AN ABSTRACT OF THE THESIS OF

Dennis Patrick Sheehy for the degree of Master of Science

in Rangeland Resources presented on May 4, 1975

Title: RELATIVE PALATABILITY OF SEVEN *ARTEMISIA* TAXA TO MULE DEER AND SHEEP

Abstract approved: Redacted for privacy

Dr. A. H. Winward

The objectives of this study were (1) to establish relative animal preference for seven sagebrush taxa, (2) to evaluate animal preference relative to seven sagebrush taxa of common genetic origin but collected from three different geographical areas and (3) to determine the influence of selected chemical constituents present in the sagebrush taxa relative to animal preference and nutritive value.

Sagebrush taxa used in this study included *Artemisia arbuscula* (low sagebrush), *A. cana* ssp. *bolanderi* (Bolander silver sagebrush), *A. nova* (black sagebrush), *A. tridentata* ssp. *tridentata* (basin big sagebrush, *A. tridentata* ssp. *vaseyana* (mountain big sagebrush), *A. tridentata* ssp. *wyomingensis* (Wyoming big sagebrush and *A. tridentata* f. *xericensis*[1/] (foothill big sagebrush).

1/ This taxon of big sagebrush, although not officially recognized, was encountered by Winward (1970).

Sagebrush taxa were collected live from three locations in eastern Oregon. Frequency information was collected at each site and arranged into an association table to assist in site identification. Collected sagebrush plants were used in Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) and sheep selectivity trials conducted during the winter and fall of 1974.

Mule deer selectively browsed the sagebrush which allowed separation of the taxa into high, intermediate and low relative preference indices. In general, it appeared that mule deer preferred foothill and mountain big sagebrush, Bolander silver sagebrush and low sagebrush. Deer utilized but did not prefer Wyoming and basin big sagebrush and showed least preference for black sagebrush.

Sheep showed less inclination to utilize the sagebrush taxa and only removed measurable quantities in the absence of other food sources. In general, sheep showed highest preference for Bolander silver sagebrush, low sagebrush and mountain and foothill big sagebrush; moderate preference for black sagebrush and low preference for Wyoming and basin big sagebrush.

Mule deer and sheep utilization of sagebrush appeared to be relatively unaffected by differences associated with collection area.

Current year's growth of low and black sagebrush had the lowest volatile oil content of the seven taxa. Foothill big sagebrush had the lowest volatile oil content of plants in the big sagebrush group. Volatile oil content, in general, appeared to have only a minor, negative influence in determining both mule deer and sheep utilization. Specific volatile oil fractions, however, appeared to have more influence (positive or negative) on animal utilization. Fractions having a negative influence appeared to be highest in sagebrush taxa which were among the least preferred.

Vegetation samples obtained seasonally from sagebrush in the field showed decreasing amounts of volatile oils for all taxa during the spring except for low and black sagebrush which increased in volatile oil content. During the summer, all taxa showed increasing volatile oil content except low and black sagebrush which decreased. This trend continued in the fall except for Bolander silver sagebrush which showed decreased volatile oil content during the fall.

The only consistent trend found in nutrient analyses of sagebrush taxa was a lower content of crude protein, acid detergent fiber and acid detergent lignin in foothill and mountain big sagebrush compared to Wyoming and basin big sagebrush. There was essentially no relationship between these variables and animal utilization.

In vitro digestibility of sagebrush was relatively high for all taxa though samples had variable volatile oil content. The deleterious effect of volatile oils on rumen microorganisms found by some researchers was discussed.

This study differed from most previous studies of animal preferences for sagebrush taxa in that (1) taxa were separated into refined taxonomic levels, (2) "relative preference" was studied and (3) trials were conducted in an "artificial" setting.

Information obtained was felt to contribute substantially to understanding of mule deer and sheep preference since animals utilized the sagebrush taxa nearly the same regardless of collection area or season of use. This information will also allow the field manager to incorporate into his total management plan the relative forage value of each taxon. This is especially important in areas where sagebrush control or game forage improvement programs (including seeding of sagebrush taxa) are being contemplated.

Relative Palatability of Seven *Artemisia* Taxa to Mule Deer and Sheep

by

Dennis Patrick Sheehy

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1975

APPROVED:

Redacted for privacy

Assistant Professor of Rangeland Resources Program
in charge of major

Redacted for privacy

Acting Director, Rangeland Resources Program

Redacted for privacy

Dean of Graduate School

Date thesis is presented May 6, 1975

Typed Ilene Anderton and Lyndalu Sikes for Dennis Patrick Sheehy

ACKNOWLEDGEMENTS

I wish to extend my thanks and sincere appreciation to Dr. Al Winward for his invaluable assistance, constructive criticism and inspiration in all phases of the research presented in the manuscript.

I also wish to thank the members of my committee, Dr. David C. Church, Dr. Roger K. Fendall, Dr. Robert L. Jarvis and Dr. William C. Krueger for their comments and suggestions for improvement of this thesis.

I am deeply indebted to the Oregon Wildlife Commission for providing technical and material assistance in capturing, transporting and maintaining the mule deer used in this study.

Numerous fellow graduate students during the two years of this study have cheerfully and willingly assisted in collection and transportation of sagebrush plants used in the animal selectivity trials. To them, I am sincerely grateful.

I wish to thank the members of my family for their assistance and encouragement throughout my graduate study. I especially wish to thank my wife, Marcia, who gave unmeasurable assistance through her typing, encouragement and understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

RELATIVE PALATABILITY OF SEVEN *ARTEMISIA* TAXA TO MULE DEER AND SHEEP

INTRODUCTION

Sagebrush (*Artemisia* spp.) is one of the most widely distributed and abundant shrubs of the western United States. Many people associated with western rangelands view this plant as an undesirable shrub.

However, the importance of sagebrush to domestic and wild animals has led to the realization that knowledge of the environmental requirements and quality and quantity of forage produced in specific sagebrush environments is essential if sagebrush ranges are to be maintained or rehabilitated (Cook and Harris 1950; Holmgren and Basile 1959; Dietz 1965; Klemmedson 1967; Plummer et al. 1968).

At the present time, confusion exists regarding which sagebrush taxa are preferred by animal consumers and what factor(s) determine the degree of animal preference for a particular taxon in a specific environment. Bedell (1973) summarized the demand for this information in his observation "that different sagebrush taxa exist along with different management possibilities for each taxon and that only when information becomes available as to palatable or non-palatable sagebrush taxa will the best management become possible for shrub dominated areas".

This study was designed to evaluate relative animal preference for seven sagebrush taxa through selectivity trials and chemical analysis. The seven taxa studied include:

1. A. arbuscula Nutt. - low sagebrush (Lo)
2. A. cana ssp. bolanderi (Gray) Ward - Bolander silver sagebrush (Bo)
3. A. nova Nelson - black sagebrush (Bl)
4. A. tridentata ssp. tridentata Nutt. - basin big sagebrush (Ba)
5. A. tridentata ssp. vaseyana (Rydb.) Beetle - mountain big sagebrush (Mo)
6. A. tridentata ssp. wyomingensis Beetle - Wyoming big sagebrush (Wy)
7. A. tridentata f. xericensis[1] - foothill big sagebrush (Fo)

Nomenclature follows Beetle (1960), Beetle and Young (1965) and Winward (1970). The identification letters were assigned for convenience of presentation in tables, figures and appendices.

Research of the type envisioned in this study is essential if management decisions concerning sagebrush dominated areas of the western United States are to be ecologically and economically sound. The objectives of this study were:

1. To establish relative animal preference for seven sagebrush taxa.

---

[1] This taxon of big sagebrush was encountered by Winward (1970). He refers to it as "form xericensis" although it is not an officially recognized taxon at the present time.

2. To evaluate animal preference relative to sagebrush taxa of common genetic origin but collected from three different geographical areas.

3. To determine the influence of selected chemical constituents present in the sagebrush taxa relative to animal preference and nutritive value.

DESCRIPTION OF STUDY AREA

Location

Three general locations were selected for study as being representative of the diverse areas in which sagebrush taxa are found in Oregon. These locations were: (1) the general vicinity of Silver Lake, Oregon, (2) on or near the Squaw Butte Experimental Range near Burns, Oregon and (3) in the general vicinity of Baker, Oregon. These locations are identified for subsequent references as Area 1, Area 2 and Area 3, respectively. These widely separated areas were selected in an attempt to determine if different environmental characteristics in an area affect animal preference for sagebrush taxa.

All seven sagebrush taxa involved in the study occurred in Area 1. Black sagebrush was not located in either Area 2 or Area 3 and Bolander silver sagebrush was not located in Area 3. Plants of these taxonomic units were obtained from locations near Burns Junction, Oregon. Low sagebrush was also missing from Area 3 and was collected from a stand southeast of Prineville, Oregon (Figure 1).

Climate

The climate of Oregon east of the Cascade Mountains is characterized by warm summers with usually cool nights and wet

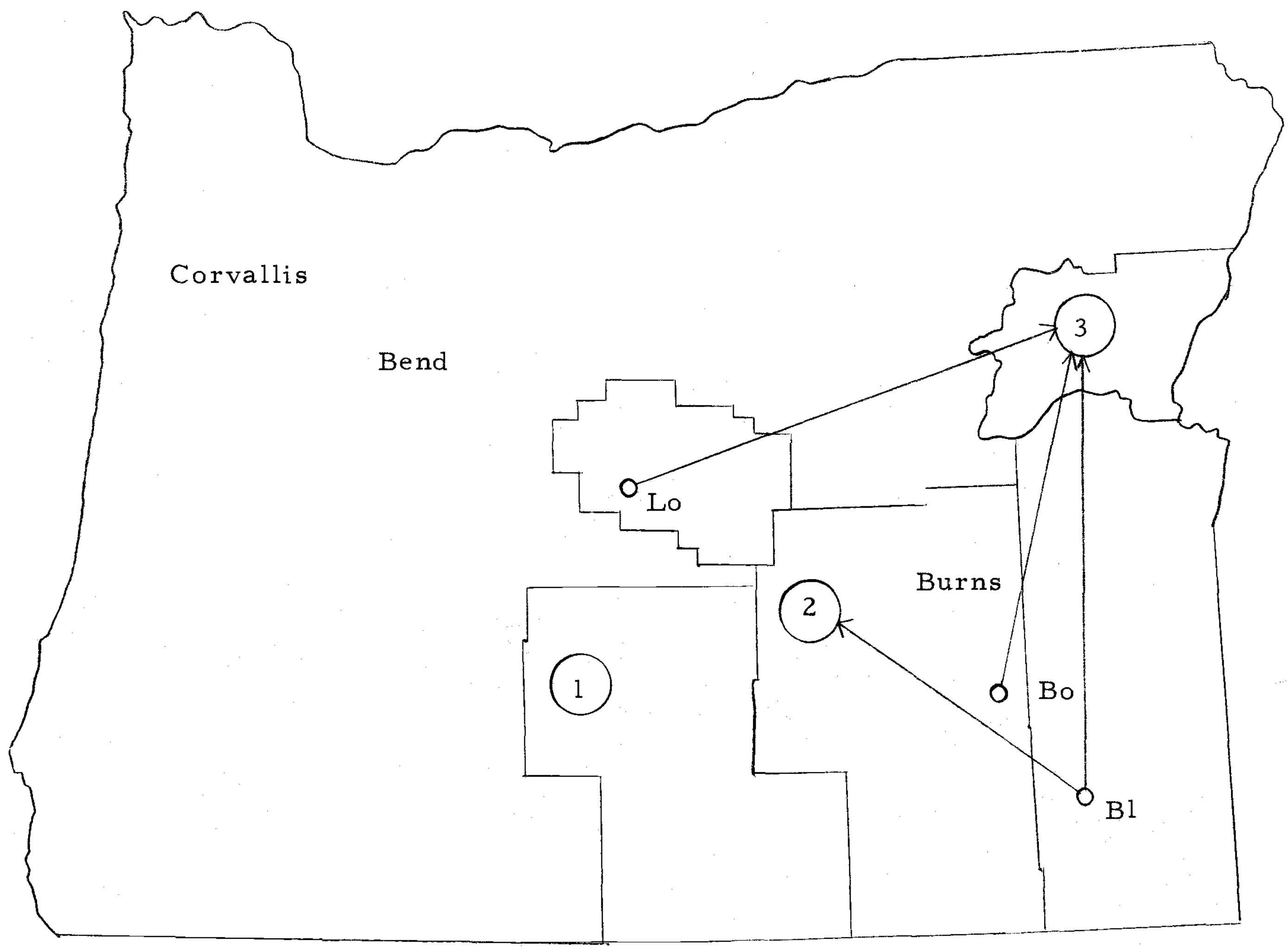

Figure 1. Collection locations for the sagebrush taxa. Those taxa not present in the collection area were obtained from other locations as shown.

winters. Precipitation usually occurs as snow during the winter months although a significant amount of rainfall may occur during April, May and June. Oregon State University (1963) lists the mean annual precipitation for the five locations from which Artemisia samples were obtained as: (1) Silver Lake - 9.7", (2) Squaw Butte Experimental Station - 11.8", (3) Burn's Junction - 8.9", (4) Baker - 8.5" and (5) Prineville Reservoir - 9.4".

Vegetation

Steppe and shrub-steppe communities dominate the Basin and Range, High Lava Plains, Owyhee Uplands provinces and the portion of the Blue Mountain province from which sagebrush taxa was collected. Sagebrush communities are the dominant vegetation in the shrub-steppe with an understory of bunchgrasses. Major sagebrush species found are big sagebrush (*Artemisia tridentata*) on deeper soils, low sagebrush (*A. arbuscula*) on shallow stony soils, scabland sagebrush (*A. rigida*) on very shallow soils and silver sagebrush (*A. cana*) on moist habitats (Franklin and Dyrness 1973).

Black sagebrush (*A. nova*), although relatively limited in occurrence, is generally found adjacent to Salt Desert Shrub communities in the Basin and Range, High Lava Plains and Owyhee Uplands provinces in the extreme southeastern portion of Oregon (Winward 1973).

Geology and Topography

The Basin and Range province and the Owyhee Uplands province from which the Area 1 and the Burn's Junction sagebrush taxa were obtained are similar geologically but differ in topography. The former is characterized by fault-block mountains enclosing basins with internal drainage while the latter is drained by the Owyhee river.

In the western portion of the Basin and Range province, the rocks consist largely of basaltic flows, pyroclastics and alluvial sediments. Further east, the two prominent rock assemblages are Miocene flows of rhyolite, dacite, andesite, altered basalt and andesite flows and tuffs overlain by tuffaceous sedimentary rocks. In the Owyhee Uplands province, Miocene and Pliocene beds of tuffaceous sedimentary rocks are capped by flows of rhyolite and basalt (Franklin and Dyrness 1973).

Area 2 sagebrush taxa were obtained from the High Lava Plains province. This province is characterized by young lava flows of moderate relief interrupted by scattered cinder cones and lava buttes. Geologic formations consist largely of Pliocene and Pleistocene lavas, tuffs and alluvium with Quaternary valley fill deposits overlying older lava flows in many areas (Franklin and Dyrness 1973).

The Blue Mountain province, from which Area 3 and the Prineville sagebrush taxa were obtained, is characterized in its western unit by Paleozoic formations of limestone, mudstone, and sandstone which outcrop along tributaries of the upper Crooked river. The eastern unit spans a large part of geologic time with Paleozoic formations of the Permian period widespread near Baker and Sumpter. These formations consist of schists, limestone, slate, argillite, tuft and chert (Franklin and Dyrness 1973).

Soils

Soils in the Basin and Range province and the Owyhee Uplands province from which the Area 1 and Burns Junction sagebrush taxa were obtained are dominantly Haplargids and Durargids. The Haplargids are derived from basalt and generally have a very stony loam surface horizon underlain by either a clay or stony loam subsoil. The Durargids are also developed on basaltic parent materials and are characterized by a very stony loam surface horizon over a clay subsoil. A silica-cemented hardpan is present at 2 to 5 decimeters. Ancient dry lakebeds in the area have deep silty lacustrine deposits. Principal well-drained soil groups are Camborthids, Duargids and Durorthids. Poorly drained soils are most often Haploquolls and Haplaquepts (Franklin and Dyrness 1973).

The soils of the High Lava Plains province, from which the Area 2 sagebrush taxa were obtained, support shrub-grassland vegetation and are deeply mantled with Camborthids, Haplargids and Durargids. Camborthids found in the central portion are formed in pumice and water laid material and are deposited in layers 1/2 to 1 meter thick over basalt bedrock. Haplargids, the most widely distributed, are derived from basalt or tuff and most commonly have very strong loam textures. Durargids are similar but have silica-cemented hardpans at depths of about 1/2 meter (Franklin and Dyrness 1973).

Soils of the Blue Mountain province, from which the Area 3 and Prineville sagebrush taxa were obtained, are grouped into two main units. One group at moderate to high altitudes is formed under predominately forest vegetation. The soils at lower elevations formed under grassland or shrub-grassland vegetation.

Soils in the forested areas are mainly Vitrandipts and Fragiorthods which most often are developed from moss and tend to be deep with a silty loam texture. Grassland and shrub-grassland soils in the eastern section of the province are Arixerolls which developed from loess and basic ignious rocks. They tend to have silt loam surface horizons and clay loam subsoils (Franklin and Dyrness 1973).

LITERATURE REVIEW

Importance of Site

Sagebrush occurs discontinuously as the dominant or partial dominant on over 1/3 of the United States west of 102° west longitude (Beetle 1960). In the past, most of the research involved with this important shrub has been based on recognition at the species level. Recent research, however, has shown that species, subspecies and forms of sagebrush exist, each with their own environmental requirements and value as forage and cover (Beetle 1960; Beetle and Young 1965; Tisdale et al. 1969; Winward 1970; Hanks et al. 1971; Brunner 1972; Hanks et al. 1973).

Recognition of sagebrush based on refined taxonomic levels is essential to understand and manage sagebrush rangelands for optimal use by livestock and game animals. Cook and Harris (1950) found that different sites affected the nutrient content of plants and plant parts through differences in the stem to leaf ratio of the plants studied. Plummer et al. (1968) recognized that each geographic area has a distinctive type of big sagebrush with variation in palatability, growth form, seed production and resistance to insect attack. They found that palatability of black sagebrush varied according to the specific area in which it was growing. Daubenmire (1968) noted that each species present in a habitat type exerted individual modifying influences on the micro and macro environment of other plant species in the habitat type. Winward (1970) found that differences in soil, moisture, elevation and temperatures existed between habitat types of big sagebrush. These differences had a modifying influence on plants of each habitat type. Habitat types had different dominant species, total number of species and different species composition. Findley (1974) found that four habitat types of big sagebrush responded differently to sagebrush control treatments.

Factors Affecting Animal Utilization

Many different factors appear to have a role in determining animal preference for and utilization of forage. Studies involving impairment of sensory perception in animals (smell, touch, taste and sight) have shown that animals rely heavily on these senses, either singularly or in combination, in making their selection (Tribe 1949; Tribe 1952; Arnold 1966a; Arnold 1966b; Longhurst et al. 1968; Krueger et al. 1974).

Crawford and Church (1971) found that selection varies between and within animal species. Deer showed preference responses to sweet, sour and bitter tastes while sheep generally showed only preference to high concentrations of sugar.

Preference displayed by any animal also varied according to plant association, type of growth, weather conditions, intensity of grazing and general activity and whims of the animal (Cook and Stoddart 1953).

Seasonal changes in plant constituents may influence animal preference. Some plant species may have concentrations of chemical constituents that always elicit relatively acceptable or unacceptable taste and smell responses in animals (Arnold 1966b).

Utilization of Sagebrush By Deer

Numerous publications refer to mule deer use of sagebrush as forage on winter ranges. The general consensus appears to be that sagebrush is a favorable and, in many cases, an essential component of mule deer winter ranges. The two species of sagebrush most often mentioned as being utilized by deer are big sagebrush and low sagebrush.

Two trends in sagebrush utilization by deer are evident in the literature. One is that the heaviest use of sagebrush, principally big sagebrush, is during the winter months. Samples from rumen contents indicated deer first began to utilize sagebrush in October or November, increased consumption in the December through March period (to as high as 80 percent of the diet) and decreased consumption in the spring as other plant species became available (Julander

1952; Lassen et al. 1952; Smith 1952; Dasmann and Blaisdell 1954; Julander 1955; Leach 1956; Wilkens 1957; Richens 1967; Trout and Thiessen 1968; Bayless 1971; Anderson et al. 1972). The second trend was that deer consumed large quantities of sagebrush only when other browse species were available (Smith 1950; Smith and Hubbard 1954; Dietz and Yeager 1959; Smith 1959; Dietz et al. 1962).

Several recent publications described utilization of big sagebrush by deer on a refined taxonomic unit basis. Hanks et al. (1971) observed considerable variation in deer use of transplanted big sagebrush plants. Mountain big sagebrush plants were grazed to an average of 60 percent with non grazed less than 40 percent and some more than 80 percent. Hanks et al. (1973), working with the same plants as in 1971, reported that one taxonomic unit (possibly analogous to the taxon described by Winward in 1970 as foothill big sagebrush) was grazed by deer an average of 83 percent. They also reported Wyoming big sagebrush was heavily grazed while basin big sagebrush received only light utilization.

References to mule deer use of other sagebrush taxa is limited. Julander (1952) and J. Smith (1952) found only limited quantities of silver sagebrush (no subspecies designation) in the rumen of mule deer. A. Smith (1952) reported during a preference trial mule deer ate very little black sagebrush. Trout and Theissen (1968) reported occurrence of low sagebrush in mule deer rumen samples with maximum occurrence in February (11 percent of the diet).

Utilization of Sagebrush by Sheep

Several publications involving study of winter ranges in the Great Basin have mentioned utilization of sagebrush by sheep. Big sagebrush and black sagebrush are the two taxa most often associated with sheep use. Green et al. (1951) found utilization on black sagebrush to be as high as 65 percent with heavy use by sheep on all areas where it was present. Cook et al. (1952) stated that sheep eat current year's growth of black sagebrush and big sagebrush for approximately a week upon reaching the winter range. Later in the season, twigs and stems are consumed with current year's growth possibly in order to reduce the burning taste of volatile oils. Cook et al. (1954) reported that big sagebrush, although the least palatable species studied, was good winter forage for sheep when occurring with normally associated grasses and shrubs. Black sagebrush was considered an excellent forage plant for sheep and was grazed during the winter, especially in mixed stands. Smith (1966) found that sheep fed sagebrush during *in vivo* digestibility trials would not consume any appreciable amount if sagebrush was fed alone.

Springfield (1960) stated that big sagebrush present on two experimental paddocks of crested wheatgrass (*Agropyron desertorum*) received 80 and 79 percent utilization over a two year period. He also reported 82 and 74 percent utilization by sheep on silver sagebrush in the same study.

Volatile Oils

Literature pertaining to volatile oils of sagebrush is limited, even though research on volatile oils has been extensive for other plant species. Consequently, only the most pertinent results from work on species other than sagebrush will be included in this review.

Chemical Constituents

Loomis (1967) stated that volatile oils are a mixture of structurally related monoterpenes and are characteristically products of plants. Composition of the monoterpenes varied between locations and seasons. Whittaker and Feeny (1971) reported that volatile oils are monocyclic and bicyclic monoterpenoids that are offshoots of metabolic pathways. Oh et al. (1967) found that volatile oils from Douglas fir (*Pseudotsuga menziesii*) could be subgrouped into monoterpene hydrocarbons, sesquiterpenes and oxygenated monoterpenes.

Adams and Oakberg (1934) used steam distillation to fractionate the oil of big sagebrush into 5 percent artemisol, 20 percent a-pinene, 7 percent cineol, 40 percent 1-camphor, 12 percent unidentified sesquiterpenes and 16 percent resins.

Function In Plants

Adams and Billinghurst (1927) suggested that volatile oils of sagebrush serve as a protection against rapid temperature changes and evaporation of water. Volatile oils were found only in the leaves and young shoots of plants and oil content increased from early spring until late summer. Nagy and Tengerly (1967) reported that volatile oils of sagebrush appeared to be affected by genetic variations within plant species and by microclimate and macroclimate.

Powell (1968) found that volatile oils of big sagebrush appeared to be directly related to the vigor of the plant and the site upon which the plant was growing. Although subspecies were not distinguished, he found that big sagebrush plants with low oil content (as low as 3.5 percent) were found on very shallow, highly calcareous and rocky soils. Plants with high oil content (as high as 6.0 percent) were found on deep, sandy loam soil with low lime content. Big sagebrush plants did not appear to increase in volatile oil content after the growing season. He also found that volatile oil content of black sagebrush averaged 2.5 percent and silver sagebrush 2.6 percent. Adams and Billinghurst (1927) steam distilled samples of big sagebrush collected at different seasons and obtained a yield of oil between 0.3 and 0.92 percent. Bissel et al. (1955) collected a yield of 12 percent volatile oils from steam distilled big sagebrush samples. Smith (1966) found that volatile oil yield from steam distilled samples of big sagebrush varied from 15.4 μl/g (O.D.) in April to 26.3 μl/g (O.D.) in August.

Effect On Other Plants

Volatile oils present in the leaves and leaders of aromatic shrubs have been found to have an allelopathic effect on associated herbs and grasses when leached into the soil. Effects include: inhibition of seed germination, retardation of shoot and root development and even death of associated species after long exposure (Evenari 1961; Reid et al. 1963; Whittaker and Feeny 1971).

Effect On Rumen Microorganisms

Considerable evidence indicated the deleterious effect of volatile oils on rumen microorganisms. Maruzzella and Lichtenstein (1956) found that 100 out of 110 volatile oils from plants tested exhibited antibacterial spectrum for both gram positive and gram negative organisms. Dietz (1965) suggested that not only are volatile oils indigestible but that they are harmful to rumen microorganisms and impair rumen function. Oh et al. (1967) reported that three subgroups of volatile oils increased or decreased microbial activity according to their concentration ratio. Monoterpene hydrocarbons and sesquiterpenes promoted sheep and deer rumen microbial activity while oxygenated monoterpenes consistently inhibited rumen microbial activity. At low levels of oil, inhibitory components were not sufficient to offset promoting effects. At higher levels, the inhibitory groups were sufficiently high to have a net negative effect. He also found that deer were capable of increasing tolerance levels to inhibitory components if exposed to low amounts for a sufficient length of time.

Volatile oils isolated from big sagebrush have been found to be one of the most potent inhibitors of deer rumen microorganisms. The relationship between lack of voluntary consumption of plants from which the oils were extracted and the antibacterial action of the oils has been explained on the basis of (1) antibacterial chemical components which cause a reduction in organism activity and (2) reduced activity which results in prolonged rumen retention time (Longhurst et al. 1968; Oh et al. 1968). Smith (1966) suggested that volatile oils may have a selective effect on microbial activity since *in vitro* digestion of sagebrush did not appear to be affected although additional volatile oils had been added to the substrate. He felt that the volatile oils might impair organisms that are not required for the fermentation of sagebrush. Warner (1968) stated that minor plant constituents such as terpenes and alkaloids may have a specific effect upon individual species of sheep microorganisms.

Chromatography Of Volatile Oils

Thin layer chromatographic (TLC) separation of sesquiterpene lactone pigments found in sagebrush volatile oils has been used to identify different taxonomic units. Identification was made by comparing Rf values of pigments from unidentified taxa with Rf values of pigments of previously identified taxa (Irwin and Geissman 1969; Shafizadeh et al. 1971; Kelsey et al. 1973; Shafizadeh and Bhadane 1973).

Volatile oils extracted from aromatic plants have been useful in determining seasonal and biological variations and phylogenetic relationships through gas liquid chromatography (GLC). This process is also a feasible method for characterizing and quantifying the chemical components of volatile oils and determining chemical characters suitable for inclusion in taxonomic analysis (von Rudloff 1961; von Rudloff 1962a; von Rudloff 1962b; DeWet and Scott 1965; Vasek and Scora 1967; Loomis 1967; Flake et al. 1969).

Nutrients in Sagebrush

Results from several studies on the nutrient composition of big sagebrush appear to be in general agreement as to protein and fiber content. Variation that does exist may partially be a reflection of species variation and site-factor influences.

Kinney and Sugihara (1943) reported that crude protein and crude fiber content of the leaves of big sagebrush were 11.2 percent and 27.9 percent, respectively. Cook et al. (1952) stated that big sagebrush contained 9.0 percent crude protein. Several studies reporting on the seasonal variation in crude protein and crude fiber have shown the highest crude protein and lowest crude fiber content to be during the green succulent stage of growth (Cook and Harris 1950; Farrel and Leach 1952; Bissel and Strong 1955; Hamilton 1958; Dietz et al. 1962; Smith 1966; Hickman 1966; Trout and Thiessen 1968).

Trout and Thiessen (1968) found that low sagebrush followed the same seasonal trend as big sagebrush, but that crude protein was relatively lower and crude fiber relatively higher.

Crude protein content of black sagebrush appeared to be approximately 8.8 percent (Esplin et al. 1937; Cook and Harris 1950; Cook et al. 1952).

Digestibility of Sagebrush

Nagy et al. (1964) found that feeding sagebrush *in vivo* to a steer caused a decrease in rumen moisture, decrease in rumen motility, a decrease in appetite and caused a reddish tint in the feces on the third day. Dietz et al. (1962) reported a coefficient of digestion of 52.4 percent in big sagebrush fed to deer. Smith et al.

(1966) found the digestible dry matter (DDM) of big sagebrush was 54 percent. Volatile oil added to digestion flasks did not appear to affect the DDM of sagebrush except when high concentrations were added. Smith (1966) reported that in vitro digestibility of big sagebrush increased during the spring and then decreased in later summer. Hickman (1966) reported that the apparent digestibility of big sagebrush ranged from 44.1 percent (June) to 49.4 percent (September) in samples analyzed during one full season. Low sagebrush samples during this same period ranged from 36.9 percent (December) to 44.9 percent (September). Ward (1971) found that the average coefficient of digestion for big sagebrush was 53.1 percent and the volatile oil content did not appear to affect digestion.

In reviewing the literature, it became apparent that a discrepancy existed relative to the effect of sagebrush volatile oils on rumen microorganisms. Sagebrush fed in vivo in digestibility trials generally appeared to have a deleterious effect on the animal. It also appeared to be the consensus that volatile oils of sagebrush, when consumed in quantity, have an adverse affect on RMO's. In vitro digestibility trials, however, generally showed that sagebrush had high digestibility. No explanation for this difference was found although sample handling prior to analysis may have been a factor.

METHODS OF STUDY

Vegetation Analysis

Vegetation composition was sampled in each of the seven sagebrush sites selected within the study areas. Sampling was conducted during June and July, 1974. Three randomly located 100 foot line transects were used for sampling at each site. The only restriction in placing the transects was that each be located within the homogenous stand of vegetation. Data collected at each site included frequency of all herbacous species and density and cover of all shrub species.

Frequency

Frequency for all species were determined through use of 1 x 2 foot plots located every 10 feet along the transect. The rooted portion of the plant had to be at least partially within the plot to be included. Frequency data were then arranged into an association table in order to identify and name sites from which each sagebrush taxon was collected (Heddle 1933; Stearns 1958; and Tueller et al. 1972).

Cover and Density

Shrub cover in each site was obtained by using the line intercept method of determining foliage cover (Canfield 1941). Foliage area of each shrub (vertical projection of the canopy on the ground) was calculated by determining the portion of the 100 foot tape intercepted by each shrub species.

Shrub density at each site was obtained by visually counting the number of shrub plants occurring in a 3 x 100 foot belt located on one side of each transect (Brown 1954; Strickler and Stearns 1962). All shrubs were included that had at least a part of their rooted portion within this area.

Values for cover and density were used to construct an association table for shrubs.

Soil Analysis

Soil descriptions were made at each site. Soil characteristics measured included horizons, color, texture and structure.

Preliminary Selectivity Trial

A preliminary animal selectivity trial was conducted on the Soap Creek Pastures near Oregon State University in September, 1973. The purpose of this preliminary trial was to determine;

(1) the feasibility of using sheep as selectivity trial animals, (2) the number of sagebrush plants that were needed for each selectivity trial and (3) the best method for transplanting and transporting sagebrush.

Twenty-four Suffolk-Romney ewes accustomed to Western Oregon ranges were used in the trial. Twenty-eight sagebrush plants representing six taxonomic units were obtained from Area 1. The plants were placed on a 2.5 acre pasture in a stratified random arrangement and the ewes were allowed to select from the plants at will. Sampling of utilization took place after 4 hours, 120 hours and 288 hours of use.

Information on utilization values obtained from the preliminary selectivity trial was used for estimating optimum number of plants from each sagebrush taxa to use in the winter 1974 selectivity trials. These values were obtained by using Stein's Two Stage Sample procedure (Stein 1945).

Shrub Collection

Sagebrush plants were collected during the fall of 1973. A total of 476 sagebrush plants from seven taxonomic units were selected, transplanted into fiber pots and transported to Corvallis, Oregon. Criteria for selection of sagebrush plants was that they be as uniform in size as possible and small enough for easy transplanting and transportation.

The plants were removed from their natural environment in a manner that allowed the soil adhering to the root system to remain intact. In order to remove the plants, a circular trench was dug around the plants. When sufficient depth was reached, the tap root was severed by sliding a shovel beneath the soil-root system. The plant and soil were then placed immediately into the wood fiber pots. Immediate transplanting aided plant survival and also facilitated handling.

Prior to transportation to Corvallis, the sagebrush plants were watered to prevent dessication. Upon arrival in Corvallis, the plants were placed in a common location. Collection of plants was completed by December, 1973.

A plant tagging system was established by labeling each fiber pot with white paint. This label included: (1) a numeral indicating the area in Oregon from which the plant originated, (2) a letter identifying the plant by taxonomic unit, (3) an individual observational number and (4) a letter signifying which animal selectivity trial the plant was to be used in. As an example the nomenclature "IA1S" signified that this particular sagebrush plant came from Area I, was low sagebrush, was the first observation for that taxonomic unit from Area I and was to be used in the sheep selectivity trials.

Shrub Sampling Design

A total of 399 sagebrush plants were used in the animal selectivity trials. Prior to the selectivity trials, the canopy of each sagebrush plant was mentally divided into two sections. The base of all branches in one section were color coded with waterproof ink in order to be able to distinguish the two sections during the selectivity trials. The unmarked section of the plant was used to obtain current year's growth samples for determining plant production and for use in volatile oil distillation. The marked section of the plant in effect became the "plant" during the animal selectivity trials and was used for obtaining utilization measurements.

Production

Production values for each of the seven sagebrush taxa were obtained for each area of origination. Fifteen randomly selected lateral and terminal leaders (with leaves) were removed from the unmarked section of each plant. These samples were weighed immediately on a Mettler balance to obtain green weight values for each sagebrush plant. After being oven dried at 110^{o} C for 24 hours, they were reweighed to obtain dry weight values. Mean oven dry weight values were then obtained for all sagebrush taxa on an area basis. Weight values were used for computing relative composition of the seven sagebrush taxa on a gram-weight basis present during the utilization period.

Utilization

Animal use on current year's growth of each sagebrush plant was calculated by visual count of the current year's leader and leaf growth on the marked section of the sagebrush plant prior to the selectivity trials. Subsequent counts were obtained at three designated intervals during the selectivity period. Percent utilization for each period of use was obtained for each plant by using the formula from Cassidy (1941):

$$\%\ \text{Utilization} = \frac{\#\ \text{leaders removed}}{\#\ \text{total leaders}} \times 100$$

Percent Composition

Percent composition of the current year's growth available on each taxonomic unit was calculated by multiplying oven dry weight values of each taxonomic unit by total number of current year's leaders available.

Relative Preference Index (RPI)

Percent composition and percent utilization values were used to construct a relative preference index (RPI). Percent diet was determined in the following manner (Laycock et al. 1972):

$$\% \text{ diet} = \frac{\% \text{ utilization x } \% \text{ composition}}{\Sigma\ (\% \text{ utilization x } \% \text{ composition})}$$

Animal preference for each sagebrush taxon was then evaluated by period of use for (1) areas, (2) trials (individual and combined) and (3) type of animal used in the trial, using a relative preference index (Van Dyne and Heady 1965):

$$\text{RPI} = \frac{\% \text{ diet}}{\% \text{ composition}}$$

RPI is indicated by the ratio between percent composition of each sagebrush taxonomic unit in the animals diet and percent composition of each sagebrush taxa used in the selectivity trial.

Volatile Oil Samples

Samples of current year's growth were obtained from the unmarked section of the plant for use in volatile oil distillations. Total current year's growth was not removed from both halves of the sagebrush plants as it was theorized that the regrowth factor might influence animal preference. Samples were placed in plastic bags and frozen until distillation.

Mule Deer Selectivity Trials

Location and Facilities

Mule deer selectivity trials were conducted at the E. E. Wilson Game Management Area near Corvallis. Two deer pens and a game corral were made available by the Oregon Wildlife Commission for the duration of the trials. During the selectivity trials, the game corral and one pen were used as holding pens for the mule deer. The other pen was used as the trial area.

Animals

Nine Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) were trapped on the Steen's mountain winter range in January, 1974. The mule deer were obtained with the cooperation of the Oregon Wildlife Commission which provided assistance in capturing the animals and a truck for transporting them to Corvallis. Mule deer selected for the trials were all females and as uniform in age as possible. The mule deer were allowed time to adjust to their new environment and change of diet before the selectivity trials commenced. Before the selectivity trials began, the mule deer were separated into two groups and moved to separate holding pens. The mule deer were maintained for the duration of the selectivity trials by supplementing with grain and alfalfa pellets and alfalfa hay.

Selectivity Trial Design

Three mule deer selectivity trials were conducted, one each in February and March 1974 (Trial 1 and 2) and one in November, 1974 (Trial 3). The third trial, although not originally planned, was conducted to determine if plant position within the fiber pot and different morphological characteristics of the taxonomic units were affecting availability of current year's growth.

Five plants of each taxonomic unit from each of the three collection areas were used resulting in 105 sagebrush plants used in each trial. The potted sagebrush plants were distributed in a stratified random arrangement in the trial pen. Sufficient area between each pot was provided to allow free movement of animals among the plants to prevent bias in selection due to plant placement. Sampling of utilization took place after 2.5 hours, 19.5 hours and 46.5 hours. These use periods were selected in order to obtain an indication of initial mule deer preference during the first period and to determine which taxa were preferred as availability of growth on the more preferred taxa decreased during the ensuing longer use periods.

In the November 1974 trial, three changes were made in the design of the selectivity trials: (1) the sagebrush plants used in the trial were selected from among those plants surviving from the winter trials, (2) the current year's growth was made completely available to the mule deer by hand clipping and removing the unavailable growth and (3) the periods of use were shortened to 1 hour, 12 hours and 27 hours. The use periods were shortened because of the lesser amount of current year's growth present on the plants and to determine if these shorter periods gave a more accurate indication of preference. During all selectivity trials, the mule deer were provided their normal maintenance ration. At the conclusion of each use period, the mule deer were returned to their holding pens.

Sheep Selectivity Trials

Location and Facilities

Sheep selectivity trials were conducted in a privately owned pasture one mile west of Oregon State University. The original intention was to fence off an area and divide it by cross fences into three separate pens for conducting the trials. New growth of subclover present in this area required that the trials be conducted in an adjacent area with little plant growth present, since the sheep preferred subclover to sagebrush. During the selectivity trials, the sagebrush was placed in this lot and the sheep were brought from the subclover pasture, which was used as a holding area, into the trial area.

Animals

Twelve Columbia type eastern Oregon range ewes were obtained from the Animal Science Department at Oregon State University. Criteria for selecting the ewes were that they be of the same breed, sex and as uniformly aged as possible.

Selectivity Trial Design

Four sheep selectivity trials were conducted, three during February and March, 1974 (Trials 1, 2, 3) and one in November, 1974 (Trial 4). As in the mule deer trials, the last trial was not originally planned but was felt necessary in order to account for the availability of current year's growth which was felt to be a problem in the spring trials. Sixty-three sagebrush plants from each of the seven taxa were used in each trial for a total of 252 plants used.

Before the selectivity trials began, the ewes were separated into three groups of four animals. Ear-tag numbers were recorded for subsequent identification. The sheep trials were conducted in the same manner as the deer trials except that sampling of utilization was obtained after longer use periods. Longer periods of use were necessary due to the reluctance of the ewes to eat the sagebrush. Utilization for both the winter and fall trials was sampled after 24 hours, 72 hours and 120 hours.

Volatile Oil Studies

Samples of current year's growth obtained from the same plant used in the animal selectivity trials were steam distilled to determine relative volatile oil content of the seven taxonomic units. Collected samples, which had been frozen, were allowed to thaw and then were weighed on a triple beam balance in order to record fresh weight values. They were then placed in a Volatile Oil, Interjoint, Pyrex Brand glass distillation flask and steam distilled for one and a half hours. The oil, which comes off as an immiscible liquid and is lighter than water, was collected in vials and placed in a refrigerator.

Volume of Volatile Oil

Some difficulty was experienced in determining a suitable method for determining relative amounts of oil present due to the small amount of oil obtained from the current year's growth samples used. The method arrived at for determining this value was to initially weigh the vial without the oil, then weigh the vial and oil together. The difference in weight was the weight of oil in that sample. Prior to each weighing, the vials were placed in a drying oven at 30° C for 48 hours. They were then placed in a dessicator until equilibration with room temperature was reached.

Volatile oils obtained from all plants in each taxonomic unit were combined by area in eastern Oregon from which they originated. Percent weight of oils was obtained by dividing the weight of oil obtained for each taxonomic unit by the total dry weight value of current year's growth obtained from that taxonomic unit.

Chemical Constituents

Gas chromatography was used to compare kind and amount of various chemical fractions present in the volatile oil samples. Five microliters (μl) of oil from each taxon in each of the three areas were injected into a gas chromatograph. Separation of the various chemical compounds was made on a 1/8 x 25 inch column of 8 percent FFAP on an 80/100 mesh chromosorb G-AW column that had been DMCS treated. Standard curves of known fractions were obtained so that identification could be made wherever possible. By comparing the emission time of known compounds with that of unknown compounds in the sagebrush, identification of several compounds was achieved. Comparison of the area under the peaks with the total area beneath the curve gave an indication of the relative amount of each compound present in the volatile oil sample (von Rudloff 1961).

Seasonal Variation in Volatile Oil Content

Samples of current year's growth collected from Area 1 of the study locations were distilled in the same manner as samples collected from the sagebrush taxa in the selectivity trials. Relative volatile oil content was obtained on a microliter of volatile oil per gram of growth (oven dry basis). Current growth samples were weighed on a triple beam balance after thawing to obtain green weight values. After distillation, the samples were oven dried at 110° C for 24 hours and then reweighed to obtain oven dry weight values.

Crude Protein, Acid Detergent Fiber, Acid Detergent Lignin

Samples of current year's growth that had been removed from the sagebrush taxa used in the selectivity trials to obtain dry weight values were also used to determine nutrient content of the seven taxa. Samples were ground in a micro-Wiley mill using a forty mesh screen. Crude protein, acid detergent fiber and acid detergent lignin of each taxonomic unit were then determined using standard procedures of modified proximate analysis (A.O.A.C. 1965).

In Vitro Digestibility

In vitro digestibility trials were conducted using current year's growth samples collected from Area 1 of the study locations. The samples were freeze-dried for 24 hours and ground in a micro-Wiley mill using forty mesh screen. Samples were weighed immediately after being ground and placed directly into *in vitro* flasks and digested according to standard procedures (Tilley and Terry 1963). These methods were followed to prevent undue loss of volatile oil content due to oil volitilization.

Samples used in the digestion trials had been collected from six of the taxa on March 22, 1974. This was the same time the winter selectivity trials were taking place in Corvallis. Samples of the seventh taxonomic unit, low sagebrush, were collected on December 1, 1974.

Statistical Analysis

Five statistical methods were used as tools in interpretation of results. These methods included: analysis of variance (completely random design), Duncan's new multiple range test, simple linear regression, multiple regression (backstep technique) and factorial arrangement of treatments.

Factorial arrangement of treatments, analysis of variance and Duncan's new multiple range test were used to interpret animal utilization of sagebrush taxa used in the selectivity trials and seasonal variation in volatile oil content of current year's growth of sagebrush taxa collected in Area 1. Utilization values were compared by area of collection, by combined areas for each trial and by combined trials for each class of animals. Seasonal variation in volatile oil content was interpreted by comparing mean values among taxonomic units on dates of collection and mean values for the same taxonomic unit on the four collection dates.

Multiple linear regression (Draper and Smith 1966), was used to compare animal utilization with sixteen chemical factors potentially capable of influencing animal selection. The dependent variable was percent utilization from the first period of use in the selectivity trials and was the average value for combined trials for each class of animal. Independent variables included: individual chemical constituents of the volatile oil compounds as determined by percent of the total area of the curve occupied by each constituent in the gas chromatograms; values for crude protein, acid detergent fiber and acid detergent lignin obtained by standard methods of modified proximate analysis; and the percent volatile oil in current year's growth of each of the seven sagebrush taxa. All statistical analyses in this thesis were tested at $P < 0.05$.

RESULTS AND DISCUSSION

Vegetation and Soils

Sites

Nine sites used for sagebrush collection were recognized and named on the basis of frequency information arranged in an association table (Table 1).

Mountain big sagebrush in all sites was collected from an *A. tridentata* ssp. *vaseyana*/*Festuca idahoensis*-*Agropyron spicatum* site.

Foothill big sagebrush in the Area 1 site was collected from an *A. tridentata* form *xericensis*/*Stipa thurburiana* site. In Areas 2 and 3, this shrub was collected from an *A. tridentata* form *xericensis*/*Festuca idahoensis*-*Agropyron spicatum* site.

Low sagebrush in the Area 1 site was collected from an *A. arbuscula*/*Stipa thurburiana* site. In the Area 1 and 2 sites, this taxonomic unit was collected from an *A. arbuscula*/*Stipa thurbiana*-*Festuca idahoensis* site.

Wyoming big sagebrush was collected from an *A. tridentata* ssp. *wyomingensis*/*Stipa thurburiana* site in Area 2 and from an *A. tridentata* ssp. *wyomingensis*/*Stipa comata* site in Area 3.

Table 1. Association table showing percent frequency of species in the seven sagebrush study sites in the three areas of eastern Oregon.

	Ar-va/ Feid-Agsp			Ar-xe/ Stth	Ar-xe/ Feid-Agsp		Ar-tr/ -----			Ar-wy/ -----	Ar-wy/ Stth	Ar-wy/ Stco
Stands	5	13	19	6	11	18	3	12	16	4	9	7
Species / Areas	1	2	3	1	2	3	1	2	3	1	2	3
Shrubs												
Artemisia ssp. vaseyana	37	13	27									
Artemisia f. xericensis				27	20	27						
Artemisia ssp. tridentata							30	13	17			
Artemisia ssp. wyomingensis										23	13	20
Artemisia ssp. arbuscula												
Artemisia ssp. bolanderii												
Artemisia nova												
Artemisia tripartita			3									
Artemisia rigida			7									
Purshia tridentata	3		7									
Chrysothamnus nauseosus			3		13							
Chrysothamnus viscidiflorus		17		27		10		30	P	20	23	
Tetradymia canescens		17				3	3		P			
Cercocarpus ledifolius	3											
Peraphyllum ramossimum						3						
Grayia spinosa												
Grasses												
Festuca idahoensis	73	93	17		40	63					3	
Agropyron spicatum	70	67	27		17	50						17
Stipa thurburiana		37		77	17			7	P		40	13
Koleria cristata	7	13		7	17	3		3			3	
Poa sandbergii	37	87	43	P	57	87			67		30	90

	Ar-ar/ Stth	Ar-ar/ Stth-Feid		Ar-ca/ -----			Ar-no/ -----	
Stands	1	10	20	7	8	15	2	14
Species / Areas	1	2	3	1	2	3	1	2
Shrubs								
Artemisia ssp. vaseyana								
Artemisia f. xericensis								
Artemisia ssp. tridentata								
Artemisia ssp. wyomingensis								
Artemisia ssp. arbuscula	30	60	13					
Artemisia ssp. bolanderii				60	87	80		
Artemisia nova							87	53
Artemisia tripartita								
Artemisia rigida		1/						
Purshia tridentata		P						
Chrysothamnus nauseosus								
Chrysothamnus viscidiflorus	3		43					
Tetradymia canescens								
Cercocarpus ledifolius								
Peraphyllum ramossimum								
Grayia spinosa							P	3
Grasses								
Festuca idahoensis		23	3					
Agropyron spicatum	20	10	3					
Stipa thurburiana	80	20	27				3	
Koleria cristata		3	17		3			
Poa sandbergii	87	80	83		37		93	P

Table 1. Continued.

	Ar-va/ Feid-Agsp			Ar-xe/ Stth	Ar-xe/ Feid-Agsp		Ar-tr/ -----			Ar-wy/ -----	Ar-wy/ Stth	Ar-wy/ Stco	Ar-ar/ Stth	Ar-ar/ Stth-Feid		Ar-ca/ -----			Ar-no/ -----	
Stands	5	13	19	6	11	18	3	12	16	4	9	7	1	10	20	7	8	15	2	14
Species Areas	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
<u>Grasses</u> (cont.)																				
<u>Sitanion</u> <u>hystrix</u>	13			57	37	10	27	37		7	37	53	7	33	17	20	10	P	80	3
<u>Bromus</u> <u>tectorum</u>	47	3	20	3	43	40	80	87	83	100	80	7	37	3	17		13	37	7	100
<u>Stipa</u> <u>occidentalis</u>																				
<u>Stipa</u> <u>comata</u>							3	P	P		P	<u>77</u>						3		
<u>Oryzopsis</u> <u>hymenoides</u>											P	3								P
<u>Mulenbergia</u> <u>richardsonis</u>				7												20				
<u>Poa</u> <u>bulbosa</u>						7														
<u>Grasslikes</u>																				
<u>Carex</u> <u>rossii</u>		7		40				10												
<u>Forbs</u> (perennial)																				
<u>Eriogonum</u> <u>umbellatum</u>	3			3																
<u>Erigonum</u> <u>heracleoides</u>		37				P									17					
<u>Erigonum</u> <u>ovaliforium</u>		20			3									P	3	7				
<u>Erigeron</u> <u>linearis</u>		17													7					
<u>Erigeron</u> <u>filifolius</u>		20			3															
<u>Penstemon</u> <u>radicosus</u>	3					20														
<u>Chenopodium</u> <u>leptophyllum</u>																		20		
<u>Phacelia</u> <u>mutabilis</u>		10																		
<u>Calachortus</u> <u>macrocarpus</u>	23	20				10			P			P	3							
<u>Lomatium</u> <u>macrocarpus</u>	3	40			3		7			3		3			17					
<u>Lupinus</u> <u>caudatus</u>	3		7	3	10	37								37				3		
<u>Brodiaea</u> <u>douglasii</u>			3		3	3														

Table 1. Continued.

	Ar-va/ Feid-Agsp			Ar-xe/ Stth	Ar-xe/ Feid-Agsp		Ar-tr/ -----			Ar-wy/ -----	Ar-wy/ Stth	Ar-wy/ Stco	Ar-ar/ Stth	Ar-ar/ Stth-Feid		Ar-ca/ -----			Ar-no/ -----	
Stands	5	13	19	6	11	18	3	12	16	4	9	7	1	10	20	7	8	15	2	14
Species / Areas	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Forbs (perennial) (cont.)																				
Lomatium triternatum		17	13		P	47						P		P	7			17	23	
Senecio canus			3																	
Castilleja chromosa		10	23																	
Agoseris glauca			3								P			7						
Lithospermum ruderale			3	10																
Crepis acuminata		37	3		3	13		P			P			10						
Antennaria rosea		27													3					
Balsamorhiza sagittata			20			P									3					
Zigadenus paniculatus			10						P			3								
Helianthella uniflora			7																	
Erigeron bloomeri				40	P	17						P		7					10	
Aster compestris		47			P						P			3						
Achillea millefolium		3				3														
Astragalus miser		3		10	3	23		P				13	P	30	37					
Viola nuttallii				33																
Viola praemorsa		7																		
Castilleja angustifolia				3									P	P						
Astragalus lentiginosus	20																			
Lomatium simplex						53														
Phlox hoodii					3	53						13		3	50					
Astragalus purshii						3			3		P	63								
Phlox longifolia					10	20			23		P			23						
Allium acuminatum						P			P		P			3					3	
Haplopappus acaulis														17						

Table 1. Continued.

	Ar-va/ Feid-Agsp			Ar-xe/ Stth	Ar-xe/ Feid-Agsp		Ar-tr/ -----			Ar-wy/ -----	Ar-wy/ Stth	Ar-wy/ Stco	Ar-ar/ Stth	Ar-ar/ Stth-Feid		Ar-ca/ -----			Ar-no/ -----	
Stands	5	13	19	6	11	18	3	12	16	4	9	7	1	10	20	7	8	15	2	14
Areas	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Antennaria dimorpha					3		P				3	20	3	7	27				3	
Lupinus leucophyllus							3				P									
Cirsium vulgare								7												
Tragopagon dubius			3			7		3												
Erigeron pumilus								33												
Arabis hoboellii													3	3	10				3	
Mertensia oblongifolia														3						
Penstemon fruticosus															3					
Forbs (annual)																				
Microsteris gracilis	27	23	23	83	37	23		77	60	27	73	3	100		53	40	33	27	60	77
Descurainia pinnata							83	7		13	13	3			7				27	
Gayophytum ramosissimum	13			90				7		3	30		30	10		43	7	3		
Collensia parviflora	93	50	63	83	100	77		93	3		63		80	97	40	33	33	70	60	13
Lepidium perfoliatum	20			17				3	23		P				53					P
Collomia grandiflora			30		27															
Collomia aristello			3		7				10											
Epilobium paniculatum			10			13			70			3								
Montia parvifolia				10					3				17							
Cryptantha circumscissa			7	7		20			3	30										
Polygonum douglasii			3			3						87								
Microseris nutans		13		3		10									P					
Cordylanthus ramosus						3						20			23					
Plagiobothrys harknesii								10		P						7				

Table 1. Continued.

	Ar-va/ Feid-Agsp			Ar-xe/ Stth	Ar-xe/ Feid-Agsp		Ar-tr/ ----			Ar-wy/ ----	Ar-wy/ Stth	Ar-wy/ Stco	Ar-ar/ Stth	Ar-ar/ Stth-Feid		Ar-ca/ ----			Ar-no/ ----	
Stands	5	13	19	6	11	18	3	12	16	4	9	7	1	10	20	7	8	15	2	14
Species Areas	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Forbs (annual) (cont.)																				
Ranuculus testiculatus									67			3								
Nemophilia breviflora													3							
Dowingia elegans																30				
Polygonum paronychia																20				
Polyctenium fremontii																13	10			
Navarretia intertexta																30				
Myosurus minimus																27	23			

[1]/ P indicates that species was present but was not encountered within the sample plot.

Original climax dominants were not identifiable, based on associated species, for Wyoming big sagebrush in Area 1. Also basin big sagebrush, Bolander silver sagebrush and black sagebrush sites in all collection areas were too severely disturbed to identify climax dominants. The dominant grass species on these sites were invader species, i.e. cheat grass (Bromus tectorum) or increaser species i.e. squirrel tail (Sitanion hystrix) and/or Sandberg's bluegrass (Poa sandbergii). All are generally indicative of disturbed conditions (Winward 1970). Mean density and foliage cover values of all shrubs encountered are summarized according to their association with each of the seven sagebrush taxa (Table 2). Examinations of these values showed that the mountain big sagebrush and foothill big sagebrush sites had more associated shrub species. The Bolander silver sagebrush sites had the highest cover and density values due primarily to the profuse growth of young shrubs encountered on these sites. Mountain big sagebrush sites had higher mean cover and density values than did the foothill big sagebrush sites possibly reflecting the more xeric conditions associated with the latter species. Basin big sagebrush had next to the highest average cover but the lowest average density. Wyoming big sagebrush sites had low average cover and density values. This was consistent with average cover and density for basin big sagebrush

Table 2. Mean percent cover (C) and density per square foot (D) of shrubs found with each sagebrush taxon.

	Mean of Areas		Mean of Areas		Mean of Areas		Mean of Areas		Mean of Areas		Mean of Areas		Mean of Areas	
Species	C	D	C	D	C	D	C	D	C	D	C	D	C	D
A. tridentata ssp. vaseyana	12.0	.088												
A. tridentata f. xericensis			10.4	.061										
A. tridentata ssp. tridentata					13.2	.057								
A. tridentata ssp. wyomingensis							9.7	.078						
A. arbuscula ssp. arbuscula									10.8	.180				
A. cana ssp. bolanderi											27.8	.330		
A. nova													11.8	.281
A. rigida			0.8	.014										
A. tripartita			0.1	.003										
Chrysothamnus nauseosus	0.2		6.0	.019										
Chrysothamnus vicidiflorus	0.8	.011	1.4	.063	3.3	.041	2.9	.046	4.2	.135				
Tetradymia canescens	1.1	.021	0.5	.002	0.2									
Purshia tridentata	4.7	.013							0.6	.005				
Atriplex confertifolia													0.3	.003
Peraphyllum ramosissimum			2.2	.009										
Symphoricarpos oreophilus			0.1	.001										
Ceanothus velutinus	0.1	.002												
Amelanchier alnifolia		.001												

habitat types sampled by Winward (1970) in Idaho and reflected ecological stage of succession.

Average cover values were lower than average density values on both the low and black sagebrush sites. This may be a reflection of normal morphological differences as well as site differences since these are low growing shrubs inhabiting harsh, rocky sites.

Soil Characteristics

Soil characteristics associated with each sagebrush taxon in the three areas of collection are summarized in Table 3.

Preliminary Selectivity Trial

The average percent utilization by period of use on four plants of each of the six sagebrush taxonomic units used in the preliminary selectivity trial are illustrated in Figure 2. In the first period of use, 85 percent of the Bolander silver sagebrush plants, 46 percent of the low sagebrush plants, 10 percent of the foothill big sagebrush plants and 2 percent of the mountain big sagebrush plants were utilized by the ewes. One percent or less of Wyoming and basin big sagebrush were utilized during this period. In the second period, utilization of the remaining growth was 76 percent and 11 percent for Bolander silver sagebrush and low sagebrush, respectively. Utilization of foothill big sagebrush increased to 83 percent and was the

Table 3. Summary of soil characteristics (horizon, color, texture and structure) and elevation associated with each sagebrush site in the three collection areas.

Site	Area	Elevation	Horizon	Color(moist)	Texture	Structure
Ar-ar/Stth	1	4860'	A_1 0-5"	10YR 3/3	sl	sb
			B 5-12"	10YR 3/2	scl	sb
			C 12"+	10YR 4/4	cl	sb
Ar-ar/Stth-Feid	2	4940'	A 0-5"	10YR 3/2	l	g
			B 5-27"	10YR 3/2	cl	sb
			C 27+"	10YR 4/3	c	sb
Ar-ar/Stth-Feid	3	4050'	A 0-1"	5YR 3/3	sl	sb
			B 1-7"	5YR 3/3	cl	
Ar-ca/----	1	4580'	A_{11} 0-8"	10YR 3/2	si c	sb
			A_{12} 8-18"	10YR 4/3	si c	sb
			B 18"+	10YR 3/3	c	m
Ar-ca/----	2	4470'	A_{11} 0-3"	10YR 4/4	si c	sb
			A_{12} 3-11"	10YR 4/4	c	sb
			C 11"+			m

Table 3. Continued.

Site	Area	Elevation	Horizon	Color(moist)	Texture	Structure
			A 0-4"	10YR 3/2	cl	sb
Ar-ca/----	3	4100'	B 4-12"	10YR 3/2	cl	sb
			C 12"+			
			A 0-4"	10YR 4/4	sl	sb
Ar-wy/----	1	4340'	B 4-10"	10YR 4/4	sl	sb
			C 10"			
			A 0-5"	10YR 3/4	sl	sb
Ar-wy/Stth	2	4430'	B 5-12"	10YR 4/4	sl	sb
			C 12+"	10YR 5/4	scl	sb
			A 0-8"	10YR 4/3	sl	sb
Ar-wy/Stco	3	3450'	B 8-30"	10YR 4/3	sl	sb
			Bca 30+"			
			A 0-10"	10YR 3/3	ls	sb
Ar-xe/Stco	1	4820'	B 10-30"	10YR 4/4	s	sb
			C 30"+	10YR 5/6	c	b

Table 3. Continued.

Site	Area	Elevation	Horizon	Color(moist)	Texture	Structure
			A 0-5"	10YR 3/3	si l	sb
Ar-xe/Feid-Agsp	2	4930'	A_3 5-9"	10YR 4/4	si c l	sb
			B 9-21"	10YR 4/4	c	b
			A 0-2"	10YR 3/2	l	g
Ar-xe/Feid-Agsp	3	5300'	B 2-16"	10YR 3/2	c	ab
			BC 16-25"	2.5YR 5/4	ls	g
			C 25+"		s	
			A_{11} 0-4"	10YR 4/4	si l	sb
Ar-tr/----	1	4280'	A_{12} 4-20"	10YR 4/4	si cl	sb
			C 20"+			m
			A 0-8"	10YR 4/4	sl	g
Ar-tr/----	2	4145'	B 8-12"	10YR 4/4	s	sb
			Bm 12"			
			A_{11} 0-5"	10YR 3/2	sl	sb
Ar-tr/----	3	3400'	A_{12} 5-13"	10YR 4/3	l	sb
			A_3 13-23"	10YR 4/4	l	sb
			B 23+"	10YR 3/3	l	sb

Table 3. Continued.

Site	Area	Elevation	Horizon	Color(moist)	Texture	Structure
			A 0-8"	10YR 3/2	sl	
Ar-va/Feid-Agsp	1	5080'	B 8-11"	10YR 3/3	cl	
			C 11+"			
			A 0-1"	10YR 3/2	sl	sb
Ar-va/Feid-Agsp	2	5000'	B 1-18"	10YR 3/2	sl	sb
			C 18+"			
			A 0-8"	10YR 3/2	sl	g
Ar-va/Feid-Agsp	3	5800'	B 8-11"	10YR 3/2	cl	sb
			C 11+"			
			A 0-3"	10YR 3/2	sl	sb
Arno/----	1	4500'	B 3-6"	10YR 4/4	cl	sb
			Bca 6-12"	10YR 5/4	sl	
			A 0-2"	10YR 3/3	sl	sb
Arno/----	2	4340'	B 2-8"	10YR 4/3	cl	sb
			Bca 8-10"			

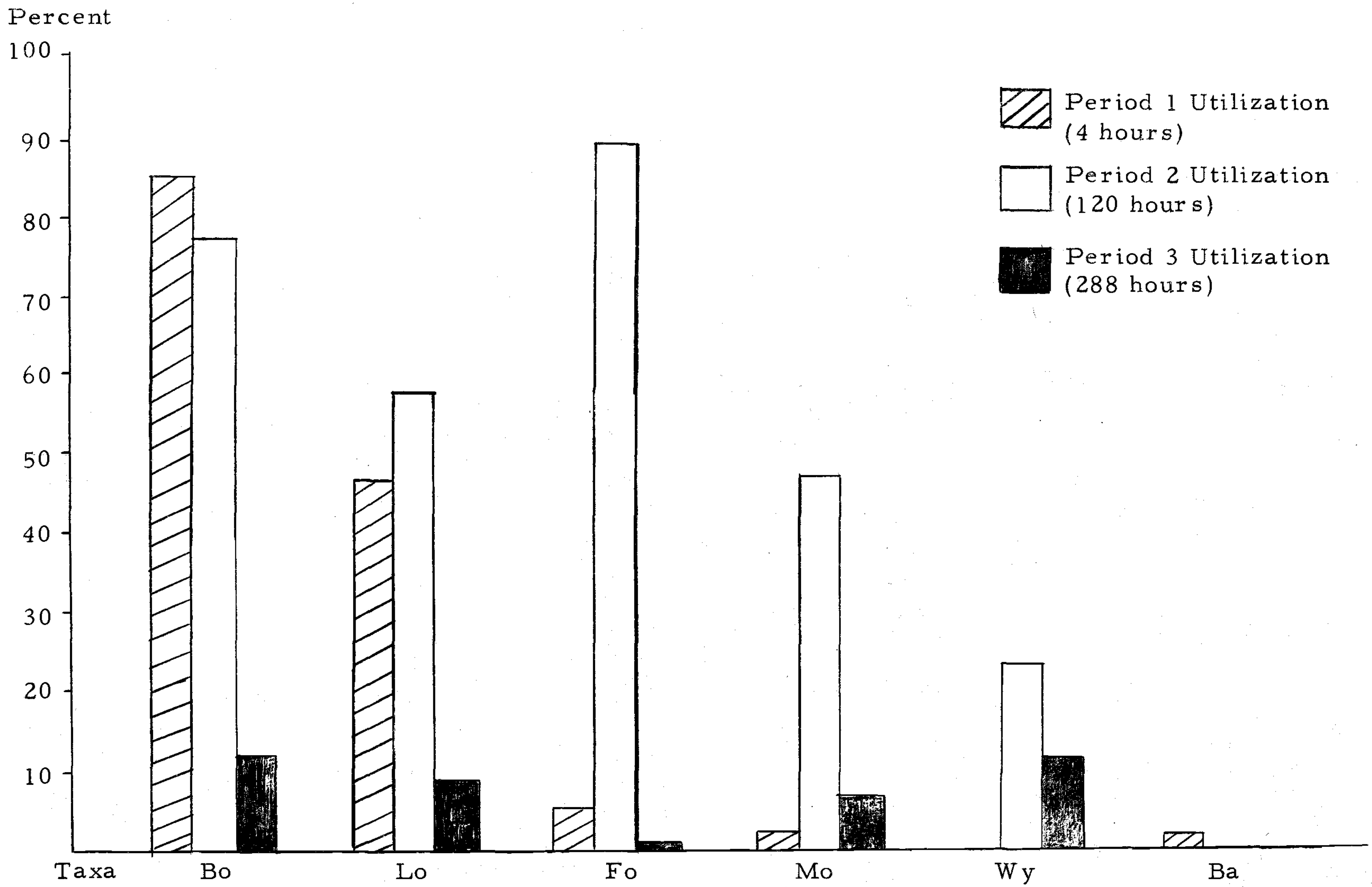

Figure 2. Percent utilization of six sagebrush taxa by sheep in three periods of use in the preliminary selectivity trials.

most heavily utilized taxon during this period. Use of mountain and Wyoming big sagebrush also showed considerable use during the second period with an increase in utilization of 44 percent and 22 percent, respectively. Basin big sagebrush was not used during this period. In the third period of use, none of the taxa were utilized more than 11 percent with foothill, Wyoming and basin big sagebrush receiving only trace amounts of use.

By the third period of use, the readily available growth on the more preferred species had been consumed, leaving only the less available plant foliage remaining. Consequently, availability to the animal rather than animal preference was strongly reflected in the utilization values of the third period. Since this pattern of use was consistent in the information obtained from subsequent trials, only the first and second period of use will be discussed for the winter and fall animal selectivity trials.

Mule Deer Trials

Mule Deer Selectivity Trials (Winter)

In the period between capture and the selectivity trials, three mule deer died leaving only six animals for use in the trials. Necropsies conducted by the Oregon State University Department of Veterinary Medicine determined that two of the deer died of stress and heavy parasite infection. The other deer died of Black Disease, a common sheep disease but never previously recorded in mule deer in Oregon (Kistner 1974). Due to the loss of these three deer and the desire to use four animals per trial, one tame mule deer doe was used in each of the winter selectivity trials.

Introduction of the mule deer into the area where the potted sagebrush plants had been randomly arranged initially caused them to become excited and nervous. After a short period of adjustment to this unfamiliar situation, they began selecting from among the sagebrush taxa. It was observed that the deer were inclined to move from plant to plant, remaining at each plant for only a short length of time. The length of time spent at each plant varied, with longer periods spent browsing the more preferred taxa.

Intertaxon Utilization and Composition

Sampling of utilization at the conclusion of the first-use period of the first trial (2.5 hours) indicated the deer had made an initial selection. Utilization and significance values among the seven taxa are shown in Figure 3.

Intensity of utilization varied from highest to lowest as follows: mountain big sagebrush, foothill big sagebrush, Bolander silver sagebrush, Wyoming big sagebrush, low sagebrush, basin big sagebrush and essentially no utilization on black sagebrush.

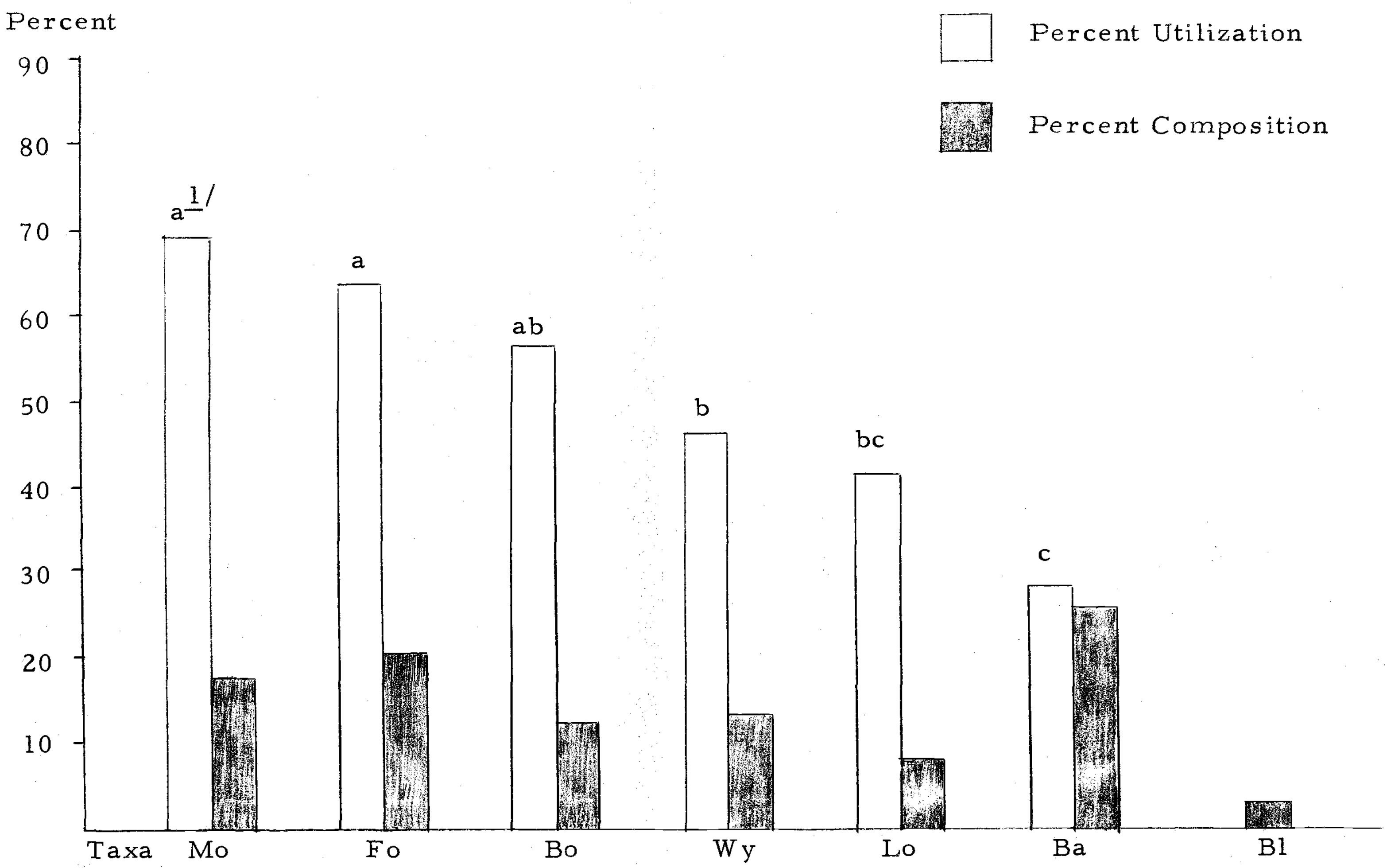

Figure 3. Percent utilization and composition of seven sagebrush taxa in Period 1 for mule deer selectivity trial 1 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

Mule deer utilization of growth at the conclusion of the first-use period of the second deer trial ranged from 46 percent for foothill big sagebrush to no utilization on black sagebrush (Figure 4). Foothill big sagebrush, Bolander silver sagebrush and mountain big sagebrush appeared to be the most utilized in this trial. Utilization on low sagebrush and basin and Wyoming big sagebrush was intermediate with black sagebrush showing the lowest values.

Percent composition of five of the taxonomic units in the first-use period of both trials was fairly uniform, varying between 20 and 8 percent. Exceptions were basin big sagebrush and black sagebrush which had the highest and lowest percent composition of growth in both trials. This was a reflection of difference in growth form of these two taxa. Percent composition appeared to have little, if any, influence on utilization of the taxa during the first use period.

At the end of the second period of utilization (17 hours), mean utilization was considerably higher during both trials than at the end of the first period. This was the result of (1) less total current year's growth on the sagebrush plants available to the deer and (2) the increased length of the use period.

Mean utilization values of the second period for the first deer trial ranged from 88 percent for Bolander silver sagebrush to 13 percent for black sagebrush (Figure 5). The major difference in

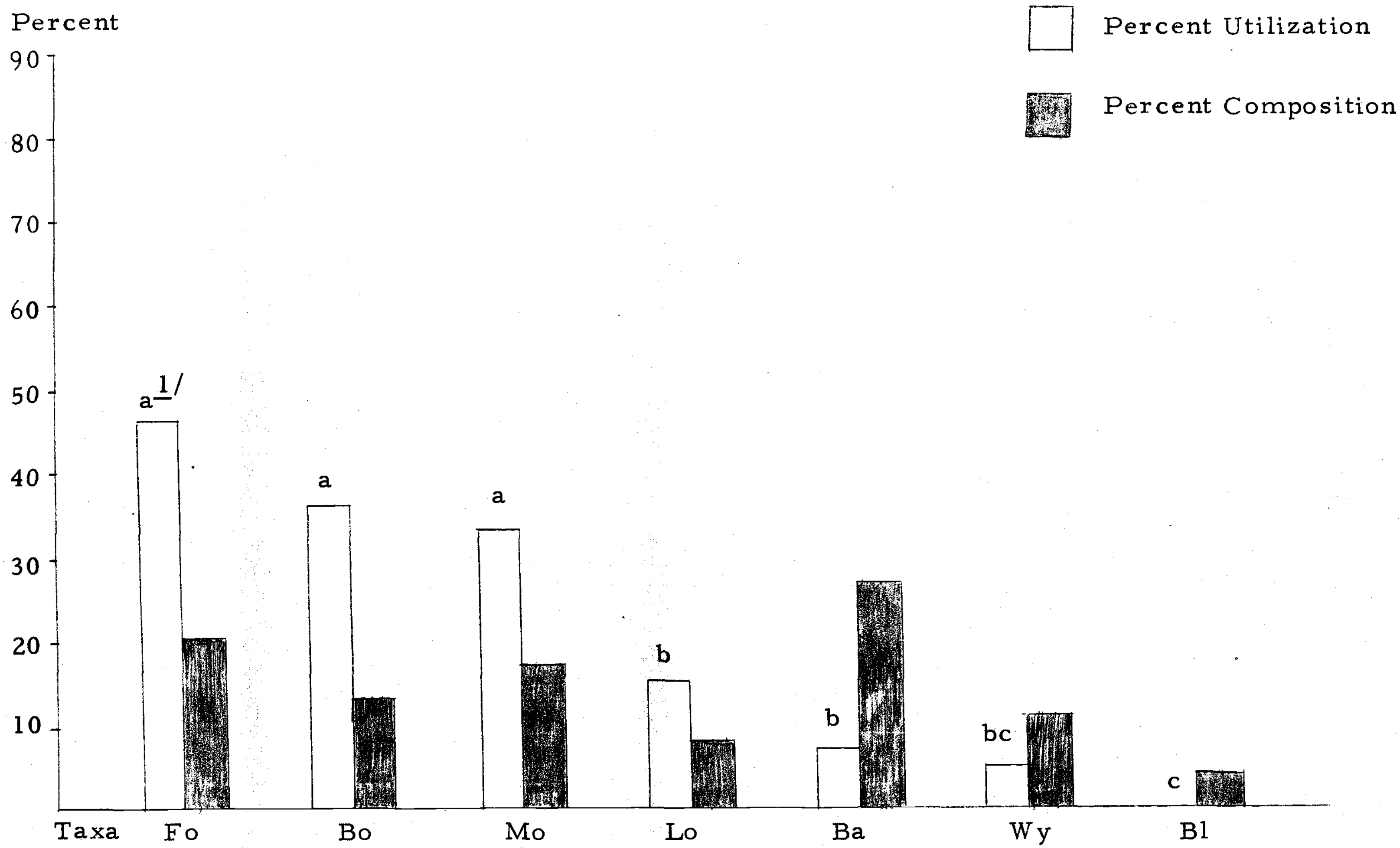

Figure 4. Percent utilization and composition of seven sagebrush taxa in Period 1 for mule deer selectivity trial 2 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

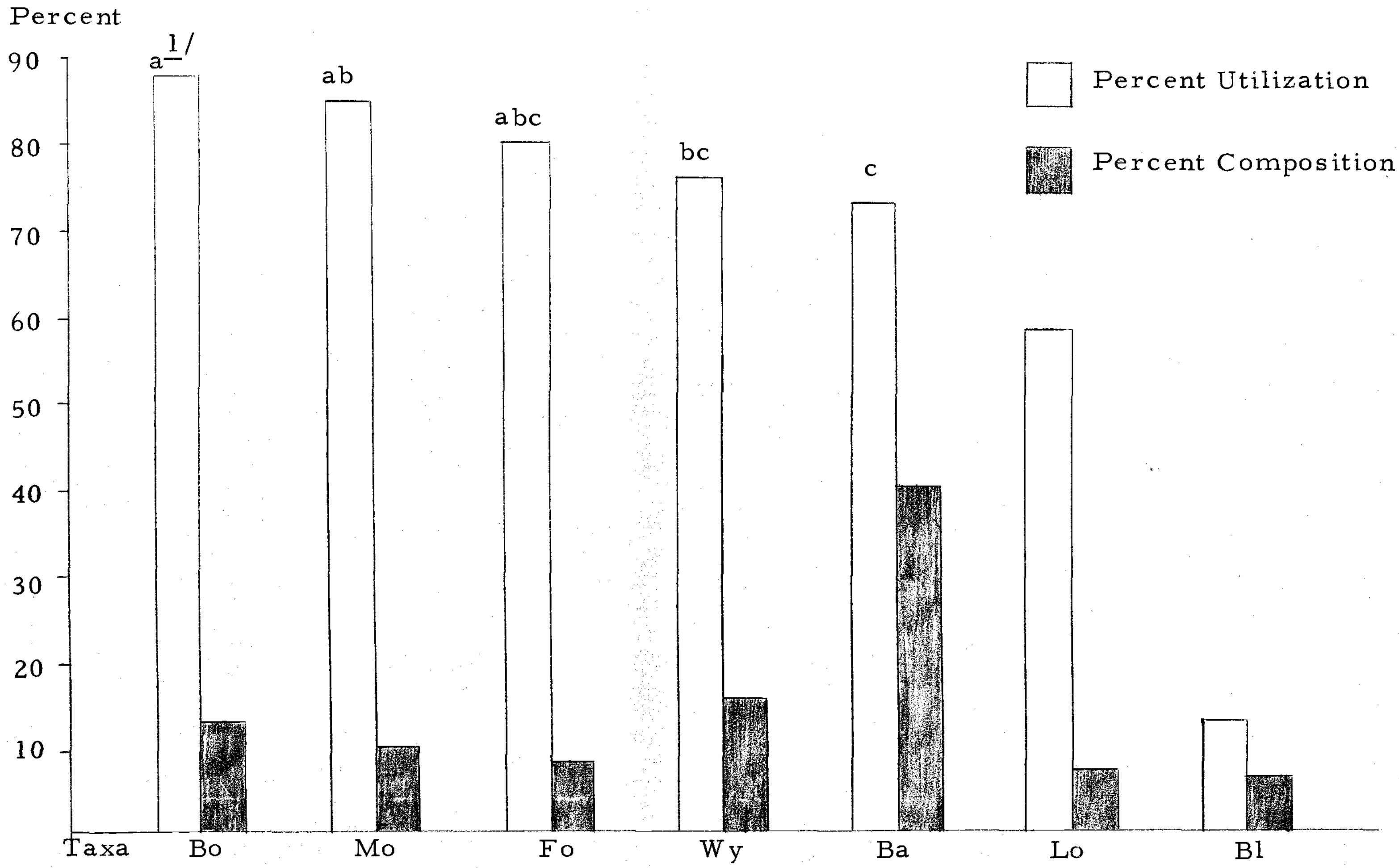

Figure 5. Percent utilization and composition of seven sagebrush taxa in Period 2 for mule deer selectivity trial 1 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

this second-use period from the first-use period was a lower utilization of low sagebrush. The second period also differed from the first in that there was more uniformity of utilization among the five taxa showing the highest utilization values.

The second-use period of deer trial 2 also showed uniformly higher utilization values (Figure 6). Values ranged from 82 percent for foothill big sagebrush to 16 percent for black sagebrush. The major difference in use period 2 compared to use period 1 was that black sagebrush was used significantly less than all other taxa. The second-use period of both trials also showed more uniformity among utilization values for all taxa.

Percent composition of the current year's growth of six of the taxa was fairly uniform during the second-use period of both trials. Composition of these six taxa varied by only 11 percent. Basin big sagebrush was the exception, with percent composition of 40 percent in the first trial and 32 percent in the second trial. This was due to the relatively greater amount of current year's growth available from the basin big sagebrush plants.

For significance ($P < 0.05$) of all factors and interactions in utilization of the seven sagebrush taxa, refer to Appendix 1a.

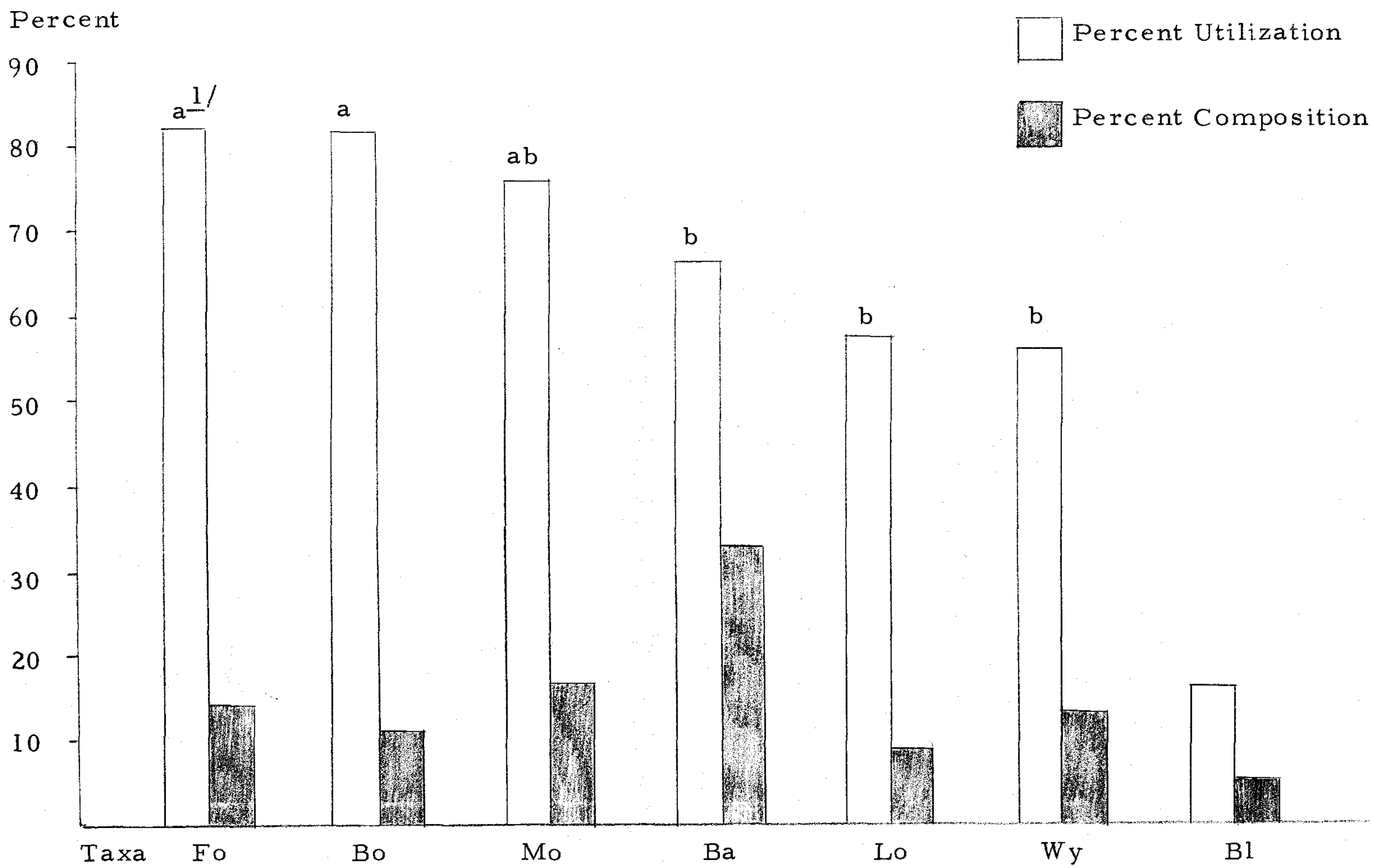

Figure 6. Percent utilization and composition of seven sagebrush taxa in Period 2 for mule deer selectivity trial 2 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

Combined Mule Deer Selectivity Data
(Pooled Trials - Winter)

Percent utilization and composition values from both winter deer selectivity trials were combined to determine if results would be different when the potential bias between trial animals was removed. This combination of values resulted in a more defined seperation of taxonomic units into groups during the first-use period (Figure 7).

Intertaxon Utilization and Composition

Combined utilization values showed an overall range from 55 percent utilization of foothill big sagebrush to trace utilization for black sagebrush. Foothill and mountain big sagebrush and Bolander silver sagebrush were the most utilized taxa followed by low sagebrush and Wyoming and basin big sagebrush which showed intermediate utilization. Black sagebrush had the lowest overall utilization.

Percent composition generally varied from 20 to 8 percent. Exceptions were basin big sagebrush and black sagebrush with 37 and 4 percent of current year's growth present, respectively.

During use period 2 of the combined selectivity trials, utilization was similar to the second period in each of the separate trials.

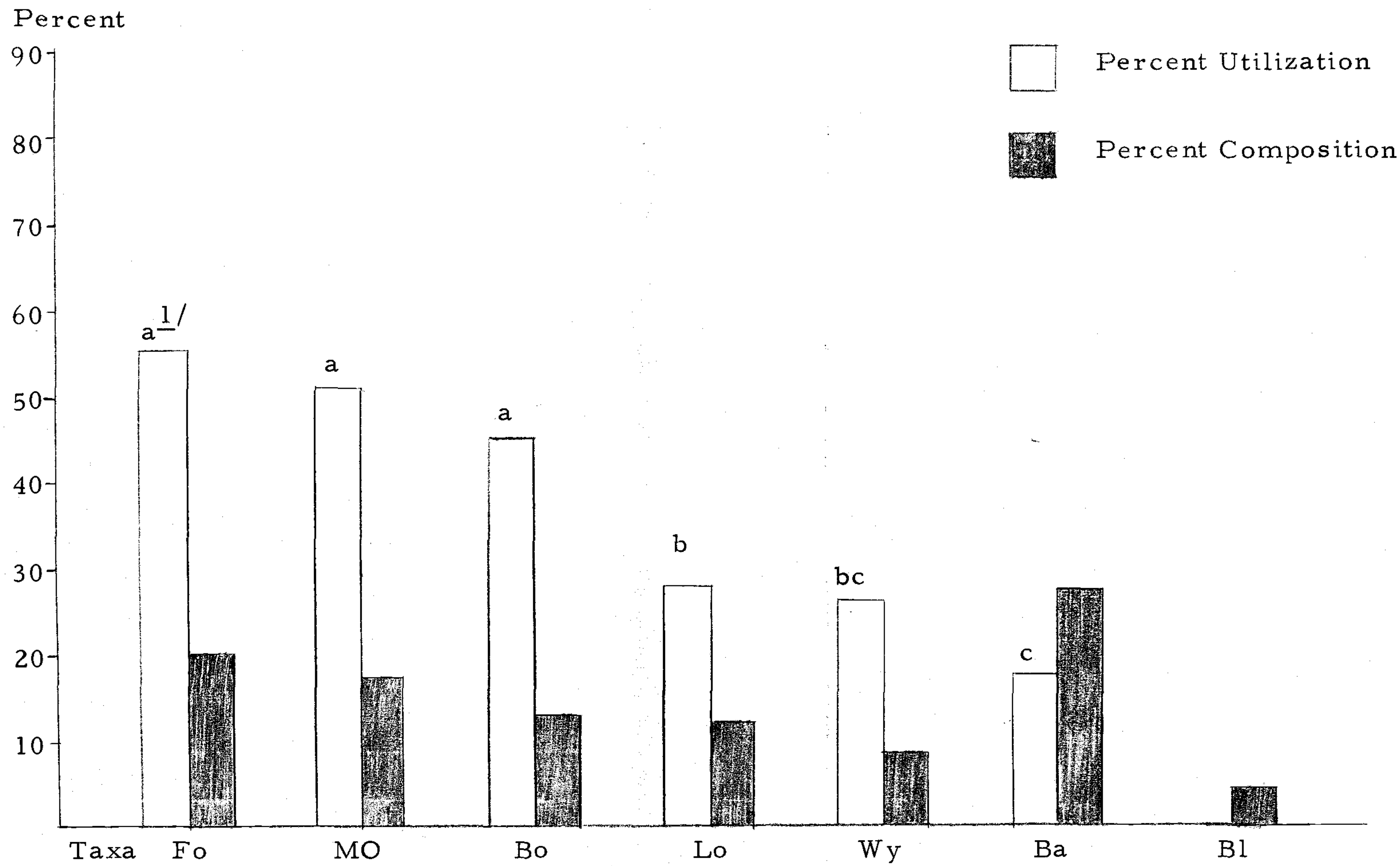

Figure 7. Percent utilization and composition of seven sagebrush taxa in Period 1 for combined mule deer selectivity trials (Winter).

[1/] Utilization values followed by the same letter were not significantly different.

Higher percent utilization was shown for all seven taxa, ranging from 85 percent for Bolander silver sagebrush to 27 percent for black sagebrush (Figure 8). Bolander silver sagebrush, mountain and foothill big sagebrush received the greatest utilization. Basin and Wyoming big sagebrush and low sagebrush were, as a group, moderately utilized. Black sagebrush was the least utilized taxa.

Composition of current year's growth available to the deer was less than 15 percent for all taxa except for basin big sagebrush. This taxon provided 36 percent of the available current year's growth during the second-use period.

Relative Preference Index (Winter)

Relative mule deer preference for the seven sagebrush taxa used in the first trial was obtained for each period of use (Table 4). During the first period, the deer showed highest preference for mountain big sagebrush, followed closely by foothill big sagebrush. Preference was not distinguished for Bolander silver sagebrush and Wyoming big sagebrush for which equal preference were shown. Low sagebrush and basin big sagebrush showed relatively low preference compared to these four taxa and black sagebrush was the least preferred.

Preference values for the seven sagebrush taxa in the first period of the second deer trial were similar to those of the first

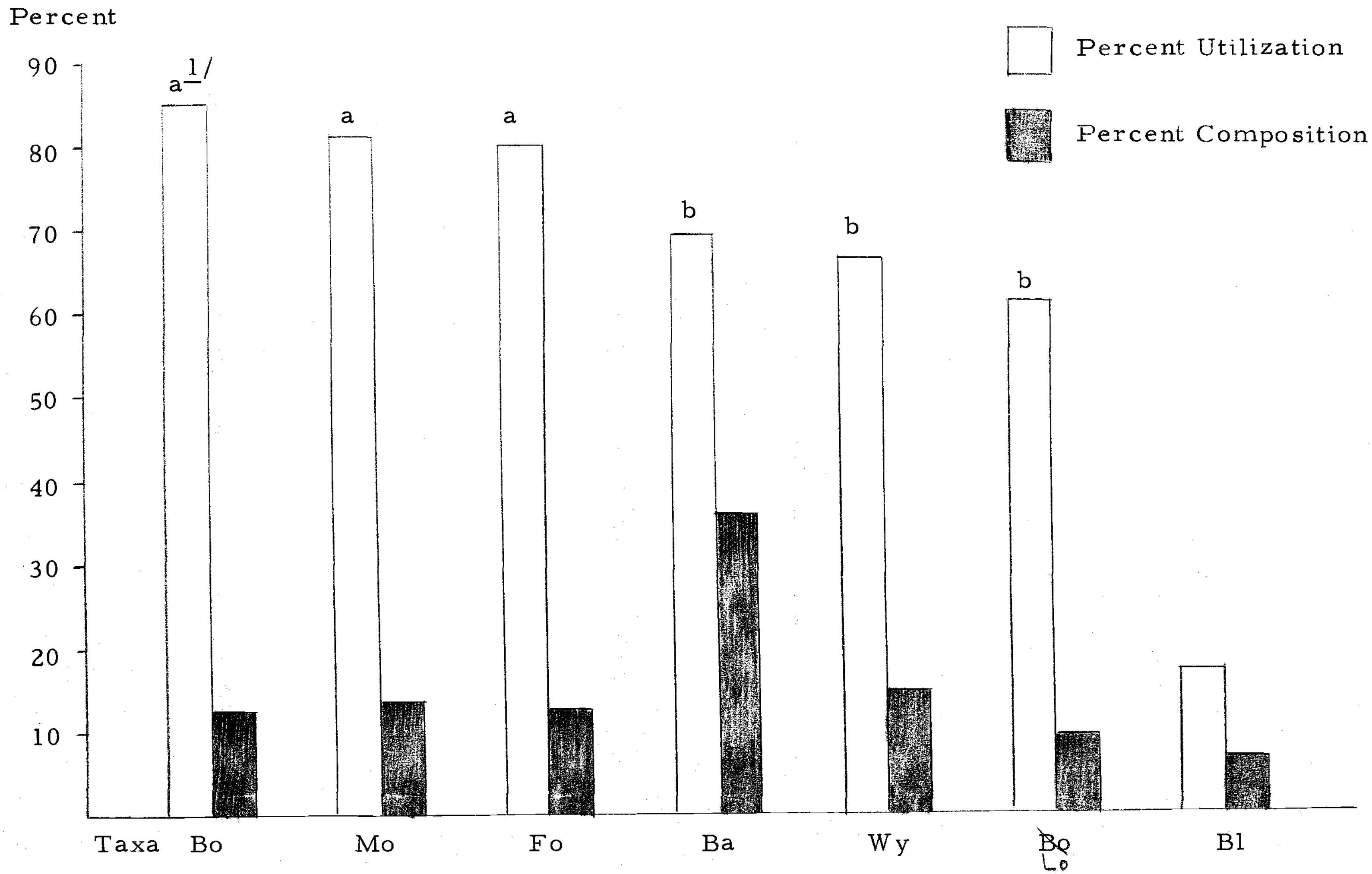

Figure 8. Percent utilization and composition of seven sagebrush taxa in Period 2 for combined mule deer selectivity trials (Winter).

1/ Utilization values followed by the same letter were not significantly different.

Table 4. Relative Preference Index (RPI) for seven sagebrush taxa by period of use (deer selectivity Trial 1 - Winter).

Period 1	Taxa	Mo	Fo	Bo	Wy	Lo	Ba	Bl
	RPI	1.4	1.3	1.1	1.1	0.8	0.6	0.0
Period 2	Taxa	Bo	Mo	Fo	Wy	Ba	Lo	Bl
	RPI	1.2	1.2	1.1	1.1	1.0	0.8	0.2

Table 5. Relative Preference Index (RPI) for seven sagebrush taxa by period of use (deer selectivity Trial 2 - Winter).

Period 1	Taxa	Fo	Bo	Mo	Lo	Ba	Wy	Bl
	RPI	2.0	1.5	1.4	0.6	0.3	0.2	0.0
Period 2	Taxa	Fo	Bo	Mo	Ba	Lo	Wy	Bl
	RPI	1.2	1.2	1.2	1.0	0.9	0.8	0.2

Table 6. Relative Preference Index (RPI) for seven sagebrush taxa by period of use (combined deer selectivity Trial - Winter).

Period 1	Taxa	Fo	Mo	Bo	Lo	Wy	Ba	Bl
	RPI	1.5	1.4	1.3	0.8	0.8	0.5	0.0
Period 2	Taxa	Bo	Mo	Fo	Ba	Wy	Lo	Bl
	RPI	1.2	1.1	1.1	1.0	1.0	0.9	0.2

trial (Table 5). Although the order and the index value differed slightly, the three taxa receiving the highest values were identical for both trials. Foothill big sagebrush was the most preferred with Bolander silver sagebrush and mountain big sagebrush following in order of preference. Low sagebrush was intermediate in preference. Basin and Wyoming big sagebrush had relatively low preference values. Again black sagebrush was the least preferred of the seven taxa.

Except for black sagebrush, relative preference values for the second-use period of the second deer selectivity trial showed very little variation in preference among the seven taxa. Black sagebrush had a considerably lower index value than the other six taxa.

Relative preference values obtained by combining the two deer trials followed the same pattern as the individual trials (Table 6). In the first period of use, foothill and mountain big sagebrush and Bolander silver sagebrush had similar preference values and appeared to be the most preferred of the seven taxa. These three taxonomic units were followed by low sagebrush and Wyoming and basin big sagebrush which had intermediate values. As in the individual trials, black sagebrush was the least preferred.

Preference values in the second combined period of use showed little variation from the individual trials and little variation among taxa, except for black sagebrush. This taxonomic unit was consistently the least preferred by mule deer of the seven sagebrush taxa studied.

Intrataxon Utilization by Areas (Winter)

In both periods of the first deer trial, the heaviest overall utilization generally appeared to be on sagebrush taxa from Area 1 (Table 7). However, there was little significant difference between utilization of taxa of common genetic origin from different areas. In the second period of the first trial, there was even less significant difference between utilization values of taxa from common genetic origin.

The greatest utilization for both periods of use in the second selectivity trial also appeared generally to be on taxa from Area 1. In this trial, there appeared to be even less significant difference between taxa of common genetic origin from the three collection areas.

Utilization values from both winter deer trials were combined to decrease the amount of potential variation which might have existed between groups of deer (Table 8). There appeared to be little significant difference in utilization values by area for black sagebrush and all taxonomic units of the big sagebrush complex. Significant difference in utilization did appear to exist between Area 1

Table 7. Comparison of mean utilization values of seven sagebrush taxa by collection area and period of use (deer selectivity Trial 1 and 2 - Winter).

		Period 1			Period 2		
		Area			Area		
Trial	Taxa	1	2	3	1	2	3
	Lo	62.5	38.4[ab]	21.1[b]	12.1	55.2[a]	47.1[a]
	Bo	67.0[a]	65.1[a]	36.4	93.6[a]	86.0[a]	85.2[a]
	Bl	28.0	0.0[a]	0.0[a]	14.0[a]	11.3[a]	14.2[a]
Trial 1	Ba	10.0[a]	22.7[a]	49.9[a]	60.0	78.3[a]	80.2[a]
	Mo	72.8[a]	56.0[a]	77.9[a]	89.3[ab]	73.3[b]	90.9[a]
	Wy	41.3[a]	18.6[a]	78.0[a]	86.0[a]	59.9	81.9[a]
	Fo	80.5	54.5[a]	54.0[a]	89.1[a]	70.8	78.8[a]
	Lo	24.6[a]	0.0[a]	21.0[a]	72.5[a]	55.6[b]	60.7[ab]
	Ba	56.3[a]	18.5[b]	34.7[ab]	96.1[a]	81.2[ab]	67.5[b]
	Bl	0.0[a]	0.0[a]	0.0[a]	14.0[a]	14.3[a]	6.1[a]
Trial 2	Ba	19.7[a]	1.3[a]	1.0[a]	67.0[a]	67.5[a]	63.5[a]
	Mo	32.4[a]	27.1[a]	38.6[a]	80.5[a]	74.3[a]	73.8[a]
	Wy	1.4[a]	5.1[a]	9.9[a]	52.2[ab]	47.7[b]	68.4[a]
	Fo	56.2[2]	32.8[a]	50.3	84.0[a]	76.8[a]	84.6[a]

and the other two areas from low sagebrush in both the first and second-use periods and for Bolander silver sagebrush during the first-use period. Aside from these two exceptions, no apparent trend in area selection for taxa of common genetic origin was noted.

Table 8. Comparison of mean utilization values of seven sagebrush taxa by collection area and period of use (combined deer selectivity trials - Winter).

	Period 1			Period 2		
	Area			Area		
Taxa	1	2	3	1	2	3
Lo	43.6	19.2[a]	21.0[a]	72.3	55.4[a]	53.9[a]
Bo	61.7	41.8[a]	35.6[a]	94.0[a]	83.6[ab]	76.3[a]
Bl	14.0[a]	0.0[a]	0.0[a]	14.0[a]	12.8[a]	10.2[a]
Ba	14.9[a]	12.0[a]	25.5[a]	63.5[a]	72.9[a]	71.8[a]
Mo	52.6[a]	41.5[a]	58.3[a]	84.9[a]	73.8[a]	82.4[a]
Wy	21.3[a]	11.8[a]	44.0[a]	69.1[a]	53.8	75.2[a]
Fo	68.4[a]	43.7[b]	52.1[ab]	86.6[a]	73.8[b]	81.7[ab]

Mule Deer Selectivity Trial (Fall)

The fall mule deer selectivity trial was conducted to determine if availability of current year's growth was influencing mule deer preference. In this trial, current year's growth on sagebrush plants of the seven taxa used in the trial was made completely available to the deer by initially hand clipping and removing all unavailable leaves and branches. Other major factors which had potential for influencing deer utilization and preference compared to the winter trials were: (1) the plants had been growing in a western Oregon environment for one full year, (2) the trial was conducted in a different season of the year, (3) many plants had been grazed in the previous trials, (4) two tame mule deer were used in this trial and (5) length of use periods were shortened.

Intertaxon Utilization and Composition

Utilization values for the fall trial, use periods one and two, are shown in Figures 9 and 10, respectively. In the first period, the major differences in utilization were between mountain big sagebrush, which was highest and black sagebrush which was lowest. All other taxa showed similar utilization values. Since this first-use period was shortened from 2.5 hours in the winter trials to 1.0 hours in this trial, utilization values of the second period more closely approximate the first-use period of the winter trials.

The major difference in the second period of this trial was in the high utilization of low sagebrush compared to its use in the winter trials. This was felt to be strongly related to the proportional increase in availability of growth on these plants brought about by the removal of unavailable growth by hand clipping prior to the trial.

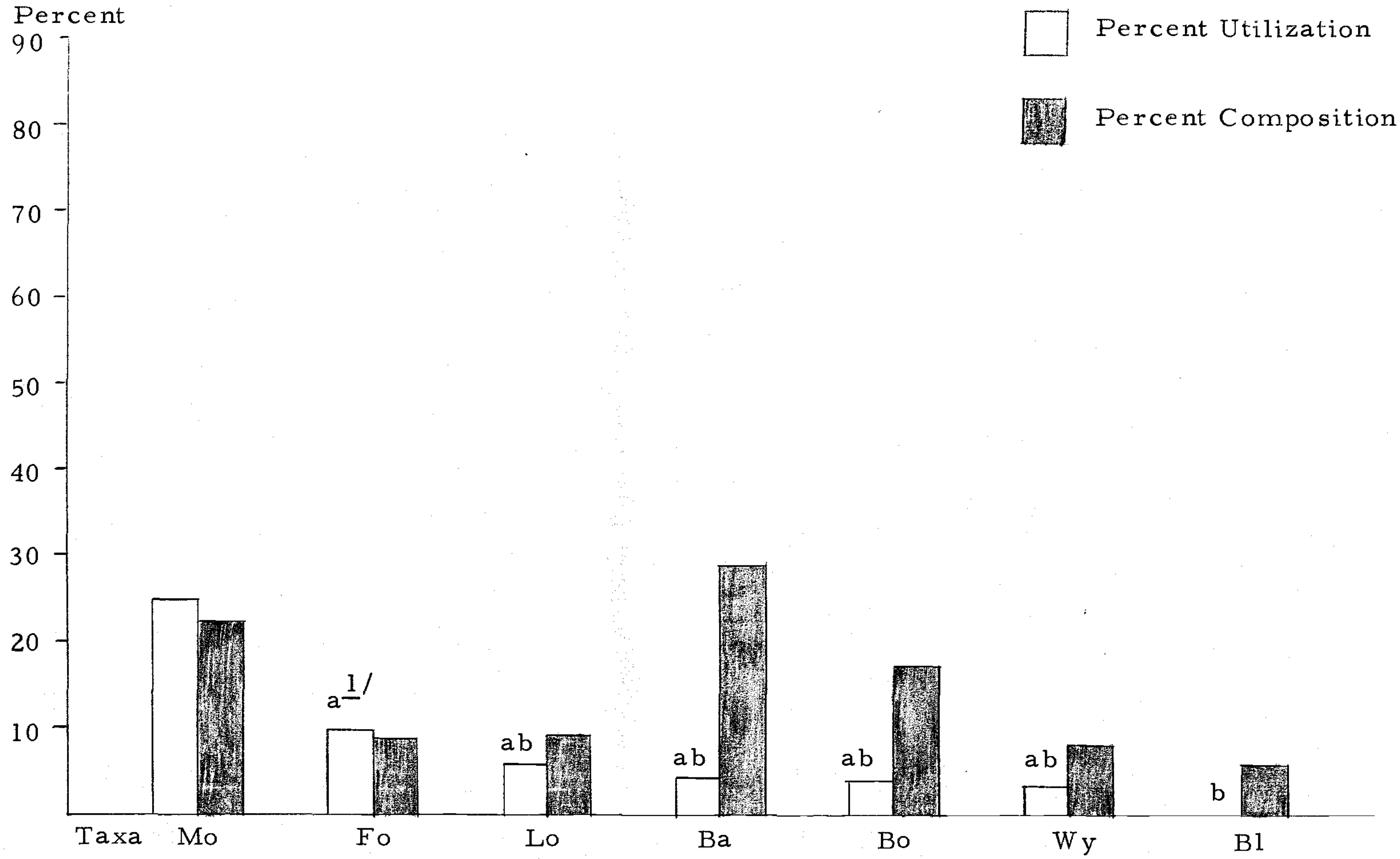

Figure 9. Percent utilization and composition of seven sagebrush taxa in Period 1 for mule deer selectivity trial 3 (combined areas - Fall).

[1]/ Utilization values followed by the same letter were not significantly different.

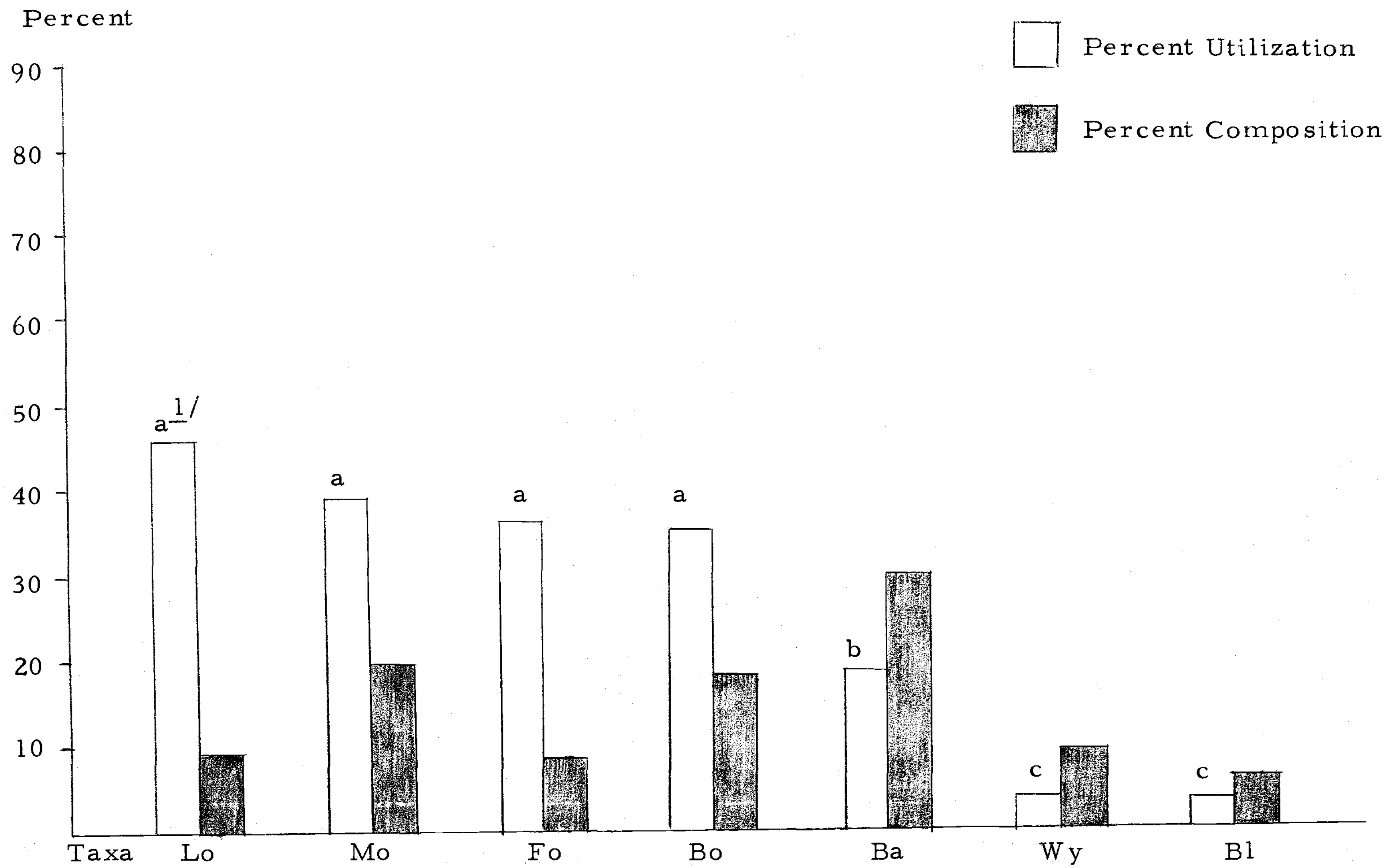

Figure 10. Percent utilization and composition of seven sagebrush taxa in Period 2 for mule deer selectivity trial 3 (combined areas - Fall).

[1] Utilization values followed by the same letter were not significantly different.

The natural growth form of low and black sagebrush is such that a lower proportion of the plant material is available for use than other taxa used in the trial. Since black sagebrush utilization remained low in this trial, the higher utilization on low sagebrush supports availability as the major factor influencing the change in percent utilization of this taxon. If this assumption is valid, this change in use was more a factor of availability than of animal selection differences among trials. However, other factors mentioned earlier may also have had some influence.

Mountain and foothill big sagebrush and Bolander silver sagebrush, which as a group were the most utilized taxa of the winter trials, remained high and showed little difference in utilization from low sagebrush in this use period. Proportional utilization on basin and Wyoming big sagebrush and black sagebrush in this trial was similar to the winter trials.

Composition of current year's growth of the seven taxa varied between 19 and 6 percent for all taxa except basin big sagebrush in both use periods of the fall trial. This taxon provided 29 and 30 percent of the growth in the two use periods, respectively. This was consistent with the pattern established in the winter trials. Black sagebrush, also consistent with the winter trials, provided the least growth in each use period.

Relative Preference Index (Fall)

Mountain big sagebrush appeared to be preferred most by mule deer in the first-use period of the fall trial (Table 9). The deer indicated more than twice the preference for this taxonomic unit over foothill big sagebrush which was the second most preferred taxonomic unit. Little difference in preference for low sagebrush, basin big sagebrush, or Wyoming big sagebrush was indicated. No preference for black sagebrush was shown.

Table 9. Relative Preference Index (RPI) for seven sagebrush taxa by period of use (deer selectivity Trial 3 - Fall).

Period 1	Taxa	Mo	Fo	Lo	Ba	Bo	Wy	Bl
	RPI	2.8	1.1	0.7	0.5	0.4	0.4	0.0
Period 2	Taxa	Lo	Mo	Fo	Bo	Ba	Wy	Bl
	RPI	1.9	1.6	1.5	1.5	0.4	0.2	0.1

In the second period of use, low sagebrush was most preferred by the deer. There appeared to be little difference in preference by the deer for mountain and foothill big sagebrush or Bolander silver sagebrush. Least preferred taxonomic units were basin and Wyoming big sagebrush and black sagebrush.

For detailed information on percent composition, utilization, and relative preference index data for all mule deer selectivity trials, refer to Appendix 2a.

Intrataxon Utilization by Areas (Fall)

Both use periods of the fall deer selectivity trial showed little significant difference in utilization values when sagebrush taxa of common genetic origin were compared by collection area (Table 10). In the first period there was no significant difference among any of the taxa from any collection area. A slight difference did appear in the second period of this trial, but there was no clear trend indicating area differences except for utilization on low sagebrush from Area 2. Generally, utilization values from collection Area 1 were higher for most taxa in Period 2. This followed the same trend established for the winter deer selectivity trial.

Table 10. Comparison of mean utilization values of seven sagebrush taxa by collection area and period of use (deer selectivity Trial 3 - Fall).

	Period 1			Period 2		
	Area			Area		
Taxa	1	2	3	1	2	3
Lo	5.9[a]	12.3[a]	0.0[a]	63.8[a]	21.9[b]	50.8[a]
Bo	7.4[a]	3.5[a]	0.4[a]	50.3[a]	23.4[b]	31.4[ab]
Bl	0.3[a]	0.0[a]	0.0[a]	5.6[a]	0.4[a]	1.4[a]
Ba	4.8[a]	4.2[a]	3.2[a]	8.2[a]	13.1[ab]	33.1[b]
Mo	26.3[a]	22.1[a]	25.8[a]	37.9[a]	37.3[a]	41.6[a]
Wy	0.4[a]	1.1[a]	4.8[a]	3.5[a]	2.3[a]	5.1[a]
Fo	20.6[a]	0.6[a]	17.7[a]	51.9[a]	21.7[b]	35.3[ab]

Sheep Trials

Sheep Selectivity Trials (Winter)

Columbia ewes from eastern Oregon were used for both winter and fall selectivity trials. The initial response of the ewes at the beginning of each selectivity trial was total disinterest in sagebrush. Little utilization on any sagebrush taxa took place until the ewes had consumed the more preferred forbs and grasses growing within the trial area.

Intertaxon Utilization and Composition

In general, sheep showed considerably less selectivity among the seven sagebrush taxa than did the deer. During the first use period (24 hours) of all three trials, only low and Bolander silver sagebrush were consistently utilized significantly higher than other taxa (Figures 11, 12 and 13). Mountain big sagebrush received intermediate utilization and foothill big sagebrush received either intermediate or high use. Wyoming and basin big sagebrush generally showed low utilization and black sagebrush received either intermediate or no utilization.

Percent composition of current year's growth of the seven taxa also was variable. Composition at the beginning of the first-use

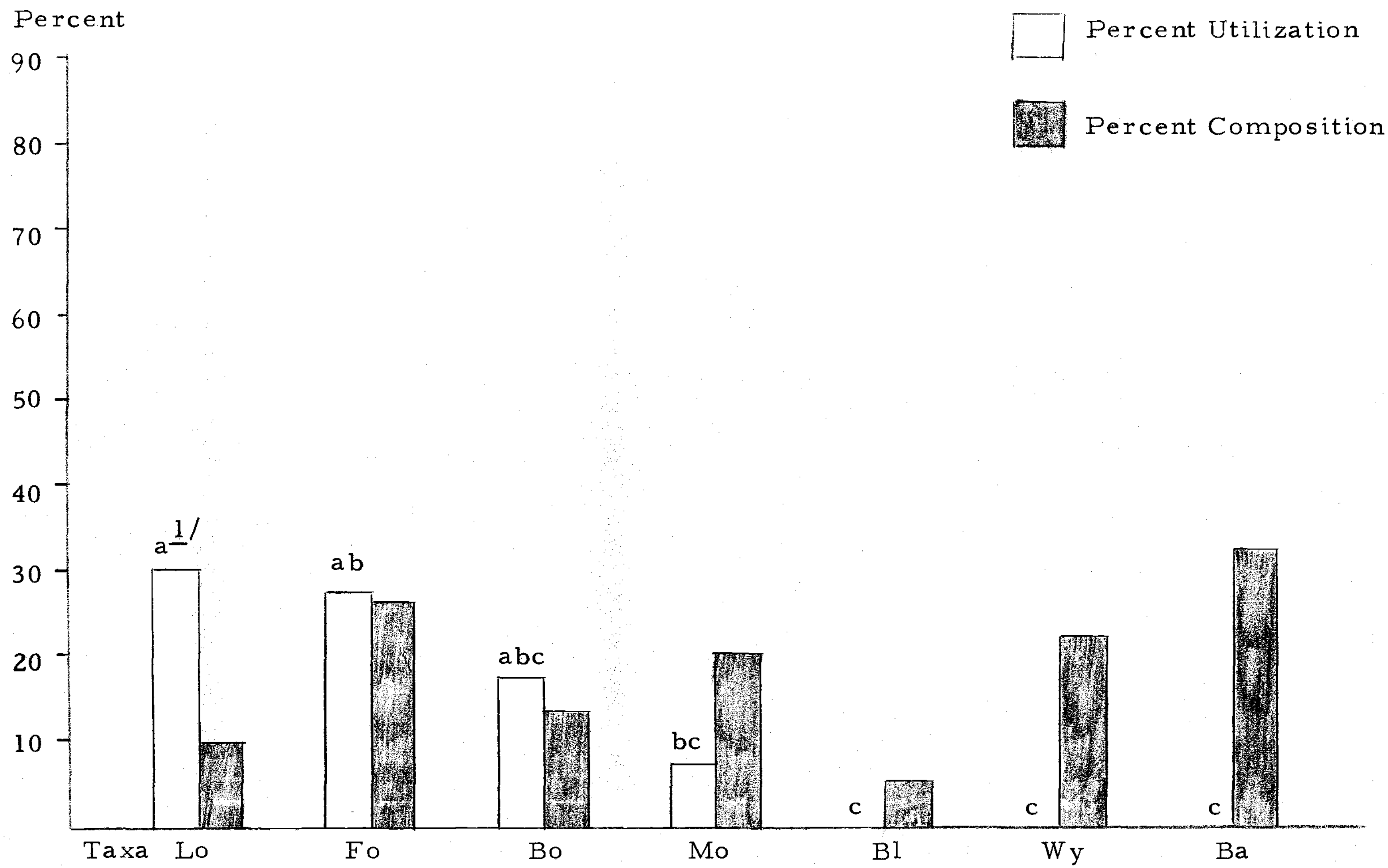

Figure 11. Percent utilization and composition of seven sagebrush taxa in Period 1 for sheep selectivity trial 1 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

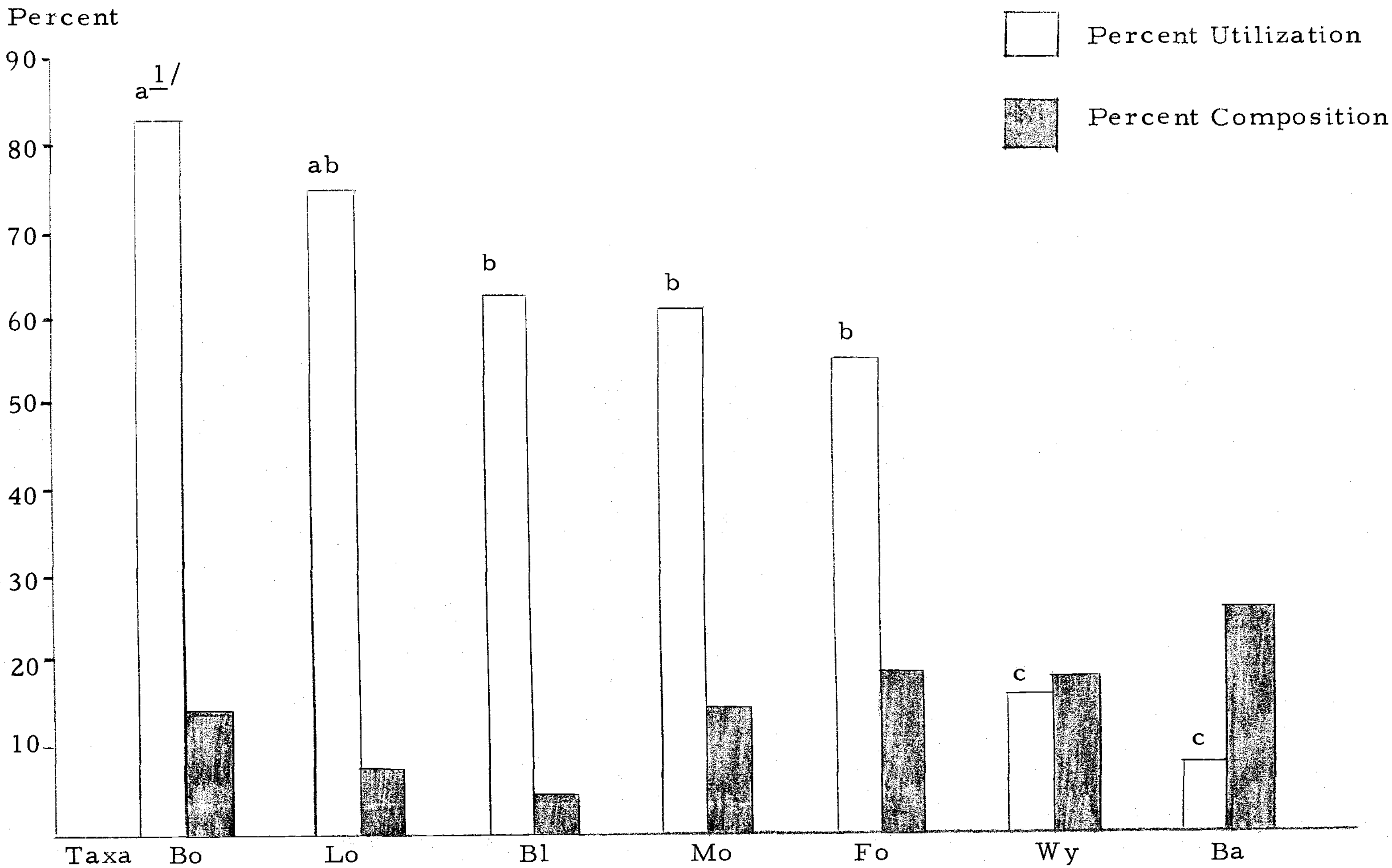

Figure 12. Percent utilization and composition of seven sagebrush taxa in Period 1 for sheep selectivity trial 2 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

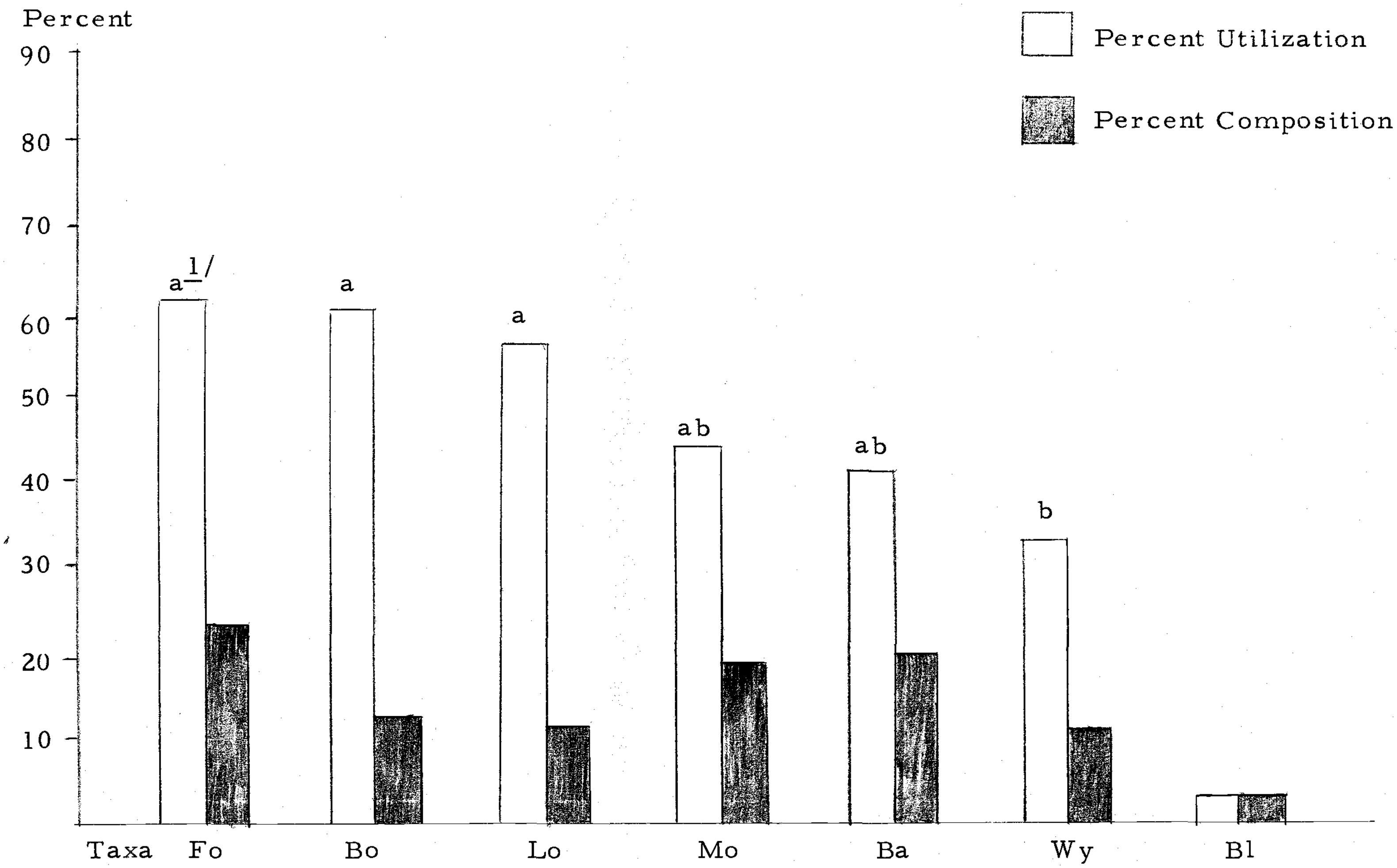

Figure 13. Percent utilization and composition of seven sagebrush taxa in Period 1 for sheep selectivity trial 3 (combined areas - Winter).

[1]/Utilization values followed by the same letter were not significantly different.

period reflected differential growth characteristics among the seven taxa. Basin big sagebrush usually had the highest percentage of growth available for the first period and black sagebrush usually had the lowest.

Sampling of utilization at the conclusion of the second-use period (48 hours) also showed considerable variation in selection by the sheep (Figures 14, 15 and 16). Although total utilization increased considerably during this period, reduced available growth on some taxa due to utilization in the first period may have had a strong influence on selection during this period. Mountain and foothill big sagebrush were consistently highly utilized. Low sagebrush received either intermediate or high utilization while the remaining taxa appeared to show no consistent trend in use.

Composition of current year's growth available on the seven taxa at the beginning of the second-use period was dependent on (1) differential growth characteristics of the seven taxa and (2) the amount of utilization that had occurred on each taxonomic unit during the first use period. Heavily utilized taxonomic units during the first-use period, such as low sagebrush and Bolander silver sagebrush, had much lower composition percentages during the second-use period which may have affected animal selection.

For significance ($P < 0.05$) of all factors and interactions in utilization of the seven sagebrush taxa refer to Appendix 1b.

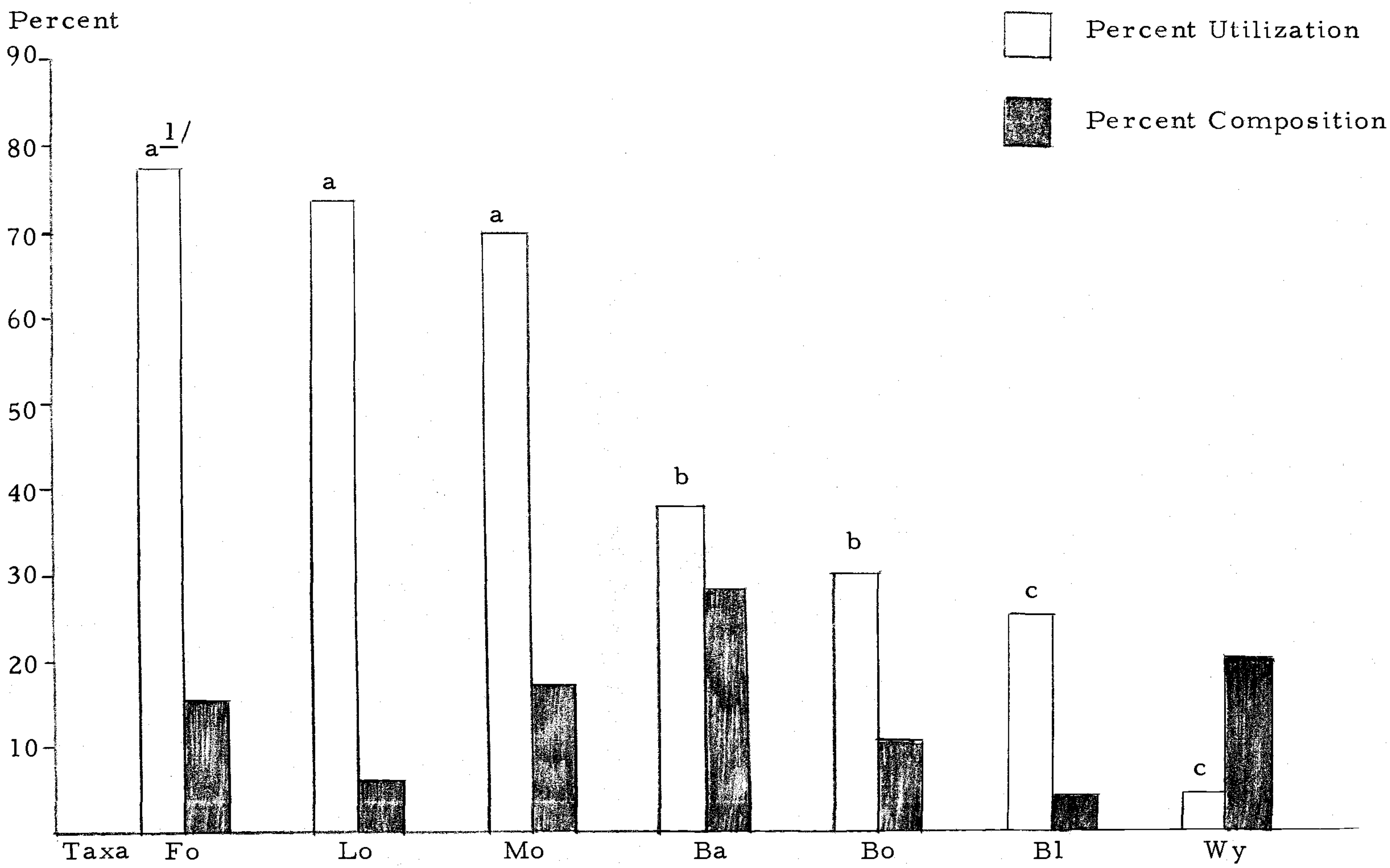

Figure 14. Percent utilization and composition of seven sagebrush taxa in Period 2 for sheep selectivity trial 1 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

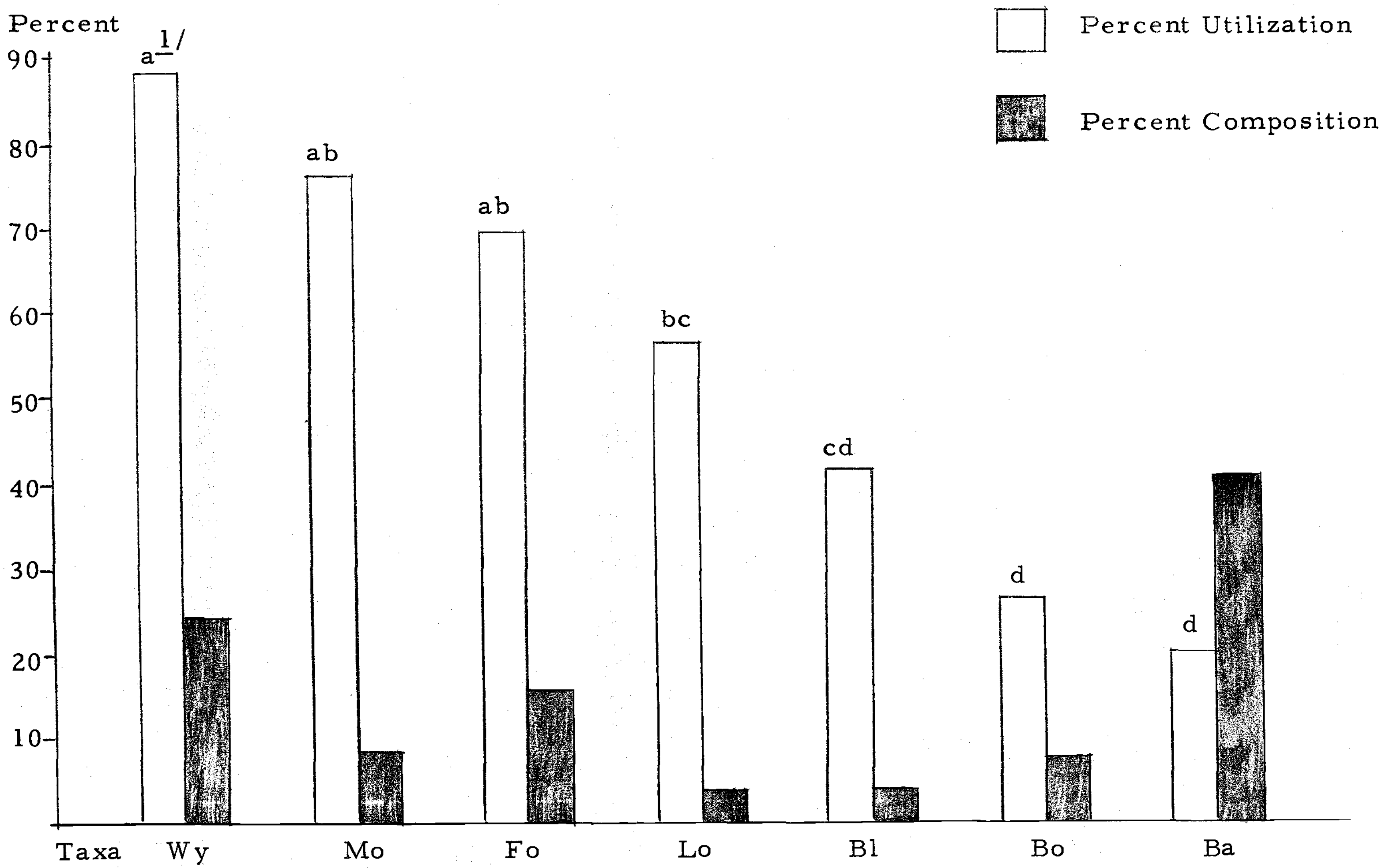

Figure 15. Percent utilization and composition of seven sagebrush taxa in Period 2 for sheep selectivity trial 2 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

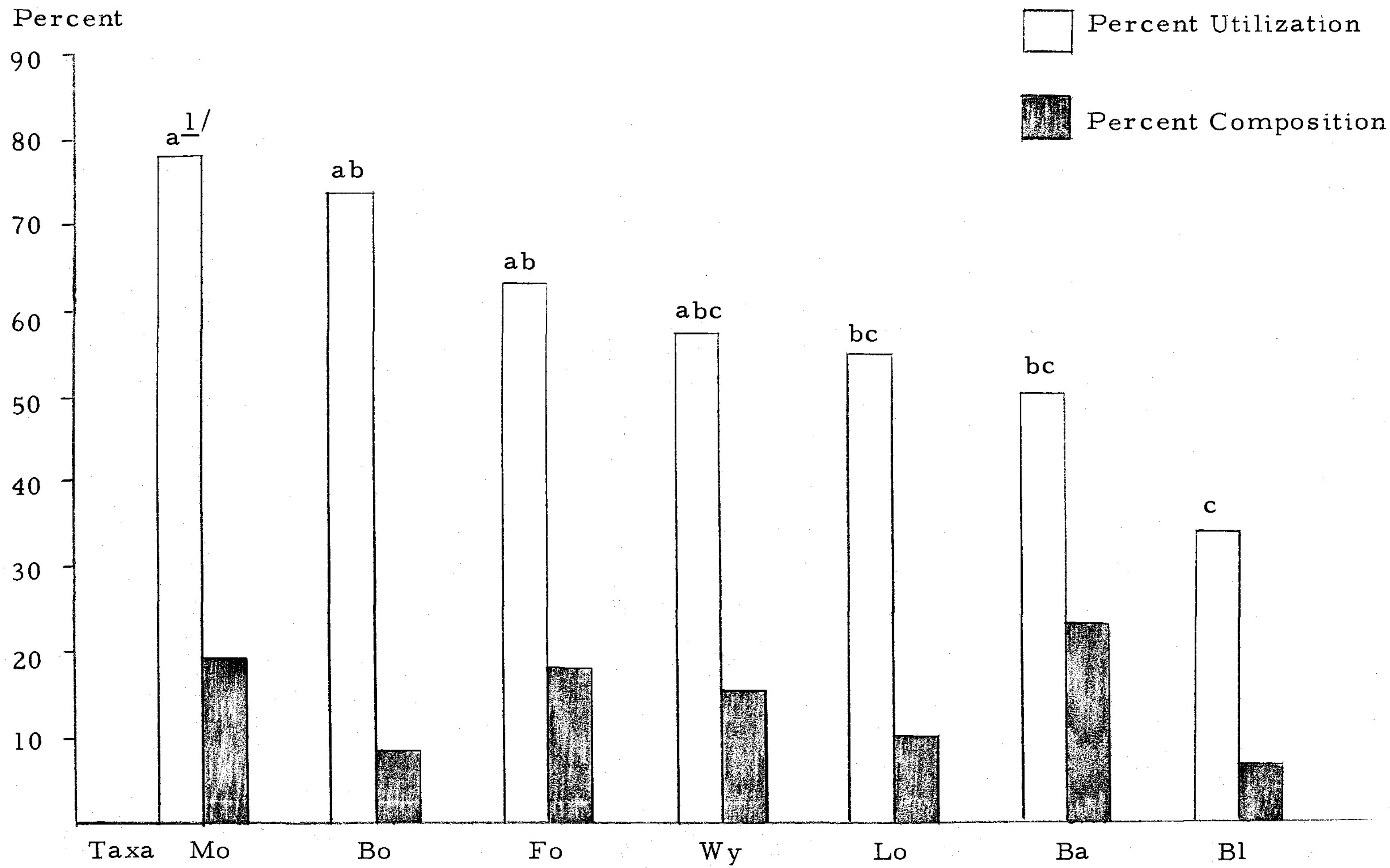

Figure 16. Percent utilization and composition of seven sagebrush taxa in Period 2 for sheep selectivity trial 3 (combined areas - Winter).

1/ Utilization values followed by the same letter were not significantly different.

Combined Sheep Selectivity Data
(Pooled Trials - Winter)

Percent utilization and composition values for each of the three winter selectivity trials were combined by taxonomic unit. The purpose of combining values was to determine potential variation in selection that may have occurred among groups of ewes in each selectivity trial.

Intertaxon Utilization and Composition

In the first-use period of the combined selectivity trial, there was little difference in utilization of low sagebrush, Bolander silver sagebrush and foothill big sagebrush (Figure 17). These three taxonomic units were the most highly utilized sagebrush taxa. Mountain big sagebrush and black sagebrush showed intermediate utilization and Wyoming and basin big sagebrush were the least utilized taxa.

Percent utilization during the second-use period of the combined selectivity trial (Figure 18) was similar to the individual selectivity trials. Utilization in this period ranged from 78 percent for mountain big sagebrush to 23 percent for basin big sagebrush. Combining utilization values assisted in providing more definitive groups of taxa.

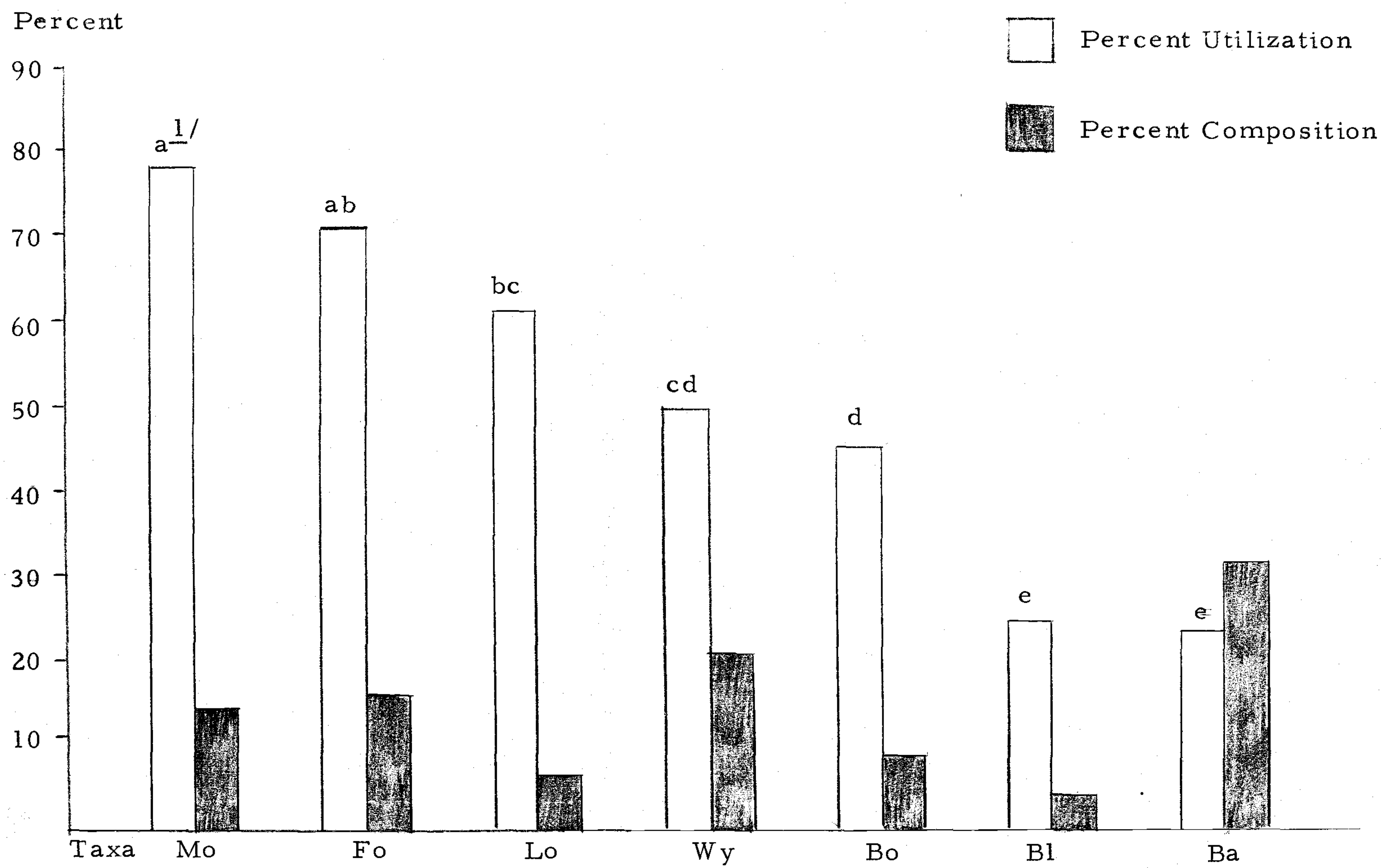

Figure 17. Percent utilization and composition of seven sagebrush taxa in Period 1 for combined sheep selectivity trials (Winter).

1/ Utilization values followed by the same letter were not significantly different.

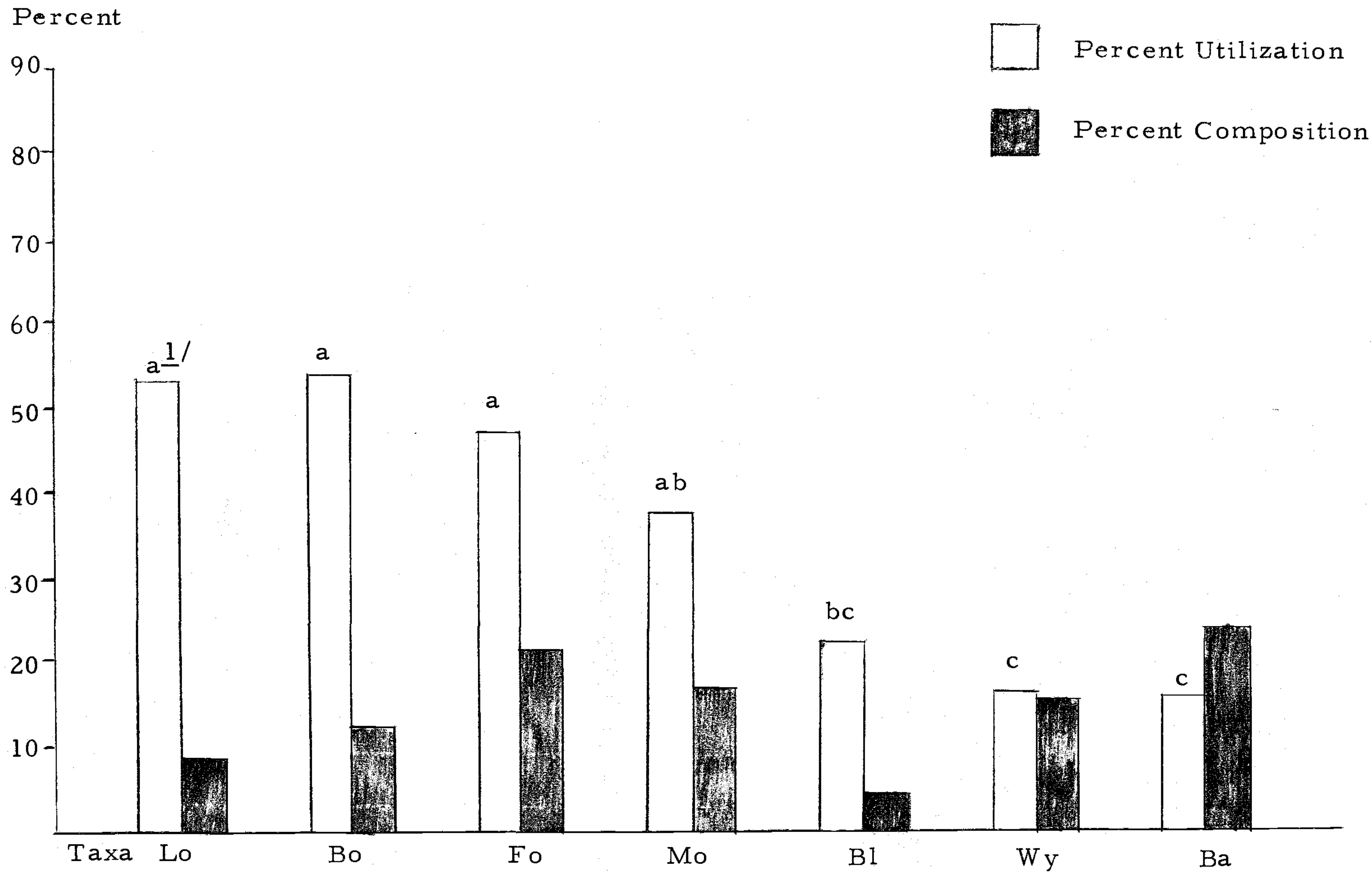

Figure 18. Percent utilization and composition of seven sagebrush taxa in Period 2 for combined sheep selectivity trials (Winter).

1/ Utilization values followed by the same letter were not significantly different.

Mountain and foothill big sagebrush were the most highly utilized taxa in this period. Wyoming big sagebrush and Bolander silver sagebrush received intermediate utilization and black sagebrush and basin big sagebrush received less utilization than all other taxa.

The percentage composition of current year's growth varied from 31 percent for big sagebrush to 4 percent for black sagebrush. Composition in this period, as in the individual trials, was dependent on plant morphology and degree of utilization in the previous period.

Relative Preference Index (Winter)

A relative Preference Index (RPI) was constructed for both use periods of the three winter sheep trials. RPI values for the first use period in each trial showed considerable variation in preference. Bolander silver sagebrush, low sagebrush and foothill and mountain big sagebrush were generally among the more preferred taxa (Table 11). Black sagebrush and basin and Wyoming big sagebrush were generally among the least preferred taxa.

The second-use period of the three winter sheep trials showed less overall variability in RPI values compared to the first period.

Foothill and mountain big sagebrush were the only taxa which consistently showed high RPI values. The remaining taxa showed too much variation among trials to categorize.

Table 11. Relative Preference Index (RPI) for seven sagebrush taxa in use Periods 1 and 2 (sheep selectivity Trials 1, 2 and 3 - Winter).

Period 1								
Trial 1	Taxa	Lo	Fo	Bo	Mo	Bl	Wy	Ba
	RPI	2.3	2.0	1.3	0.5	0.0	0.0	0.0
Trial 2	Taxa	Bo	Lo	Mo	Bl	Fo	Wy	Ba
	RPI	2.0	1.8	1.5	1.4	1.3	0.4	0.2
Trial 3	Taxa	Fo	Bo	Lo	Mo	Ba	Wy	Bl
	RPI	1.3	1.2	1.2	0.9	0.9	0.7	0.1
Period 2								
Trial 1	Taxa	Fo	Lo	Mo	Ba	Bo	Bl	Wy
	RPI	1.8	1.7	1.6	0.9	0.7	0.1	0.1
Trial 2	Taxa	Wy	Mo	Fo	Bl	Bo	Lo	Ba
	RPI	1.7	1.5	1.4	0.6	0.6	0.4	0.4
Trial 3	Taxa	Mo	Bo	Fo	Wy	Lo	Ba	Bl
	RPI	1.3	1.2	1.1	0.9	0.9	0.8	0.6

RPI values for the combined sheep selectivity trials followed the same trends as the individual selectivity trials (Table 12). In the first-use period, the overall most highly preferred taxa were low sagebrush, Bolander silver sagebrush and foothill and mountain big sagebrush. Black sagebrush, and Wyoming and basin big sagebrush, as a group, were the least preferred of the seven taxa.

Table 12. Relative Preference Index (RPI) for seven sagebrush taxa by period of use (combined sheep selectivity Trials - Winter).

Trial 1	Taxa	Lo	Bo	Fo	Mo	Bl	Wy	Ba
	RPI	1.6	1.6	1.4	1.1	0.6	0.5	0.5
Trial 2	Taxa	Mo	Fo	Lo	Wy	Bo	Bl	Ba
	RPI	1.6	1.5	1.3	1.0	0.9	0.5	0.5

In the second-use period mountain big sagebrush, foothill big sagebrush and low sagebrush were the three most preferred taxa. The latter two taxonomic units were the only taxa which consistently showed high preference by the sheep in this period of the winter trials. Bolander silver sagebrush, which was highly preferred in the first use period, and Wyoming big sagebrush were intermediate in preference. Black sagebrush and basin big sagebrush were the least preferred taxa, as was generally found in the winter trials.

Table 13. Comparison of mean utilization values of seven sagebrush taxa by collection area and period of use (sheep selectivity Trial 1, 2 and 3 - Winter).

		Period 1			Period 2		
		Area			Area		
Trial	Taxa	1	2	3	1	2	3
Trial 1	Lo	56.4^{a}	9.7^{b}	23.2^{ab}	58.3^{a}	87.5^{a}	77.0^{a}
	Bo	43.0	0.0^{a}	0.0^{a}	50.7^{a}	28.1^{ab}	10.3^{b}
	Bl	0.0^{a}	0.0^{a}	0.0^{a}	13.5^{a}	96.7	1.3^{a}
	Ba	0.0^{a}	0.0^{a}	0.0^{a}	1.1^{a}	0.0^{a}	0.0^{a}
	Mo	0.0^{a}	15.6^{a}	4.2^{a}	50.7^{a}	62.3^{ab}	93.9^{b}
	Wy	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	12.2^{a}	0.0^{a}
	Fo	68.1	0.0^{a}	11.9^{a}	95.8^{a}	77.5^{a}	60.2^{a}
Trial 2	Lo	90.4^{a}	76.6^{ab}	54.9^{b}	40.0^{a}	75.2^{a}	52.8^{a}
	Bo	100.0^{a}	94.5^{a}	54.5	0.0	66.7^{a}	86.7^{a}
	Bl	90.0^{a}	58.6^{ab}	38.0^{b}	24.3^{a}	50.6^{a}	47.5^{a}
	Ba	0.0^{a}	0.0^{a}	24.6^{a}	36.7^{a}	16.7^{a}	43.0^{a}
	Mo	65.2^{ab}	31.9^{a}	85.3^{b}	71.5^{a}	92.4^{a}	63.8
	Wy	37.3^{a}	0.0^{b}	11.4^{ab}	83.1^{a}	87.0^{a}	96.7^{a}
	Fo	99.1	16.5^{a}	49.2^{a}	13.3	94.6^{a}	100.0^{a}
Trial 3	Lo	58.1^{a}	53.1^{a}	57.8^{a}	44.3^{a}	75.1^{a}	41.5^{a}
	Bo	74.6^{a}	30.8	73.3^{a}	63.1^{a}	93.3^{a}	64.4^{a}
	Bl	0.0^{a}	0.0^{a}	86.3	59.5^{a}	23.3^{a}	20.4^{a}
	Ba	48.2^{a}	32.8^{a}	41.3^{a}	33.2^{a}	45.8^{a}	70.0^{a}
	Mo	39.8^{a}	33.4^{a}	59.7^{a}	63.6^{a}	91.8^{a}	77.9^{a}
	Wy	46.5^{a}	16.4^{a}	36.1^{a}	60.8^{a}	52.3^{a}	57.0^{a}
	Fo	62.6^{a}	41.8^{a}	72.7^{a}	67.7^{a}	59.7^{a}	62.0^{a}

Intrataxon Utilization by Area (Winter)

Mean percent utilization values obtained for each taxonomic unit were analyzed to determine if different site characteristics influenced sheep preference (Table 13). In both periods of the three winter sheep selectivity trials, only limited differences in utilization were apparent among the same taxa collected from the three geographic areas. In general, utilization values of the seven taxa from Area 1 did appear to show more significant difference as a group from the same taxa of the other two areas. Where variation was present, it tended to occur in those taxa which were most highly preferred by the sheep, specifically low sagebrush, Bolander silver sagebrush and foothill big sagebrush. This also was characteristic of utilization values of the combined selectivity trials (Table 14).

Table 14. Comparison of mean utilization values of seven sagebrush taxa by collecting area and period of use (combined sheep selectivity Trials - Winter).

	Period 1			Period 2		
	Area			Area		
Taxa	1	2	3	1	2	3
Lo	68.3	46.4[a]	45.3[a]	47.5[a]	79.3	57.1[a]
Bo	72.5	41.7[a]	42.6[a]	37.9[a]	42.7[ab]	53.8[b]
Bl	30.0[a]	19.5[a]	15.5[a]	32.4[a]	25.0[a]	23.1[a]
Ba	16.1[a]	10.9[a]	22.0[a]	11.6[a]	20.9[a]	37.6
Mo	35.0[ab]	26.9[b]	47.9[a]	61.9	88.2[a]	78.5[a]
Wy	28.0[a]	5.5	15.8[a]	48.0[a]	50.5[a]	51.2[a]
Fo	76.6	19.4	44.5	59.0	77.3[a]	78.5[a]

Sheep Selectivity Trial (Fall)

Sheep selectivity Trial 4 was conducted in the fall of 1974. The purpose of this trial was to determine if non-availability of current year's growth due to differential growth characteristics of taxonomic units had affected sheep preference in the winter trials. Current year's growth on all plants of the seven taxa was made totally available in this trial by methods described earlier (page 69). Other factors which had potential for influencing animal selection were also described.

Intertaxon Utilization and Composition

Utilization of the seven sagebrush taxa followed the general trend in utilization established in the preliminary trial and in the winter sheep trials. Bolander silver sagebrush and low sagebrush were the most utilized (Figure 19). Mountain and foothill big sagebrush and black sagebrush received intermediate utilization and Wyoming and basin big sagebrush received the least, in this case, no utilization.

Several differences in utilization by sheep in the second-use period of the fall trial were apparent when compared to the winter trials (Figure 20). Low sagebrush received the highest utilization of the seven taxa. Black sagebrush was more highly utilized during

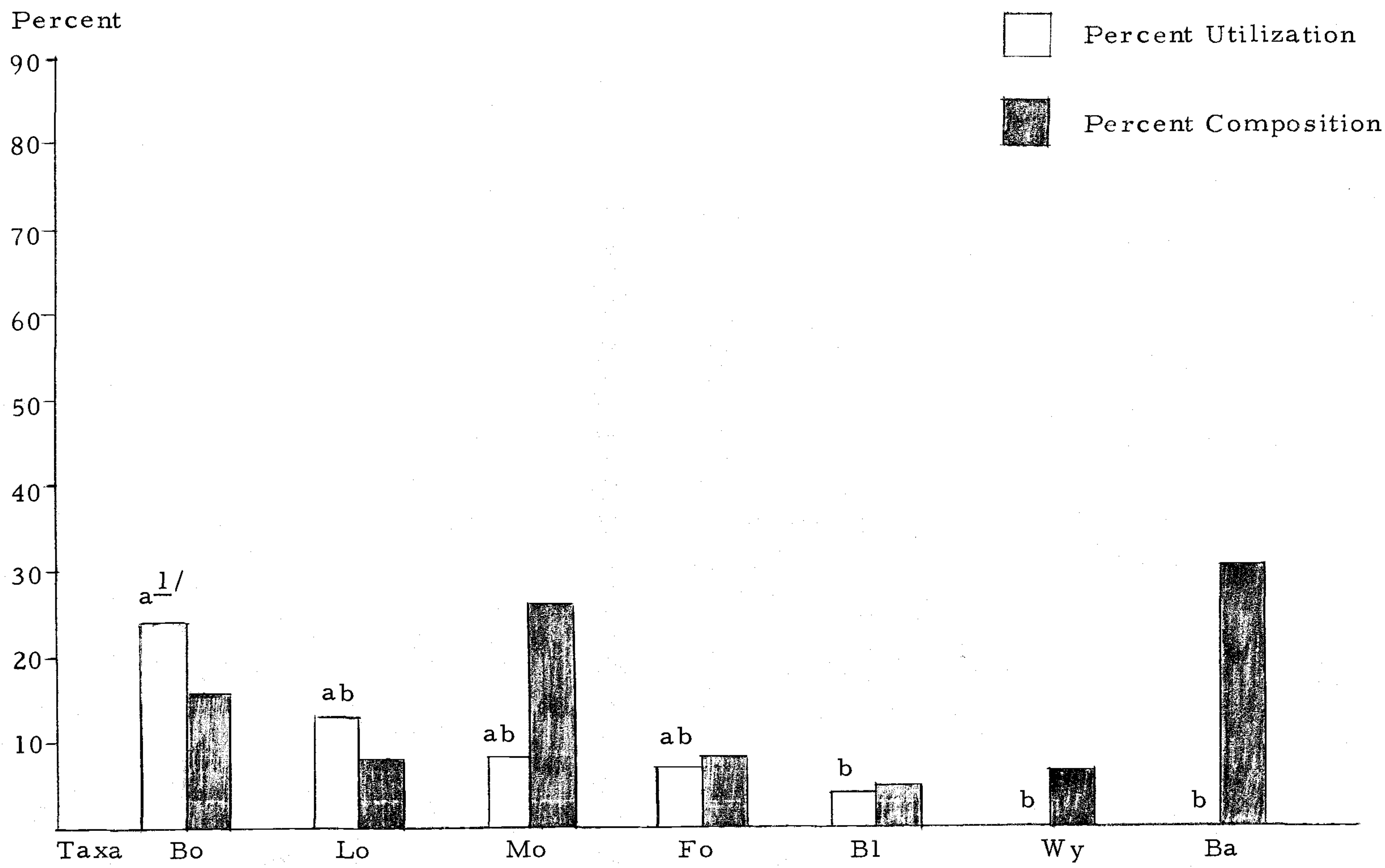

Figure 19. Percent utilization and composition of seven sagebrush taxa in Period 1 for sheep selectivity trial 4 (combined areas - Fall).

1/ Utilization values followed by the same letter were not significantly different.

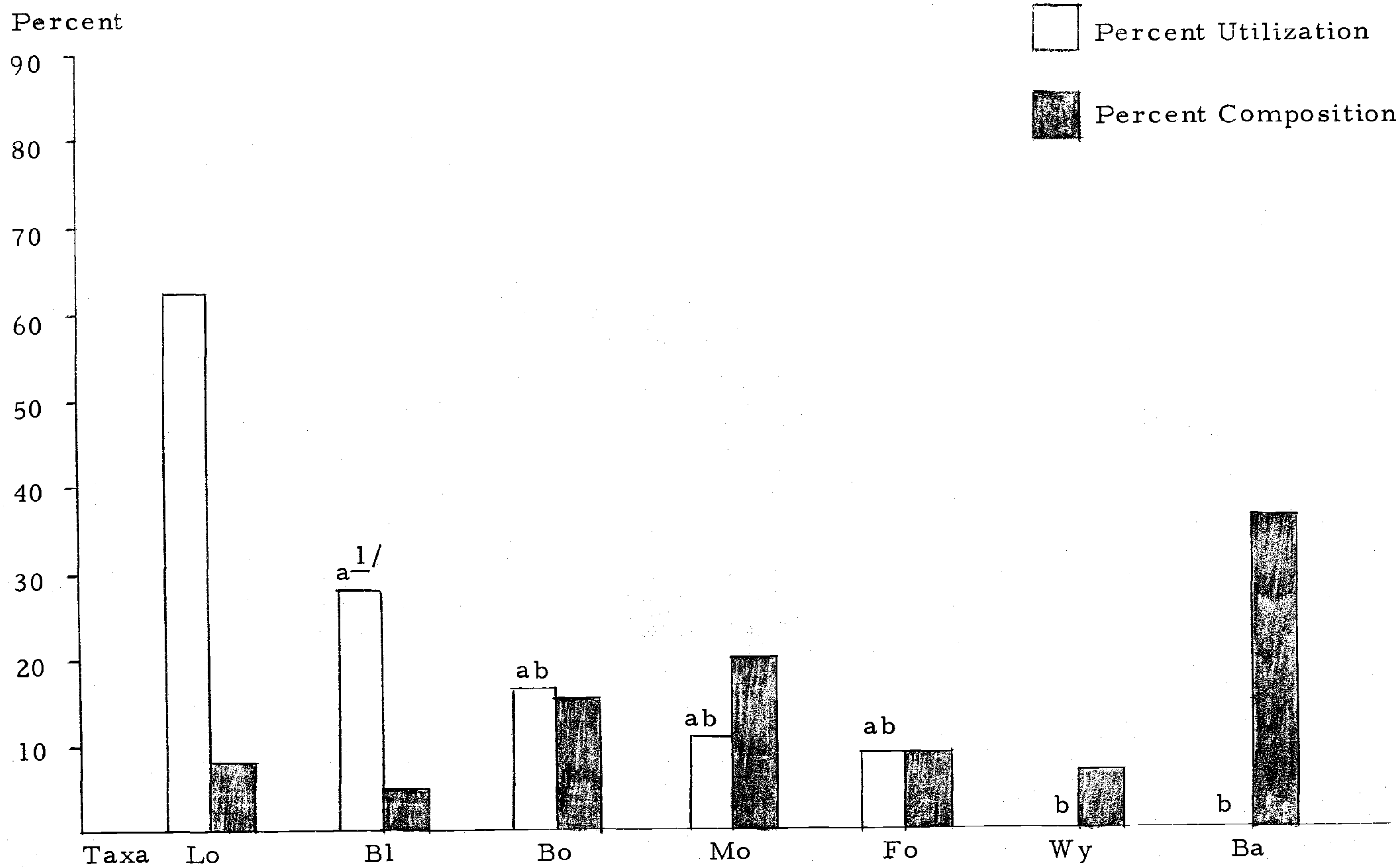

Figure 20. Percent utilization and composition of seven sagebrush taxa in Period 2 of sheep selectivity trial 4 (combined areas - Fall).

1/ Utilization values followed by the same letter were not significantly different.

this period than it was during the same period of the winter trials. There remained a continued high utilization on Bolander silver sagebrush and mountain and foothill big sagebrush while Wyoming and basin big sagebrush received the least utilization (in this trial - no use).

These differences in utilization may be related to factors affecting this trial which were not present in the winter trials as described earlier.

Percent composition of growth in both periods of use in the fall trial followed the same trend as in the winter trials. Differences in growth characteristics among taxa was the major factor influencing amount of growth available in the first-use period. In the second-use period, the amount of utilization on individual taxa during the first-use period also was a major factor determining percent composition available for use.

Relative Preference Index (Fall)

RPI values for both use periods of the fall trial are shown in Table 15. In the first period the sheep showed the highest preference for Bolander silver sagebrush with low sagebrush the next most preferred taxonomic unit. Mountain and foothill big sagebrush were moderately preferred and were followed in order of preference by black sagebrush. Wyoming and basin big sagebrush, which were not

Table 15. Relative Preference Index (RPI) for seven sagebrush taxa in use Periods 1 and 2 of the Fall sheep selectivity trial.

Period 1	Taxa	Bo	Lo	Mo	Fo	Bl	Wy	Ba
	RPI	3.2	1.6	1.0	0.9	0.5	0.0	0.0
Period 2	Taxa	Lo	Bl	Bo	Mo	Fo	Wy	Ba
	RPI	5.2	2.3	1.3	1.0	0.8	0.0	0.0

Table 16. Mean utilization of seven sagebrush taxa comparing taxonomic units from three collection areas (sheep selectivity Trial 4 - Fall).

	Period 1			Period 2		
	Area			Area		
Taxa	1	2	3	1	2	3
Lo	17.5[a]	6.0[a]	14.3[a]	8.2[a]	5.4[a]	64.7
Bo	56.7	16.5[a]	0.0[a]	30.6[a]	16.1[ab]	0.0[b]
Bl	0.0[a]	9.8[a]	9.8[a]	34.4[a]	57.7[a]	33.8[a]
Ba	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Mo	0.0[a]	0.0[a]	23.5	3.8[a]	3.8[a]	30.1
Wy	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Fo	17.2[a]	4.3[a]	0.0[a]	23.3[a]	0.0[a]	3.6[a]

utilized, were the least preferred taxa. This ranking in preference followed very close to the preference order of the winter trials.

In the second use period, low sagebrush was the most highly preferred taxon followed by black sagebrush. Use on these taxa was considerably higher than in the winter trials. Mountain and foothill big sagebrush dropped to only a moderate preference rating while Bolander silver sagebrush stayed near the same in ranking (intermediate). Basin and Wyoming big sagebrush remained with lowest preference ranks.

For detailed information on percent composition, utilization and RPI for the seven sagebrush taxa by area of collection, refer to Appendix 2b.

Intrataxon Utilization by Area (Fall)

Mean percent utilization values from each collection area were compared for each of the seven taxonomic units of sagebrush for use Periods 1 and 2 (Table 16). Comparison of utilization on the same taxon from each collection area showed little overall difference relative to area. An exception was mountain big sagebrush which showed higher utilization for plants from Area 3 in both trial periods.

Volatile Oils

Percent Volatile Oil Content

Current year's growth samples collected from sagebrush plants of the seven taxa were steam distilled to obtain percent volatile oil content on an oven dry weight basis. Preliminary distillations indicated that the size of the sample from individual plants was insufficient to provide a measurable volume of volatile oil. Consequently, volatile oil distilled from individual plants was combined by taxonomic unit for each collection area from which the plants had been obtained in eastern Oregon. Insufficient current year's growth was available even using this method for black sagebrush and for low sagebrush from two collection areas. Statistical analysis was not used to evaluate differences in volatile oil content since sufficient observations were not available after grouping the plant samples by taxa.

Percent weight of volatile oil are presented by taxonomic unit for each collection area in Table 17. Basin and mountain big sagebrush were the only taxa which showed consistently high volatile oil percentages in all three collection areas. Bolander silver sagebrush from Area 3 and Wyoming big sagebrush from Area 2 also had relatively high percentages. Foothill big sagebrush was consistently lower in volatile oil percentages in samples from all three areas.

Table 17. Percent volatile oil content of current year's growth (O. D.) for seven sagebrush taxa for each collection area.

	Volatile Oil (%)		
	Area		
Taxa	1	2	3
Lo	----[1/]	0.05	----
Bo	0.31	0.27	0.81
Bl	----	----	----
Ba	1.34	0.77	0.53
Mo	1.11	1.25	0.60
Wy	0.19	0.95	0.28
Fo	0.07	0.33	0.05

[1/] A measurable quantity of volatile oil was not distilled from taxonomic units from these areas using comparable fresh weight samples.

Effect on Utilization

Total volatile oil content had a slight negative influence on mean utilization of the seven sagebrush taxa for both the sheep and mule deer (Appendixes 3a and 3b). The volatile oil content appeared to account for 28.1[2/] percent of the variation in utilization of the seven

[2/] These values are the coefficient of correlation squared.

taxa in the sheep selectivity trials but only 5.8 percent of the variation in utilization in the deer trials.

Major Volatile Oil Fractions

The majority of all fractions were emitted and graphed within forty minutes after injection of the volatile oil sample into the gas chromatograph. Total number and relative volume of volatile oil fractions varied, both intertaxonomically and intrataxonomically. Only the major peaks (10^1 in relative area) were used for comparisons. Thirty-four major peaks were represented in the gas chromatographs, although all were not necessarily present in each chromatograph of a taxon.

Percentage values for each of the thirty-four peaks were compared to determine the possible influence that each fraction might have on animal preference (Appendix 4). Sixteen[3/] of the thirty-four major fractions were selected for further analysis (Table 18). Criteria used for selection were that (1) each fraction was present in volatile oil samples of some but not all taxonomic units from the three areas or that (2) each fraction was present in volatile oil samples from all taxonomic units but with considerable variation in relative amount. As an example, fraction #8 was

---

[3/] Sixteen independent variables was the maximum number that could be compared in one multiple regression analysis.

Table 18. Sixteen volatile oil fractions selected as independent variables for Multiple Regression Analysis for comparing influence of the fractions on animal utilization on seven sagebrush taxa.[1]

Taxa	Lo[2]			Bo			Ba			Mo			Wy			Fo		
Area	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
FRACTION																		
2	1.00	1.00	1.00	0.72	1.32	34.10	1.05	1.02	0.92	2.00	0.54	1.09	1.24	1.80	3.23	0.23	0.00	0.14
4	0.64	0.64	0.64	5.94	0.43	2.32	0.92	0.89	1.52	1.58	1.39	11.82	2.03	0.76	1.73	0.85	0.20	0.51
6	1.53	1.53	1.53	1.01	11.32	9.35	27.28	21.64	8.18	2.86	1.05	3.97	4.65	8.25	4.39	0.33	0.36	2.69
8	0.65	0.65	0.65	11.84	2.07	2.66	3.26	3.15	1.58	12.62	7.85	11.97	1.22	2.11	3.82	27.34	3.87	1.86
12	77.40	77.40	77.40	0.00	0.22	2.54	2.30	2.19	21.74	12.75	6.88	1.55	39.93	66.50	36.47	2.34	81.39	64.93
15	1.69	1.69	1.69	0.49	1.77	4.71	24.47	23.46	4.27	0.46	0.70	0.02	6.81	6.63	5.76	1.34	0.60	0.90
16	0.45	0.45	0.45	0.26	8.59	2.42	0.66	0.99	11.82	0.47	0.31	0.33	1.65	1.09	4.67	0.81	0.63	2.69
20	0.20	0.20	0.20	0.27	1.01	0.32	0.29	0.21	0.27	0.00	0.00	0.00	0.47	0.17	0.69	0.00	0.00	0.00
23	0.28	0.28	0.28	57.96	34.60	15.45	1.11	1.02	1.12	0.00	0.14	0.13	0.82	0.49	0.87	0.07	0.26	0.38
24	0.00	0.00	0.00	0.00	1.70	0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.63
25	5.86	5.86	5.86	1.10	1.84	1.81	22.51	24.01	26.88	8.42	13.10	61.63	21.28	4.38	19.20	51.32	5.99	13.10
29	0.32	0.32	0.32	0.26	0.52	0.39	0.41	0.37	0.44	0.98	0.08	0.00	0.62	0.32	0.95	0.23	0.17	0.39
30	0.18	0.18	0.18	2.67	0.00	2.54	0.53	0.39	0.52	0.62	0.17	0.28	0.39	0.10	0.22	1.14	0.34	0.31
32	0.43	0.43	0.43	0.55	2.25	1.86	0.32	0.42	0.49	0.77	0.24	0.66	1.16	0.87	1.43	1.10	0.61	1.16
33	0.40	0.40	0.40	0.20	0.94	0.52	27.53	28.45	1.86	0.82	0.39	0.47	0.83	0.16	0.46	1.59	0.96	0.84
34	0.82	0.82	0.82	0.00	0.00	0.00	0.35	0.33	0.32	0.00	0.00	0.00	1.27	0.90	2.01	0.00	0.00	0.00

[1] Volatile oil samples from current year's growth of black sagebrush were not obtained.

[2] Volatile oil was obtained from low sagebrush only from Area 2. Fraction percentages from this area were used for Areas 1 and 2 for comparison purposes.

relatively low in low sagebrush, moderately high in Bolander silver sagebrush (except in Area 1), moderately high for Wyoming and basin big sagebrush and high for mountain and foothill big sagebrush.

Generally, a chemical fraction was present in volatile oil samples obtained from a taxon in each of the three areas in the same relative proportion. Amount and kinds of fractions found in a particular taxon were generally consistent regardless of collection area. Although some variation was present intrataxonomically, most of the variation was on an intertaxonomic basis.

Although most of the volatile oil fractions were unknown, five fractions were tentatively identified. Identification consisted of injecting a pure sample of a known fraction into the gas chromatograph and comparing the retention time of the sample with the retention times of the unknown sagebrush fractions. The five volatile oil fractions identified were a-pinene (#2), b-pinene (#4), 1, 8-cineol (#8), dl-camphor (#25) and a-terpineol (#30).

Additional analysis for the sixteen volatile oil fractions consisted of multiple linear regression to determine their effect upon relative animal utilization on the seven sagebrush taxa (Appendix 3c and 3d).

Effect Upon Utilization

Multiple regression analysis of the sixteen chemical fractions compared with utilization revealed that eight volatile oil fractions accounted for 90 percent of the variation in utilization on the seven sagebrush taxa by mule deer (Table 19). Chemical fractions number 8 (1, 8-cineol) and 15 (unknown) accounted for 74 percent of the total variation.

In the sheep selectivity trials, twelve volatile oil fractions were needed to account for approximately 90 percent of the variation in sheep utilization (Table 20). Chemical fractions of the volatile oil compounds appeared to have, individually, much less effect on utilization in the sheep trials.

Seven chemical fractions were found to be common influences in accounting for 90 percent of the variation present in both mule deer and sheep utilization (Table 21). The majority of these seven fractions affected utilization positively. Only fractions 33 (unknown) and 2 (a-pinene) had a negative influence on mule deer utilization and only fraction 33 had a negative influence on sheep utilization.

Fraction 15 (unknown) had a high negative influence on deer utilization but did not appear to be a factor in determining 90 percent of the variation in sheep utilization. This influence on variation in

Table 19. Seven volatile oil fractions and R^2 values accounting for ninety percent of the variation in utilization in mule deer selectivity trials.

Fraction No.	R^2
8	.51
15	.74
33	.81
32	.84
4	.86
30	.87
2	.88
23	.90

Table 20. Twelve volatile oil fractions and R^2 values accounting for ninety percent of the variation in utilization in the sheep selectivity trials.

Fraction No.	R^2
6	.25
30	.37
25	.41
24	.47
16	.55
20	.63
32	.66
23	.76
2	.82
33	.86
8	.89
4	.90

utilization of the seven sagebrush taxa was exceeded only by fraction 8 (1, 8-cineol) which had a positive influence.

Table 21. Volatile oil fractions accounting for ninety percent of the variation and their specific influence (positive or negative) on utilization of the seven sagebrush taxa. Fractions are arranged according to their common or individual effect on deer and/or sheep utilization.

Common (Deer and Sheep)		Individual (Deer)		Individual (Sheep)	
Fraction No.	Ident.	Fraction No.		Fraction No.	Ident.
8	1,8-Cineol(+)	15	Unknown(-)	6	Unknown(-)
33	Unknown(-)			25	dl-camphor(+)
32	Unknown(+)			24	Unknown(+)
4	B-pinene(+)			16	Unknown(-)
30	a-terpineol(+)			20	Unknown(-)
2	a-pinene(+, -)[1/]				
23	Unknown(+)				

[1/]This fraction showed positive influence for deer but negative influence for sheep on utilization of the seven sagebrush taxa.

Five volatile oil fractions that were not found to be influential in accounting for 90 percent of the variation in deer utilization did have an influence in accounting for 90 percent of the variation in sheep utilization.

Generally, fractions having a negative influence appeared to be highest in sagebrush taxa that were among the least preferred for both mule deer and sheep (Table 18). For example, basin and

Wyoming big sagebrush, which were taxa that were generally among the least preferred by sheep and deer, had higher concentrations of fraction 6 (unknown) which showed a negative influence. The more preferred taxonomic units such as low sagebrush, Bolander silver sagebrush and foothill and mountain big sagebrush had intermediate concentrations of this fraction.

Seasonal Variation in Volatile Oil Content

Volatile oil samples (μl/g-O.D.) distilled from the seven sagebrush taxa collected from sites in Area 1 revealed considerable seasonal difference in volatile oil content. Difference in relative oil content was found between taxa and between periods for the same taxonomic unit (Figure 21). Members of the big sagebrush complex followed a similar trend of decreasing oil content between the March and May collection dates. This period covered the time through the end of winter dormancy to appearance of new growth on these plants. Bolander silver sagebrush showed only a slight decrease in oil content while black and low sagebrush showed an increase in volatile oil content during this period. Foothill big sagebrush had the greatest decrease in volatile oil content and had the lowest volatile oil content of any taxa studied at the end of this period.

The May to August period corresponds to the period of increasing drought stress upon the plants of these areas. During

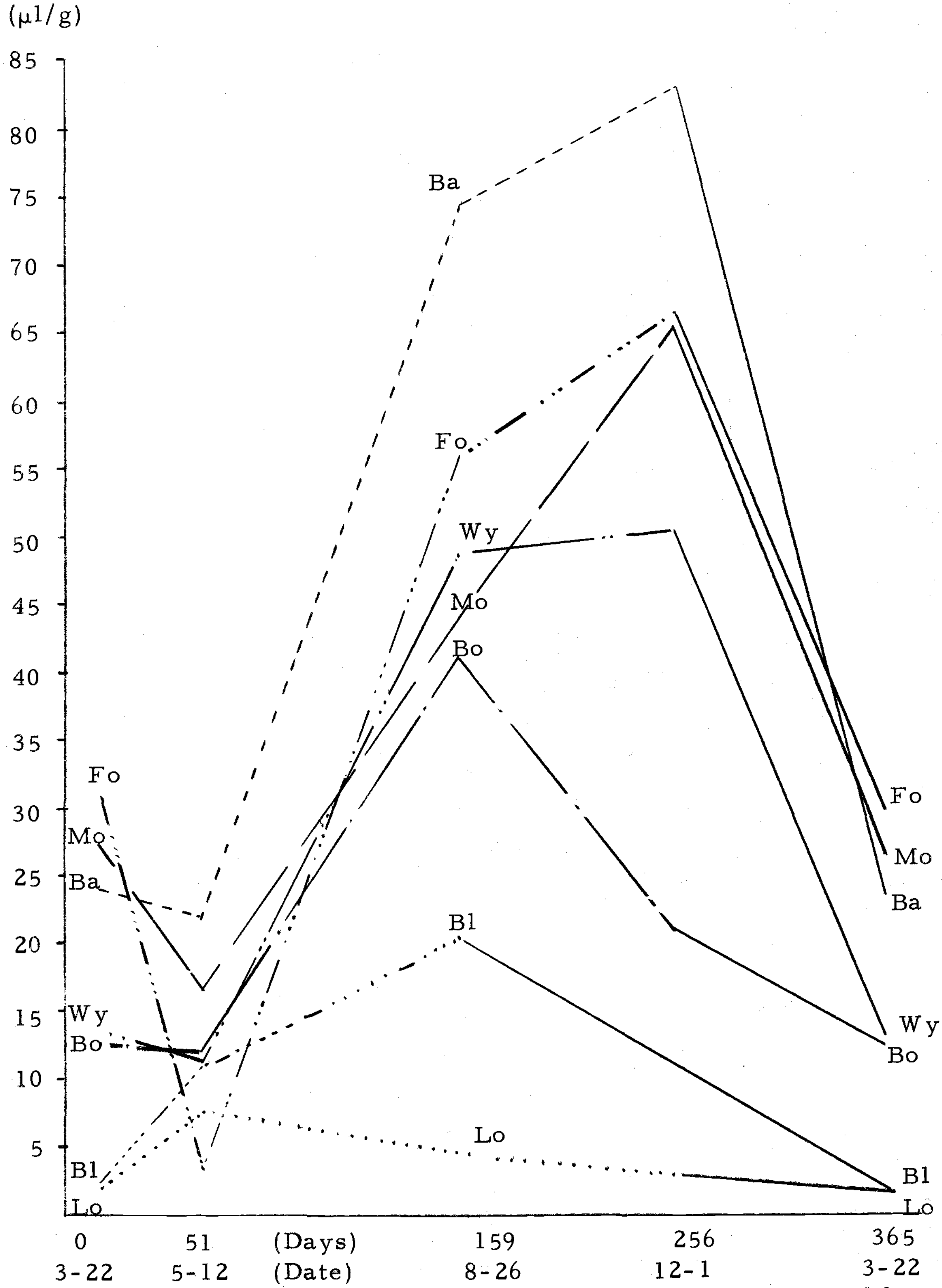

Figure 21. Relative volatile oil content (µl/g-O.D.) of seven sagebrush taxa at four seasonal dates. Trends indicated by the solid portion of each line were not derived from actual measurements but were included to complete the graph to levels found in the dormant season (3-22-74).

this period, volatile oil content increased for all taxonomic units except low sagebrush. Volatile oil content of this taxon began decreasing at approximately the May sampling date and showed continued decrease for subsequent growth periods sampled.

Between the August and December collection dates, volatile oil content of all members of the big sagebrush group was still increasing while oil content in Bolander silver sagebrush and low sagebrush was decreasing. No measurements were taken from black sagebrush in the December sampling period, consequently it is not known when it began to decrease in oil content. Growth samples from the seven sagebrush taxa were not collected the following March, but based on the decreasing volatile oil content of the preceeding period, it was assumed that this decreasing trend would continue in the December to March period.

Foothill big sagebrush reflected the greatest variation from season to season of the seven taxa studied. This taxonomic unit had the highest oil content of all taxa on the March collection date and the lowest oil content of all taxa on the May collection date. Volatile oil content of current year's growth was compared inter-taxanomically and intrataxanomically by collection date (Tables 22 and 23). The March collection date showed that foothill, mountain and basin big sagebrush, as a group, had the highest oil content. Wyoming big sagebrush and Bolander silver sagebrush had

Table 22. Intertaxon volatile oil content (μl/6-O. D.) of the seven sagebrush taxa during four seasonal stages of growth.

	Dates			
Taxa	3-22	5-12	8.26	12.1
Lo	1.7[c]	7.6[bc]	4.7[c]	3.1
Bo	12.6[b]	11.8[b]	41.4[ab]	21.3
Bl	2.1[c]	10.9[bc]	20.5[c]	----[1/]
Ba	23.9[a]	22.1[a]	74.8	83.2[a]
Mo	25.7[a]	16.5[ab]	44.2[ab]	65.7[ab]
Wy	13.6[b]	11.3[bc]	48.6[ab]	50.7[b]
Fo	30.8[a]	3.3[c]	56.0[a]	66.7[ab]

[1/] Current year's growth samples were not collected from this taxonomic unit on this date.

Table 23. Intrataxon volatile oil content (μl/g-O. D.) of the seven sagebrush taxa during four seasonal stages of growth.

	Dates			
Taxa	3-22	5-12	8-26	12-1
Lo	1.7[b]	7.6[a]	4.7[ab]	3.1[ab]
Bo	12.6[b]	11.8[b]	41.4[a]	21.3[ab]
Bl	2.1	10.9	20.5	----[1/]
Ba	23.9[b]	22.1[b]	74.8[a]	83.2[a]
Mo	25.7[a]	16.5[a]	44.2	65.7
Wy	13.6[b]	11.3[b]	48.6[a]	50.7[a]
Fo	30.8	3.3	56.0[a]	66.7[a]

[1/] Current year's growth samples were not collected from this taxa on this date.

intermediate oil content while black and low sagebrush had the least volatile oil content.

The May collection showed less variation in volatile oil content among sampling dates. Only basin and mountain big sagebrush, which had the highest oil content, appeared to have a major difference in oil content.

In the August collection period, basin big sagebrush had the highest oil content of the seven taxa. Bolander silver sagebrush and mountain, Wyoming and foothill big sagebrush, as a group, were intermediate in oil content. Low and black sagebrush had the lowest oil content of the taxa.

The members of the big sagebrush complex had the highest oil content on the December collection date. The other three taxa, although variable in oil content had, as a group, lower oil content on this date.

Intrataxon analysis comparing the affect of season of sampling on oil content is shown in Table 22. Major changes in volatile oil content took place between the May to August collection periods while limited changes occurred between the March to May and August to December period.

Percent Dry Matter, Crude Protein, Acid Detergent Fiber, and Acid Detergent Lignin

Percent dry matter content, crude protein, acid detergent fiber and acid detergent lignin were determined for the seven sagebrush taxa used in the selectivity trials. Values for each of the seven taxa were obtained for each area of collection (Table 24).

Dry Matter

Dry matter content did not show appreciable difference among taxa or among the taxa collected from each area. The mean dry matter content was 97.1 percent for all sites.

Crude Protein

Crude protein showed the greatest variation among taxa that were collected from sites in Areas 1 and 3. Although some variation did exist, the only pattern that seemed to be evident was that mountain and foothill big sagebrush were consistently lower in percent crude protein (10.4 and 10.2, respectively) than basin and Wyoming big sagebrush (13.1 and 12.5, respectively).

Table 24. Percent dry matter (D. M.), crude protein (C. P.), acid detergent fiber (ADF) and acid detergent lignin (ADL) in each of the seven sagebrush by collection area.

	Taxa	D. M.	C. P.	ADF	ADL
	Lo	96.8	12.6	33.7	13.6
	Ba	97.7	13.6	29.1	11.5
	Bl	96.9	9.8	----[1]	----
Area 1	Bo	97.8	11.1	27.6	11.6
	Mo	86.7	10.2	25.4	9.0
	Wy	96.6	14.0	30.8	13.2
	Fo	97.0	9.4	25.9	11.1
	Lo	96.4	12.6	27.2	10.1
	Bl	96.8	12.5	26.4	10.2
	Bl[2]	96.7	12.6	30.5	13.5
Area 2	Ba	97.0	12.8	27.2	10.0
	Mo	97.7	11.7	23.8	9.0
	Wy	97.7	12.0	25.8	9.4
	Fo	97.3	10.0	25.2	8.7
	Lo	96.8	9.1	30.1	11.7
	Bo	97.3	13.4	28.9	10.0
	Bl	96.7	12.6	30.5	13.5
Area 3	Ba	97.0	15.3	31.4	12.8
	Mo	96.9	9.4	25.4	10.0
	Wy	97.0	11.5	27.0	10.6
	Fo	97.5	11.2	24.8	9.0

[1] Missing data.

[2] Black sagebrush samples for Areas 2 and 3 were collected from the same site.

Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL)

Although there was more variability in ADF and ADL values, the only consistent pattern found was that mountain and foothill big sagebrush were lower in ADF and ADL than basin and Wyoming big sagebrush. Percent ADF for mountain and foothill big sagebrush was 24.9 and 25.3, respectively, and 28.7 and 27.9 for basin and Wyoming big sagebrush, respectively. Percent ADL for mountain and foothill big sagebrush was 9.3 and 9.6, respectively, and 11.5 and 11.1 for basin and Wyoming big sagebrush, respectively. No other taxa showed trends in ADF or ADL either among taxa or within collection areas.

Effect on Utilization

Linear regression was used to compare C.P., ADF and ADL, plus other selected variables with utilization of the seven sagebrush taxa by mule deer and sheep (Appendix 3a and 3b). Essentially no relationship to utilization was found among these variables. In the deer trial, C.P. and ADF content appeared to have a slight negative influence and accounted for 13.0[4/] and 7.3 percent (r^2), respectively of the variation in utilization of the seven taxa. ADL, which

[4/] Values are coefficient or correlation squared.

accounted for only 2.9 percent of the variation in utilization, had a slight positive influence.

In the sheep selectivity trials, crude protein appeared to also have a negative effect on utilization but only accounted for 3.6 percent of the variation in mean utilization. ADF and ADL had positive influences and accounted for 4.0 and 6.2 percent, respectively of the variation in mean utilization.

In Vitro Digestible Dry Matter (DDM)

The main purpose of the digestion trials was to determine if major differences in digestibility did exist between taxonomic units. There was little variation in the apparent digestibility of the growth samples, except for low sagebrush (Table 25). Since samples for low sagebrush were collected in December while samples from other taxa were collected in March, a direct comparison of percent DDM values was not feasible.

Table 25. Mean percentages of *in vitro* percent digestible dry matter (DDM) of current year's growth of seven sagebrush taxa (Area 1).

Taxa	Lo[1/]	Bo	Bl	Ba	Mo	Wy	Fo
DDM	44.3	55.4	53.1	56.8	53.6	53.1	53.5

[1/] All current year's growth samples were collected from Area 1 on March 22, 1974 except low sagebrush. This sample was collected on December 1, 1974.

Basin big sagebrush had the highest DDM value of the remaining six taxonomic units followed by Bolander silver sagebrush. Black sagebrush and mountain, Wyoming and foothill big sagebrush had similar DDM values.

Based on this information, it would appear that little difference existed in digestibility among the current year's growth samples of these taxa. Statistical analysis of in vitro DDM values was not possible since only a small number of samples were used.

In order to obtain more complete information concerning differences in digestibility among taxa, digestion coefficients should be determined for current years growth samples collected at different phenological growth stages. A more complete study of sagebrush digestibility was not attempted in this study due to time limitations.

SUMMARY AND CONCLUSIONS

The objectives of this study were (1) to establish relative animal preference for seven sagebrush taxa (Artemisia ssp.), (2) to evaluate animal preference relative to seven sagebrush taxa of common genetic origin but collected from three different geographical areas and (3) to determine the influence of selected chemical constituents present in the sagebrush taxa relative to animal preference and nutritive value.

In order to accomplish the objectives, plants of the seven sagebrush taxa were collected live from three locations in eastern Oregon and transported to Corvallis, Oregon. Principle areas of shrub collection were Lake County near Silver Lake, Oregon (Area 1), the Squaw Butte Experimental Range in Harney County (Area 2) and Baker County near Baker, Oregon (Area 3). Frequency information collected at each site was arranged into an association table to assist in identification of sites.

The seven sagebrush taxa and the sites from which they were collected in each area were:

1. Low sagebrush from an A. arbuscula/Stipa thurburiana site in Area 1 and from an A. arbuscula/Stipa thurburiana-Festuca idahoensis site in Areas 2 and 3.

2. Mountain big sagebrush from an A. tridentata ssp. vaseyana/Festuca idahoensis-Agropyron spicatum site in all three collection areas.

3. Foothill big sagebrush from an *A. tridentata* form *xericensis/Stipa thurburiana* site in Area 1 and from an *A. tridentata* form *xericensis/Festuca idahoensis-Agropyron spicatum* site in Areas 2 and 3.

4. Wyoming big sagebrush from an *A. tridentata* ssp. *wyomingensis/Stipa thurburiana* site in Area 2 and from an *A. tridentata* ssp. *wyomingensis/Stipa comata* site in Area 3. The site for Wyoming big sagebrush was not identifiable due to the disturbed site condition in Area 1.

5. Basin big sagebrush, Bolander silver sagebrush and black sagebrush sites were not identifiable at all three collection areas due to disturbed site conditions.

Relative preference for the seven sagebrush taxa was established for wild-trapped mule deer and for domestic sheep. Two mule deer and three sheep selectivity trials were conducted in the winter (1974) and one mule deer and one sheep selectivity trial was conducted in the fall (1974). Prior to each trial, relative composition of each taxon was determined. The animals were allowed to select at will from among the sagebrush taxa during three use periods and utilization was sampled at the end of each period. Values for utilization and plant composition of the seven taxa were than used to construct relative preference indices (RPI) for the seven taxa.

Samples of current year's growth were removed from the sagebrush plants prior to the selectivity trials for use in chemical analysis. Analyses included relative volatile oil content, volatile oil constituents, crude protein, acid detergent fiber and acid detergent lignin.

Samples of current year's growth were collected seasonally from Area 1 to determine seasonal variation in oil content among the seven taxa. Samples from one collection date were also used for *in vitro* digestibility trials.

Mule deer selectively browsed sagebrush taxa that were available during the trials. Both use periods of the winter trials indicated that the seven sagebrush taxa could be divided into high, intermediate and low RPI groups. These groups, in order of preference, were (1) foothill and mountain big sagebrush and Bolander silver sagebrush, (2) low sagebrush and Wyoming and basin big sagebrush and (3) black sagebrush.

The only major difference in the fall trial, although it was conducted under different conditions, was that deer showed a higher preference for low sagebrush while retaining relatively the same preference order for the other six taxa. It was felt that mule deer preference for low sagebrush was strongly influenced by the availability of current year's growth (due to growth form) since it was the only taxon that showed considerable increase in use after the availability factor had been removed. Black sagebrush, with similar growth form, showed little change between trials. High preference by mule deer for low sagebrush has also been observed under field conditions (Leckenby 1973).

In general, it appears that mule deer preferred foothill and mountain big sagebrush, Bolander silver sagebrush and low sagebrush. They utilized, but did not prefer, Wyoming and basin big sagebrush and they showed least preference for black sagebrush.

Sheep showed less inclination to utilize the sagebrush taxa and only removed measurable quantities when other food sources were absent. RPI values, possibly for this reason, were more variable both between taxa and between use periods. The sheep consistently showed preference for Bolander silver sagebrush, low sagebrush and foothill and mountain big sagebrush in the first-use period of the winter trials. Black sagebrush and basin and Wyoming big sagebrush were generally among the least preferred taxa.

At the conclusion of the second-use period, mountain and foothill big sagebrush and low sagebrush were the three most preferred taxa. Bolander silver sagebrush, which was highly preferred in the first use period, and Wyoming big sagebrush were only intermediately preferred. Black sagebrush and basin big sagebrush were the least preferred taxa.

In the fall sheep selectivity trial, sheep indicated relatively the same preference for the seven sagebrush taxa as in the first-use period of the winter trials. Bolander silver sagebrush, low sagebrush and mountain and foothill big sagebrush were the most preferred. Black sagebrush was moderately preferred and Wyoming and basin big sagebrush were least preferred.

A major difference in the second-use period compared to the winter trials was the higher preference indicated for black sagebrush. Preference for other taxa remained relatively the same. High preference shown for black sagebrush in the fall trial was felt to be an indication of increased availability of current year's growth. This increased preference for black sagebrush in the fall trial was similar to the increased mule deer preference for low sagebrush in the fall trial when current year's growth was made completely available.

In general, it appeared that sheep showed highest preference for Bolander silver sagebrush, low sagebrush and mountain and foothill big sagebrush; moderate preference for black sagebrush and low preference for Wyoming and basin big sagebrush.

Mule deer and sheep preference for the seven sagebrush taxa appeared to be affected very little by differences related to collection area. No consistent trends were recognizable from statistical analysis of utilization values compared by area of collection.

Analysis of volatile oil content of current year's growth of the sagebrush taxa showed that two of the seven taxa from the three collection areas yeilded lower volume of volatile oils. Generally, low sagebrush and black sagebrush yielded the lowest quantity of oil from samples removed from trial plants. Foothill big sagebrush from all collection areas had the lowest volatile oil yield of plants of the big sagebrush complex. This taxon was among the most preferred by both mule deer and sheep in the selectivity trials.

Volatile oil content, in general, had a slight negative influence on both mule deer and sheep utilization. Relative volatile oil content of the seven taxa had the most influence of 16 variables on sheep utilization and accounted for 30 percent of the variation in utilization. Mule deer, however, appeared to be more influenced by specific chemical fractions within the volatile oils.

When only specific chemical fractions in the volatile oils were compared with animal utilization, eight volatile oil fractions accounted for 90 percent of the variation in deer utilization. Twelve volatile oil fractions, however, were necessary to account for 90 percent of the variation in sheep utilization. Generally, volatile oil fractions having a negative influence on both mule deer and sheep utilization appeared to be highest in sagebrush taxa that were among the least preferred.

Samples of current year's growth of sagebrush taxa from Area 1 showed considerable variation in volatile oil content between taxa, when measured at different seasons of the year. All taxa showed a decrease in volatile oil content during the green, succulent growth stage (spring) except for low and black sagebrush which increased in oil content. Foothill big sagebrush had the lowest oil content of the seven taxa in this period. During the season of summer drought stress, all taxa showed a rapid increase in volatile oil content except for low and black sagebrush which decreased. In the fall, members of the big sagebrush complex continued to show an increase while low sagebrush continued to decrease in oil content. Bolander silver sagebrush also showed decreased volatile oil content in this period. Major changes in volatile oil content took place between the May and August collection periods while only limited changes occurred in the March to May and August to December periods. Powell (1968) found similar trends in his study of seasonal variation of oil content in big sagebrush.

The only consistent trend found in nutrient analysis of the sagebrush taxa used in the selectivity trials was that crude protein, acid detergent fiber and acid detergent lignin were lower in foothill and mountain big sagebrush than Wyoming and basin big sagebrush. These latter two taxa were generally less preferred by both mule deer and sheep while the former two were among the highest preferred. However, regression analysis showed essentially no relationship of these variables to utilization by either mule deer or sheep.

Current year's growth of six sagebrush taxa sampled in March showed little variation in percent digestible dry matter (DDM). Of the six taxa, basin big sagebrush and Bolander silver sagebrush had the highest DDM values while the other four had approximately the same digestibility. Low sagebrush, which was sampled in December, had a much lower DDM value but direct comparison to other taxa was not feasible due to differences in time of sampling. DDM values for the big sagebrush complex approximated values found by Ward (1971) for big sagebrush plants collected on March 12, 1969 and by Smith (1966) for late spring collections.

Few animal preference studies conducted in the past have separated sagebrush into units below the species level. Awareness of refined taxonomic levels in this study contributed substantially to an understanding of mule deer and sheep preference for sagebrush and to the potential for application of this knowledge in the field.

Another factor present in the design of these trials was that "relative preference" was studied. Trial animals were given the opportunity to select at will from seven sagebrush taxa that would, in all probability, not all be found growing in a single location. This differs from many of the studies described in the literature in that study of animal preference was confined to only one or two taxonomic units. As a result, preference indicated by differential utilization in their trials may have been biased since animals were forced to select only from those species present. Since reseeding of sagebrush is becoming a part of some game range improvement programs, an attempt should be made to seed those taxa which show higher preference values, keeping in mind ecological requirements of each taxon.

Although this study was conducted in an "artificial" setting i.e. (1) plant species were grouped together even though they may not normally be found together in the field and (2) the trials were held in an unnatural environment, the results obtained from the selectivity trials indicated that the information was still relevant to management. Specifically, animal preference for the sagebrush taxa was nearly the same irregardless of collection area or season of the year in which particular trials were held.

Information obtained from this study should enable the field manager to incorporate into his total management plan the relative forage value of each taxon. This information is especially important in areas where sagebrush control or game forage improvement programs are being contemplated. Since this research was conducted in Oregon only, applicability of the data to sagebrush areas of other states is unknown.

Several factors can be related to volatile oil content of sagebrush and animal utilization. Total volatile oil content and relative amounts of chemical fractions present in the volatile oils may be influenced by (1) season of collection, (2) methods of sampling, handling and storing samples, (3) the portion of the plant sampled and (4) the specific taxonomic unit from which samples were obtained. Each of these, individually or in combination, have the potential to influence utilization and, perhaps, are related to some of the confusion that exist in the literature.

Percent digestible dry matter of sagebrush taxa obtained from _in vitro_ digestion conducted in this study approximated values found by other researchers. Values showed relatively high digestibility of sagebrush. However, some research has shown that consumption of sagebrush, due to its volatile oil content, had a deleterious effect on rumen microorganisms which normally would influence digestibility. This inconsistency may be a result of the following factors: (1) The standard _in vitro_ procedure may not be accurate for volatile oil containing substances, (2) A change in the chemical structure of the volatile oil either before or during _in vitro_ digestion may reduce or negate the harmful effect on microflora, (3) Rumen microorganisms which are affected adversely by volatile oils are not necessary for _in vitro_ digestion, (4) The quantity of volatile oil present during _in vitro_ digestion is too low to affect digestion, or (5) Samples which include leader growth give the sample such a high cellulose to volatile oil ratio that rumen microflora are relatively unaffected. Research is needed to determine if any or all of these factors have an influence on _in vitro_ digestibility of sagebrush.

LITERATURE CITED

Adams, M. and F. S. Oakberg. 1934. Essential oils in desert plants. J. Amer. Chem. Soc. 56:457-459.

Anderson, A. E., D. E. Medin and D. C. Bowden. 1972. Mule deer numbers and shrub yield-utilization on winter range. J. Wildl. Manage. 36:571-578.

Assocation of Official Agricultural Chemists. 1965. Official Methods of Analysis. (10th ed.) Ass. Offic. Agr. Chem. Washington, D. C. 957 p.

Arnold, G. W. 1966a. The special senses in grazing animals. (I) Sight and dietary habits in sheep. Aust. J. Agr. Res. 17: 521-529.

Arnold, G. W. 1966b. The special senses in grazing animals. (II) Smell, taste and touch and dietary habits in sheep. Aust. J. Agri. Res. 17:531-542.

Bayless, S. 1971. Relationships between big game and sagebrush. Northwest Sect. Wildl. Soc. Ann. Meeting. 14 p.

Bedell, T. E. 1973. Wyoming Range Roundup. Wyoming Agr. Exp. Sta. Bull. 16. 4 p.

Beetle, A. A. 1960. A study of sagebrush. The section _Tridentatae_ of _Artemisia_. Wyoming Agr. Exp. Sta. Bull. 368. 83 p.

Beetle, A. A. and A. Young. 1965. A third subspecies of the _Artemisia tridentata_ complex. Rhodora 67:405-406.

Bissell, H. D., B. Harris, H. Strong and F. James. 1955. The digestibility of certain natural and artificial foods eaten by deer in California. Cal. Fish and Game. 41:57-58.

Bissell, H. D. and H. Strong. 1955. The crude protein variations in the browse diet of California deer. Cal. Fish and Game. 41:145-155.

Brown, D. 1954. Methods of surveying and measuring vegetation. Commonwealth Bur. Pasture and Field Crop Bull. 24. 223 p.

Brunner, J. R. 1972. Observations on Artemisia in Nevada. J. Range Manage. 25:205-208.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. J. Forest. 39:388-394.

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

Cook, C. W. and L. A. Stoddart. 1953. The quandary of utilization and preference. J. Range Manage. 6:329-335.

Cook, C. W. and L. E. Harris. 1950. The nutritive value of range forage as affected by vegetation type, site and stage of maturity. Utah Agr. Exp. Sta. Bull. 344. 45 p.

Crawford, J. C. and D. C. Church. 1971. Response of black-tailed deer to various chemical taste stimuli. J. Wildl. Manage. 35:210-215.

Daubenmire, R. 1968. Plant Communities. New York, Harper and Row. 300 p.

Dasmann, W. P. and J. A. Blaisdell. 1954. Deer and forage relationships on the Lassen-Washoe interstate deer range. Cal. Fish and Game. 40:215-235.

DeWet, J. M. J. and B. D Scott. 1965. Essential oils as taxonomic criteria in Bothriochloa. Bot. Gaz. 126:209-214.

Dietz, D. R. and L. E. Yeager. 1959. The apparent role of sagebrush in the management of mule deer winter range. Proc. Conf. West. Ass. State Game and Fish Comm. 39:151-158.

Dietz, D. R. 1965. Deer nutrition research in range management. Trans. North Amer. Wildl. and Nat. Resour. Conf. 30:274-285.

Dietz, D. R., R. H. Udall and L. E. Yeager. 1962. Chemical composition and digestibility by mule deer of selected forage species, Cache la Poudre Range, Colorado. Colo. State Game and Fish Dep. Tech. Publ. 14. 89 p.

Draper, R. N. and H. Smith. 1966. Applied Regression Analysis. John Wiley and Sons Inc., New York. 407 p.

Esplin, A. C., J. E. Greaves and L. A. Stoddart. 1937. A study of Utah's winter range. Utah Agr. Exp. Sta. Bull. 277. 48 p.

Evenari, M. 1961. Chemical influences of other plants (alleopathy). In W. Rukland (Ed.) Encycl. Plant Physiol. 16:691-736.

Ferrel, C. M. and H. R. Leach. 1952. The pronghorn antelope of California with special reference to food habits. Cal. Fish and Game. 38: 285-295.

Findley, R. R. 1974. Changes in plant communities following rangeland brush control. M. S. Thesis. Oregon State Univ., Corvallis. 98 p.

Flake, R. H., E. von Rudloff and B. L. Turner. 1969. Quantitative study of clinal variation in Juniperus virginiana using terpenoid data. Proc. Nat. Acad. Sci. 64:487-494.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA, Pacific Northwest For. and Range. Exp. Sta. Portland, Oreg. U. S. Forest Serv. Gen. Tech. Rep. PNW-8. 417 p.

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

Hamilton, J. W. 1958. Chemical composition of certain forage plants. Wyoming Agr. Exp. Sta. Bull. 356. 44 p.

Hanks, D. L., J. R. Brunner, D. R. Christenson and A. P. Plummer. 1971. Paper chromatography for determining palatability differences in various strains of big sagebrush. USDA, Intermountain Forest and Range Exp. Sta., Ogden, Utah, U. S. Forest Serv. Res. Pap. INT-101. 9 p.

Hanks, D. L., E. D. MacArthur, R. Stevens and A. P. Plummer. 1973. Chromatographic characteristics and phylogenetic relationships of Artemisia, section tridentatae. USDA, Intermountain Forest and Range Exp. Sta., Ogden, Utah, U. S. Forest Serv. Res. Pap. INT-141. 24 p.

Heddle, R. G. 1933. The specific frequency method. Agr. Prog. 10:232.

Hickman, O. E. 1966. Seasonal trends in nutritive content of important range forage species near Silver Lake, Oregon. M. Agr. Paper. Oregon State Univ., Corvallis. 95 p.

Holmgren, R. C. and J. V. Basile. 1959. Improving southern Idaho deer winter ranges by artificial vegetation. Idaho Dep. Fish and Game. W-111-R. 61 p.

Irwin, M. A. and T. A. Geissman. 1969. Sesquiterpene lactones of Artemisia species. New lactones from A. arbuscula ssp. arbuscula and A. tripartita ssp. rupicola. Phytochem. 8:1411-1416.

Jones, L. L. I. 1952. Measurement of palatability. 6th Int. Grassl. Congr. Proc. II:1348-1353.

Julander, O. 1952. Forage habits of mule deer during the late fall, as measured by stomach content analysis. USDA, Intermountain Forest and Range Exp. Sta., Ogden, Utah, U. S. Forest Serv. Res. Note 2. 5 p.

Julander, O. 1955. Deer and cattle relations in Utah. Forest Sci. 1:130-139.

Kelsey, R. G., M. S. Morris, N. R. Bhadane, and F. Shafizadeh. 1973. Sesquiterpene lactones of Artemisia: TCL analysis and taxonomic significance. Phytochem. 12:1345-1350.

Kinney, C. R. and J. Sugihara. 1943. Constituents of Artemisia tridentata. (II) J. of Org. Chem. 8:290-294.

Kistner, T. P. 1974. Associate Professor, Oregon State University, Dept. of Vet. Med. Personal Communication. Corvallis, Oregon.

Klemmedson, J. O. 1967. Big game winter range--a diminishing resource. Trans. Proc. North Amer. Wildl. Conf. 32:259-269.

Krueger, W. C., W. A. Laycock and D. A. Price. 1974. Relationships of taste, smell, sight and touch to forage selection. J. Range Mange. 27:258-262.

Lassen, R. W., C. M. Ferrel and H. Leach. 1952. Food habits, production and condition of the Doyle mule deer herd. Cal. Fish and Game. 38:181-192.

Laycock, W. A., H. Buchanan, and W. C. Krueger. 1972. Three methods of determining diet, utilization and trampling damage on sheep ranges. J. Range Manage. 25:352-356.

Leach, H. R. 1956. Food habits of the Great Basin deer herds in California. Cal. Fish and Game. 42:243-308.

Leckenby, D. A. 1974. Habitat Biologist, Oregon Wildlife Commission. Research Division. Personal Communication. Silver Lake, Oregon.

Longhurst, W. K., H. K. Oh, M. B. Jones and R. E. Kepner. 1968. A basis for the palatability of deer forage plants. Trans. North Amer. Wildl. and Nat. Resour. Conf. 33:181-192.

Loomis, W. D. 1967. Biosynthesis and metabolism of monoterpenes. In: Terpenoids in plants. (J. B. Pridham, E. D.). Academic Press, London. 59-82 p.

Maruzzella, J. C. and M. B. Lichtenstein. 1956. The in vitro antibacterial activity of oils. J. Amer. Pharm. Ass. (Sci. Ed.) 45:378-381.

Nagy, J. G., H. W. Steinhoff and G. M. Ward. 1964. Effects of essential oils of sagebrush on deer rumen microbial function. J. Wildl. Manage. 28:785-790.

Nagy, J. G. and R. P. Tengerly. 1967. Antibacterial action of essential oils of Artemisia as an ecological factor. Appl. Microbiol. 15:819-821.

Oh, H. K., T. Sakai, M. D. Jones and W. M. Longhurst. 1967. Effect of various essential oils isolated from Douglas fir needles upon sheep and deer rumen microbial activity. Appl. Microbiol. 15:777-784.

Oregon State University. 1963. Temperature and water balance for Oregon weather station. Oregon Agr. Exp. Sta. Spec. Rep. 150. 127 p.

Plummer, A. P., D. R. Christensen, and S. B. Monsen. 1968. Restoring big game range in Utah. Utah Div. Fish and Game. Publ. No. 68-3. 183 p.

Powell, J. 1968. Site factor relationships with volatile oils in big sagebrush. PhD. Thesis. Colorado State Univ., Fort Collins. 82 p.

Reid, A., S. W. Ver Straten and C. F. Wilkie. 1963. Antibiotic effects produced by four species of sagebrush in Wyoming. Wyoming Range Mange. 176. 5 p.

Shafizadeh, F., N. R. Bhadane, M. S. Morris, R. G. Kelsy and S. N. Khanna. 1971. Sesquiterpene lactones of big sagebrush. Phytochem. 10:2745-2754.

Shafizadeh, F. and N. R. Bhadane. 1973. Sesquiterpene lactones of Artemisia arbuscula and A. tridentata. Phytochem. 12: 857-862.

Smith, A. D. 1950. Sagebrush as a winter feed for deer. J. Wildl. Manage. 14:285-289.

Smith, A. D. 1952. Digestibility of some native forages for mule deer. J. Wildl. Manage. 16:309-312.

Smith, A. D. and R. S. Hubbard. 1954. Preference ratings for winter deer forages from North Utah ranges based on browsing time and forage. J. Range Manage. 7:262-265.

Smith, A. D. 1959. Adequacy of important browse species in overwintering of mule deer. J. Range Manage. 12:8-13.

Smith, G. E. 1966. Nutritional effects of big sagebrush (Artemisia tridentata) Nutt. on deer. M. S. Thesis. Oregon State Univ., Corvallis. 111 p.

Smith, G. E., D. C. Church, J. E. Oldfield, and W. C. Lightfoot. 1966. Effects of sagebrush on forage digestibility by lambs. Proc. West. Sect. Amer. Soc. Anim. Sci. 17:373-378.

Smith, J. G. 1952. Food habits of mule deer in Utah. J. Wildl. Manage. 16:148-155.

Springfield, H. W. 1960. Shrub use by sheep on seeded range. U. S. Dep. Agr., Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo., U. S. Forest Serv., Res. Note 49. 4 p.

Stearns, F. W. 1958. Floristic composition as measured by plant number, frequency of occurrence and plant cover. Proc. Range Method, Tifton, Georgia.

Stein, C. 1945. A two-sample test for a linear hypothesis whose power is independent of the variance. Ann. Math. Stat. 16:243-258.

Strickler, G. S. and F. W. Stearns. 1962. The determination of plant density. USDA. Misc. Publ. 940. 40 p.

Tilley, J. M. A. and R. A. Terry. 1963. A two stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.

Tisdale, E. W., M. Hironaka and M. A. Fosberg. 1969. The sagebrush region in Idaho, a problem in resource management. Univ. Idaho Agr. Exp. Sta. Bull. 512. 14 p.

Tribe, D. E. 1949. The importance of the sense of smell to grazing sheep. J. Agr. Sci. 39:309-312.

Tribe, D. E. 1952. The relation of palatability to nutritive value and its importance in the utilization of herbage by grazing animals. 6th Int. Grassl. Congr. Proc. II:1265-1270.

Trout, L. E. and J. L. Theissen. 1968. Food habits and condition of mule deer in Owyhee County. Proc. West. Ass. State Game and Fish Comm. 48:188-200.

Tueller, P. T., G. L. Lorain, K. Kipping and C. Wilke. 1972. Methods for measuring vegetation changes on Nevada rangelands. Nevada Agr. Exp. Sta. No. 116. 15 p.

Van Dyne, G. M., and H. F. Heady. 1965. Botanical composition of sheep and cattle diets on a mature annual range. Hilgardia 36:465-492.

Vasek, F. C. and R. W. Scora. 1967. Analysis of the oils of western North American junipers by gas-liquid chromatography. Amer. J. Bot. 54:781-789.

von Rudloff, E. 1961. Gas-liquid chromatography of terpenes. (IV) The analysis of the volatile oils of the leaves of eastern white cedar. Can. J. Chem. 39:1206.

von Rudloff, E. 1962a. Gas-liquid chromatography of terpenes. (V) The volatile oils of the leaves of black, white and Colorado spruce. Tappi. 45:181-184.

von Rudloff, E. 1962b. Gas-liquid chromatography of terpenes. (IX) The volatile oil of Thuja plicata Donn. Phytochem 1:195-202.

von Rudloff, E. 1963. Gas-liquid chromatography of terpenes. (IX) The volatile oil of the leaves of Juniperus sabina L. Can. J. Chem. 41:2876-2881.

Ward, A. L. 1971. In vitro digestibility of elk winter forage in southern Wyoming. J. Wildl. Manage. 35:681-688.

Warner, A. C. I. 1962. Some factors influencing microbial populations. J. Gen. Microbiol. 28:129-146.

Whittaker, R. H. and P. O. Feeny. 1971. Allelochemics: Chemical interactions between species. Sci. 171:757-770.

Wilkens, B. T. 1957. Range use, food habits and agricultural relationships of the mule deer, Bridger Mountains, Montana. J. Wildl. Manage. 21:159-169.

Winward, A. H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. PhD. Thesis. Univ. of Idaho, Moscow. 80 p.

Winward, A. H. 1973. Assistant Professor, Oregon State Univ., Rangeland Resources Program. Personal Communications. Corvallis, Oregon.

APPENDICES

APPENDIX 1a

Analysis of variance for factorial arrangement of treatments in winter mule deer selectivity trials (Period 1).

Source of Variation	D. F.	Mean Square	F
Trial	1	26998.30	67.09*
Area	2	3249.75	8.08*
Taxa	6	11822.90	29.38*
Trial and	2	65.53	0.16^{NS}
Trial and Taxa	6	1338.90	3.33*
Area and Taxa	12	996.13	1.48*
Trial and Area and Taxa	12	1164.55	2.89*
Error	168	402.39	

*Significant at $P < 0.05$

Analysis of variance for factorial arrangement of treatments in winter mule deer selectivity trials (Period 2).

Source of Variation	D. F.	Mean Square	F
Trial	1	1411.81	7.89*
Area	2	1257.00	7.02*
Taxa	6	118.74	$.66^{NS}$
Trial and Area	2	18467.10	103.22*
Trial and Taxa	6	495.13	2.77*
Area and Taxa	12	487.66	2.72*
Trial and Area and Taxa	12	239.04	1.34*
Error	168	179.00	

*Significant at $P < 0.05$

APPENDIX 1b

Analysis of variance for factorial arrangement of treatments in sheep selectivity trials (Period 1)

Source of Variation	D. F.	Mean Square	F
Trial	2	28132.70	63.03*
Area	2	7887.85	17.67*
Taxa	6	1131.80	2.54*
Trial and Area	4	7438.91	16.66*
Trial and Taxa	12	2461.21	5.51*
Area and Taxa	12	1148.69	2.57*
Trial and Area and Taxa	24	13.39	0.16^{NS}
Error	126	446.35	

*Significant at $P < 0.05$

Analysis of variance for factorial arrangement of treatments in sheep selectivity trials (Period 2).

Source of Variation	D. F.	Mean Square	F
Trial	2	8039.07	15.68*
Area	2	2627.00	5.09*
Taxa	6	2740.04	5.32*
Trial and Area	4	10764.10	20.89*
Trial and Taxa	12	4112.13	7.98*
Area and Taxa	12	681.14	1.32*
Trial and Area and Taxa	24	1279.27	2.48*
Error	126	515.21	

*Significant at $P < 0.05$

APPENDIX 2a

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in mule deer selectivity trial 1 (Winter)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
	Fo	22.9	80.5	1.6	Ba	55.3	49.9	1.3
	Mo	18.6	72.8	1.5	Wy	10.0	44.8	1.2
	Bo	8.4	67.0	1.4	Bl	5.3	27.7	0.7
Area 1	Lo	8.9	62.5	1.3	Bo	5.4	26.6	0.7
	Wy	7.8	41.2	0.8	Mo	9.5	16.5	0.4
	Ba	30.4	10.0	0.2	L0	6.6	9.5	0.3
	Bl	2.9	2.8	0.1	Fo	7.9	8.6	0.2
	Bo	7.6	65.0	1.8	Ba	32.1	55.6	1.5
	Mo	11.9	55.9	1.6	Wy	28.1	41.3	1.1
	Fo	20.8	54.5	1.5	Bo	3.8	20.9	0.6
Area 2	Lo	7.5	38.4	1.1	Mo	8.9	19.4	0.5
	Ba	26.7	22.7	0.6	Lo	6.0	16.7	0.5
	Wy	21.5	18.5	0.5	Fo	14.9	16.3	0.5
	Bl	3.9	0.0	0.0	Bl	6.2	11.3	0.3
	Mo	22.9	77.9	1.7	Bo	33.4	55.9	1.6
	Fo	13.2	54.0	1.2	Ba	17.8	30.3	0.9
	Ba	19.2	49.9	1.1	Lo	12.1	26.0	0.8
Area 3	Wy	11.2	32.0	0.7	Fo	11.2	24.8	0.7
	Bo	22.6	29.2	0.6	Wy	9.2	23.9	0.7
	Lo	7.7	21.1	0.5	Bl	6.5	14.2	0.4
	Bl	3.2	0.0	0.0	Mo	9.9	13.0	0.4

APPENDIX 2a (Cont.)

Percent composition (C), utilization (U), and relative preference index (RPI) of seven sagebrush taxa in mule deer selectivity Trial 2 (Winter)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
Area 1	Bo	10.6	56.3	1.7	Wy	7.5	50.7	1.2
	Fo	21.4	56.1	1.7	Mo	25.7	48.0	1.1
	Mo	25.1	32.4	1.0	Lo	6.1	47.9	1.1
	Lo	5.7	24.6	0.7	Ba	34.2	47.3	1.1
	Ba	29.7	19.7	0.6	Bo	8.3	39.8	0.9
	Wy	5.1	1.4	0.4	Fo	14.5	27.9	0.6
	Bl	2.5	0.0	0.0	Bl	3.7	14.0	0.3
Area 2	Fo	20.4	32.8	2.6	Ba	34.2	66.1	1.2
	Mo	10.9	27.1	2.2	Bo	8.5	62.7	1.2
	Bo	9.2	18.4	1.5	Lo	10.3	55.6	1.1
	Ba	30.1	1.3	0.5	Mo	9.0	47.2	0.9
	Wy	16.4	5.0	0.4	Fo	15.8	44.0	0.8
	Lo	9.0	0.0	0.0	Wy	17.8	42.0	0.8
	Bl	3.9	0.0	0.0	Bl	4.4	14.3	0.3
Area 3	Fo	17.0	50.3	1.9	Ba	24.0	78.5	1.7
	Mo	15.1	38.6	1.4	Wy	13.6	58.5	1.3
	Bo	24.4	34.7	1.3	Lo	10.1	39.7	0.9
	Lo	9.8	21.0	0.8	Mo	12.9	35.1	0.8
	Wy	10.6	9.9	0.6	Fo	10.7	34.2	0.7
	Ba	17.5	1.0	0.1	Bo	20.9	32.8	0.7
	Bl	5.6	0.0	0.0	Bl	7.8	6.1	0.1

APPENDIX 2a (Cont.)

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in mule deer selectivity Trial 3 (Fall)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
Area 1	Mo	19.9	26.3	2.6	Lo	4.9	63.8	2.5
	Fo	9.8	20.6	2.0	Fo	8.4	51.9	2.0
	Bo	14.7	7.4	0.7	Ba	15.4	50.3	2.0
	Lo	6.6	5.9	0.6	Mo	17.6	37.9	1.5
	Ba	29.6	4.8	0.5	Ba	31.8	8.2	0.3
	Wy	11.9	0.4	0.1	Bl	8.4	5.6	0.2
	Bl	7.4	0.3	0.1	Wy	13.4	3.5	0.1
Area 2	Mo	27.8	22.1	2.4	Mo	23.9	37.2	1.8
	Lo	10.8	12.3	1.3	Ba	15.3	23.4	1.1
	Ba	26.0	4.2	0.5	Lo	10.1	21.9	1.1
	Bo	14.2	3.5	0.4	Fo	8.7	21.7	1.1
	Wy	9.1	1.1	0.1	Ba	27.4	13.1	0.6
	Fo	8.0	0.6	0.1	Wy	10.0	2.3	0.1
	Bl	4.0	0.0	0.0	Bl	4.4	0.4	0.0
Area 3	Mo	15.9	25.8	3.3	Lo	11.4	50.8	1.5
	Fo	8.9	17.7	2.3	Mo	13.0	41.6	1.3
	Wy	4.1	4.8	0.6	Fo	7.6	35.3	1.1
	Ba	31.5	3.2	0.4	Ba	32.9	33.1	1.0
	Bo	23.3	0.4	0.1	Bo	24.7	3.1	1.0
	Lo	10.7	0.0	0.0	Wy	4.4	5.1	0.2
	Bl	5.6	0.0	0.0	Bl	6.0	1.4	0.1

APPENDIX 2b

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in sheep selectivity Trial 1 (Winter)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
	Fo	27.7	58.1	2.6	Fo	13.1	95.8	3.3
	Lo	6.9	56.7	2.2	Lo	5.2	58.2	2.0
	Ba	5.9	50.3	2.0	Mo	21.1	50.7	1.7
Area 1	Bl	2.9	0.0	0.0	Ba	4.0	50.7	1.7
	Mo	16.1	0.0	0.0	Bl	3.8	13.5	0.5
	Wy	11.9	0.0	0.0	Ba	37.3	1.1	0.1
	Ba	28.5	0.0	0.0	Wy	15.5	0.0	T
	Mo	16.2	15.5	4.9	Lo	6.3	87.4	2.7
	Lo	6.6	9.6	3.1	Fo	17.6	75.5	1.9
	Fo	17.1	0.0	0.0	Mo	1.41	62.3	1.9
Area 2	Ba	8.2	0.0	0.0	Ba	8.4	28.1	0.9
	Bl	3.5	0.0	0.0	Wy	24.2	12.2	0.4
	Wy	23.4	0.0	0.0	Bl	3.6	1.0	T
	Ba	25.0	0.0	0.0	Ba	25.8	0.0	0.0
	Lo	8.5	23.2	5.1	Mo	15.9	93.9	3.0
	Fo	15.9	11.9	5.1	Lo	7.3	77.0	2.5
	Mo	15.6	4.2	0.9	Fo	14.6	60.2	1.9
Area 3	Bo	18.2	0.0	0.0	Bo	18.8	10.3	0.3
	Bl	4.9	0.0	0.0	Bl	5.1	1.3	T
	Ba	21.1	0.0	0.0	Ba	21.9	0.0	0.0
	Wy	15.9	11.9	0.0	Wy	16.5	0.0	0.0

APPENDIX 2b (Cont.)

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in sheep selectivity Trial 2 (Winter)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
Area 1	Bo	7.2	100.0	1.9	Wy	16.0	20.0	3.4
	Fo	20.8	99.1	1.9	Mo	14.2	71.4	3.0
	Lo	3.6	90.4	1.8	Lo	0.7	0.0	1.7
	Bl	3.2	90.0	1.7	Fo	0.4	20.0	0.8
	Mo	18.3	65.2	1.3	Bo	66.3	67.8	T
	Wy	15.0	37.3	0.7	Bl	0.8	0.0	0.0
	Ba	31.9	0.0	0.0	Bo	0.0	0.0	0.0
Area 2	Bo	7.7	94.5	3.5	Fo	23.7	94.6	1.5
	Lo	10.6	76.5	2.8	Mo	8.1	92.4	1.4
	Bl	4.3	58.6	2.2	Wy	29.5	87.0	1.3
	Mo	9.8	31.9	1.2	Lo	3.3	75.2	1.2
	Fo	19.3	16.5	0.6	Bl	2.2	50.6	0.8
	Wy	22.9	0.0	0.0	Ba	32.8	16.7	0.3
	Bo	25.4	0.0	0.0	Bo	0.3	6.6	0.1
Area 3	Mo	12.9	85.3	1.9	Fo	17.3	100.0	1.3
	Lo	5.1	54.9	1.2	Wy	24.3	96.7	1.2
	Bo	29.3	54.5	1.2	Mo	3.0	95.7	1.2
	Fo	13.4	49.2	1.1	Bo	24.2	86.7	1.1
	Bl	4.2	38.0	1.1	Lo	4.3	52.8	0.7
	Ba	20.3	24.6	0.6	Bl	4.7	48.5	0.6
	Wy	14.8	11.4	0.3	Ba	22.0	43.0	0.5

APPENDIX 2b (Cont.)

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in sheep selectivity Trial 3 (Winter)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
Area 1	Bo	12.9	74.6	1.4	Fo	26.0	67.7	1.2
	Fo	31.9	62.6	1.2	Mo	31.0	63.6	1.1
	Lo	12.3	58.1	1.1	Bo	7.7	63.1	1.1
	Ba	11.5	48.2	0.9	Wy	5.6	60.8	1.0
	Wy	4.5	46.6	0.9	Bl	4.8	59.5	1.0
	Mo	24.7	39.8	0.7	Lo	12.6	44.3	0.8
	Bl	2.1	0.0	0.0	Ba	12.2	35.2	0.6
Area 2	Lo	10.5	53.1	1.6	Bo	7.1	93.3	1.6
	Fo	21.0	46.2	1.4	Mo	9.8	91.8	1.6
	Mo	9.6	33.4	1.0	Lo	7.3	75.1	1.3
	Ba	27.4	32.8	1.0	Fo	18.0	59.7	1.0
	Bo	7.2	30.8	0.9	Wy	24.2	52.3	0.9
	Wy	19.9	16.4	0.5	Ba	27.0	45.8	0.8
	Bl	4.5	0.0	0.0	Bl	6.6	23.3	0.4
Area 3	Bo	16.5	73.3	1.3	Mo	20.2	77.9	1.2
	Fo	12.8	72.7	1.3	Ba	31.6	69.9	1.1
	Mo	21.6	59.7	1.1	Bo	12.0	64.4	1.0
	Lo	10.3	57.8	1.1	Fo	7.2	62.0	1.0
	Ba	24.5	41.3	0.8	Wy	12.5	57.0	0.9
	Wy	10.1	36.1	0.7	Lo	9.3	41.5	0.7
	Bl	4.2	8.6	0.2	Bl	7.2	20.4	0.3

APPENDIX 2b (Cont.)

Percent composition (C), utilization (U) and relative preference index (RPI) of seven sagebrush taxa in sheep selectivity Trial 4 (Fall)

	Period 1				Period 2			
	Taxa	C	U	RPI	Taxa	C	U	RPI
Area 1	Bo	17.5	56.7	4.6	Lo	7.1	68.2	5.4
	Lo	7.3	17.5	1.4	Bl	6.7	44.4	3.5
	Fo	7.1	17.2	1.4	Ba	7.7	30.6	2.4
	Mo	18.6	0.0	0.0	Fo	7.1	23.3	1.8
	Wy	7.9	0.0	0.0	Mo	21.4	3.8	0.3
	Ba	35.7	0.0	0.0	Wy	9.0	0.0	0.0
	Bl	5.8	0.0	0.0	Bo	41.0	0.0	0.0
Area 2	Bo	14.4	16.5	4.0	Lo	10.5	51.7	6.7
	Bl	5.0	9.8	2.5	Bo	12.4	16.1	2.1
	Lo	10.6	6.0	1.5	Bl	4.7	5.4	0.7
	Fo	9.1	4.3	1.1	Mo	25.7	0.4	0.1
	Mo	24.6	0.0	0.0	Fo	8.9	0.0	0.0
	Wy	8.8	0.0	0.0	Wy	9.1	0.0	0.0
	Ba	27.5	0.0	0.0	Ba	28.7	0.0	0.0
Area 3	Mo	16.6	23.5	4.6	Lo	7.2	64.7	6.2
	Lo	7.9	14.3	2.8	Bl	5.0	33.8	3.3
	Bl	4.8	2.0	0.4	Mo	12.0	30.1	2.9
	Fo	9.9	0.0	0.0	Fo	10.5	3.6	0.3
	Bo	20.5	0.0	0.0	Ba	21.9	0.0	0.0
	Wy	3.9	0.0	0.0	Wy	4.5	0.0	0.0
	Ba	36.2	0.0	0.0	Ba	38.8	0.0	0.0

APPENDIX 3a

Summary table of Coefficients of Determination (multiple R^2) and Coefficient of Correlation (linear r) for twelve volatile oil fractions and percent weight of volatile oil (V. O.), crude protein (C. P.), acid detergent fiber (ADF), and acid detergent lignin (ADL) compared with utilization in winter mule deer selectivity Trials

Independent variable	Identification	R^2	r
8	1, 8-cineol	.52	.29(+)
15	Unknown	.74	.63(-)
33	Unknown	.81	.46(-)
32	Unknown	.84	.16(+)
30	a-terpineol	.86	.33(+)
40	ADL	.87	.17(-)
39	ADF	.88	.27(-)
20	Unknown	.90	.29(-)
34	Unknown	.91	.50(-)
37	V. O.	.91	.24(-)
23	Unknown	.91	.32(+)
16	Unknown	.92	.11(-)
24	Unknown	.93	.24(-)
25	dl-camphor	.93	.24(+)
38	C. P.	.93	.36(-)

APPENDIX 3b

Summary table of Coefficients of Determination (multiple R^2) and Coefficients of Correlation (linear r) for twelve volatile oil fractions and percent weight of volatile oil (V. O.), crude protein (C. P.), acid detergent fiber (ADF), and acid detergent lignin (ADL) compared with utilization in winter sheep selectivity Trials

Independent variable	Identification	R^2	r
37	V. O.	.29	.53(-)
8	1, 8-cineol	.57	.50(+)
30	a-terpineol	.67	.43(+)
34	Unknown	.71	.30(-)
16	Unknown	.76	.29(-)
40	ADL	.81	.25(+)
24	Unknown	.86	.10(+)
15	Unknown	.92	.53(-)
33	Unknown	.94	.39(-)
20	Unknown	.96	.17(-)
6	Unknown	.97	.52(-)
38	C. P.	.98	.19(-)
23	Unknown	.98	.42(+)
32	Unknown	.99	.07(+)
39	ADF	.99	.20(+)
25	dl-camphor	.99	.05(+)

APPENDIX 3c

Summary table of Coefficients of Determination (multiple R^2) and Coefficients of Correlation (linear r) for fifteen volatile oil fractions compared with utilization of seven sagebrush taxa in the winter mule deer selectivity Trials.

Independent variable	Identification	R^2	r
8	1, 8-cineol	.52	.72(+)
15	Unknown	.74	.63(-)
33	Unknown	.81	.46(-)
32	Unknown	.84	.17(+)
4	B-pinene	.86	.41(+)
30	a-terpineol	.87	.33(+)
2	Unknown	.88	.09(-)
23	dl-camphor	.88	.32(+)
25	Unknown	.90	.24(+)
12	Unknown	.92	.27(-)
29	Unknown	.95	.15(-)
34	Unknown	.97	.50(-)
16	Unknown	.97	.12(-)
24	Unknown	.97	.17(+)
6	Unknown	.98	.57(-)

APPENDIX 3d

Summary table of Coefficients of Determination (multiple R^2) and Coefficients of Correlation (linear r) for fifteen volatile oil fractions compared with utilization of seven sagebrush taxa in winter sheep selectivity Trials.

Independent variable	Identification	R^2	r
6	Unknown	.25	.50(-)
30	a-terpineol	.37	.37(+)
25	dl-camphor	.41	.08(+)
24	Unknown	.47	.05(+)
16	Unknown	.55	.28(-)
20	Unknown	.63	.06(-)
32	Unknown	.66	.14(+)
23	Unknown	.76	.34(+)
2	a-pinene	.82	.01(+)
33	Unknown	.86	.40(-)
8	1, 8 cineol	.89	.39(+)
4	B-pinene	.90	.26(+)
29	Unknown	.93	.37(+)
34	Unknown	.96	.10(-)
15	Unknown	.96	.46(-)

APPENDIX 4

Thirty-four major volatile oil fractions determined through gas chromatography of volatile oils obtained from current year's growth of six sagebrush taxa.[1/]

Taxa	Lo[2/]	Bo			Ba			Mo			Wy			Fo		
Area	2	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
FRACTION																
1	0.00	0.00	0.00	0.00	0.07	0.00	0.06	0.76	0.00	0.01	0.00	0.00	0.00	0.00	0.07	0.07
2	1.00	0.72	1.32	34.10	1.05	1.02	0.92	2.00	0.54	1.09	1.24	1.80	3.23	0.23	0.00	0.14
3	0.18	1.54	0.00	2.03	0.11	0.00	0.08	0.57	0.20	1.14	0.13	0.07	0.00	1.16	0.00	0.09
4	0.64	5.94	0.43	2.32	0.92	1.89	1.52	1.58	1.39	11.82	2.03	0.76	1.73	0.85	0.20	0.51
5	0.00	0.48	0.06	0.44	0.05	0.00	0.10	0.26	0.09	0.75	0.00	0.00	0.00	0.00	0.00	0.00
6	1.53	1.01	11.32	9.35	27.28	21.64	8.18	2.86	1.05	3.97	4.65	8.25	4.39	0.33	0.36	2.69
7	0.00	0.20	0.09	0.16	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
8	0.65	11.84	2.07	2.66	3.26	3.15	1.58	12.62	7.85	11.97	1.22	2.11	3.82	27.34	3.87	1.86
9	0.00	0.38	0.19	0.29	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.16	1.55	0.44	1.71	0.52	0.78	0.89	1.13	0.25	0.51	0.51	0.27	0.40	0.29	0.03	0.08
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.18	0.73	0.00	0.00	0.00
12	77.40	0.00	0.22	2.54	2.30	2.19	21.74	12.75	6.88	1.55	39.93	66.50	36.47	2.34	81.39	64.93
13	0.59	7.37	9.70	5.69	0.21	0.12	0.15	0.00	0.00	0.00	6.08	6.62	2.64	1.65	0.00	0.00
14	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.69	0.49	1.77	4.71	24.47	23.46	4.27	0.46	0.70	0.02	6.81	6.63	5.76	1.34	0.60	0.90
16	0.45	0.26	8.59	2.42	0.66	0.99	11.82	0.47	0.31	0.33	1.65	1.09	4.67	0.81	0.63	2.69
17	0.00	0.00	0.66	0.67	0.76	0.54	2.82	0.00	0.00	0.00	0.48	0.11	0.27	0.69	0.10	0.26
18	0.00	0.39	1.16	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 4 (Continued)

Taxa	Lo[2]	Bo			Ba			Mo			Wy			Fo		
Area	2	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
FRACTION																
19	1.05	0.70	0.00	0.00	0.31	0.30	2.12	33.03	1.16	0.21	1.97	1.13	1.74	0.30	1.65	1.27
20	0.20	0.27	1.01	0.32	0.29	0.21	0.27	0.00	0.00	0.00	0.47	0.17	0.69	0.00	0.00	0.00
21	0.35	0.29	1.20	0.64	0.16	0.03	0.16	0.30	1.93	0.12	0.23	0.15	0.21	0.20	0.08	0.24
22	0.00	0.07	0.68	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.28	57.96	34.60	15.45	1.11	1.02	1.12	0.00	0.14	0.13	0.82	0.49	0.87	0.07	0.26	0.38
24	0.00	0.00	1.70	0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.80	0.00	0.63
25	5.86	1.10	1.84	1.81	22.51	34.01	26.88	8.42	13.10	61.63	21.28	4.38	19.20	51.32	5.99	13.10
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
27	0.23	0.36	0.60	0.44	1.48	1.66	1.51	1.75	0.41	0.50	0.77	0.00	0.00	1.95	0.64	0.28
28	0.62	0.12	0.44	0.72	0.44	0.55	0.68	0.53	0.16	0.33	0.91	0.66	1.34	0.96	0.26	0.82
29	0.32	0.26	0.52	0.39	0.41	0.37	0.44	0.98	0.08	0.00	0.62	0.32	0.95	0.23	0.17	0.39
30	0.18	2.67	0.00	2.54	0.53	0.39	0.52	0.62	0.17	0.28	0.39	0.10	0.22	1.14	0.34	0.31
31	0.36	0.80	8.35	4.65	2.09	2.23	1.62	1.86	0.29	0.37	0.51	0.21	0.57	1.09	0.49	0.42
32	0.43	0.55	2.25	1.86	0.32	0.42	0.49	0.77	0.24	0.66	1.16	0.87	1.43	1.10	0.61	1.16
33	0.40	0.20	0.94	0.52	27.53	28.45	1.86	0.82	0.39	0.47	0.83	0.16	0.46	1.59	0.96	0.84
34	0.82	0.00	0.00	0.00	0.35	0.33	0.32	0.00	0.00	0.00	1.27	0.90	2.01	0.00	0.00	0.00

[1]/Volatile oil samples from current years' growth of black sagebrush were not obtained.

[2]/Volatile oil was obtained from low sagebrush only from Area 2.