# Sagebrush Identification, Ecology, and Palatability Relative to Sage-Grouse

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**Abstract**—Basic identification keys and comparison tables for 23 low and big sagebrush (*Artemisia*) taxa are presented. Differences in sagebrush ecology, soil temperature regimes, geographic range, palatability, mineralogy, and chemistry are discussed. Coumarin, a chemical produced in the glands of some *Artemisia* species, causes UV-light fluorescence of the leaves. Coumarin-containing taxa, such as mountain, xeric, subalpine big, subalpine early, black, and low sagebrush, each fluoresce a bright bluish-white color. These taxa are also the most palatable. A table of UV-light fluorescence of 20 sagebrush taxa in water solution is provided. How plant chemicals, such as coumarin and methacrolein and their seasonal variation, relate to palatability and animal preference is discussed in terms of sage-grouse. Restoration guidelines for some sagebrush taxa are also presented.

**Keywords**: Sagebrush, *Artemisia*, sage-grouse, palatability, preference, UV-light fluorescence

## Introduction

The woody sagebrushes (*Artemisia*) are a major food source of and provide critical habitat for the declining sage-grouse (*Centrocercus urophasiamus*), icon of Western rangelands (Braun and others1977; Connelly and others 2000; Drut and others 1994). Improved identification of the types of sagebrush this species eats and uses for nesting and cover will help in its management. To the biologist and general public who are unfamiliar with the many different species and subspecies of sagebrush, this ecosystem may appear to be a bewildering array of variability. However, sagebrush communities are actually repetitive and easily identifiable (Beetle 1960; West 1988). Recognizing them is important because they are indicators of a given local ecosystem composed of specific vegetation types, soil depth, climate, topography, and wildlife species. Each type of sagebrush has moderate to vastly different palatability and structural characteristics, which influence their particular values for wildlife (Sheehy and Winward 1981).

Woody sagebrush species have been of major interest and concern to land managers, but have received only occasional study by the plant taxonomist (Hall and Clements 1923). Most contemporary plant taxonomists have not studied Western North America's woody *Artemisias* in detail, as they are generally back at their academic institutions by fall when sagebrush taxa flower and are most distinctive. Consequently, this genus could include more genetic and morphological groups than are currently described. As more studies are conducted on the taxonomy of *Artemisia*, many of the subspecies and variety-level taxa will likely be raised to that of the species; new subspecies and varieties can be expected as well. The sagebrushes have been successful, in large part, due to their ability to exchange genetic material by hybridization and introgression (Hanks and others 1973; McArthur and others 1988), thus maintaining genotypic variation with sufficient plasticity to allow the development of ecotypes. This genetic variability may have also helped minimize disease and herbivory, which weaken and limit less genetically diverse species.

Why bother determining sagebrush and other vegetation to the specific or even subspecific level? As former, and now deceased, University of Montana Professor Mel Morris used to say, "The better the plant is at indicating ecological condition or palatability, the more one should learn to identify that plant." Winward and Tisdale (1977) state that separation of big sagebrush into subspecies assists in the recognition of (1) habitat types (fig. 1), (2) production potential, (3) chemical content, and (4) palatability preference. When Nuttall described *Artemisia tridentata* in 1841, more than 20 present-day taxa were included. This broad species concept would not help us today in managing the 23 named sagebrush taxa that comprise sage-grouse habitat.

Palatability is defined as "plant characteristics or conditions that stimulate a selective response by animals" (Heady 1964). Webster defines the word "palatable" as pleasing to the taste. The term "preference" is reserved for selection by the animal and is essentially behavioral. Relative preference or relative palatability is a proportional choice among two or more foods. Items positively correlated with preference include (1) high protein content, (2) linolenic and butyric acids, (3) fat content, (4) sugar, and (5) phosphate and potash. Food items negatively correlated with preference include (1) high lignin content, (2) crude fiber, (3) tannins, and (4) nitrates (Heady 1964). In general, sagebrush species and populations that are more palatable to mule deer are also more palatable to sheep, cows, insects, and sage-grouse (Kelsey and Shafizadeh 1978; Sheehy and Winward 1981; Wambolt 2001; Wambolt and others 1991; Welch and Davis 1984; Welch and others 1983).

It is well documented that some sagebrush species are more palatable due to their chemical content (Morris and others 1976; Sheehy and Winward 1981; Wambolt 2001; Welch and others 1983). The difference in palatability is

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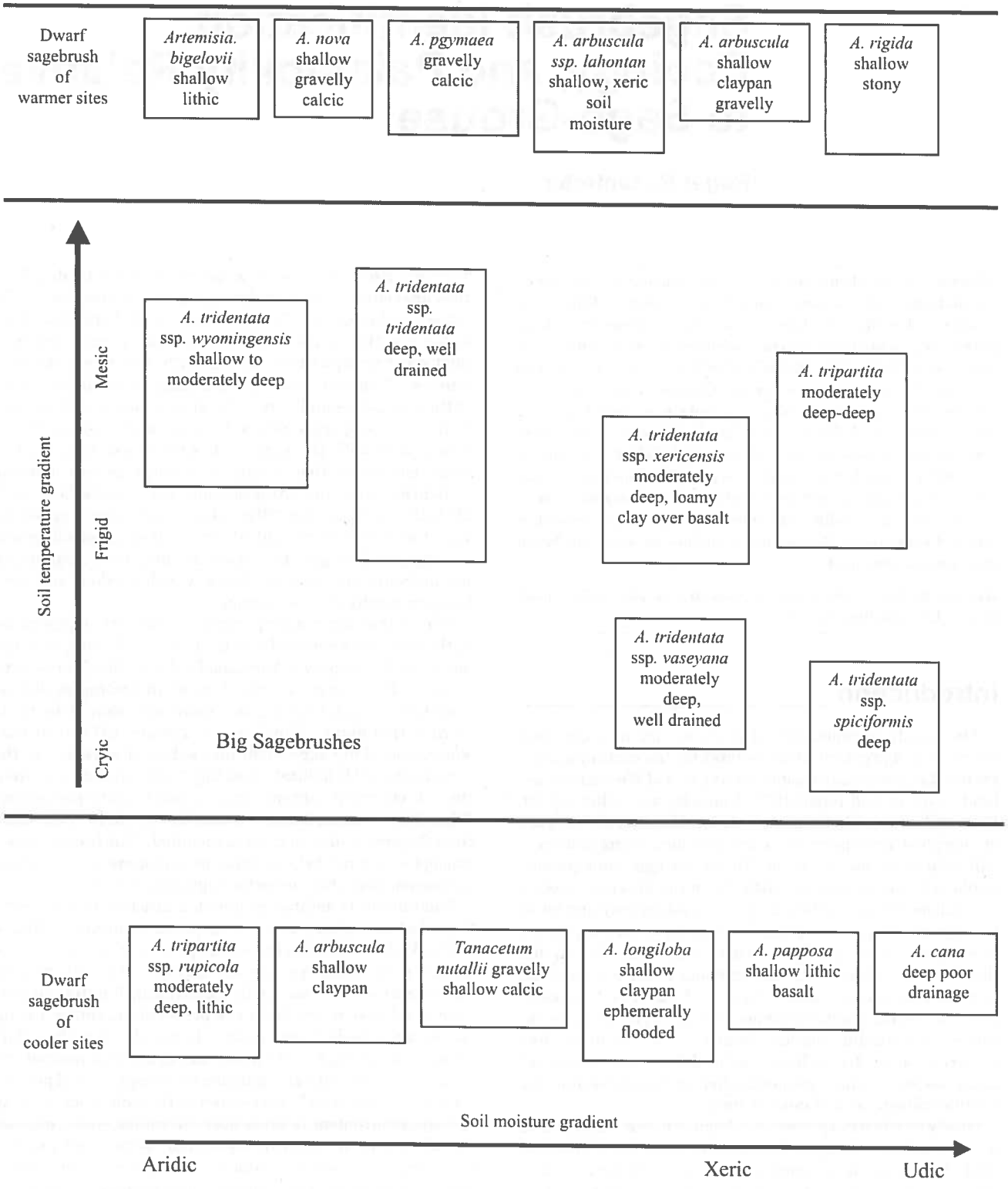


**Figure 1**—Environmental distribution of woody *Artemisia* taxa arranged by soil moisture, depth, texture, mineralogy, and soil temperature (modified from West 1988).

based on plant chemistry and the amount of volatile chemicals present in sagebrush leaf glands (Kelsey and others 1984; Striby and others 1987). Glands vary seasonally in the amount and concentration of chemicals they contain, with concentrations highest in spring and lowest in winter (Cedarleaf and others 1983; Kelsey and others 1984). This is due to the semievergreen nature of sagebrush and the presence of persistent leaves, produced in the spring, with glands full of volatile chemicals to discourage herbivory. In fall and early winter, gland cell walls and neck cells age and break open. These volatile chemicals are the distinctive fragrance one smells after a rain in the sagebrush desert. After releasing these chemicals, the sagebrush leaf becomes more digestible. This difference has been shown through "in vitro" digestibility of sagebrush leaves and alfalfa with the addition of sagebrush-specific volatile compounds (Striby and others 1987; Wambolt and others 1991). So, while some sagebrush species' high crude protein content encourages herbivory, others contain chemicals, such as volatiles, methacrolein, acetone, and 1-8 cineole, that discourage feeding (Kelsey and others 1982; Wambolt 1996; Wambolt and others 1991).

The amount of methacrolein in the three common subspecies of big sagebrush is consistent with their order of food preference (Wambolt and others 1991). It might be reasonable to assume that the chemicals that mule deer, sheep, and insects avoid will also be avoided by sage-grouse. The seasonal change in volatile oils also supports the premise for greater wildlife use of sagebrush foliage in the winter, as compared with spring and summer. However, in spite of what is known, palatability information for the different *Artemisia* species and subspecies is incomplete and somewhat based on assumption. This information gap is in part due to the inability of wildlife researchers to distinguish common sagebrush species, as well as a lack of awareness of less common species that may have seasonal importance. I hope this paper helps improve this situation and stimulates research and discussion about the seasonal vegetative needs and preferences of the declining sage-grouse.

## Methods

This paper summarizes current literature and the author's personal field and laboratory knowledge of woody sagebrush. Unfortunately, most of the sagebrush identification and ecological literature has been treated on a State-by-State rather than regional basis (Beetle 1960; Beetle and Johnson 1982; Morris and others 1976; Winward and Tisdale 1977). Broader treatments using detailed flower characteristics for species divisions have been developed (Hall and Clements 1923; McArthur 1979; Ward 1953); however, because they rely on the presence of the tiny sagebrush flowers, they are impractical for most of the calendar year, or for the biologist with no dissecting scope or herbarium reference material. Most plant characteristics referred to in this paper are visible with the naked eye or a 10x hand lens during any season. All woody shrub and subshrub sagebrush utilized by sage-grouse for food and habitat are included. The geographic scope includes the Great Basin sagebrush steppe and adjacent portions of the Great Plains and Colorado Plateau that have currently or historically supported sage-grouse (Connelly and others 2000). The 23 sagebrush species and subspecies treated are listed in table 1, arranged by their common and scientific names. The table includes one non-*Artemisia* taxon, *Tanacetum nuttallii* (chicken sage), a low-growing woody species that vegetatively resembles *Artemisia* and is utilized by sage-grouse.

Most palatability information does not come from sage-grouse use observations, since they are difficult to raise in captivity, but are based on observations of other wildlife species and on digestibility experiments by Kelsey, Wambolt, and others (Barnett and Crawford 1994; Kelsey and others 1982; Schwartz and others 1980; Sheehy and Winward 1981; Wambolt 2001; Wambolt and others 1991; Yabann and others 1987). Much of the sagebrush chemistry literature is reported in highly technical chemistry-oriented journals and is in need of synthesis and interpretation for sage-grouse biologists and managers. Palatability of sagebrush and other plants is dependant on the individual animal or population of animals feeding on it. In addition to the chemical content of food, learned behaviors may also dictate the food choices animals make. Availability of the plant is also a factor since hoofed animals may avoid, for example, a low sagebrush site that is sloped and rocky, while sage-grouse can readily use this type of terrain and the low sagebrush it supports.

**Table 1**—Twenty-three sagebrush taxa (species and subspecies) are listed in the order they are treated. Nomenclature follows McArthur (1983), with additional, newly described subspecies following Goodrich and others (1985), Rosentreter and Kelsey (1991), and Winward and McArthur (1995). The author chose to exclude taxa that are either beyond the geographic scope of this paper or that can be accounted for at a higher rank.

| Scientific name | Common name |
|---|---|
| **Dwarf sagebrush** | |
| *Artemisia rigida* | Stiff sagebrush |
| *A. spinescens* | Bud sagebrush |
| *A. papposa* | Fuzzy sagebrush |
| *A. tripartita* ssp. *rupicola* | Wyoming threetip sagebrush |
| *A. bigelovii* | Bigelow sagebrush |
| *A. pygmaea* | Pygmy sagebrush |
| *Tanacetum nuttallii* | Chicken sage |
| *Artemisia longiloba* | Early sagebrush |
| *A. arbuscula* ssp. *longicaulis* | Lahontan sagebrush |
| *A. nova* | Black sagebrush |
| *A. arbuscula* | Low sagebrush |
| ***Tall sagebrush*** | |
| *A. cana* ssp. *cana* | Plains silver sagebrush |
| *A. cana* ssp. *bolanderi* | Bolander's silver sagebrush |
| *A. cana* ssp. *viscidula* | Mountain silver sagebrush |
| *A. tripartita* ssp. *tripartita* | Threetip sagebrush |
| *A. tridentata* ssp. *spiciformis* | Subalpine big sagebrush |
| *A. tridentata* ssp. *vaseyana* | Mountain big sagebrush |
| *A. tridentata* ssp. *vaseyana* var. *pauciflora* | |
| *A. tridentata* ssp. *wyomingensis* | Wyoming big sagebrush |
| *A. tridentata* ssp. *tridentata* | Basin big sagebrush |
| A. *tridentata* ssp. *xericensis* | Xeric big sagebrush |
| **Subshrub sagebrush** | |
| *Artemisia frigida* | Fringed sagebrush |
| *A. pedatifida* | Bird foot sage |

# Results and Discussion

## Taxonomy and the UV-Light Test

Several keys and comparison tables for field and lab identification of woody *Artemisia* species are presented. The environmental distribution of these species is displayed by soil moisture, depth, texture, mineralogy, and soil temperature (fig. 1). Field identification can be done year round; however, sagebrush specimens collected in the fall are much easier to identify to species and subspecies. Ecological site knowledge and preferred soil mineralogy also help narrow down the possible taxa that might occur at a given location (fig. 1).

It is easier to distinguish the different species and subspecies of sagebrush using both morphological and chemical characteristics. Chemical analysis is a good tool to verify field determinations and can help eliminate identification problems due to morphological variation (Brunner 1972; Scholl and others1977; Stevens and McArthur 1974). A water extract of fresh or dried leaves of sagebrush can be viewed under a long-wave ultraviolet (UV) light. Prior to applying UV-light, several whole leaves are placed in a glass vial with 10 ml or more of water and shaken. Leaves must be from the same shrub rather than a composite sample since one leaf with positive fluorescence will yield a false positive result (Stevens and McArthur 1974). Table 2 contains the UV-light response for each taxon.

Glass vials must be thoroughly cleaned between samples to avoid contamination from previous tests. A voucher specimen of mountain big sagebrush should be the standard for sample comparison. A positive test produces a bluish-white fluorescence or glow, with the light held several inches from the vial of leaf/water solution. Testing is best done in a dark room or closet. Taxa cannot be distinguished solely by water extract color differences, but the test is useful for taxa likely to be confused based on morphology. This method can also be applied to digested sagebrush from sage-grouse scats in the field, using a portable UV-light and a dark-pigmented bag, or the sample can be returned to the lab.

**Table 2**—UV-light fluorescence of sagebrush taxa in water. Fluorescence intensity is indicated as: (1) intense—very bright bluish white that can be seen in a lighted room indoors; (2) strong—bright bluish white that can serve as a good standard for comparison in a dark location; (3) moderate—bluish white in a dark location; (4) light—very light blue and must be tested in complete darkness; and (5) colorless—no fluorescence.

| Bluish white | Colorless |
|---|---|
| Early (intense) | Basin big sagebrush |
| Subalpine big (intense) | Wyoming big |
| Mountain big (strong) | Bud |
| Xeric big (strong) | Fuzzy |
| Bigelow (moderate) | Stiff |
| Low (moderate) | Chicken sage |
| Lahontan (moderate) | Black "type b" |
| Black "type a" (moderate) | |
| Pygmy (moderate) | |
| Silver (light) | |
| Three-tip (light) | |
| Wyoming three-tip (light) | |

## Palatability and the UV-Light Test

A positive test with blue fluorescence indicates the presence of coumarin, a chemical compound in certain sagebrush species (Heywood and others 1977; McArthur and others 1988). These compounds, principally isocopoletin, scopoletin, and esculentin, are water soluble and fluoresce under ultraviolet light. The higher the compound concentration in a plant, the brighter the leaf/water fluorescence will be (Stevens and McArthur 1974). Coumarin appears to correlate with increased palatability in most sagebrush taxa. Palatability differences of individuals of the same taxa have even been shown to correlate with UV-light fluorescence intensity (Wambolt and others 1987, 1991; Welsh and others 1983).

Coumarin presence is a taxonomic indicator, separating several of the sagebrush taxa (Kelsey and others 1982); however, there are two exceptions to this. Wyoming big sage has little to no fluorescence, but is still highly palatable. Bigelow sagebrush, which has a light-colored fluorescence, contains volatile monoterpenes that discourage herbivory (fig. 2). Hybrids of taxa that brightly fluoresce are intermediate in their response.

The UV-light test is an essential tool for sagebrush identification and palatability testing and should be used by

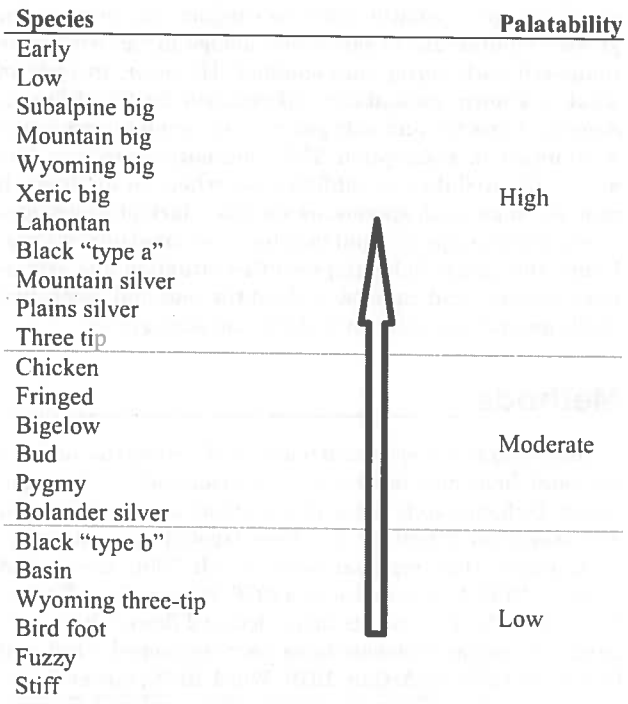


**Figure 2**—Relative palatability gradient of sagebrush for sage-grouse, from most to least palatable. Palatability is defined as "plant characteristics or conditions that stimulate a selective response by animals" (Heady 1964). Webster's New World Dictionary (Guralnik 1972) defines palatable as "pleasing to the taste." The term "preference" is reserved for selection by the animal and is essentially behavioral. Relative preference or relative palatability is a proportional choice among two or more foods.

sagebrush botanists and sage-grouse wildlife biologists. Palatability of sagebrush stands and individual plants can be ranked based on their fluorescence intensity, without even knowing the species. The palatability of nonsagebrush taxa is also of interest to sage-grouse biologists, as there are several common species listed that these birds prefer. However, little information exists about the less common plants associated with sage-grouse. Of the 429 sensitive plant species known from sagebrush ecosystems in the Western United States and found on BLM's sensitive species lists and the Nature Conservancy's target species list from their Columbia Plateau Ecoregional Plan (TNC 1997), 223 are highly palatable to sage-grouse; unfortunately, all 223 of these species are declining. The decline in these species presents a considerable obstacle for the long-term viability of sage-grouse.

## Chemical Ecology

As previously mentioned, sagebrush chemicals are produced in glandular trichomes (Diettert 1938). These glands cover 21 to 35 percent of both sides of a leaf's surface and are hidden beneath a dense mat of hairs (Slone and Kelsey 1985). Glands contain coumarin as well as monoterpenes and sesquiterpene lactones, all of which influence a plant's palatability. Presence of these volatile monoterpenes contributes to the characteristic smell of sagebrush. Because these compounds are volatile, their concentration changes seasonally, with lower concentrations in fall and winter.

The sesquiterpene lactones are the pasty, black material found in sage-grouse scat, indicating that even sage-grouse cannot digest these tar-like lactones. These chemicals are probably deterrents to herbivory (Kelsey and others 1984; Welch and others 1983). In laboratory experiments, a 10-percent solution of lactones, extracted from big sagebrush leaves and placed in potato dextrose agar (PDA), completely inhibited growth of the common fungal mold, *Alternaria* sp. A 5-percent solution of these lactones inhibited the growth of *Alternaria* to as little as 25 to 61 percent of the control (Rosentreter 1984).

## Sagebrush Identification Guidelines

In order to identify sagebrush with a key, a few simple rules must be followed. First, there are three types of leaves on most sagebrush species (Miller and Shultz 1987; Winward and Tisdale 1977). The "persistent" overwintering leaf is the representative leaf shape and size used in the keys (Diettert 1938). The "ephemeral" leaf is generally larger and often irregularly lobed. Ephemeral leaves are produced in spring and shed in the summer when there is drought stress. These odd-shaped leaves should be ignored, because they are fast growing and atypical. The third leaf type is on the flowering stalk. These leaves are often entire and lack the typical lobes and shape of persistent leaves.

Comparison tables (tables 2, 4, and 5) and a dichotomous key to all woody sagebrush species and subspecies are provided. Leaf characteristics are based on overwintering persistent leaves. Bell-shaped leaves have curved margins, strap-shaped leaves have straight margins, and cleft-shaped leaves are three parted. An "even crown" refers to flat-topped shrubs with seedstalks originating at the same height across a plant's crown. A 10-power (10x) hand lens can be used to examine leaf glands and hairs.

# Individual Species Descriptions

Descriptions of each taxa are provided, including the preferred mineralogy, palatability, ecology, distribution, and management recommendations (figs. 1, 2). Dwarf sagebrush are discussed below as a group (also see table 3), followed by tall sagebrush and subshrub taxa (see table 4).

## Dwarf Sagebrush

**A. Stiff Sagebrush (*A. rigida*)**—Stiff sagebrush occurs on very shallow skeletal basalt soils (Daubenmire 1982). Stiff sagebrush has also been called scabland sage due to the scabby, skeletal sites it prefers. Geographically, it grows in the Pacific Northwest portion of the United States and evades drought by being deciduous. Stiff sagebrush has brittle or stiff branches and grows from 12 to16 inches tall. Leaves are not reported to be palatable to any wildlife, but sheep will eat the flowering stalks in late summer and fall (Rosentreter 1992). Flower stalks are full of seeds that are relatively high in protein. Stiff sagebrush has a large seed (0.3 inch) that germinates quickly in 2 to 5 days (Rosentreter, unpublished data). Sites are ephemerally saturated, and contain a large diversity and cover of forbs when the sites are not degraded (Rosentreter 1992; Rosentreter and McCune 1992). Sandberg bluegrass (*Poa secunda*) is the most common grass in these habitats due to the shallow soils. Stiff sagebrush is not a resprouter as some authors have reported. It provides good spring and summer brood-rearing habitat for sage-grouse. Suitable sites of stiff sagebrush should be maintained and restored. The large seeds make restoration of stiff sage feasible and easier than many other sagebrush species.

**B. Bud Sagebrush (*A. spinescens*)**—Bud sagebrush grows on shallow, often saline soils at lower elevations, and is frequently mixed with salt desert shrub vegetation. It flowers in the spring (April to May). Bud sagebrush is geographically widespread, occurring from Montana to Arizona. It has palmately divided leaves that are deciduous. The leaves are fragrant and smell different than the other species. Bud sage is considered to have low palatability, yet on degraded sites it will be heavily used in the early spring by antelope, sheep, and cattle. Bud sage has a relatively large seed similar to stiff and fuzzy sagebrush, two other spring-flowering, deciduous species. Bud sagebrush has not been used in restoration projects, but with its large seeds, it would appear to be feasible.

**C. Fuzzy Sagebrush (*A. papposa*)**—Fuzzy sagebrush occurs at midelevations (>5,000 ft) on shallow soils similar to low sagebrush sites (Rosentreter 1992). However, fuzzy sagebrush is always on basalt bedrock, often with very shallow to almost no soil over the skeletal basalt. Fuzzy sagebrush is generally found on large, flat basalt tables that ephemerally flood at the landscape level. It occurs in Idaho and Oregon (Rosentreter 1992). It is deciduous and has relatively large red or yellow flowers in late spring. By late summer, plants are dried up and domestic sheep, horses,

## Key to the Woody Sagebrush of the Great Basin and Adjacent Areas

1. Short or tall shrubs with woody twigs ..... 2
1. Short subshrubs with nonwoody twigs ..... Key A
   2. Dwarf shrubs, mature plants generally <24 inches tall ..... Key B
   2. Tall to medium-sized shrubs, mature plants generally ≥24 inches tall ..... Key C

## Key A. Subshrubs with nonwoody twigs, woody at the base only

1. Leaf surface silvery, canescent ..... Fringed sage, *Artemisia frigida*
1. Leaf greenish gray, pubescent ..... 2
   2. Old flowering branches reduced to long spines, leaves dehiscent after spring, occurs at low elevations (also keyed as a dwarf shrub in Key B) ..... Bud sage, *A. spinescens*
   2. Plants without spines, leaves persistent, occurs at higher elevations in Wyoming and Montana ..... Bird foot sage, *A. pedatifida*

## Key B. Dwarf shrubs generally <24 inches tall

1. Plants deciduous, losing all their leaves in winter ..... 2
1. Plants semievergreen, retaining some leaves through winter ..... 4
   2. Leaves three lobed and linear ..... Stiff sagebrush, *A. rigida*
   2. Leaves multilobed ..... 3
3. Woody stems spiny, leaves light green ..... Bud sage, *A. spinescens*
3. Woody stems lacking spines, leaves palmately lobed, gray green and fuzzy with many hairs on the surface ..... Fuzzy sagebrush, *A. papposa*
   4. Persistent leaves deeply cleft up to 1.5 inches, grows on shallow soils on ridges at high elevations (7,500 to 9,000 ft) ..... Wyoming threetip sagebrush, *A. tripartita* ssp. *rupicola*
   4. Persistent leaves shallow lobed ..... 5
5. Pointed lobe tips, shallow lobes, and sharply three-toothed leaves ..... Bigelow sagebrush, *A. bigelovii*
5. Rounded lobe tips ..... 6
   6. Persistent leaves multilobed (>3 lobes), restricted to calcareous gravelly soil in Utah ..... Pygmy sagebrush, *A. pygmaea*
   6. Persistent leaves three lobed ..... 7
7. Mature plants <4 inches tall, large flowered, growing only on windswept calcareous gravel ridges in Idaho and Montana ..... Chicken sage, *Tanacetum nuttallii*
7. Mature plants >4 inches tall, smaller flowers, growing on various habitats ..... 8
   8. Early-maturing plants, flower in early summer; seed set by late August, often layering, leaves broadly cuneate with relatively well-developed lobes, large seeds (4 times the size of low sage seeds) ..... Early sagebrush, *A. longiloba*
   8. Late-maturing plants, flower in late summer or fall with seed set in October or November ..... 9
9. Plant crown flat topped (even), flower stalks long and prominent, mostly above the plant, middle leaf lobe barely fits between the outside lobes ..... Lahontan sagebrush, *A. arbuscula* ssp. *longicaulis*

## Key to the Woody Sagebrush of the Great Basin and Adjacent Areas (con.)

9. Plant crown irregular not flat topped (uneven), flower stalks shorter and irregularly oriented, scattered throughout the crown, leaves smaller with lobes of similar size .... 10
   10. Leaves with numerous glands on the surface best visible at 10x, leaves sticky to touch, when mashed between fingers, yields a glossy green to a black color, old flower stalks brown and persistent, flower heads with 3–5 florets ..... Black sagebrush, *A. nova*
   10. Leaves lack glands visible at 10x, gray green to silver-colored leaves, old flower stalks tan and nonpersistent, flower heads with 5–11 florets ..... Low sagebrush, *A. arbuscula*

## Key C. Tall to medium sized shrubs (generally ≥24 inches tall)

1. Persistent leaves linear, layering ..... Silver sagebrush, *A. cana*
1. Persistent leaves three lobed, layering absent or rare ..... 2
   2. Persistent leaves deeply cleft ..... Three-tipped sagebrush, *A. tripartita* ssp. *tripartita*
   2. Persistent leaves shallowly lobed ..... 3
3. Leaves large, 1.5 to 2.5 inches long and up to 0.75 inch wide, leaves dark green, broadly cuneate, often layering, only found at high elevations ..... Subalpine sagebrush, *A. tridentata* ssp. *spiciformis*
3. Leaves smaller, gray green, not layering ..... 4
   4. Plant crown flat topped (even), flower stalks long and prominent, mostly above the plant, leaf margins tapered, leaves widest just below the lobes, leaves in water fluoresce bright bluish white under UV light ..... Mountain big sagebrush, *A. tridentata* ssp. *vaseyana*
   A. Persistent leaves widest at base of lobes. Inflorescence a spike or raceme with relatively few heads, plants occasionally layering ..... var. *vaseyana*
   B. Persistent leaves widest slightly below the base of the lobes. Inflorescence a panicle with numerouse heads, plants do not layer ..... var. *pauciflora*
   4. Plant crown irregular (uneven), not flat topped, flower stalks smaller and irregularly oriented, scattered throughout the crown ..... 5
5. Mature shrubs short, <3 ft tall, leaves bell shaped, grows at lower elevations, plant is U shaped ..... Wyoming big sagebrush, *A. tridentata* ssp. *wyomingensis*
5. Mature shrubs taller, generally >3 ft tall, leaves not bell-shaped, grows at low to high elevations, plant is Yshaped with a central stalk, rather than U shaped or with cupped growth form of many other species ..... 6
   6. Leaf margins straight, leaves long and strap shaped, leaves in water do not fluoresce, prefers deep well-drained soils, widespread geographically and ecologically ..... Basin big sagebrush, *A. tridentata* ssp. *tridentata*
   6. Leaf margins tapered, leaves widest just below the lobes, leaves fluoresce bright blue under UV light, grows only in loamy clay soils in western Idaho ..... Xeric big sagebrush, *A. tridentata* ssp. *xericensis*

**Table 3**—Morphological and chemical characteristics that distinguish the low sagebrushes.

| Species or subspecies | Crown | Leaf shape and color | Leaf margin[a] | Plant architecture[b] | Layering | Preferred soil mineralogy and soil temperature | Color of sage/water solution under UV light[c] | Flowering begins |
|---|---|---|---|---|---|---|---|---|
| Low sagebrush | Uneven-even  | Gray  | Slightly bell shaped | Dwarf spreading, U shaped | No | Shallow claypan, granitic or basalt; aridic-cryic | Moderately bluish white | August |
| Lahontan sagebrush | Even, due to the long flower stalks  | Gray, larger leaf than low sage  | Elongated bell shape, ephemeral leaves often very large | U shaped, often taller than the often low sages | No | Shallow clay soil; aridic-mesic | Moderately bluish white | August |
| Black sagebrush | Uneven-even  | Dark green  | Bell shaped | Dwarf, spreading, U shaped | No | Calcareous; shallow, aridic-frigid | Moderately bluish white; some colorless populations exist | August |
| Early sagebrush | Even  | Dark gray green  | Broadly bell shaped with an obviously cleft central lobe | Dwarf, spreading, U shaped | Yes | Shallow claypan, often in ephemerally flooded but not always alkaline areas; frigid-cryic | Intense bluish white | June-July |

[a] Leaf margin refers to the overall shape of the leaf, the curvature of its margin, and how wide it is at its apex.
[b] Plant architecture refers to a species' basal branching pattern—multiple stems bestow an overall "U shape," and one to few stems produce a wider appearance at the top or a "Y shape."
[c] Consider all taxonomic characteristics in combination when making a determination. A long-wave UV light should be used to test the sagebrush leaf/water solution in a dark location.

**Table 4**—Morphological and chemical characteristics that distinguish the big sagebrushes.

| Species or subspecies | Crown | Leaf shape | Leaf margin[a] | Plant architecture[b] | Layering | Preferred soil mineralogy and soil temperature | Color of sage/water solution under UV light[c] | Flowering begins |
|---|---|---|---|---|---|---|---|---|
| Basin big sagebrush | Uneven  | Long and narrow  | Straight | Y shaped, erect | No | Deep, well drained, aridic-mesic | Colorless | Late August |
| Mountain big sagebrush | Even  | Broadly cuneate  | Tapered | U shaped basal branching | No/ occasionally | Well drained, frigid-cryic | Strong bluish white | July (5 flowers/ inflorescense) |
| Wyoming big sagebrush | Uneven  | Belled  | Bell shaped | U shaped | No | Shallow to moderately deep soil, aridic | Light bluish white or colorless | August |
| Xeric big sagebrush | Uneven  | Broadly cuneate  | Tapered | Y shaped, radiate | No | Loamy clay over basalt, mesic-xeric | Strong bluish white | Late August |
| Subalpine big sagebrush | Even  | Large leaves  | Tapered to elongated bell shape | Spreading, multiple stemmed | Yes | Deep, noncalcareous, often a clay layer, frigid | Intense bluish white | July (>6 flowers/ inflorescense) |

[a] Leaf margin refers to the overall shape of the leaf, the curvature of its margin, and how wide it is at its apex.
[b] Plant architecture refers to a species' basal branching pattern—multiple stems bestow an overall "U shape," and one to few stems produce a wider appearance at the top or a "Y shape."
[c] Consider all taxonomic characteristics in combination when making a determination. A long-wave UV light should be used to test the sagebrush leaf/water solution in a dark location.

and many wildlife species will eat the mature flower stalks (Rosentreter 1992). Its leaves are generally not palatable and are avoided except by horses (personal observation by the author in Idaho and Oregon).

**D. Wyoming Threetip Sagebrush (*A. tripartita* ssp. *rupicola*)**—Wyoming threetip sagebrush is a dwarf shrub rarely more than 7 inches tall, with relatively long (1-1.2 inch), deeply cleft leaves and narrow (1 mm wide) linear lobes. It occurs only in cold sites at high elevations greater than 7,200 ft, east of the Continental Divide in Wyoming and Montana. It is chemically similar to tall threetip sagebrush (*A. tripartita* ssp. *tripartita*) and is not very palatable. It will resprout weakly following physical disturbance or fire, unlike the tall and more common threetip sagebrush that readily resprouts. Because of their high elevation, most Wyoming threetip sagebrush sites are not heavily impacted by livestock, but the shallow rocky soils along ridgelines can be impacted by off-highway trail proliferation.

**E. Bigelow Sagebrush (*A. bigelovii*)**—Bigelow sagebrush can be confused with both low and Wyoming big sage; however, Bigelow sage leaves are more shallowly lobed and sharply pointed. The pointed leaf tips make identification of this species easy, as long as biologists and managers are aware of its potential presence. It occurs on arid and mesic calcareous soils and on highly decomposed granite. It grows throughout the Southwest from California to west Texas and north to northwest Colorado. Bigelow sage is one of the only sagebrush taxa that fluoresces, but is not considered highly palatable (silver sage is another). Increased awareness of Bigelow sagebrush by the wildlife community, particularly in Colorado, may provide additional information on its palatability in the future.

**F. Pygmy Sagebrush (*A. pygmaea*)**—Pygmy sagebrush grows on dry alluvial fans at elevations from 5,000-7,000 ft. It occurs in shallow soils less than 20 inches deep with a gravelly soil surface texture, often mixed with black sagebrush. It is found only in Utah, Nevada, and northern Arizona. Pygmy sagebrush has moderate palatability and may be utilized by wildlife in the winter, due to its availability at moderately low-elevation sites.

**G. Chicken Sage (*Tanacetum nuttallii*)**—Taxonomically, chicken sage has been treated as either *Tanacetum nuttallii* or *Sphaeromeria nuttalli*. Both of these genera are closely related to the genus *Artemisia*. Chicken sage grows on windswept benches and large flat areas on very shallow, calcareous gravels in Idaho, Montana, and Wyoming. Chicken sage looks like a diminutive low sagebrush, but it has smaller leaves and flowers in early summer. Flower heads are relatively large with a small pappus forming around the seed. Due to the presence of the small scalelike pappus, it has not been classified as an *Artemisia*, despite its other similar morphological characteristics. Chicken sage is woody and has three-lobed leaves like many *Artemisia*s. Palatability of this species is moderate, based on its use by antelope (Brent 1976; Thomas and Rosentreter 1992). Sage grouse are found where this species is common, but it is unknown if they utilize it for food. Its branches are less than 4 inches tall and growth form is low spreading to almost creeping. It does not provide structural or hiding cover for sage-grouse. Brent (1976) recorded antelope spending large amounts of time in windswept, normally snow-free chicken sage sites. This suggests their availability for sage-grouse in winter as well.

**H. Early Sagebrush (*A. longiloba*)**—Early sagebrush grows on shallow, ephemerally flooded soils, often with a claypan or skeletal rock layer near the surface (Robertson and others 1966). It is frequently found in low-drainage areas of flats, plateaus, or tables. Early sagebrush is a prolific seed producer and could be used for restoration in appropriate, shallow soil sites (Beetle and Johnson 1982; Monsen and Shaw 1986). It layers and can resprout after cool fires. Early sagebrush is one of the most valuable taxa for sage-grouse, and many of the largest leks in Idaho are in areas dominated by this species (Camas Prairie, south of Fairfield, ID) (fig. 1) (Robertson and others 1966). It flowers very early in the summer, in contrast to other low-stature species. Early sagebrush has been confused with low-growing Wyoming big sage because of its broadly cuneate 3-lobed leaves, and with low sage because of its dwarf size. Early sagebrush is palatable to sheep and, historically, stands were commonly used as lambing areas (Beetle and Johnson 1982). These areas should be monitored to prevent heavy spring grazing by domestic livestock. Early sagebrush has also been referred to as "alkali sage," although sites may or may not be alkaline (Robertson and others 1966).

**I. Lahontan Sagebrush (*A. arbuscula* ssp. *longicaulis*)**—Lahontan sagebrush is a type of low sage that grows on shallow clay soils formed on the shore of Pleistocene Lake Lahontan. It grows in northwest Nevada and adjacent California and Oregon at elevations from 3,400-6,600 ft. It differs from low sagebrush chemically and by its longer floral stalks and larger leaves. Lahontan sagebrush occurs on soils similar to low sage, but in areas that receive less precipitation (5-12 inches). It is moderately to highly palatable (Winward and McArthur 1995).

**J. Black Sagebrush (*A. nova*)**—There appear to be at least two chemical races of black sagebrush in the West (Kelsey 2002, personal communication; McArthur and Plummer 1978). One race, with grayer leaves, is highly palatable, while the greener leafed race has low palatability (fig. 2) (McArthur and Plummer 1978). This latter form does not fluoresce under UV light. Additional studies are needed to determine the geographic ranges and correlation with physical characteristics for these two races. Black sagebrush has been greatly reduced or eliminated on some ranges where sheep graze in winter (Clary 1986). The best feature to identify this species is its flower stalks. The stiff, erect stalks dry to brown and persist through the following year. Most populations have leaf glands visible with a 10x hand lens (Kelsey and Shafizadeh 1980). Black sagebrush grows well on very shallow stony soils, often on windswept slopes and ridges at mid- to high elevations where annual precipitation is more than 10 inches (Behan and Welch 1985). It prefers calcareous or well-decomposed granitic soils that seem to mimic calcareous sites due to weathering of calcium feldspars. Black sagebrush is a widespread species, second only in its distribution to basin big sagebrush.

**K. Low sagebrush (*A. arbuscula*)**—Low sagebrush grows on shallow soils with a restrictive layer of bedrock or

clay pan. This species is usually found where annual precipitation is greater than 12 inches. Parent material is noncalcareous. Low sage is one of the most palatable sagebrushes for sage-grouse. It is a wide-ranging species, found throughout the Great Basin. Black, early, Bigelow, Lahontan, and chicken sage are often misidentified as low sagebrush.

## Tall Sagebrush

**L. Silver Sagebrush (*A. cana*)**—Silver sagebrush is a tall shrub with three subspecies that grow in distinctly different habitats. All three subspecies are root-sprouters and layer vegetatively. The three subspecies are distinguished as:

1. Mature plants 3 to 5 ft tall, leaves mostly >0.8 inch long and strongly pubescent, a plant of arid riparian drainages . Plains silver sagebrush, *A. cana* ssp. *cana*
1. Mature plants <40 inches tall, leaves mostly <0.8 inch long ..... 2
2. Leaves pubescent and silver gray, plant of playas (internally drained basins)
..... Bolander silver sagebrush, *A. cana* ssp. *bolanderi*
2. Leaves sparsely pubescent and dark green, plant of high elevations
..... Mountain silver sagebrush, A. *cana* ssp. *viscidula*

Mountain and plains silver sage are considered highly palatable (Wambolt 2001), while Bolander silver sage is only moderately palatable. The former two species generally grow where they receive additional moisture from the surrounding vegetation. All three subspecies are within the range of sage-grouse. Plains silver sage is often the only *Artemisia* used by grouse on the flat plains of central and eastern Montana.

**M. Threetip Sagebrush (*A. tripartita* ssp. *tripartita*)**—Threetip sagebrush is a fairly tall, erect shrub (4 to 6 ft). It grows on deep, well-drained soils, often mixed with Basin or mountain big sagebrush. It will seldom layer without disturbance, but will vigorously stump sprout and layer after burning. It is considered highly palatable to wildlife (Wambolt 2001); however, there is high seasonal variation in its utilization. Livestock, including sheep, appear to avoid utilization of this species. Beware of control or prescribed burning in threetip sage habitat, as it can increase well beyond the site's preburn density. It is common in Washington, Idaho, Montana, Wyoming, Utah, and Colorado.

**N. Subalpine Big Sagebrush (*A. tridentata* ssp. *spiciformis*)**—Subalpine big sagebrush grows on deep, cryic soils and is highly palatable. Sage grouse reportedly use this species; however, it probably becomes unavailable in late winter due to snow cover. It frequently grows where large snowdrifts form, unlike dwarf sagebrush types that grow in windswept areas. Subalpine sagebrush can occur on ridgelines, similar to some of the dwarf and low-stature sagebrushes. These ridgelines are frequently used by sage-grouse. Chemically, subalpine sage appears to be a choice food for sage-grouse and other wildlife species. It layers vegetatively and resprouts following defoliation from heavy snow. It occurs in Idaho, Wyoming, Montana, Utah, and Colorado (Goodrich and others 1985; McArthur and Goodrich 1986).

**O. Mountain Big Sagebrush (*A. tridentata* ssp. *vaseyana*)**—This write-up covers both variety *pauciflora* and *vaseyana*. Mountain big sagebrush is a flat-topped shrub that grows to 3 ft tall (Tisdale and Hironaka 1981). It has a U-shaped crown and is found on moderate to deep, well-drained, frigid soils, generally above 5,000 ft. Mountain big sage can grow as low as 3,000 ft, and when it does, soils are typically very well drained. It is highly palatable to most wildlife; however, limited access in the winter and the chemical content in spring and summer may discourage herbivory (Kelsey and Shafizadeh 1978; Kelsey and others 1984). Mountain big sagebrush is a major food source for sage-grouse in the winter months. Sage-grouse scats from Wyoming big sage-dominated sites in Idaho and Colorado generally test positive under UV light, indicating that grouse eat mountain big sage when a choice is available (Rosentreter 2001, unpublished data; Vasquez 2002). In the Gunnison Basin of Colorado, sage-grouse utilize a hybrid of ssp. *vaseyana* and ssp. *wyomingensis* (Vasquez 2002).

Compared to other sagebrush taxa, mountain big sagebrush has a greater potential to increase its density due to its general ecology and the higher moisture its habitat receives. Stands can become so dense they are difficult for humans to walk through. In much of the West, heavy livestock use, both historic and current, has reduced forb, perennial grass, and biological soil crust components, allowing sagebrush and exotic annual grasses to become dense (Billings 1994; Rosentreter and Eldridge 2002). Mechanical control, burning, or seeding followed by rest from grazing, is necessary in many areas to restore the vegetative and structural diversity needed for optimal wildlife habitat. "Hobble Creek" mountain big sage, a highly palatable cultivar of ssp. *vaseyana*, is recommended for restoration projects with the goal of improving wildlife winter range (Welch and others 1990).

**P. Wyoming Big Sagebrush (*A. tridentata* ssp. *wyomingensis*)**—Wyoming big sagebrush is a medium sized shrub from 1 to 3 ft tall. It branches from the base, giving it a U-shaped architecture. Wyoming big sage grows at warmer, lower elevations and is more available as forage in winter and early spring (Wambolt 1998). It occurs at sites receiving from 8 to 12 inches of precipitation. This species is generally palatable, though its palatability is highly variable. Many Wyoming big sagebrush sites have been severely degraded and converted to exotic annual grasslands; thus, in harsh winters, they are no longer available for sage-grouse use (Hilty and others 2003).

Nondegraded, lightly grazed Wyoming big sage sites have a high percent cover of biological soil crusts and low percent cheatgrass cover (Kaltenecker and others 1999; Rosentreter 1986; Rosentreter and Eldridge 2002). Due to their susceptibility to invasion and domination by cheatgrass and other exotic annuals, use of fire to manage them must be approached with caution. Wyoming big sage sites should be managed for retention of the biological soil crust component. Late fall, winter, and early spring is the most appropriate season of use for this low-elevation vegetation type. Four to 6 weeks of moist soil conditions in late spring facilitates

regrowth of biological soil crusts disturbed by trampling (Memmott and others 1998; Rosentreter and Eldridge 2002). "Gordon Creek" Wyoming big sage, a highly palatable cultivar, is recommended for restoration projects aimed at improving wildlife winter range (Welch and others 1992).

**Q. Basin Big Sagebrush (*A. tridentata* ssp. *tridentata*)**—Basin big sagebrush is the least palatable of the big sages (Wambolt 1998), though it is chemically and genetically (2n = 18 or 36) highly variable. It is considered of low palatability relative to other sagebrush taxa (fig. 2), and it is also the tallest. Its architecture is somewhat single trunked (tree like) or Y shaped, with lateral branches diverging from the main stem at a different angle than either Wyoming or mountain big sage. This prolific seed producer grows on deep, well-drained soil (Daubenmire 1975). The extra moisture runoff from roads can create artificial sites for this subspecies, even in soils normally occupied by Wyoming big sagebrush. Large areas dominated by Wyoming big sage will frequently have basin big sagebrush adjacent to the road ditch. Basin big sagebrush seed comprises a large portion of the wild seed collected for Wyoming and mountain big sage restoration projects, which has expanded the range of this taxon (Lowe-Dalzell and others 2003). Basin big sagebrush leaves have rarely been identified in sage-grouse scats (Rosentreter 2001, unpublished data; Vasquez 2002). However, even small dense stands of this shrub can provide good nesting habitat for sage-grouse in Colorado's Gunnison Basin.

**R. Xeric Big Sagebrush (*Artemisia tridentata* ssp. *xericensis*)**—Xeric big sagebrush is a tall shrub (>3 ft) with Y-shaped architecture similar to basin big sagebrush. However, its chemistry, leaf shape, and palatability are most similar to mountain big sage. This Idaho subspecies is restricted to heavy clay-loam soils at lower elevations (2,500-4,500 ft) and on drier, xeric soils than mountain big sagebrush. In Idaho, mountain big sage grows between 4,000 and 9,500 ft, in moister "Udic" soils. Xeric big sagebrush is heavily utilized in winter by mule deer and, based on its chemistry (high crude protein) (Rosentreter and Kelsey 1991), is likely preferred by sage-grouse. It can increase in density similar to mountain big sage, with heavy spring, summer, or early fall cattle grazing.

## Subshrub Sagebrush

**S. Fringed Sagebrush (*A. frigida*)**—Fringed sagebrush is a small subshrub, woody only at the base. It is the most widespread species treated in this paper, extending into other North American and Asian biomes, such as alpine meadows, the Great Plains, and mountain meadows. It was described from Siberia before being identified in North America. Fringed sage occurs in a variety of soil types and depths, but prefers shallow soils with "frigid" soil temperatures (Morris and others 1976). Some sites are windswept and are readily available to wildlife in the winter. Fringed sage is moderately palatable. In the Gunnison Basin, sage-grouse have been observed eating fringed sage seedlings in early spring (Young 2001).

**T. Bird Foot Sage (*A. pedatifida*)**—Bird foot sage is a small subshrub, weakly woody at the base. It occurs in dry shallow soils at high elevations with frigid soil temperatures in Wyoming, Montana, and Idaho. This subshrub is most commonly found in montane grasslands and on windswept sites. It is 1 to 5 inches tall with finely canescent, basal leaves. Leaves are once or twice ternately divided into linear divisions with finely white-tomentulose hairs. Flowers are brownish. Bird foot sage has low palatability.

## Conclusion

Coumarin-containing taxa such as mountain, xeric, subalpine big, subalpine early, black, and low sagebrush all fluoresce a bright bluish-white color. These taxa are also the most palatable. Plant chemicals such as coumarin and methacrolein and their seasonal variation affect shrub palatability and animal, including sage-grouse, preference. Because sagebrush species also differ vastly in their structural characteristics and habitat requirements, knowledge of *Artemisia* ecology will enhance our ability to improve and manage habitat for sage-grouse.

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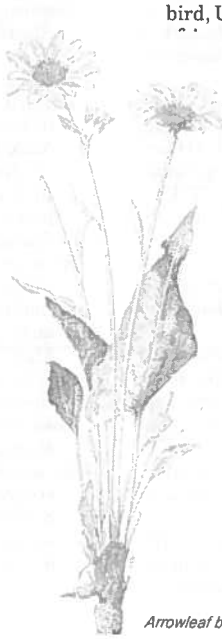

*Arrowleaf balsamroot*