenological stages. The nutrient deficient at more growth stages than any other element was phosphorus. The next most deficient, based on nutritive requirement for gestation and maintenance was digestible protein. To assure that animals are not subjected to nutrient deficiencies a variety of plant species should be available for grazing so that a deficiency in one can be offset by an excess in another.

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INTRODUCTION

Range forage, unlike most cultivated crop feeds is harvested by the grazing animal in an assortment of species and portions of plants determined by the selectivity of the animal. This selectivity may be influenced by kind of animal, intensity of grazing, plant species present, stage of growth, abundance of forage and general climatic conditions. As a result of this selectivity, the nutritive content of the grazing animals is difficult to evaluate. Evaluation of range forage is further complicated by many variables that affect chemical composition of forage plants. This may be affected by soil type, range site, stage of growth, climate and degree of weathering. In the same way diet may vary widely, thereby exerting a profound influence on the actual intake of nutrients by the grazing animal.

To evaluate the nutritive intake by grazing animals it is necessary to determine the digestibility of the ingested nutrients. This is necessary to calculate the quantities of the various plant constituents actually available for animal use.

Digestion coefficients are considered a direct means of determining availability of nutrients. They may vary greatly, however, according to age and species of animal, and the nutrient composition of the forage or forages being tested. Individual plant species differ in chemical composition and when eaten in various combinations their digestibility may be different than when eaten separately.

However, information on the availability of nutrients in a forage, even if an approximation, is a useful index to the nutritional quality of range herbage available to livestock in a given area. This should help a rancher and other range managers in planning the season of use of important forage species and the type of supplements which might be required at various times of the year. This data also can serve as a guide to determining the species of plant to use as supplemental or alternative forage.

SITE DESCRIPTIONS

The areas selected for the collection of the plants represent the important species on the principal grazing regions in Colorado.

Southeastern Colorado Branch Experiment Station

This Experiment Station is situated about 12.8 kilometers (km.) southwest of Springfield, Colorado, on two principal range sites, Bacca clay loam and Campo loam range sites (Underwood 1962).

1. The Bacca clay loam is a shallow moderately heavy soil with depths of free lime varying from 0-15 cm.
2. The Campo loam is a deep, moderately sandy soil with depths to free lime varying from 30-40 cm.

The topography is nearly level, usually less than 2%, and the elevation is near 1,524 m. The area is a semi-arid, temperate, continental type with irregular rainfall patterns between seasons and years. The average rainfall from the U.S. weather station which is located at the headquarters is 37 cm. During the current sampling year there was above average precipitation of 44.3 cm. About 80% of the annual precipitation normally comes during the growing season. Winter snows are infrequent and are of little importance in contributing to soil moisture.

Strong gusty winds are common throughout the year, but are more frequent in spring and autumn. The average annual temperature since 1957 is 11.6°C with an annual maximum near 38°C and the minimum -22°C. The period between frosts is approximately from the middle of April to the last of September.

The three types of pastures based on previous use in this area of the Great Plains are: seeded, native, and old field (Beck 1969). The two grasses that occur most frequently in the seeded pastures are sideoats grama (Bouteloua curtipendula) (65%) and blue grama (Bouteloua gracilis) (13%). On the native portion of the pastures blue grama (38%) and buffalograss (Buchloe dactyloides) (41%) occur most frequently. The common grasses on the old field pastures are buffalograss (27%), sand dropseed (Sporobolus cryptandrus) (38%), and threeawn (Aristida spp.) (12%). Lambsquarters (Chenopodium album), kochia (Kochia scoparia) and fetid marigold (Dyssodia papposa) are the more common forbs found throughout each of the three vegetative types.

Knowledge of the nutritional value of sideoats grama, blue grama, buffalograss, sand dropseed, threeawn, lambsquarters and kochia would provide information on more than 80 percent of the species on these range sites.

San Juan Basin Experiment Station

This station is located 10 km. south of Hesperus in southwestern Colorado at an elevation of 2,319 m. The soils are mainly silt loams on the surface with clay loam subsoils. At varying depths, terrace cobble underlies the station.

The average annual precipitation is 47.7 cm. over the period that records have been kept. Precipitation is usually irregularly distributed throughout the year for this area. Normally, two-thirds of the annual precipitation falls during the winter and one-third during late summer. This is typical of southwestern Colorado and may result in spring drought.

The temperatures in 1971 ranged from a high of 33°C in June to a low of -23°C. There was a three-month growing season from mid-June to mid-September. The rainfall during the year was 46 cm.

The station includes 2556 hectares, with 2339 hectares in native oakbrush (Querecus gambelii) rangeland, 149 hectares of irrigated farmland and 18 hectares of dry seeded pasture. The most important native species of grasses on the station are western wheatgrass (Agropyron smithii), needle-and-thread (Stipa comata), Kentucky bluegrass (Poa pratensis), mountain muhly (Muhlenbergia montana), Arizona fescue (Festuca arizonica), mutton grass (Poa fenderiana), Junegrass (Koeleria cristata) and squirreltail (Sitanion hystrix).

Needle-and-thread grass, Kentucky bluegrass, squirreltail, mutton grass, western wheatgrass and June grass were collected from the brushy-loam (monticello) range site which has 3 to 12% slopes and elevation of about 2325 meters. This range site has reddish colored soil with a loamy surface and a loam to silty clay loam subsoil. The present plant community consists of oakbrush, rabbit-brush, sagebrush and the above-mentioned grasses.

Arizona fescue and mountain muhly were collected in a ponderosa pine grazable woodland site at 2400 meters elevation on 3 to 12% slopes. The surface soil is a moderately deep brownish colored loam overlying rocks and cobbles. The subsoil is a reddish colored clay or clay loam. Vegetation consists of ponderosa pine, oakbrush, native grasses and forbs.

Manitou Experimental Forest

The Manitou Experimental Forest is situated on the Pike National Forest, 45 km. northwest of Colorado Springs at an elevation of 2359 m. The dry sub-humid climate is characteristic of most eastern slope areas in Colorado (Thornthwaite 1941). Influences of the distinctly continental climate are apparent with winters often being dry and cold for long periods while the summers are wet and cool.

Annual precipitation for the area is 39.1 cm. with a range from 19.3 cm. in 1939 to 59.5 cm. in 1947. During 1971 the rainfall was 38 cm.

Yearly temperatures at Manitou Experimental Forest average 4.5°C. The mean monthly temperatures have varied from -5°C in January to 15.5°C in July. Assuming the mean daily temperatures of 4.4°C or higher are required for growth of aerial portions of most range grasses (Chapline and Cooperrider 1941; J. Clarke et al. 1947), the effective growing season averages about 180 days from early April until late October.

The soils within the area were developed primarily from alluvial deposits of Pikes Peak granite. Principle components are quartz, orthoclase and microcline. Biotite is an accessory mineral (Retzer 1949).

Surface soils are normally 12 to 18 cm. deep. They are reddish-brown, low in organic matter, slightly acid, loose, and vary from sandy loam to loam. Despite gentle topography, surface soils erode readily when disturbed or not protected by adequate ground cover. The better developed soils have 6 to 12 cm. thick subsoil with a moderately developed structure and a sandy clay texture.

Subsoils are commonly sandy loams that grade into unconsolidated gravelly parent material at depths of 30 to 40 cm.

There are four main range types within the experimental ranges:

1. Dense timber - this is mostly ponderosa pine with a closed canopy and little besides litter in the understory.
2. Open timber - an open forest of pine with a ground cover of herbaceous vegetation and pine litter.
3. Grassland - parks on openings in the forest that are dominated by native bunchgrass, have never been cultivated, and have a minimum diameter of more than 1 chain.
4. Abandoned fields - areas once cultivated, then abandoned, and now slowly returning to native cover.

The main species of plants grazed by animals here are mountain muhly, Arizona fescue, blue grama, Nebraska sedge (Carex nebraskensis), western wheatgrass and fringed sagebrush (Artemisia frigida). The samples which were collected for analysis were gathered from a sandy clay loam range site.

Black Hawk

Thurbers fescue (Festuca thurberi) was collected at the Dory Hill Cemetery which is located 10 kilometers north of Black Hawk at an elevation of 2900 meters. The average annual precipitation for this area is between 38 to 50 cm. with over half the moisture coming as snow. Unfortunately, there is no climatic data for this area due to the remoteness from any weather station.

The soils are fairly deep, have good moisture capacity and are principally medium textured. Soils are mostly chestnuts and chestnut brown intergrades, but browns occur at low effective moisture areas and mountain prairie soils occur where effective moisture is greatest. The sample of Thurbers fescue was collected on a mountain loam range site.

Craig

This site is located 10 km. west of Maybelle. The average annual precipitation amounts to approximately 23-24 cm., most of which falls during the period November through May. There was 28.3 cm. of rain in 1971. Occasional summer thunderstorms occur and may be very intense, causing rapid runoff. This increases soil erosion due to the very sandy soils, which are highly susceptible to water forces. Temperature extremes have been recorded at the Sunbeam and Maybelle weather stations of a high 39°C in the summer and low -45°C in the winter. The mean annual temperature is approximately 6°C.

The vegetative type at the site is antelope bitterbrush (Purshia tridentata) grass type; the soil is very sandy and the topography is gentle rolling and the elevation is approximately 1900 meters above sea level. The samples were collected on a sandy slope range site.

Nunn

Central Plains Experimental Range is about 19 km. northeast of Nunn, Colorado and 40 km. south of Cheyenne, Wyoming.

The average precipitation varies from 25 to 28 cm. About 80% of the precipitation falls during the summer months of May through September. Most of the storms are in the form of light summer thunderstorms, which on some occasions can be greater than 2.5 cm.

During the twelve month collection period there was 25 cm. of rainfall.

There are four different soil types in this gently rolling area. The Renohill and Shinbe series are formed on shale and siltstone outcrops of the Piecne sedimentary formation, while the Ascalon series is formed predominantly by fluvial outwash materials. The coarser outwash materials are from the Vona soil series. Interspersed among the upland soils are alluvial plains of more recent origin which are high in clay content.

The monthly average temperature for the area since 1947 (Jameson 1969) shows that there is a range from -4°C in January to about 30°C in July. This shortgrass range is basically blue grama and buffalograss supplemented in some areas by thread leaf (Carex filifolia) and needle leaf (Carex eleocharis) sedges (Klipple and Costello 1960). Some areas also support western wheatgrass, needle-and-thread, and little bluestem (Andropogon scoparius) in conjunction with the shortgrass. The shrubs include fourwing saltbush (Atriplex canescens), winterfat (Eurotia lanata), and forbs include scarlet globemallow (Sphaeralcea coccinea), slim flower scurffea (Psoralea tenuiflora) and scarlet gaura (Gaura coccinea).

The species studied here were blue grama, fourwing saltbrush, scarlet globemallow, and western wheatgrass. The samples were collected from a sandy loam range site.

LITERATURE REVIEW

There have been a number of studies devoted to determining the digestibility of the nutrients in range forages. The first work of this nature was done in Nevada (Kennedy and Dinsmore 1909). These authors found that sheep, when fed forage, collected from the range did not show normal selectivity for the plants or portions of the plants and frequently did not eat adequate amounts for a maintenance ration.

McCall (1940) and McCall et al. (1943) found that animals ate some forage plants more readily than others and that species differed materially in digestibility of the various constituents.

Nutritional Requirements of Range Livestock

Range livestock need protein for growth and repairing worn out tissue; fats and carbohydrates for production of heat and energy; vitamins for important physiological processes; and minerals for general body functions and for bone building.

Cook and Harris (1968) found that the most important deficiencies on the range in the western United States are protein, energy, phosphorus and carotene (vitamin A). Such deficiencies are more apt to occur when forage is mature, during periods of drought, or when overgrazing occurs. These deficiencies may appear singly or in any combination.

It is not feasible to make recommendations on supplementing animals until the specific nutrient requirements of the animal (Table 1) as well as the nutrient content of the range forage is known.

Table 1. Recommended nutrient requirements for cattle and sheep under range conditions during gestation and lactation, on a dry matter basis[2].

	Percentage of ration or amount/Kilogram of feed					
Phase of Production	DP[3,1] (%)	DE[4,1] Kcal/kg.	Calcium[6] (%)	Phosphorus[1] (%)	Carotene[1,5] (I.U./kg)	Magnesium[6] (%)
Gestation	4.4	1826	.24	0.17	528	.06
Lactation						
First 8 weeks	5.4	2464	.32	0.22	1408	.08
Last 12 weeks	4.5	1936	.30	0.20	1408	.08

1. Cook and Harris 1968
2. Nutrient requirements are slightly higher for sheep because smaller animals have a somewhat higher metabolic requirement per unit of body weight.
3. DP represents digestible protein
4. DE represents digestible energy
5. I.U. represents international units
6. Cook 1972

The feed intake by animals on the range cannot be regulated as well as farm animals. The quantity of feed consumed by the grazing animal is influenced by the physiological state of the animal, the plant species present, stage of plant growth, abundance of forage, and general climatic conditions. Therefore, the intake and composition of the diet varies from day to day and from one range to another (Cook and Harris 1968).

The Importance of Specific Nutrients to Animals

Protein - About 80 percent of the total nitrogen of forages is in the proteins, most of which are in the cytoplasm but some are in the cell walls. The number of different proteins is great, perhaps as many as 10,000 in a plant cell (Bonner 1965; Vennesland 1960).

All leaf proteins contain the so-called essential amino acids and apparently in amounts sufficient for ruminant animals. Specific amino acid deficiencies have never been demonstrated in ruminants (Woodham 1962), partly because of the difficulty of compounding rations for such large animals and also because of the probability of synthesis of all necessary amino acids by microorganisms both in the rumen and in the alimentary tract.

The ability to maintain ruminants for even a short time on urea as a sole source of nitrogen is evidence that the synthesis of the necessary amino acids takes place in the rumen (Virtanen 1966). All naturally occurring amino acids, whether they occur free or in proteins, are metabolized in the rumen, by one or another of the microorganisms. They are broken down to ammonia and short-chain organic acids, which may be absorbed through the rumen wall into the bloodstream, or they are carried from the rumen into the alimentary tract, or are synthesized into bacterial bodies, which are in turn digested (McLaren 1964). As further evidence that particular amino acids are not essential, it has been shown that the amino acid contents of proteins isolated from rumen bacteria are markedly similar for all host animals on all rations; the same is true for the proteins of rumen protozoa (Meyer et al. 1967; Purser and Buechler 1966; Bergen et al. 1968).

There are other minor nitrogenous constituents of forages such as ammonia which occurs as a salt at the carboxyl end of a protein or amino acid. Amide nitrogen is a constituent of the dicarboxylic amino acids; both of these contribute to the nitrogen metabolism in the rumen. Other nitrogenous compounds, quantitatively negligible, are the nucleic acids, glycosides, pigments, nitrates and alkaloids.

The crude protein therefore includes protein and non-protein nitrogen. The non-protein nitrogen, expressed in percentage of total nitrogen, shows a considerable range from forage to forage, from 12 up to over 40 percent. High proportions of non-protein nitrogen are usually found in plants containing high levels of total nitrogen and in young, rapidly growing plants. Digestive disturbances have been associated with high levels of non-protein nitrogen (Greenhill 1936).

Digestible crude protein is a more exact measure of protein value to the animal than crude protein. The digestion coefficients of protein are "apparent" because of the presence in the feces of other than undigested protein and the presence in the urine of nitrogen derived from the diet and from body metabolism (Maynard and Loosli 1962; Annison and Lewis 1959). The apparent digestibility of crude protein shows a wide range; a typical study showed a range of 35 to 80 in the apparent digestion coefficients of crude protein of grasses and of 52 to 80 in alfalfa (Sullivan 1964). The lower values were obtained from forages with low crude protein contents and the higher from forages with high crude protein contents. Therefore, a relation exists between the percentage of crude protein and the digestion coefficient of crude protein, the correlation having a high significance (French et al. 1967).

Vitamin A - Known as retinal, is one of the fat-soluble growth factors. It is not present as such in forages but is produced in the liver of animals from certain carotenoids that are present in the chloroplasts of the forage plants. Of the carotenoids that have value as provitamins, the most important is B-carotene, a hydrocarbon with the general formulae $C_{40}H_{56}$; one molecule of it may theoretically by cleavage, give rise to two molecules of retinal, whereas some isomers of B-carotene give rise to only one or to none. For practical purposes, B-carotene and vitamin A are, therefore, interchangeable.

Retinal may be determined biologically, and either B-carotene or the crude carotene by chemical analysis. By definition, 0.6 micrograms of B-carotene is equivalent to one international unit (IU) of vitamin. Crude carotene has less, but more variable, activity than B-carotene. For example, only 72.7 percent of the crude carotene of grass was B-carotene, but the vitamin equivalent was 77.1 because some of the other carotenoids i.e., alpha carotene, had partial activity (Kemmer et al. 1944).

Carotene is relatively high in young grass plants and decreases as the plants age and become stemmier, a typical decrease being from about 400 ppm to about 100 ppm (Moon 1939). This decrease is due in part to the fact that carotene, which is a yellow pigment, is unstable in light and is readily oxidized by enzymes and is relatively stable in the presence of antioxidants.

Vitamin A is required by all classes of livestock; one of its many functions is to keep the epithelium of surface tissues of the mucous membrane healthy and another is to prevent degeneration of the nervous system. One method of measuring vitamin A requirements is by determining the minimum carotene dosage necessary to cause the disappearance of night blindness in animals from which vitamin A store is depleted. In cattle, this amount furnished by alfalfa hay is sufficient to contain between 26 and 33 micrograms of crude carotene daily per kilo of animal weight (Guilbert and Hart 1935). More recently published, but not significantly different, requirements are described in the bulletins of the National Research Council (1963, 1968). Assuming a 450 kilo animal (1,000 pounds), the requirements of 29 micrograms per kilo, would be 13.05 mg of carotene. Ten times this daily requirement would be supplied by less than 2 pounds of forage containing only 200 ppm of B-carotene.

Cellulose - Like starch, is a polymer of glucose (B-1, 4 linkage). The difference between cellulose and starch is fundamentally of the spatial direction of the linkage between glucose units (Whistler and Smart 1953). This difference is sufficient to allow cellulose to have great molecular size, as thousands of units, and to arrange itself in long fibers that permit impregnation by other substances, the hemicelluloses and lignin. Cellulose occurs in both primary and secondary walls though these differ in degrees of polymerization and crystallinity of the cellulose and in fiber arrangement. The microfibrillar units of cellulose are nonhomogenous and allow the interpretation of the two major encrusting substances, hemicellulose and lignin (Youatt 1958).

Cellulose itself amounts to 20-40 percent of the dry weight of forages (Hansen et al. 1958). Like total cell wall matter, it is higher in grasses than in legumes and higher in more mature plants than in younger ones. It is readily degraded by microorganisms under certain conditions, but it is digested with difficulty in the raw state because of the presence of lignin.

O Energy - Is derived from all organic substances that an animal ingests with the majority coming from carbohydrates. The rumen microorganisms ferment the carbohydrate changing it into microbial cells and waste products such as volatile fatty acids, heat and methane which can be used or excreted. The ruminant absorbs volatile fatty acids directly from the rumen to provide about 70 percent of the energy requirements of the animal.

Major organic elements are required by animals for the construction of ~~body~~ tissue and as sources of energy for work done by the animal. The ability of a forage to supply energy is thus of importance in determining its nutrient value (McDonald et al. 1966).

O The gross energy in a forage is measured by converting it into heat energy and determining the amount of heat produced. Gross energy values are inaccurate estimates of the energy available to grazing animals as different foods are digested to different degrees

(McDonald et al. 1966). Cook and Harris (1968) suggest that metabolizable energy may be a more meaningful index to the energy value of some plants. This is due to high concentrations of volatile oils in some shrubs. These oils are not usable to the animal and are excreted in the urine.

Mineral Elements

Ash - The minerals of a forage are found with a few exceptions in the ash obtained by combustion of the forage; the incineration causes losses in whole or in part of many constituents, such as those of chlorine, iodine and organic sulfur. Most forages yield 5-10 percent of crude ash, but its composition is more important than its amount as some of the minerals of the ash are of minor or no importance to animals. The crude ash may be separated into acid-soluble and acid-insoluble fractions; the latter is composed in large part of silica. Some silica may be present in a forage as a result of contamination by soil or dust, the quality of crude ash may be misleading as a criterion of mineral content. The soluble fraction contains most of the nutritionally important elements and its quantity is correlated significantly with the content of some of the major essential minerals, as has been shown for calcium and for phosphorus by Sullivan and Garber (1947).

The composition of the ash rests on a number of factors, the most important of which are the kind of forage and the fertility of the soil (Beeson 1941). In grasses the individual elements tend, with some exceptions, to diminish in concentration as the plants approach maturity (Van Riper and Smith 1959; Pritchard et al. 1964).

Leaves tend to be higher than stems in all minerals. The levels of minerals in forage also rest on the content and availability of minerals in the soil (Anon. 1965; Snider 1946). In forage regrowth fluctuations in ash content are irregular and are influenced, in addition to soil fertility and soil amendments, by season and climate, the effects of which are difficult to separate. The requirements of animals of certain minerals vary with the kind of animal and with its condition. Whether a forage furnishes the required amounts of a nutrient depends not only on the content of that nutrient but also on its availability, a condition likely to be affected by numerous interactions.

Calcium - Most of the calcium is in the form of salts, both organic and inorganic and about 40 percent of the total is water soluble. Most of the water soluble is in the leaves rather than in the stems. Little is known of the quantitative distribution within tissues but a considerable amount of calcium is associated with the cell. There are no stable complexes of calcium, though the salts of the pectins may be considered fairly stable. Calcium neutralizes organic acids; in legumes that have a higher nitrogen metabolism than grasses, more calcium is needed to neutralize the acids formed. Most of the calcium absorbed by the plant is soon immobilized.

Calcium is required for maintenance, growth and productivity of animals. A large part of the calcium of the diet and of phosphorus as well, that is retained by the animal is deposited in the bones; this mineral is therefore most important to growing animals. A factor in the computation of requirements is the availability of the element, that is the percentage of the element present in the diet that is in a form that can be used. The availability of calcium has been assumed to be about 70%.

Mitchell and McClure (1937) summarized the requirements as the percentage of calcium in the feed and noted a decreasing requirement for calcium in relation to the total feed as the animal grows. For 150 and 400 kilogram animals the requirements for calcium are 0.43 and 0.11 percent, respectively, for growing beef steers and 0.33 and 0.08 percent for growing dairy cows. During pregnancy the calcium requirement increases; that of a 400 kilogram cow is 0.10 percent of the feed in the fourth month of gestation 0.19 percent in the eighth month, and 0.42 percent in the ninth month. Sheep require between 0.11 and 0.17 percent in the feed and horses 0.20 percent; the requirements are increased by pregnancy and lactation. The requirements published by later investigators, as those of Mitchell (1947), Guilbert and Loosli (1951), Crampton (1952) and the National Research Council (1963, 1968) do not differ materially from those of Mitchell and McClure but those of J.A.B. Smith et al. (1965) rested on availabilities that are lower than 70 percent.

Large amounts of calcium, contributing to a high calcium-phosphorus ratio, are detrimental to some animals. With grazing animals ratios as high as 6.5 have not proved detrimental. If disturbances occur with animals fed forages having a high ratio, they may be attributed to phosphorus deficiency or to an insufficiency of vitamin D.

Phosphorus - Occurs as a phosphate linked to organic and inorganic ions. It is a constituent of complexes of nucleic acids, nucleotides, phospholipids, proteins, phytin, and inorganic salts. It participates in nearly all chemical reactions in the plant cell as synthesis, hydrolysis, rearrangement, and change of state; and during these reactions it is combined temporarily, at least, with carbohydrate, lipids, and nitrogenous compounds (Albaum 1952). One of the forms, phytin, occurs in most seeds and has been reported, but not clearly established, to be present in foliage (Marrese 1958).

Phosphorus is higher in young, rapidly growing tissue than in older tissue (except for some seeds); it is therefore more abundant in leaves than in stems; and in rapidly growing aftermath that is grazed or mowed frequently. There are lower percentages in the foliage of mature plants (Van Riper and Smith 1959), partly because some phosphorus has been translocated to the developing seeds. There is little and inconsistent seasonal variation because, as stated above, the amount of available phosphorus in the soil is the most important factor affecting the quantity in the plant, particularly in the grasses (Ward 1959; Reith et al. 1964).

All forms of phosphorus appear to be available to the ruminant, except perhaps for a minor quantity contained in some nonsaponifiable lipids which seem to have low digestibility. Its availability is discussed by Smith et al. (1965). About 90 percent of the phosphorus of the diet is available to cattle weighing 110 pounds (50 kilos) and this availability decreases with increasing animal size to reach about 55 percent in an animal weighing 1,100 pounds (500 kilos). Like calcium, phosphorus is a constituent of bones, and rapidly growing animals require proportionally larger amounts. Assuming a 70 percent availability, the phosphorus requirement given by Mitchell and McClure (1937), as percentage of the feed are as follows: 130 kilogram and 530 kilogram pound growing beef steers, 0.35 and 0.17 percent; and for pregnant cows the requirement increases from 0.17 percent in the fourth month of gestation to 0.31 in the ninth month. Sheep require between 0.11 and 0.15 percent of phosphorus in the feed and horses 0.20 percent.

These requirements are not met on a diet of herbage alone in many areas throughout the world. In such areas phosphorus deficiency diseases are found and more frequently in cattle than in sheep, partly because the requirements of cattle are greater and partly because cattle are less able than sheep to select those younger parts of plants which are relatively richer in phosphorus. The symptoms of phosphorus deficiency are complicated by calcium deficiency when the two deficiencies occur together. The diseases of cattle caused by a deficiency of phosphorus or calcium, or both, are forms of osteomalacia, called by various local names because of the different manifestations. In the United States such local names are "creeps", "stiffs", "sweeny", and "loin disease". One symptom is pica or depressed appetite, an appetite for things not ordinarily classed as food. From eating decayed bones of carcasses, botulism may result. Discussions of this subject have been offered by Beeson (1941) and Hemingway (1967).

Calcium-Phosphorus Ratio - It has been shown that large amounts of calcium, contributing to a high calcium-phosphorus ratio, are detrimental to some animals. With some animals such as rats a ratio between 1.0 and 2.0 in the feed has been shown to be optimum; ratios which are higher will create disturbances. With grazing animals ratios as high as 6.5 have not proved to be detrimental. If disturbances do occur with animals on a high ratio feed, it may be attributed to phosphorus deficiency or to an insufficiency of vitamin D (Smith et al. 1965).

Magnesium - Is required for bone structure but is required in much smaller amounts than are calcium and phosphorus. Muscle and nerve tissue also must have appreciable amounts of magnesium. In general, animal requirements appear to be small but are actually larger than the magnesium content of animal tissues indicates. Magnesium has a low availability, which varies with the type of food and with the animal. Smith et al. (1965) quote data of 18 percent availability of magnesium in freshly cut herbage fed to cows and 27 percent in silage fed to steers. The same authors give requirements, obtained by balance trials, of 0.40 grams of magnesium per day for growing cattle weighing 50 kilos and of 6.65 grams for cattle weighing 400 kilos. The requirements are greater for cattle making rapid weight gains. As with other elements, pregnancy and lactation increase the requirements. These requirements are met by most forages but never-the less, such low levels are not adequate for animal health.

The levels of magnesium in the forage and in the blood of animals have been of great interest in connection with a disease known as grass or lactation tetany. This ailment is more intense in dairy cows than in other livestock, but it does occur occasionally in sheep. It is more common in certain areas and at certain times of the year. Some of the symptoms are a low magnesium content of the blood, loss of appetite, and respiratory and nervous disorders (Rook and Rowland 1962; Wilson 1962). This disease occurs often but not always with a low magnesium diet; it is not definitely established that it is caused by a simple magnesium deficiency but the opinion is that low magnesium is a contributing factor. A low blood magnesium always accompanies the disease which may be relieved by injection of magnesium and calcium salts; but it is not always relieved by feeding forage of higher magnesium content. It often develops when cattle are first turned on to pasture in the spring; at this time the magnesium content of the forage may be low but is rising. It is observed at other times of the year, particularly after heavy rainfall, after fertilization, or during winter feeding of forage of low magnesium content. It has been observed that the application of nitrogen and potassium fertilizers, which reduce the magnesium content of the forage, is associated in point of time with the occurrence of tetany, but it is difficult to produce tetany at will by this means. The quantitative relationship of cations and anions may be involved (Rahman et al. 1960); a high K/(Ca+Mg) ratio in the plants has been suspected; over 2.26 is dangerous (de Roo 1963). A suspected role of phytin in causing magnesium deficiency in ruminants has not been established (Dutton and Fontenot 1967). A hormonal deficiency in the animal may be involved (Maynard and Loosli 1962). A high histamine content of herbage has been proposed as the cause of the trouble, which is aggravated by low magnesium and high potassium (O'Sullivan 1968). An organic acid, transaconitic, is suspected of reducing the availability of both calcium and magnesium (Stout et al. 1967). The exact relationship of the composition of the forage to this ailment has not been determined.

Nutrition and Digestion as Affected by the Plant

The nutritive value of plants can be altered by many factors. Some are: temperature, season, soil, weather, species, insects, disease and amount that they are used in the past. It has been shown by Cook and Harris (1950) that site conditions and the stage of growth are among the important factors affecting the nutritive value of range forage.

Site can seem to make a difference in the stem-leaf ratios, thereby affecting the palatability and nutrient content of the diet since leaves are more preferred and differ from stems in chemical composition.

Numerous workers have investigated the effects of season and stage of growth on the nutritive value of plants. From these one concludes that the nutritive value of forage depends primarily on the stage of maturity of the plants (Minson et al. 1960). Stoddard and Greaves (1942) indicated ash and protein content decreased as the summer season progressed while Blaser (1961) indicated a reduction in nutritive value with advanced growth because of decreased consumption and decreased digestible energy due to increased structural carbohydrates and lignification, reduced soluble carbohydrates in foods, and reduction in digestible protein when it is used for energy. Cook et al. (1959) analyzed salt-desert grasses and shrubs throughout the growing season. They found grasses decreased in ether extract, protein and other carbohydrates while increasing in lignin and cellulose as the growing season advanced. They also found lignin and ash to be in higher concentrations as the basal portion of stems compared to stem tips. Further work by Minson et al. (1960) indicated that for some species of grasses the rate of decrease in digestibility was small prior to flower emergence but was considerable after this stage of maturing with nitrogen and structural carbohydrates showing the most fluctuation.

Nutrition and Digestion as Affected by the Animal

The main ways in which an animal may affect nutrient utilization are by growth, reproduction and lactation which can also interact with environmental factors. It has also been shown that age, breed, previous nutrition have varied the intake of sheep (Langlands 1968). Raymond et al. (1954) reported that in sheep there was a trend of increasing digestibility with increasing age, which is probably due to increased rumen size and numbers of bacteria and protozoa there. Blaxter et al. (1962) found that this age affect was not applicable to cattle.

Cook et al. (1961) showed that lactating ewes consumed 26 percent more forage than those on maintenance. However, pregnancy or lactation does not effect the digestibility of food stuff (Cook et al. 1961).

Determining Digestibility Using the IN VIVO Nylon Bag Technique

The technique of using the nylon bag is a very simple and rapid method of testing the digestibility of large numbers of forage samples. The samples after being weighed into a nylon bag are placed in a ruminal fistulated steer and allowed to digest for a specific time. The bags are then removed, washed, dried and digestion is calculated by the loss of components during the period of time in the rumen, (Van Dyne 1962; Sims 1967).

The technique was further standardized by Quinton and Sims (1970) when they compared nylon bag to a conventional trial and concluded that there was no significant difference between these two techniques.

if very defined procedures are followed. They utilized a 5 x 10 cm. nylon bag constructed of parachute material.

METHODS AND MATERIALS

Collection of Plants

Plants were collected at 2-week intervals during the period of rapid growth in the early spring, then as the growth rate slowed down, collections were made every 3-4 weeks until the end of the summer. Another collection was made during the period of dormancy around mid-winter. These collections were based on the phenological stage of growth of the plant.

Portion of Plant Collected

The portion of the plant collected simulated that which was utilized by a grazing animal under a moderate grazing system. This was accomplished by observing grazed plants, or grazed portions of plants, and then selecting ungrazed material comparable to that already removed by grazing.

Drying, Grinding and Storage

About 50 gms. (dry weight) were collected and placed in bags. The plants were then dried at 50-60°C for 24 hours. They were then ground in a Wiley Mill through a 1 mm screen and then stored for subsequent analysis. The only exception to this were the samples which were used for vitamin A analysis. These samples were collected and frozen immediately.

Digestion Studies

Once the samples were collected, digestibility studies were run on them, utilizing nylon bags placed in a fistulated steer. The samples were placed in the steer in duplicate, along with 4 standards which were used to make corrections for variation between steers and between trials. The samples were left in the rumen for 48 hours, taken out, washed, dried and then analyzed.

Chemical Determinations

Organic matter, nitrogen, cellulose, gross energy, calcium, phosphorus, magnesium and vitamin A were determined on samples before they were digested in the steer. After *in vivo* nylon bag digestion organic matter, cellulose, gross energy and the nitrogen content of the samples were determined.

Nitrogen was determined by the boric acid method (A.O.A.C. 1965). The apparatus used was a modification of the microkjeldahl reported by Brenner (1965). The Fisher automatic titrator model DG was used. Crude protein content was calculated by multiplying the percent nitrogen by a factor of 6.25. A Parr adiabatic oxygen calorimeter was used for determining gross energy.

Cellulose was determined by the procedure outlined by Kurschner and Hanak (1930), with a slight modification as introduced by Phillips and Smith (1943), to alleviate the use of a centrifuge.

Ash was determined by a procedure outlined in A.O.A.C. (1965) and the loss in dry matter was regarded as organic matter. A Perkin-Elmer automic absorption spectrometer model 290 B was used to determine calcium and magnesium. Samples were prepared using a HNO_3-HCl digest as outlined in A.O.A.C. (1965). Phosphorus was calculated utilizing a spectronic 20 and a procedure outlined by Barton (1948). The method used to determine carotene was that outlined in A.O.A.C. (1965). These samples were analyzed by Industrial Laboratories in Denver, Colorado.

Computer Program

A computer program to bring all the different digestion trials in the fistulated steer to a common trial, was devised by Bonham (1971). Two observations were utilized to generate sixteen random numbers. These sixteen generated numbers were actually simulated observations and were used to complete a correction coefficient, which in turn gave two corrected observations which were averaged and utilized as the digestion coefficient for that steer.

Blosser and Taylor (1971) developed a computer program which calculated all the digestion coefficients of each sample and then using Bonham (1971) program as a subroutine, brought everything to one common trial. The program then listed out all the information which was available on each sample.

RESULTS AND DISCUSSION

To predict nutrient deficiencies and make practical recommendations for supplementing the basal ration received from range forage, it is important to establish a recommended level for critical nutrients for optimum production and greatest economic returns. Then the nutritive content of the forage which is growing on the range should be determined to see if it meets these requirements.

The forages which were collected and evaluated are discussed in regard to their importance to the area of the state in which they were collected (Table 2).

Southeastern Colorado Branch Experiment Station

BLUE GRAMA: Blue grama is a perennial, warm-season, shortgrass which is usually a bunchgrass under moderate grazing intensities although under heavier grazing it forms a sod. Blue grama is distributed widely on sandy to heavy textured soils of the plains, sandhills and mesas (Herzman et al. 1967). At Springfield blue grama was sampled from clay loam range sites.

Blue grama, although usually low in productivity, is still the primary forage producing species on this site and forms a major portion of the diet of livestock in summer and winter. Blue grama may decrease under heavy grazing pressure, often giving way to buffalograss. The chemical composition and digestibility of blue grama is shown in Appendix A - Table 1. The digestible energy, magnesium and calcium are sufficient to meet the requirements of livestock. However, halfway through the plant's growth and again when it matures digestible protein becomes deficient. Phosphorus is deficient in early and late growth.

Table 2. The species of forage and the area of the state from which they were collected.

AREA	COMMON NAME	SCIENTIFIC NAME
Southeastern Colorado Branch Experiment Station	Blue grama	Bouteloua gracilis
	Sideoats grama	Bouteloua curtipendula
	Sand dropseed	Sporobolus cryptandrus
	Buffalo grass	Buchloe dactyloides
	Kochia	Kochia scoparia
	Lambsquarters	Chenopodium album
	Yucca	Yucca glauca
San Juan Basin Experiment Station	Western wheatgrass	Agropyron smithii
	Arizona fescue	Festuca arizonica
	Mountain muhly	Muhlenbergia montana
	Kentucky bluegrass	Poa pratensis
	Needle-and-thread grass	Stipa comata
	Mutton grass	Poa fenderiana
	Junegrass	Koeleria cristata
	Squirreltail grass	Sitanion hystrix
Manitou Experimental Forest	Arizona fescue	Festuca arizonica
	Fringed sagebrush	Artemisia frigida
	Blue grama	Bouteloua gracilis
	Mountain muhly	Muhlenbergia montana
	Nebraska sedge	Carex nebraskeni
	Western wheatgrass	Agropyron smithii
Black Hawk	Thurbers fescue	Festuca thurberi
Craig	Fringed sagebrush	Artemisia frigida
	Rabbitbrush	Chrysothamus viscidiflorus
	Antelope bitter-brush	Purshia tridentata
Nunn	Western wheatgrass	Agropyron smithii
	Fourwing saltbrush	Atriplex canescens
	Blue grama	Bouteloua gracilis
	Scarlet globe-mallow	Sphaeralcea coccinea

SIDEOATS GRAMA: Sideoats grama, an erect bunchgrass, is usually an important source of forage in the Southern Great Plains. This warm season perennial is preferred by all classes of livestock, however with prolonged heavy grazing it may be replaced by blue grama. Sideoats grama usually grows on less developed soils as well as in desert and semi-desert shrub communities (Herzman et al. 1967). At Springfield, sideoats grama is found on a clay loam range site (Fig. 1).

The nutritive value of sideoats grama is shown in Appendix A - Table 2. The vitamin A content of dormant sideoats grama was 62,700 international units, which is much higher than required. The digestible energy meets the requirements of a cow in gestation. The magnesium and calcium content are adequate for an animal in gestation, while phosphorus becomes deficient as the plant matures. The digestible protein is deficient all year round.

SAND DROPSEED: Sand dropseed is a tufted perennial which grows on sandy or gravelly soils. Sand dropseed is a prolific seed producer and has a high drought tolerance. The uppermost leaf sheath, partially encloses the seedhead and as it weathers away, seed is disseminated all year. Under some situations when there are fall rains there is some regrowth. This new growth causes the base of the stems to remain green most of the winter. The green material makes the plant fairly palatable, and under these conditions sand dropseed is readily eaten during the winter. When fall regrowth does not occur, the forage is composed of stems with fairly small leaves which causes the plant not to be eaten (Cook et al. 1954). Sand dropseed grows on a clay loam range site at Springfield (Fig. 2).

Fig. 1. Sideoats grama (Bouteloua curtipendula)

Fig. 2. Sand dropseed (Sporobolus cryptandrus)

The chemical composition and digestibility of this plant is shown in Appendix A - Table 3. The low digestion coefficient of protein along with the low protein content cause sand dropseed to be limiting in digestible protein all year round. The digestible energy of sand dropseed is barely adequate in the early spring but is deficient in the fall. Calcium has a similar trend as digestible energy. However, phosphorus is deficient when the seeds are ripening and again when sand dropseed becomes dormant.

BUFFALOGRASS: Buffalograss which is a perennial, warm season shortgrass grows mainly on medium and fine textured soils. Buffalograss reproduces by means of stolons and usually the male and female plants are on different plants. In certain portions of the central plains, buffalograss can produce an abundant amount of forage. Buffalograss is grazed by just about all livestock and increases under heavy grazing pressure. If the area is continually overgrazed any blue grama there will be replaced by buffalograss (Herzman et al. 1967). Buffalograss was collected from a clay loam range site here at Springfield.

Appendix A - Table 4 shows the chemical composition and digestibility of buffalograss. The magnesium and calcium content are sufficient to meet the requirements as suggested by Cook (1972). However, the phosphorus content is deficient in early growth and for a short while as the plant disseminates its seeds and starts to dry. The low digestibility of protein along with the low protein content make protein deficient for animals in gestation nearly all year round. Digestible protein meets the requirements only when the heads come out. The digestible energy is deficient in the early spring and when the seeds are ripening due to the low digestibility of energy.

KOCHIA: Kochia, also known as fireweed or burning bush, is found in dry open places as well as fertile uncultivated soil (Johnson and Nichols 1970). At Springfield, kochia grows on a clay loam range site. The nutritive value of kochia is shown in Appendix A - Table 5.

Kochia is distinct in that it has a very high magnesium and calcium content. The magnesium reaches as high as .87% and calcium can reach over 1%. Phosphorus however seems to be produced in waves. During early spring growth phosphorus is deficient, then at later growth stages there is sufficient phosphorus to meet the requirements of an animal in gestation. However, when the seeds start ripening and disseminating, and again when the plant matures, a marked drop occurs. The vitamin A content is sufficient all year round, along with the digestible protein and digestible energy for livestock in gestation.

LAMBSQUARTERS: Lambsquarters is also known as pigweed and white goosefoot. This is a pale annual forb which grows at low and medium elevations in fields, along roadsides and waste places. Lambsquarters grows at Springfield on clay loam range sites. It varies from poor to good sheep feed and as a rule lambsquarters is grazed by cattle at some growth stages (Dayton 1960). The chemical composition and digestibility of lambsquarters is shown in Appendix A - Table 6.

The digestible protein, digestible energy, vitamin A, magnesium and calcium are far above what is needed by livestock. Phosphorus is deficient when the seeds are disseminating and when the plant is dormant.

YUCCA SEED PODS: Yucca, also known as bear grass or small soapweed, grows at Springfield on a clay loam range site. Young plants are often eaten by sheep and cattle. Livestock eat the flower clusters of both the young and old plants (Johnson and Nichols 1970). Appendix A - Table 7 shows the chemical composition and digestibility of yucca seed pods.

Yucca pods in early growth are very highly digestible, and as they mature this decreases. They supply enough digestible energy, digestible protein, magnesium, calcium, and phosphorus to meet the requirements of a lactating animal. The pods are deficient in vitamin A when mature.

San Juan Basin Experiment Station

WESTERN WHEATGRASS: Western wheatgrass is also known as bluestem wheatgrass and bluejoint wheatgrass because the foliage is bluish in color. Western wheatgrass is a cool season, sod forming grass with rhizomes, hence it grows as single stems on small tufts. These small tufts are usually not formed under arid or semi-arid conditions. Western wheatgrass is tolerant to moderately alkaline soils and can be found on soils varying from clay to sand, although western wheatgrass prefers soils which are relatively fine textured (Cook et al. 1954). In the Hesperus area western wheatgrass is generally in brushy-loam range type (Fig. 3).

This grass withstands grazing rather well and animals still utilize western wheatgrass when it matures even though it becomes

Fig. 3. Western wheatgrass (<u>Agropyron smithii</u>)

stiff and coarse. The chemical composition and digestibility of this plant is shown in Appendix A - Table 8. At late stages of growth, western wheatgrass is deficient in digestible protein. The vitamin A content is very high in the early stages of growth but drops off very quickly as the plant matures, however there is still enough to meet livestock requirements. Digestible energy is deficient when the plants are dormant before fall regrowth. Calcium and magnesium are sufficient to meet an animal in gestation. Phosphorus is very deficient in early and late stages of growth and is only adequate when the plants start to dry off.

ARIZONA FESCUE: Arizona fescue (Fig. 4) is a dense bunchgrass which produces a fair amount of forage principally during the summer months. Arizona fescue grows in the mountains from 2,000 to 3,000 meters, on rocky slopes, open parks, mesas and open ponderosa pine types. At Hesperus it grows on ponderosa pine grazable woodland range sites. Arizona fescue appears to be not as palatable as some other grasses although it is grazed fairly well by livestock in late spring and early summer. Heavy grazing over a sustained period will soon reduce a stand of Arizona fescue (Herzman et al. 1967).

The chemical composition and digestibility of Arizona fescue is shown in Appendix A - Table 9. The vitamin A content of Arizona fescue runs from 51,480 international units in the early leaf growth to 10,412 international units in fall regrowth, all of which is above lactation requirements. The magnesium,calcium and phosphorus content are deficient in the early and late stage of plant growth, and at other times the plant has enough minerals for an animal in gestation. After

Fig. 4. Arizona fescue (Festuca arizonica)

the seeds start disseminating, Arizona fescue does not have enough digestible protein for livestock, however its digestible energy content is adequate for a gestating animal.

MOUNTAIN MUHLY: Mountain muhly is an important forage in ponderosa pine forests. It is a bunchgrass which grows in canyons, rocky hillsides and mesas. While young, it is relatively palatable, however its palatability decreases with maturity. This midgrass grows best during the spring and summer months. At Hesperus it grows on ponderosa pine grazable woodland range sites (Herzman et al. 1967).

Mountain muhly is deficient in digestible protein at all stages of growth and its digestible energy content declines and becomes deficient as the plant matures (Appendix A - Table 10). Gestating animals require more calcium and magnesium than is supplied by this species in its late stages of growth. The phosphorus content is deficient in early and late stages of growth. The vitamin A content of mountain muhly at the anthesis was 62,700 I.U. which was in excess of the 1,408 I.U. required by a lactating animal.

KENTUCKY BLUEGRASS: Kentucky bluegrass (Fig. 5) is a cool season, sod-forming grass with many slender rhizomes. It grows at elevations from 1,500 to 3,300 meters in open woods, fields and meadows. At Hesperus it grows on brushy loam range sites. Kentucky bluegrass is a very hardy grass which tends to increase under heavy grazing. However, Kentucky bluegrass is not a very heavy producer of forage, but that which is produced is readily grazed by all livestock (Herzman et al. 1967).

Fig. 5. Kentucky bluegrass (Poa pratensis)

The digestibility of Kentucky bluegrass is very high in its early stages of growth (Appendix A - Table 11). As a source of digestible energy Kentucky bluegrass is very good and it is only deficient in digestible protein during the dormant stage of growth. The magnesium content exceeds the needs of livestock, while calcium is deficient for an animal in gestation at five different stages of growth. Phosphorus deficiency in Kentucky bluegrass has a cyclic effect being deficient in early, middle and late stages of growth.

NEEDLE-AND-THREAD GRASS: Needle-and-thread grass (Fig. 6) which is sometimes referred to as needlegrass or speargrass is an erect leafy bunchgrass 30 to 60 cm. high. It is characterized by sharp pointed seeds which have a long curling awn 4-6 cm. long. This cool season grass which grows on a brushy-loam range type at Hesperus is valuable because of its high palatability and frequently produces new growth for winter grazing following favorable fall rains. However, when it is grazed during the time awns are bountiful, injury may occur to the eyes, mouth and skin of sheep. Cattle and other large herbivores are usually unaffected. When grazing sheep, it is best to graze it before the awn appear and/or after they are dropped in late summer (Cook et al. 1954).

Table 12 (Appendix A) shows the chemical composition and digestibility of needle-and-thread grass. Protein and energy meet the requirements of livestock early in the season, as the season progresses though, these two components of needle-and-thread grass are deficient. The cellulose in this plant is very highly digestible, even in the winter time. Phosphorus and calcium are adequate for

Fig. 6. Needle-and-thread grass (Stipa comata)

animals in gestation however, at several stages they are inadequate for lactating animals. During early growth and in the winter, needle-and-thread grass is deficient in magnesium.

MUTTON GRASS: Mutton grass is a good forage for all livestock and is grazed mainly from early spring to midsummer. This bunchgrass grows mainly in the mountains between 1,500 and 3,000 meters on an open, dry woods and rocky hills (Herzman et al. 1967). Mutton grass grows on a brushy loam range site at Hesperus.

The nutritive evaluation of mutton grass indicates that the digestible energy and digestible protein content of mutton grass is very good, and meets the gestation requirements of livestock (Appendix A - Table 13). The digestibility of cellulose is very high ranging from 65 to 80%. The vitamin A content for these samples analyzed was very good, however the minerals, calcium, phosphorus and magnesium were deficient at several stages of growth.

JUNEGRASS: Junegrass (Fig. 7) also known as prairie junegrass is a cool season, bunchgrass. It often grows on sandy soils or plains and open woods. It is a fairly good forage although it does not produce that much total forage since the leaves are basal and short. It is desired by all livestock and some wildlife, such as elk, but can not withstand intensive grazing (Herzman et al. 1967). At Hesperus it is found on the brushy loam range site. The protein content runs from 9.6 to 4.6 and because of the digestibility of the protein this makes the plant deficient as the plant matures (Appendix A - Table 14). The digestible energy, vitamin A, magnesium and phosphorus supply sufficient nutrients for an animal in gestation. However, the

Fig. 7. Mutton grass (Poa fenderiana)

calcium content is deficient toward the middle of the growth of the plant.

SQUIRRELTAIL GRASS: Squirreltail grass is a perennial bunchgrass which grows from 10 to 45 cm. high. It tolerates saline and alkaline soils but chiefly grows in dry gravelly soils. Before the seed heads are fully developed this is a fair to good forage for sheep and cattle. However, after the awns appear squirreltail becomes fairly objectionable to livestock. During late summer or fall, most of the objectionable bristles fall from the plant and it again becomes palatable for livestock. Early fall rains can produce new growth which helps supplement fall grazing (Cook et al. 1954). At San Juan it grows on a brushy loam range site (Fig. 8).

Appendix A - Table 15 shows the chemical composition and digestibility of squirreltail growing at Hesperus. The vitamin A, magnesium, calcium and digestible energy of squirreltail all meet the requirements of livestock for gestation. However, as the plant matures its digestible protein and phosphorus become deficient.

Manitou Experimental Forest

ARIZONA FESCUE: At Manitou, Arizona fescue grows on a sandy clay loam range site (Fig. 4). The growing characteristics of Arizona fescue were discussed at the Hesperus collection site.

Nutritive value of Arizona fescue is shown in Appendix A - Table 16. The organic matter digestibility ranges from 70% in early growth down to 41% when the plant is dormant. The protein content is nearly 12.9% when the flowers are in the boot stage.

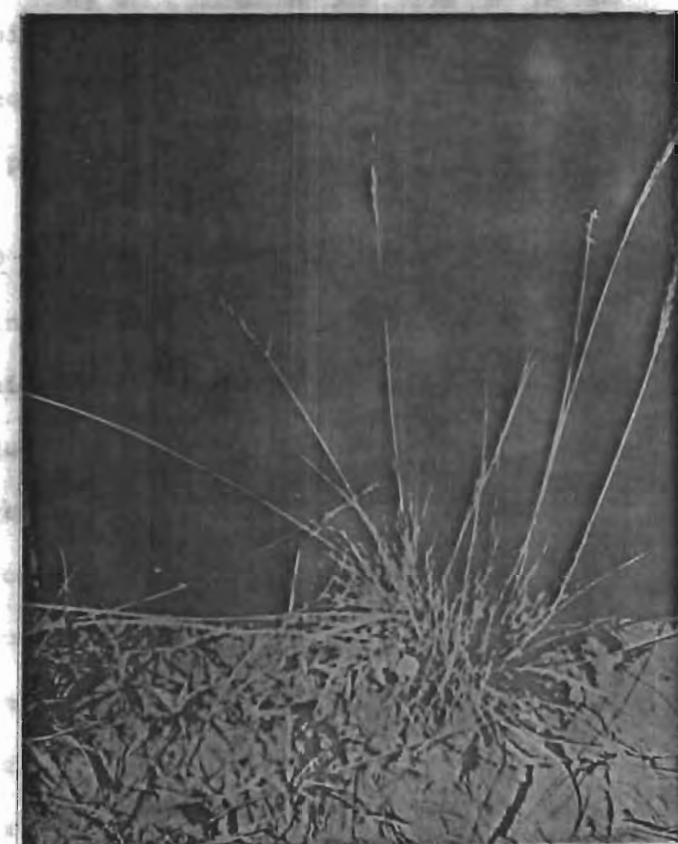

Fig. 8. Squirreltail grass (Sitanion hystrix)

However, as the plant matures the protein content drops markedly and is inadequate to meet the maintenance requirements of cattle. Digestible energy follows a similar but less marked trend. As should be expected, the cellulose content of the plant increases with maturity.

The vitamin A content is very high when the plant is young and declines rapidly during late summer and fall and is deficient for gestation requirements. Arizona fescue is nearly always deficient in calcium, phosphorus and magnesium.

FRINGED SAGEBRUSH: Fringed sagebrush (Fig. 9) which is also known as fringed wormwood, is a half-shrub which is found on dry plains and hills. At Manitou it is found on a sandy clay loam range site. Fringed sagebrush is often grazed by cattle and is considered a good forage for sheep and elk. Areas which have been seriously overgrazed for a long time may become dominated by this plant (Johnson and Nichols 1970).

The chemical composition and digestibility of this plant is shown in Appendix A - Table 17. The energy, vitamin A and magnesium are above what is required for the maintenance of livestock during gestation and lactation. However, as the plant gets older the calcium content decreases and it appears that the plant is deficient in phosphorus all year round. When the plant is dormant it is deficient in digestible energy.

BLUE GRAMA: The characteristics of blue grama were described earlier at the Springfield collection site. Here at Manitou it grows on a sandy clay loam site.

Fig. 9. Fringed sagebrush (Artemisia frigida)

Appendix A - Table 18 shows the chemical composition and digestibility of this plant. Blue grama barely meets the digestible energy requirements in early lactation when the plant is young, and it becomes deficient for a cow in gestation when it matures. The digestible protein content is adequate in early growth but drops down to a very low 1.1% in the winter which is below maintenance requirement. There is however, a surge of protein content to 8.11% in the fall regrowth of the plant.

The vitamin A content seemed to remain constant around 4,000 international units throughout the year, however no plant was analyzed during the winter dormant period. The magnesium content and the calcium content appeared to be adequate for gestation in the early part of the plant growth. However as the plant matured it became deficient in both minerals. A similar trend was noticed for phosphorus.

MOUNTAIN MUHLY: The growth habits of mountain muhly were described at the Hesperus collection site. At Manitou, mountain muhly grows on a sandy clay loam range site.

The cellulose content of mountain muhly seems to remain constant, however as it gets older its digestibility drops as the plant matures (Appendix A - Table 19). The vitamin A content is satisfactory throughout the year for animals in gestation. However, when mountain muhly is winter dormant, it does not meet the vitamin A requirements during lactation. The protein content of 10.1% in early growth is sufficient for all forms of livestock. However, when it is winter dormant it only has 2.5% protein. The digestible energy is readily available to the animal when the plant is young, however after the seeds are disseminated the plant does not meet a gestating cow's requirements.

Magnesium is bordering on a deficiency for lactating animals throughout its growing season. Phosphorus, except for two stages in early growth, is deficient. Calcium in most cases meets the requirements for lactation, but in the winter it is deficient.

NEBRASKA SEDGE: Nebraska sedge occurs at elevations up to 3,000 meters in Colorado. Throughout its range this sedge occurs exclusively in such wet sites as along slow streams, near springs, in shallow, swampy areas (Dayton et al. 1932), and wet meadows. At Manitou it grows on a sandy clay loam range site (Fig. 10).

The palatability of this sedge varies with the amount and distribution of palatable grasses associated with it. Generally it is a fair forage for sheep and a good forage for cattle. Its strongly developed rootstocks make Nebraska sedge well adapted to withstand abusive grazing. The nutritive value of Nebraska sedge can be seen in Appendix A - Table 20. This grasslike plant is 90% digestible in the early spring and decreases in digestibility until winter time when the dry matter digestibility is 50%. The digestible protein content is 13.3% in the early spring, however in the fall it drops down to 2.6% which is not enough to meet an animal's needs. The digestible energy, vitamin A, magnesium and calcium content of the forage are sufficient to meet livestock requirements for gestation. However phosphorus is deficient towards the end of the growing season.

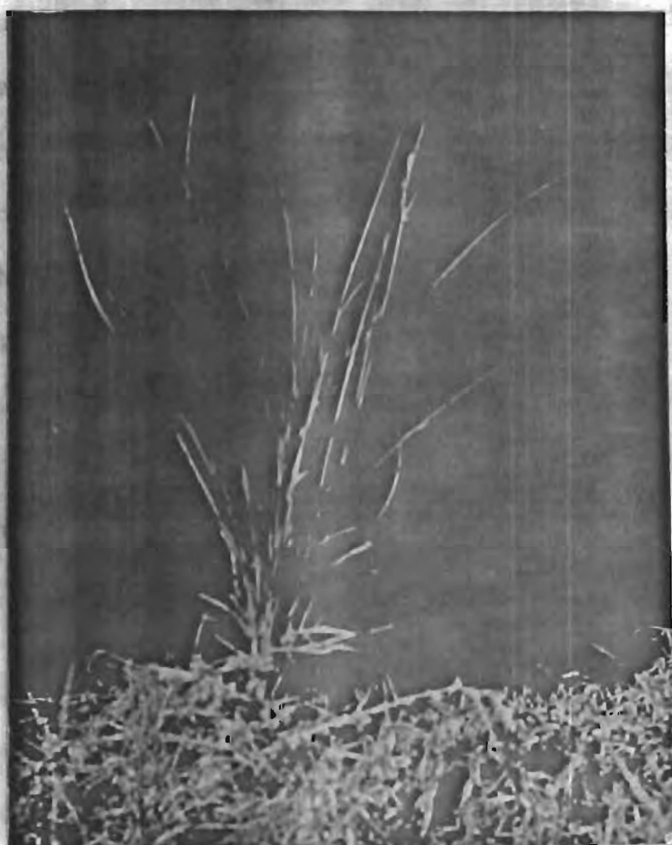

Fig. 10. Nebraska sedge (Carex nebraskeni)

WESTERN WHEATGRASS: In the Manitou area western wheatgrass is generally found on sandy clay loam range sites (Fig. 3). The growth habits were discussed earlier at the Hesperus collection site.

This grass withstands grazing rather well, and animals still utilize it when it matures, even though it becomes stiff and coarse. Appendix A - Table 21 shows the chemical composition and digestibility of western wheatgrass at Manitou. The digestibility of dry matter, organic matter, early in the season have a digestion coefficient of around 85% and in the winter it averages about 48%. This has a bearing on the fact that protein and energy are adequate in early spring growth and that they are deficient in the fall. The vitamin A content appears to meet requirements as does calcium. However, magnesium is deficient in the winter. Phosphorus is deficient when the plant is at the seed ripening stage and when the plant is dormant before fall regrowth.

Black Hawk

THURBERS FESCUE: Thurbers fescue is a robust bunchgrass which grows in dense tufts 49 to 73 cm. tall. It grows at elevations from 1,800 to 3,600 meters during the spring and summer on hillsides, open parks and open stands of spruce (Herzman et al. 1967). It usually prefers sandy loam soil and at Black Hawk it grows on a sub-alpine loam range site (Fig. 11).

The chemical composition and digestibility of Thurbers fescue is shown in Appendix A - Table 22. Thurbers fescue is adequate in protein, energy and vitamin A early in the season. However it is deficient in calcium, magnesium and phosphorus. When the plant is about half way through its phenological development it is deficient

Fig. 11. Thurbers fescue (Festuca thurberi)

in protein, however magnesium and calcium are adequate for livestock, while phosphorus is deficient. When Thurbers fescue matures it is deficient in all of the nutrients analyzed.

Craig

FRINGED SAGEBRUSH: At Craig, fringed sagebrush (Fig. 9) is found on a sandy slope range site. The growth habits of fringed sagebrush were discussed earlier at the Manitou collection site.

The nutritive value of fringed sagebrush is shown in Appendix A - Table 23. The digestibility of fringed sagebrush is low, which in turn, makes the amount of digestible protein available to livestock lower than that which is recommended at all stages of the plant growth. The amount of digestible energy that is available is barely sufficient to meet livestock requirements for gestation, except for two or three of the early stages of growth.

The calcium and magnesium content of fringed sagebrush are above that which is needed. Phosphorus is deficient at nearly all stages of phenology except when the plant is in full leaf. The vitamin A content of fringed sagebrush was only analyzed once and this was when the plant was dormant. At this stage of growth it far exceeded the requirement.

RABBITBRUSH: Rabbitbrush is a bushy plant and is commonly called rabbitsage, yellowbrush and rayless-goldenrod. Rabbitbrush is a characteristic shrub from sea-level to 3,000 meters and is a conspicuous component of the vegetation on alkaline plains and stream banks throughout the semi-region of the west. Some species of

Fig. 12. Rabbitbrush (Chrysothamnus viscidiflorus)

rabbitbrush grow in mixed types in the foothills and mountains while at Craig rabbitbrush grows on a sandy slope range site (Fig. 12).

Most species of rabbitbrush have little forage value. However, species C. viscediflorus ranks as a fair to good forage for sheep and cattle (Dayton et al. 1932). The chemical composition and digestibility of rabbitbrush is shown in Appendix A - Table 24. The protein content of this species of rabbitbrush runs from 12.7% down to 3.8% which along with its high digestibility for protein make this plant fulfill protein requirements for livestock in gestation except when it is in full leaf. In early spring, rabbitbrush is barely adequate in vitamin A for livestock in gestation and is deficient for any that are lactating. However, as it develops the plant far exceeds the requirements. Unfortunately, no samples were analyzed for vitamin A when the plant was mature.

Rabbitbrush has a high magnesium and calcium content, and in most stages it has a low phosphorus content. This leads to a high CA:P ratio which can get as high as 12.2:1. The plant seems to supply enough energy although when the plant is in full leaf, and again when it is dormant it does not have enough digestible energy for a cow in gestation.

<u>ANTELOPE BITTERBRUSH</u>: Antelope bitterbrush is also known as quinine-brush, black sage and deerbrush. It grows mainly on well drained, sandy, gravelly soils on open southerly exposures at elevations ranging from sea level up to 2,800 meters. At Craig, it grows on a sandy slope range site.

In many areas in the west, bitterbrush is regarded as the single most important browse species. The leaves and younger twigs are readily utilized by goats, sheep and cattle. The palatability bitterbrush is usually good for both sheep and cattle (Dayton et al. 1932). Appendix A - Table 25 shows the chemical composition and digestibility of bitterbrush.

The digestible energy content of this browse meets the requirements of livestock in gestation all year. The digestible protein is unusual in that it is deficient during the middle stages of phenology and adequate at other times. Vitamin A and phosphorus also show this same pattern. The calcium and magnesium content are much higher than is required.

Nunn

WESTERN WHEATGRASS: In the Nunn area western wheatgrass (Fig. 3) is found generally on a sandy loam range type. A general description of western wheatgrass was given earlier at the Hesperus collection site.

This grass withstands grazing rather well and animals still utilize it when it matures even though it becomes stiff and coarse. The nutritive value of this plant is shown in Appendix A - Table 26. The digestible protein content of western wheatgrass hardly meets the requirements for gestation or lactation after the heads are fully out. Calcium and phosphorus are deficient for lactating and in most instances gestating animals. Vitamin A was sufficient in early growth when it was analyzed. Magnesium was only deficient during fall regrowth. The digestible energy content meets the requirements for animals in gestation, however it becomes deficient for lactating animals after the seeds have been disseminated.

FOURWING SALTBUSH: Fourwing saltbush is found in arid and semi-arid areas of the west. It is a perennial, shrub which grows to 1 meter. Fourwing saltbush is a valuable forage for both livestock and wildlife in arid areas. It exhibits hardiness to cold, and a remarkable ability to withstand drought because of its tremendous root development which sometimes penetrates to 6 meters (Johnson and Nichols 1970). At Nunn it grows on a sandy loam range site (Fig. 13).

There is evidence to suggest that occasionally this plant will cause bloat when eaten too liberally and that too concentrated feeding of the species will cause scours in range cattle. Appendix A - Table 27 shows the chemical composition and digestibility of fourwing saltbush.

The magnesium and calcium content of fourwing saltbush are way above what is required, however the phosphorus content is generally below that recommended. This combination of analysis gives us a high calcium phosphorus ratio reaching 11.2:1. The vitamin A content is very high in the spring. As should be expected, the cellulose content increases with the maturity of the plant and its digestibility decreases. Fourwing saltbush towards the end of its phenological development does not supply enough energy and protein for lactation or enough protein for gestation.

BLUE GRAMA: The growing characteristics of blue grama was discussed at the Springfield collection site.

Fig. 13. Fourwing saltbrush (Atriplex canescens)

The chemical composition and digestibility of blue grama is shown in Appendix A - Table 28. It appears that once the seeds start being disseminated from blue grama it becomes deficient in protein. The digestible energy is deficient only at the latter stages of growth for an animal that is in early lactation. Calcium and magnesium are in sufficient amounts for an animal in gestation. However, magnesium at most stages of phenology doesn't meet the requirements for a lactating animal nor does calcium when the plant is mature. Blue grama which grows at Nunn is deficient in phosphorus all year round.

SCARLET GLOBEMALLOW: Scarlet globemallow (Fig. 14) which is also known as red falsemallow is usually found on dry sites. It is a low-growing perennial forb which grows from 7 to 30 cm. tall. At Nunn, the forb grows on a sandy loam range site. Scarlet globemallow is a very drought resistant forb due to its ability to shed leaves. This forb is readily eaten by livestock and where an area is overgrazed it will increase in abundance (Johnson and Nichols 1970). The chemical composition and digestibility of scarlet globemallow is shown in Appendix A - Table 29.

The high digestibility of scarlet globemallow contributes to the plants ability to supply the requirements of digestible energy and digestible protein for livestock. The vitamin A content is high in early growth which were the only time that it was analyzed. The magnesium and calcium content far exceed the requirements, while phosphorus is borderline to being deficient. The extremely high calcium content, which is over 2% all year round, coupled with a low

Fig. 14. Scarlet globemallow (Sphaeralcea coccinea)

phosphorus, give calcium phosphorus ratios which reach as high as 19.2:1.

SUMMARY AND CONCLUSIONS

This study was undertaken to investigate the nutritive value of the most important forage species grazed by livestock in various areas of Colorado. The samples were analyzed for energy, protein, cellulose, vitamin A, calcium, phosphorus and magnesium. The digestibility coefficients of the plant, protein, energy and cellulose were also determined by the in vivo nylon bag technique.

The plants collected at the Southeastern Colorado Branch Experiment Station are all, except yucca pods, deficient in phosphorus at some stage of growth. Blue grama, sideoats grama, sand dropseed, and buffalograss are all deficient in digestible protein while sand dropseed and buffalograss are deficient in energy at some stage of growth. Yucca pods are deficient in vitamin A when the pods mature. Sand dropseed becomes deficient in calcium as the plant matures.

All plants analyzed except for needle-and-thread and Junegrass at the San Juan Basin Experiment Station were deficient in phosphorus at some stage of growth. Western wheatgrass and mutton grass were the only two plants which did not have a deficiency in digestible protein at some stage of phenology. A calcium, phosphorus and magnesium deficiency was noticed in both mountain muhly and mutton grass. Magnesium was also deficient in needle-and-thread grass and Arizona fescue. Calcium was deficient in Kentucky bluegrass and Junegrass. Western wheatgrass, mountain muhly and needle-and-thread grass were deficient in digestible energy at some stage of phenology.

Plants which were collected at Manitou Experimental Forest seem to have a protein and a mineral deficiency. All the plants have a phosphorus deficiency at some stage of growth and all but Nebraska sedge and western wheatgrass have a calcium deficiency. Magnesium was noted to be deficient in Arizona fescue, blue grama and western wheatgrass. Vitamin A and energy were deficient in Arizona fescue and mountain muhly. Digestible energy was also deficient in blue grama and western wheatgrass. All plants, except for fringed sagebrush which were collected at Manitou were deficient in protein at some stage of growth. Thurbers fescue which was collected at Black Hawk was found to be deficient in all nutrients when it matured. Early in its growth though, it is adequate in protein, energy and vitamin A, while being deficient in the minerals analyzed.

At the Craig collection site phosphorus and digestible protein were deficient at some stage of growth in all plants. Rabbitbrush and antelope bitterbrush are deficient in vitamin A while fringed sagebrush and rabbitbrush were deficient in digestible energy.

Phosphorus was again deficient in all samples collected at Nunn, during some stage of the plant's growth. Magnesium and calcium was also noted to be deficient in western wheatgrass. Protein was deficient in western wheatgrass, fourwing saltbrush, and blue grama. The energy content of blue grama and fourwing saltbrush was also deficient for animals in gestation.

In conclusion, it can be said that in all species studied at least one of the elements analyzed was deficient. Probably the most outstanding deficiency is that of phosphorus which was deficient in nearly all plants. This would be followed secondly by a deficiency in digestible protein. To make sure that animals are not subjected to these deficiencies, animals should be grazed on several species of plants so that a deficiency in one can be offset by an excess in another.

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APPENDIX A

APPENDIX A

Table 1. Average chemical composition and digestibility of Blue Grama at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1970.

Phenological Stage Grass	Dry Matter Diges- tibility	Organic Matter Diges- tibility	Protein %	Diges- tible Protein %	Energy Cal/gm	Diges- tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. Per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	48	48	9.6	5.6	4650	2579	28.0	11.9	80,080.	.060	.38	.15	2.5:1
Spring Leaf Growth 4 - 5 Leaves	59	60	8.9	5.6	3732	2139	29.0	15.4	------	.052	.43	.16	2.8:1
Flowers in Boot	59	73	7.8	5.5	3782	2651	37.3	26.5	------	.096	.41	.16	2.4:1
Heads Fully Out	60	72	4.1	1.7	4819	2977	37.3	21.5	------	.112	.44	.17	2.4:1
Seeds Ripening	48	72	4.0	1.2	3977	1888	36.1	12.7	------	.109	.37	.29	1.2:1
Seeds Being Disseminated	44	60	6.0	3.27	4075	2145	38.2	21.2	------	.122	.43	.26	1.6:1
Plants Drying	59	59	7.2	4.81	4050	2433	31.6	18.1	------	.066	.41	.27	1.8:1
Plants Dormant	55	56	7.3	4.6	4195	2215	31.2	17.3	------	.073	.41	.36	1.8:1
Fall Regrowth	58	50	6.1	2.2	4071	1973	33.1	17.0	------	.066	.43	.21	2.0:1
Winter Dormant	52	49	5.3	2.0	3716	2019	34.6	18.8	------	.062	.33	.15	2.1:1

APPENDIX A

Table 2. Average chemical composition and digestibility of Side oats grama at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1970.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	48	56	4.4	2.2	4335	2471	33.7	17.8	------	.095	.20	.24	.84:1
Spring Leaf Growth 4 - 5 Leaves	52	53	7.4	2.6	4216	2301	28.7	15.2	------	.091	.40	.19	2.0:1
Flowers in Boot	57	51	4.4	2.3	4432	2510	34.7	20.2	------	.101	.45	.17	2.5:1
Heads Fully Out	53	53	7.0	3.7	4412	2380	35.2	18.9	------	.145	47	.18	1.9:1
Flowers at Anthesis	52	53	4.9	2.4	4765	2552	30.2	15.3	------	.114	.46	.24	1.9:1
Seeds Ripening	55	62	3.7	1.8	4550	2538	31.6	13.1	------	.112	.38	.20	1.9:1
Seeds Being Disseminated	52	56	3.0	1.5	4661	2150	30.3	15.0	------	.142	.33	.17	1.8:1
Plants Drying	53	53	4.8	1.3	4129	2124	28.6	15.9	------	.118	.47	.15	3.0:1
Plants Dormant	52	54	4.5	1.5	4264	2163	33.4	18.0	------	.118	.34	.24	1.3:1
Fall Regrowth	53	53	2.8	1.4	4464	2440	29.7	16.1	------	.122	.49	.14	4.6:1
Winter Dormant	49	41	2.6	1.2	4830	2054	34.3	15.0	62,700.	.107	.22	.15	2.7:1

APPENDIX A

Table 3. Average chemical composition and digestibility of <u>Sand dropseed</u> at various stages of growth, collected at <u>Springfield</u>, Colorado on a <u>Clay Loam</u> Range Site in 1970.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	47	51	5.4	2.3	4076	2143	28.3	9.2	12,848	.092	.26	.22	.6:1
Spring Leaf Growth 4 - 5 Leaves	47	51	6.6	3.9	4362	2612	30.2	9.9	------	.115	.32	.27	.9:1
Flowers in Boot	50	52	5.9	2.6	4347	2307	30.6	15.5	------	.125	.38	.39	1.2:1
Heads Fully Out	47	47	4.6	2.5	4824	2134	40.0	14.7	------	.096	.19	.33	.6:1
Seeds Ripening	62	52	4.8	2.5	4464	2639	30.3	16.2	------	.113	.39	.15	2.5:1
Seeds Being Disseminated	66	56	6.0	2.6	4365	2125	37.2	18.9	------	.111	.33	.18	1.8:1
Plants Drying	45	40	7.0	3.5	3789	1279	38.0	18.5	------	.102	.27	.17	1.5:1
Fall Regrowth	33	31	5.3	2.0	4132	1243	38.3	14.5	------	.079	.19	.26	.7:1
Winter Dormant	39	35	3.5	.9	4006	1526	40.6	18.2	------	.090	.19	.18	1.0:1

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Table 4. Average chemical composition and digestibility of Buffalo grass at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1970.

Phenological Stage Grass	Dry Matter Digestibility	Organic Matter Digestibility	Protein %	Digestible Protein %	Energy Cal/gm	Digestible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	43	55	6.5	2.7	4291	1972	27.2	12.6	------	.050	.30	.15	1.9:1
Spring Leaf Growth 4 - 5 Leaves	45	57	7.1	4.2	4321	2551	28.3	14.2	------	.063	.35	.18	1.9:1
Flowers in Boot	47	60	6.0	3.0	4523	2211	27.2	12.2	60,940	.071	.38	.21	2.1:1
Heads Fully Out	65	63	7.8	4.6	4773	2349	37.9	16.3	------	.081	.30	.29	1.0:1
Seeds Ripening	49	34	4.6	2.0	4522	1615	32.5	12.9	------	.093	.36	.12	2.9:1
Seeds Being Disseminated	59	46	4.6	2.3	4485	1870	34.2	13.4	------	.087	.35	.12	2.8:1
Plants Drying	58	52	5.7	2.2	4876	2658	33.2	15.0	------	.091	.30	.14	2.1:1
Plants Dormant	63	64	5.5	2.8	3876	2358	28.8	9.0	------	.101	.45	.30	1.4:1
Fall Regrowth	66	46	5.5	2.7	4274	2206	35.7	11.3	------	.071	.30	.21	1.4:1
Winter Dormant	49	43	6.0	2.6	4114	2663	32.8	12.3	------	.066	.28	.21	1.3:1

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Table 5. Average chemical composition and digestibility of Kochia at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1971.

Phenological Stage Forbs	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Early Leaf Growth	57	85	14.5	13.5	3265	2972	21.7	18.3	39160	.572	1.08	.16	6.1:1
Full Leaf Growth	57	86	18.0	15.5	3614	3021	21.2	16.8	------	.870	1.15	.19	5.9:1
Flower Stalks Developing	54	85	19.8	16.9	4016	3303	19.0	16.0	------	.533	1.08	.27	3.9:1
Seed Ripening	68	54	17.9	14.3	4025	2314	20.6	17.3	------	.379	.94	.03	24.5:1
Seed Disseminating	74	69	17.3	13.3	3807	2652	22.8	16.2	17996	.457	.90	.03	23.6:1
Plants Dry	53	84	16.8	12.2	4336	3693	24.3	18.8	------	.486	.93	.34	2.9:1
Fall Regrowth	51	71	16.3	10.0	4263	2980	28.6	21.0	------	.432	1.55	.38	3.9:1
Dry or Dormant	59	56	12.3	7.9	3597	1908	29.9	16.5	5808	.278	.93	.03	29.1:1

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Table 6. Average chemical composition and digestibility of Lambsquarters at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1971.

Phenological Stage Forbs	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Early Leaf Growth	58	90	9.6	8.6	4036	3593	11.9	10.0	83,600	.604	1.09	.23	4.3:1
Full Leaf Growth	54	93	15.1	14.4	4361	4021	13.3	11.9	14,340	.632	1.18	.26	4.4:1
Flower Stalks Developing	76	92	16.3	15.0	4314	4028	17.4	15.8	16,274	.500	.89	.33	2.7:1
In Bloom	76	81	17.7	15.7	4422	3578	16.2	11.2	16,060	.496	.98	.44	2.2:1
Seed Ripening	71	67	18.1	12.7	4511	3121	20.7	12.4	14,124	.188	.76	.16	4.7:1
Seed Disseminating	70	66	17.4	11.8	3886	2513	23.8	14.0	5,786	.497	.92	.16	5.4:1
Plants Dry	68	61	17.5	11.6	3715	2900	20.5	14.8	------	.465	1.00	.31	3.2:1
Fall Regrowth	59	66	17.2	13.4	3621	2138	22.3	14.2	2,134	.439	.86	.20	4.1:1
Dry or Dormant	57	62	12.3	8.2	3421	2033	24.2	13.9	------	.391	1.02	.10	10.0:1

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Table 7. Average chemical composition and digestibility of Yucca pods at various stages of growth, collected at Springfield, Colorado on a Clay Loam Range Site in 1971.

Phenological Stage Yucca Pods	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Pre-Bloom	83	96	9.0	8.7	4321	4171	26.0	25.0	7700	.132	.42	.31	1.3:1
Bloom	75	88	11.0	9.85	4586	4095	27.3	23.8	1606	.123	.43	.32	1.3:1
Green Pods	60	65	10.2	7.3	4573	3036	29.2	17.4	616	.128	.57	.33	1.6:1
Seeds Disseminating	55	59	9.0	5.4	4558	2592	32.7	15.4	330	.255	1.02	1.17	.9:1

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Table 8. Average chemical composition and digestibility of Western wheatgrass at various stages of growth, collected at Hesperus, Colorado on a Brushy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	85	73	6.9	5.4	4236	3173	31.5	21.4	56760	.063	.25	.07	3.4:1
Spring Leaf Growth 4 - 5 Leaves	82	83	10.5	8.9	4124	3412	26.8	21.0	------	.074	.24	.08	2.8:1
Flowers in Boot	69	78	13.3	11.51	4580	3478	31.8	23.6	57640	.060	.29	.12	2.2:1
Flowers at Anthesis	69	66	9.1	7.0	4290	2838	30.9	19.6	25960	.087	.30	.12	2.5:1
Seeds Ripening	66	70	8.0	6.3	4313	3187	26.6	17.5	------	.093	.36	.16	2.2:1
Seeds Being Disseminated	66	69	9.0	7.1	4392	3110	33.4	24.2	41800	.077	.29	.15	1.9:1
Plants Drying	63	66	6.7	5.0	4192	2670	35.5	24.1	3542	.090	.32	.19	1.6:1
Plants Dormant	44	48	6.3	2.4	4131	1783	35.2	10.7	------	.082	.41	.09	4.3:1
Fall Regrowth	58	60	5.3	2.8	4207	2173	32.0	18.5	------	.078	.38	.08	4.7:1
Winter Dormant	66	69	3.1	2.5	4370	2219	39.2	21.9	------	.077	.24	.09	2.3:1

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Table 9. Average chemical composition and digestibility of Arizona fescue at various stages of growth, collected at Hesperus, Colorado on a Ponderosa Pine-Grazable Woodland Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	74	67	8.1	6.1	4547	3046	20.1	11.5	51480	.038	.10	.09	1.1:1
Spring Leaf Growth 4 - 5 Leaves	61	65	10.5	8.9	3846	2455	24.9	12.8	------	.063	.16	.14	1.1:1
Flowers in Boot	68	70	10.3	8.5	4205	2923	37.7	27.5	------	.085	.21	.26	.82:1
Flowers at Anthesis	58	65	10.0	6.3	3931	2303	35.0	23.8	46640	.059	.29	.33	.88:1
Seeds Ripening	52	54	6.9	4.4	4400	2479	42.9	26.8	44880	.057	.23	.20	1.1:1
Seeds Being Disseminated	66	65	7.5	4.6	4063	2576	40.5	23.7	------	.067	.22	.19	1.2:1
Plants Drying	50	54	6.5	3.9	4404	2334	44.1	28.3	------	.065	.24	.18	1.3:1
Plants Dormant	46	51	6.5	2.8	4207	2173	32.0	18.5	69960	.074	.31	.24	1.3:1
Fall Regrowth	53	52	6.0	3.1	4336	2313	40.6	27.5	10912	.080	.24	.13	1.9:1
Winter Dormant	65	67	5.9	4.4	3948	2632	41.4	30.1	------	.043	.13	.07	1.8:1

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Table 10. Average chemical composition and digestibility of Mountain muhly at various stages of growth, collected at Hesperus, Colorado on a Ponderosa Pine-Grazable Woodland Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	45	74	3.0	1.58	4112	2984	31.7	22.9	------	.078	.31	.12	2.4:1
Flowers in Boot	70	59	8.3	4.2	4327	2663	33.0	19.4	14454	.083	.25	.14	1.7:1
Flowers at Anthesis	57	57	6.3	3.3	4416	2590	40.3	22.8	62700	.086	.26	.17	1.5:1
Seeds Being Disseminated	39	43	6.6	2.9	4313	1750	35.6	8.6	------	.070	.27	.17	1.6:1
Plants Drying	61	38	4.0	2.8	4237	1648	34.2	7.8	------	.088	.32	.13	2.3:1
Fall Regrowth	46	34	6.9	2.8	4377	1318	41.8	12.0	------	.047	.18	.11	1.6:1
Winter Dormant	49	48	2.9	1.4	4240	1434	45.3	27.8	------	.035	.11	.07	1.4:1

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Table 11. Average chemical composition and digestibility of Kentucky bluegrass at various stages of growth, collected at Hesperus, Colorado on a Brushy-Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	87	84	9.3	7.7	4036	3396	26.9	22.0	------	.135	.26	.07	3.4:1
Spring Leaf Growth 4 - 5 Leaves	79	82	8.0	6.7	4174	3438	23.3	18.8	8228	.108	.21	.06	3.2:1
Flowers in Boot	83	88	14.4	13.7	4258	3745	25.4	21.8	------	.159	.42	.28	1.5:1
Flowers at Anthesis	72	77	12.3	11.0	4338	3369	27.1	21.5	20548	.112	.22	.25	.91:1
Seeds Ripening	80	79	12.4	10.1	4421	3560	35.5	24.0	------	.075	.18	.05	3.3:1
Seeds Being Disseminated	64	67	8.0	5.7	4154	2822	38.7	27.9	4818	.085	.17	.09	1.9:1
Plants Dormant	55	59	6.5	3.6	3930	2281	37.8	23.7	------	.070	.28	.17	1.6:1
Fall Regrowth	55	59	8.8	5.9	3870	2225	32.5	18.3	54560	.102	.20	.30	.66:1
Winter Dormant	58	60	5.2	3.2	4505	2745	47.7	32.1	------	.081	.32	.12	2.5:1

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Table 12. Average chemical composition and digestibility of Needle-and-thread at various stages of growth, collected at Hesperus, Colorado on a Brushy-Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 4 - 5 Leaves	74	67	10.3	7.0	4136	2814	26.6	17.2	25960	.078	.26	.25	1:1
Flowers in Boot	73	76	10.6	8.0	4736	3562	28.2	22.2	38720	.055	.39	.36	1.1:1
Flowers at Anthesis	66	71	12.1	9.1	3984	2775	37.1	28.8	------	.054	.26	.18	1.4:1
Seeds Ripening	56	59	6.9	3.9	4210	2535	42.0	30.1	------	.095	.25	.19	1.2:1
Seeds Being Disseminated	74	73	7.6	5.4	4021	2871	31.3	23.3	22440	.083	.26	.17	1.4:1
Plants Drying	55	59	7.0	4.7	4133	2394	41.7	28.3	31460	.073	.28	.18	1.7:1
Plants Dormant	46	55	5.4	2.0	3984	2234	41.9	27.4	------	.063	.32	.18	1.7:1
Fall Regrowth	65	73	8.0	4.0	4210	3043	36.2	28.5	32120	.076	.27	.22	1.2:1
Winter Dormant	46	61	3.8	1.1	3850	1974	35.9	20.8	------	.049	.34	.23	1.4:1

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Table 13. Average chemical composition and digestibility of Mutton Grass at various stages of growth, collected at Hesperus, Colorado on a Brushy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	69	77	6.3	4.8	4283	3244	31.6	26.7	------	.075	.19	.07	2.9:1
Flowers in Boot	70	80	6.8	5.4	4416	3485	31.7	25.0	------	.06	.33	.12	2.8:1
Heads Fully Out	51	75	10.4	8.8	4370	3267	35.8	27.9	------	.056	.19	.23	.83:1
Flowers at Anthesis	86	75	7.5	6.0	4294	3239	33.9	25.3	25740	.063	.21	.18	1.1:1
Seeds Ripening	52	70	7.6	5.9	4122	2812	35.5	24.3	------	.072	.15	.21	.68:1
Seeds Being Disseminated	39	64	8.0	5.9	4328	2848	36.1	25.0	------	.049	.13	.21	.62:1
Plants Drying	38	66	7.3	5.6	4661	3170	33.9	22.0	------	.059	.16	.17	.94:1
Fall Regrowth	74	67	9.9	7.8	4350	2993	35.0	25.4	12540	.043	.12	.12	.99:1

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Table 14. Average chemical composition and digestibility of Junegrass at various stages of growth, collected at Hesperus, Colorado on a Brushy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Digestibility	Organic Matter Digestibility	Protein %	Digestible Protein %	Energy Cal/gm	Digestible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	59	79	9.6	7.6	3911	3037	30.1	23.3	------	.083	.31	.20	1.5:1
Flowers in Boot	64	83	8.3	6.9	4002	3273	38.6	32.9	------	.082	.35	.17	2:1
Heads Fully Out	58	85	7.0	5.9	4009	3390	39.7	34.4	------	.088	.29	.17	1.6:1
Flowers at Anthesis	63	73	8.3	6.5	4052	2950	34.4	24.8	8030	.060	.13	.19	.72:1
Seeds Ripening	58	73	6.8	5.1	4350	3210	33.3	24.6	10274	.111	.28	.29	1:1
Seeds Being Disseminated	41	59	5.5	3.2	4116	2417	43.4	28.9	------	.065	.18	.18	1:1
Plants Drying	47	57	5.0	2.7	4020	2309	45.5	30.8	------	.061	.17	.100	1.7:1
Fall Regrowth	65	67	4.6	3.9	4545	3730	34.5	28.7	29920	.107	.29	.20	1.4:1

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Table 15. Average chemical composition and digestibility of Squirreltail Grass at various stages of growth, collected at Hesperus, Colorado on a Brushy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	75	76	8.5	7.2	4009	3033	30.8	22.1	29700.	.079	.21	.18	1.1:1
Spring Leaf Growth 4 - 5 Leaves	77	79	11.0	9.0	4003	3209	30.3	23.9	------	.081	.22	.19	1.1:1
Flowers in Boot	44	76	9.9	8.2	4132	3143	30.6	24.2	44880	.063	.26	.20	.8:1
Flowers at Anthesis	41	68	7.7	5.7	4136	2874	39.6	28.8	------	.078	.26	.28	.9:1
Seeds Ripening	53	67	5.8	3.9	4431	3001	32.7	23.2	20064	.090	.31	.21	1.4:1
Seeds Being Disseminated	63	67	5.7	3.7	4126	2716	39.4	28.0	------	.061	.24	.17	1.5:1
Plants Drying	49	61	6.0	4.2	4085	2522	44.0	30.3	------	.072	.29	.15	1.9:1
Fall Regrowth	69	80	5.3	4.2	4021	3153	33.4	25.5	14784.	.099	.40	.16	2.4:1

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Table 16. Average chemical composition and digestibility of Arizona fescue at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1971

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	71	63	9.2	6.9	3478	2052	35.1	21.9	78320	.037	.14	.12	1.1:1
Spring Leaf Growth 4 - 5 Leaves	73	70	10.9	6.2	3945	2786	32.2	22.3	36200	.041	.15	.12	1.2:1
Flowers in Boot	46	43	12.9	3.7	4245	1869	29.5	19.5	20878	.070	.26	.31	.84:1
Heads Fully Out	64	58	11.0	5.3	4321	2554	34.8	19.6	17666	.080	.27	.32	.84:1
Flowers at Anthesis	60	56	9.4	3.9	4526	2494	35.2	19.2	58740	.060	.20	.13	1.4:1
Seeds Ripening	75	69	6.1	4.6	3736	2464	36.4	25.7	32120	.063	.23	.11	2:1
Seeds Being Disseminated	51	47	5.5	2.5	4150	1842	34.0	19.4	------	.057	.24	.09	2.6:1
Plants Drying	46	46	5.4	2.3	4103	1734	36.2	12.8	------	.053	.23	.09	2.5:1
Plants Dormant	52	47	5.4	2.3	4095	1823	37.3	13.8	1936	.058	.23	.12	1.9:1
Fall Regrowth	51	48	4.6	1.5	3914	1638	42.3	23.9	748	.052	.17	.11	1.5:1
Winter Dormant	38	41	2.4	1.0	3926	1514	51.4	19.3	------	.035	.15	.11	1.3:1

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Table 17. Average chemical composition and digestibility of Fringed Sagebrush at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Flower Buds Swelled	62	61	13.8	9.5	3876	2315	20.3	15.1	65120	.079	.36	.10	3.5:1
In Full Bloom	81	76	12.4	10.7	4045	3011	27.6	17.8	11848	.084	.49	.11	4.3:1
Fruit Formed	77	70	16.2	13.6	4145	2965	22.6	15.8	12518	.089	.51	.11	4.4:1
Fruit Ripe	61	63	16.6	11.9	4473	2865	20.9	13.6	10032	.173	.30	.12	2.3:1
Fruit Dropped	61	54	15.3	9.21	4446	2733	29.2	15.1	3212	.150	.30	.12	2.4:1
In Full Leaf	62	57	12.1	6.3	4321	2516	30.2	13.3	------	.123	.31	.15	2:1
Leaves Dropping	63	60	8.6	4.9	4264	2419	31.0	12.7	8030	.100	.31	.15	2:1
Dormant	44	45	6.6	2.2	4362	2069	49.4	15.0	48080	.099	.25	.12	1.9:1
Fall Regrowth	68	61	8.3	4.6	4465	2717	30.6	19.0	11242	.094	.23	.11	2.0:1

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Table 18. Average chemical composition and digestibility of Blue Grama at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1972.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	64	61	7.7	4.9	3893	2027	33.2	23.9	4806	.06	.25	.23	1.0:1
Flowers in Boot	68	64	8.8	5.7	4099	2627	31.3	20.9	4045	.07	.31	.17	1.7:1
Heads Fully Out	74	68	8.6	6.7	4154	2930	33.3	23.6	4840	.08	.20	.15	1.3:1
Flowers at Anthesis	66	65	7.3	4.7	4010	2593	33.9	22.8		.08	.21	.16	1.3:1
Seeds Being Disseminated	61	57	5.6	2.8	3868	2165	32.3	18.8	------	.08	.20	.13	1.4:1
Plants Drying	47	46	4.3	2.1	4410	2341	37.3	14.2	3652	.04	.20	.07	2.7:1
Plants Dormant	47	41	5.2	1.73	4184	1937	36.2	18.3	4004	.07	.29	.16	1.8:1
Fall Regrowth	49	49	10.8	8.11	3884	1922	39.6	20.4	------	.05	.20	.12	1.6:1
Winter Dormant	33	37	2.6	1.1	4322	1865	40.9	13.5	------	.03	.14	.11	1.2:1

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Table 19. Average chemical composition and digestibility of Mountain Muhly at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	73	70	9.9	6.5	3973	2830	31.3	21.8	------	.068	.31	.26	1.1:1
Spring Leaf Growth 4 - 5 Leaves	68	64	10.1	5.9	4063	2570	34.1	23.4	------	.056	.29	.10	2.7:1
Heads Fully Out	59	54	10.1	6.3	4166	2237	35.2	20.5	5456	.081	.18	.16	1.12:1
Flowers at Anthesis	57	56	6.5	3.4	4201	2292	35.8	20.6	------	.078	.28	.14	1.89:1
Seeds Ripening	51	52	4.3	1.7	4053	1984	33.6	14.8	------	.062	.20	.15	1.33:1
Seeds Being Disseminated	47	43	4.6	1.1	4079	1561	32.6	6.5	57200	.071	.28	.10	2.8:1
Plants Drying	47	46	4.0	.8	4117	1677	33.6	11.6	------	.066	.23	.14	1.6:1
Plants Dormant	42	38	3.8	1.3	4023	1050	32.5	8.2	5346	.060	.35	.12	2.7:1
Fall Regrowth	33	34	3.5	1.2	4165	1424	30.2	7.2	------	.040	.25	.10	2.5:1
Winter Dormant	31	35	2.5	.9	4214	1382	32.7	11.7	990	.062	.13	.11	1.1:1

Table 20. Average chemical composition and digestibility of Nebraska Sedge at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 4 - 5 Leaves	90	82	14.7	13.3	3473	2767	27.5	22.0	10200	.085	.35	.22	1.6:1
Flowers in Boot	88	83	11.8	10.5	3718	3029	28.0	22.6	25740	.083	.37	.22	1.6:1
Heads Fully Out	93	87	10.1	9.7	4052	3504	28.1	24.3	------	.088	.30	.26	1.1:1
Flowers at Anthesis	75	73	11.3	8.8	4273	3111	28.0	19.7	60280	.097	.25	.12	2.0:1
Seeds Ripening	85	81	12.0	10.8	4309	3563	28.3	22.0	77660	.090	.40	.20	1.9:1
Seeds Being Disseminated	81	69	9.6	7.2	4321	3030	28.3	17.8	92840	.106	.28	.12	2.2:1
Plants Drying	78	66	6.7	4.3	4465	3059	26.7	19.0	21406	.153	.65	.15	4.2:1
Plants Dormant	66	72	5.5	2.2	4173	2356	31.2	18.9	20878	.140	.64	.17	3.6:1
Fall Regrowth	71	63	5.5	2.7	4152	2538	27.9	12.8	7040	.165	.40	.14	2.8:1
Winter Dormant	50	40	8.3	2.6	3769	1021	40.8	20.8	1430	.054	.29	.15	1.9:1

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Table 21. Average chemical composition and digestibility of Western Wheatgrass at various stages of growth, collected at Manitou, Colorado on a Sandy Clay Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	84	85	15.1	11.5	4053	3218	22.3	16.2	30580	.071	.24	.18	1.2:1
Spring Leaf Growth 4 - 5 Leaves	87	88	16.7	14.5	4273	3777	25.4	21.8	13376	.091	.36	.28	1.3:1
Flowers in Boot	87	87	16.2	15.0	4281	3772	27.6	23.9	25740	.093	.37	.28	1.3:1
Heads Fully Out	68	68	11.0	9.1	4351	2946	30.9	19.9	21406	.071	.26	.20	1.2:1
Flowers at Anthesis	63	64	11.3	7.7	4316	2651	30.3	18.7		.143	.27	.21	1.2:1
Seeds Ripening	59	61	8.3	4.5	4512	2591	31.3	15.2	42680	.134	.25	.16	1.5;1
Plants Drying	60	60	6.8	3.6	4730	2827	32.8	18.3	------	.099	.28	.18	1.5:1
Plants Dorment	59	61	5.7	2.3	4523	2746	26.9	12.3	16060	.111	.27	.13	2.1:1
Fall Regrowth	57	66	7.0	4.9	4456	2877	34.2	22.8	------	.089	.44	.19	2.3:1
Winter Dormant	44	47	3.9	1.6	3934	1728	42.7	25.0	------	.055	.24	.17	1.4:1

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Table 22. Average chemical composition and digestibility of Thurber Fescue at various stages of growth, collected at BlackHawk, Colorado on a Mountain Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	89	83	17.1	14.3	4461	3750	31.8	26.8	20064.	.053	.22	.16	1.3:1
Spring Leaf Growth 4 - 5 Leaves	83	79	12.0	10.2	4493	3607	30.7	24.8	37400.	.059	.24	.16	1.4:1
Heads Fully Out	78	75	11.3	8.7	4532	3430	31.8	23.7	48180.	.059	.22	.37	5.9:1
Flowers at Anthesis	70	58	6.5	3.0	4662	2856	32.3	18.5	60940.	.072	.33	.12	2.9:1
Seeds Ripening	73	61	5.6	3.9	4698	3033	34.2	21.3	64240.	.080	.32	.13	2.4:1
Plants Drying	73	63	5.8	3.9	4321	2662	34.8	22.1	40260.	.047	.11	.12	1.4:1
Plants Dormant	45	49	4.0	1.8	4250	2112	37.3	17.3	12848.	.046	.17	.09	1.9:1
Winter Dormant	31	35	2.3	1.0	4171	1301	42.7	18.6	------	.036	.12	.09	.85:1

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Table 23. Average chemical composition and digestibility of Fringed Sagebrush at various stages of growth, collected at Craig, Colorado on a Sandy Slopes Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
In Full Bloom	45	44	6.0	2.59	4114	1400	36.1	15.4	------	.424	.361	.093	3.8:1
Fruit Formed	51	55	10.5	4.81	4647	2366	31.0	15.1	------	.102	.392	.126	1.7:1
Fruit Ripe	50	54	5.0	2.10	4140	2103	32.3	16.6	------	.091	.451	.164	2.7:1
In Full Leaf	61	57	4.1	2.51	4199	2384	32.3	16.2	------	.100	.401	.203	1.9:1
Leaves Dropping	43	47	6.7	3.23	4240	1724	38.3	21.8	------	.096	.431	.190	2.2:1
Dormant	49	45	6.0	2.23	4362	2069	49.4	25.0	32120.	.099	.255	.088	2.8:1

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Table 24. Average chemical composition and digestibility of Rabbitbrush at various stages of growth, collected at Craig, Colorado on a Sandy Slopes Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Flower Buds Swelled	83	78	12.7	11.5	4598	3690	20.7	12.5	528.	.123	.80	.35	2.2:1
In Full Bloom	71	67	9.5	7.8	4730	3426	20.7	11.6	------	.200	1.14	.10	10.9:1
Fruit Formed	67	72	10.18	8.5	4730	3541	23.7	14.5	2244.	.181	1.53	.18	8.3:1
Fruit Ripe	64	70	8.9	7.4	4849	3314	25.6	16.6	------	.218	1.36	.13	10. :1
Fruit Dropped	62	60	9.0	5.5	4169	2411	26.3	17.3	------	.172	.82	.21	3.8:1
Leaf Buds Swelled	51	54	8.9	4.9	3662	2793	33.8	11.8	13486.	1.86	1.29	.10	12.2:1
In Full Leaf	53	54	5.6	3.8	3665	1518	37.5	17.4	20240	.083	.88	.13	6.5:1
Leaves Dropping	56	63	6.9	5.0	3645	2161	30.6	18.6	------	.160	1.14	.15	7.2:1
Dormant	59	60	6.0	4.8	3422	1793	42.3	29.0	------	.107	1.04	.10	10.0:1

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Table 25. Average chemical composition and digestibility of Antelope Bitterbrush at various stages of growth, collected at Craig, Colorado on a Sandy Slope Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Flower Buds Swelled	65	63	8.4	6.3	3576	2160	21.1	10.0	7700.	.100	.89	.23	3.7:1
In Full Bloom	65	68	6.9	5.2	4626	3022	22.0	11.0	12122.	.100	.90	.24	3.7:1
Fruit Ripe	91	84	4.5	3.4	4785	3947	19.9	16.7	-----	.101	.92	.26	3.4:1
Fruit Dropped	69	65	5.3	5.8	4821	3096	20.0	10.8	------	.159	.96	.10	9.1:1
In Full Leaf	48	49	7.1	4.9	4943	2577	34.5	14.0	704	.066	.41	.13	3.1:1
Leaves Dropping	43	49	8.9	5.9	4893	2455	33.2	15.3	------	.135	.99	.17	5.5:1
Dormant	46	49	8.1	6.0	4135	2425	34.3	21.3	8030.	.094	.52	.19	3.8:1
Fall Regrowth	51	53	8.5	6.5	3719	1920	35.7	19.5	------	.108	.71	.22	3.1:1

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Table 26. Average chemical composition and digestibility of Western Wheatgrass at various stages of growth, collected at Nunn, Colorado on a Sandy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	68	64	8.4	5.9	4055	2675	35.1	22.6	125,180	.083	.20	.10	1.9:1
Spring Leaf Growth 4 - 5 Leaves	78	72	10.2	7.1	3943	2776	30.4	19.1	39,600	.089	.21	.11	1.8:1
Heads Fully Out	74	71	9.3	7.4	4037	2801	28.6	20.0	------	.090	.22	.11	1.9:1
Flowers at Anthesis	76	65	6.6	4.2	4185	2634	30.5	17.2	------	.093	.26	.13	1.9:1
Heads Being Disseminated	47	49	6.8	4.0	3996	1864	32.6	14.5	------	.061	.21	.15	1.3:1
Plants Dormant	55	59	7.5	2.8	4017	2264	30.2	16.4	------	.076	.32	.19	1.6:1
Fall Regrowth	50	55	5.4	4.5	4287	2368	31.2	17.7	------	.041	.20	.13	1.4:1
Winter Dormant	46	48	5.2	1.8	4193	1991	31.3	14.4	------	.069	.24	.14	1.7:1

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Table 27. Average chemical composition and digestibility of Fourwing Saltbrush at various stages of growth, collected at Nunn, Colorado on a Sandy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Flower Buds Swelled	66	71	15.2	11.2	4016	2877	22.0	12.8	19,272	.401	.69	.16	4.2:1
Fruit Formed	81	77	10.3	7.8	4137	3191	22.4	15.0	------	.521	.89	.17	5.1:1
Fruit Ripe	66	61	9.0	7.0	4126	2546	21.2	8.9	------	.532	1.08	.19	5.6:1
Leaf Buds Swelled	50	45	7.4	2.9	4016	2452	33.1	9.3		.194	.56	.07	7.6:1
In Full Leaf	53	62	7.3	5.9	4123	2386	36.2	21.1	------	.367	.79	.22	3.5:1
In Fall Color	58	60	5.8	3.1	4381	2734	38.1	20.7	------	.400	.91	.13	6.7:1
Dormant	41	40	5.2	1.6	4163	1879	36.8	12.6	------	.192	.72	.06	11.2:1

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Table 28. Average chemical composition and digestibility of Blue Grama at various stages of growth, collected at Nunn, Colorado on a Sandy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Spring Leaf Growth 1 - 3 Leaves	65	62	4.5	2.9	3927	2299	33.5	22.1	8,030	.078	.37	.09	4.0:1
Spring Leaf Growth 4 - 5 Leaves	80	73	8.3	5.6	4130	2895	27.2	19.4	35,420	.081	.38	.12	3.0:1
Flowers at Anthesis	73	68	9.2	7.5	4197	2781		16.0		.123	.37	.12	2.9:1
Seeds Being Disseminated	56	59	5.5	2.4	4213	2442	20.1	6.1	------	.062	.35	.16	2.1:1
Plants Drying	42	43	5.2	2.1	4179	1842	23.1	4.8	------	.056	.28	.14	1.9:1
Plants Dormant	53	47	8.4	5.3	4112	1777	20.6	6.3	------	.155	.34	.12	2.7:1
Winter Dormant	43	44	4.0	2.5	4106	1824	33.1	12.9	------	.044	.20	.13	1.5:1

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Table 29. Average chemical composition and digestibility of Scarlet Globemallow at various stages of growth, collected at Nunn, Colorado on a Sandy Loam Range Site in 1971.

Phenological Stage Grass	Dry Matter Diges-tibility	Organic Matter Diges-tibility	Protein %	Diges-tible Protein %	Energy Cal/gm	Diges-tible Energy Cal/gm	Cellulose %	Digestible Cellulose %	Vitamin A in I.U. per kilogram	Magnesium in Percent	Calcium in Percent	Phosphorus in Percent	Calcium Phosphorus Ratio
Early Leaf Growth	65	76	8.9	7.2	4045	2975	22.4	15.1	25,740	.173	2.06	.15	13.5:1
In bloom	88	79	9.2	8.1	4394	3486	21.2	15.3	48,180	.182	2.13	.17	12.4:1
Seed Ripening	84	80	12.8	10.7	4401	3496	22.6	16.8	------	.193	2.13	.18	11.7:1
Seed Disseminating	92	78	12.9	10.1	4574	3625	28.9	21.1	------	.203	2.12	.10	19.2:1
Fall Regrowth	71	71	10.1	8.0	4361	3189	35.3	25.9	------	.137	2.31	.15	14.5:1
Dry or Dormant	71	74	8.0	6.6	4326	3159	36.4	25.0	------	.197	2.75	.15	17.7:1