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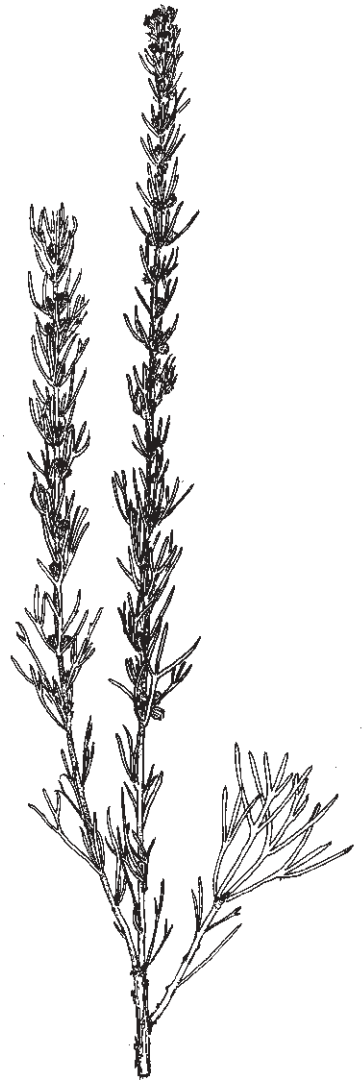
Chapter 21

Composite Shrubs



The sunflower family (Compositae or Asteraceae) is the largest family of flowering plants. Its many species occur around the world as annual and perennial herbs and as shrubs and trees (Benson 1957; Cronquist 1968; Wagenitz 1977). Three shrubby genera of the family—sagebrush (*Artemisia*), rabbitbrush (*Chrysothamnus*), and matchbrush (*Gutierrezia*)—make plants of this family among the most common and important plants of the Intermountain area (McArthur and others 1979a; table 1). Shrubs of these genera provide critically needed ground cover on arid Western ranges, are important sources of browse for domestic livestock and big game, and serve as cover and forage for many wildlife species. A number of sagebrush and rabbitbrush species are important as cover for small birds, game birds, and mammals, and as browse plants for big game animals, especially on winter and early spring ranges. Some species also provide forage for livestock (sheep and cattle). Horsebrush and matchbrush also contribute more forage than is generally believed; however, both plants may, under certain conditions, be harmful to domestic livestock (Benson and Darrow 1945; Johnson 1974a; McArthur and others 1979a) and cause allergies in humans (Lewis and Elvin-Lewis 1977; Rodriguez and others 1976).

Chapter Contents by Species

Various forms of sagebrush and rabbitbrush may also be directly seeded or transplanted for landscaping, stabilizing, and beautifying disturbed landscapes and may have potential for supplying industrial chemicals. Young wildings of both sagebrush and rabbitbrush transplant easily. Usually within 3 to 7 years, direct seeded or transplanted plants are established sufficiently to reproduce naturally from seed. Both establish well when properly aerially or drill seeded (McArthur and others 1974; Plummer 1977; Plummer and others 1968).

In this chapter, we prefer to limit the term sagebrush to members of the subgenus *Tridentatae* (McArthur 1979; McArthur and others 1981). Other woody members of the genus *Artemisia* then become "sage" or "wormwood." However, in the broad sense in this chapter, use of sagebrush alone may refer to any woody, native North American *Artemisia* species.

Sagebrush and rabbitbrush species that are especially important on low elevation Intermountain area ranges include big sagebrush (*A. tridentata*), black sagebrush (*A. nova*), threetip sagebrush (*A. tripartita*), low sagebrush (*A. arbuscula*), budsage (*A. spinescens*), fringed sage (*A. frigida*), sand sage (*A. filifolia*), early sagebrush (*A. longiloba*), rubber rabbitbrush (*C. nauseosus*), low rabbitbrush (*C. viscidiflorus*), Greene's rabbitbrush (*C. greenei*), spreading rabbitbrush (*C. linifolius*), and Parry's rabbitbrush (*C. parryi*). Some of these species, for example, threetip sagebrush and Parry's rabbitbrush, are usually found on ranges at higher elevations than the others.

Virtually all of these species include an array of ecotypes. Some are large taxonomic units that include several subspecies (big sagebrush, rubber rabbitbrush, low rabbitbrush, and Parry's rabbitbrush) (McArthur and others 1979a). These shrubs, especially under conditions of heavy grazing, may form closed stands. However, in many locations they mix with grasses and forbs. Big sagebrush often occurs with the grasses, bluebunch wheatgrass, western wheatgrass, the

Table 1—Important Composite shrubs of the Intermountain area.

Common name	Scientific name
Oldman wormwood[a]	*Artemisia abrotanum*
Low sagebrush	*Artemisia arbuscula*
Bigelow sagebrush	*Artemisia bigelovii*
Silver sagebrush	*Artemisia cana*
Sand or oldman sage	*Artemisia filifolia*
Fringed sage	*Artemisia frigida*
Longleaf sage	*Artemisia longifolia*
Alkali sagebrush	*Artemisia longiloba*
Black sagebrush	*Artemisia nova*
Birdsfoot sage	*Artemisia pedifida*
Pygmy sagebrush	*Artemisia pygmaea*
Stiff or scabland sagebrush	*Artemisia rigida*
Budsage	*Artemisia spinescens*
Big sagebrush	*Artemisia tridentata*
Threetip sagebrush	*Artemisia tripartita*
Alkali rabbitbrush	*Chrysothamnus albidus*
Dwarf rabbitbrush	*Chrysothamnus depressus*
Spreading rabbitbrush	*Chrysothamnus linifolius*
Greene's rabbitbrush	*Chrysothamnus greenei*
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Parry rabbitbrush	*Chrysothamnus parryi*
Vasey rabbitbrush	*Chrysothamnus vaseyi*
Low rabbitbrush	*Chrysothamnus viscidiflorus*
Small headed matchbrush	*Gutierrizia microcephala*
Broom snakeweed	*Gutierrizia sarothrae*
Gray horsebrush	*Tetradymia canescens*
Littleleaf horsebrush	*Tetradymia glabrata*
Nuttall horsebrush	*Tetradymia nuttallii*
Spiny horsebrush	*Tetradymia spinosa*

[a]Introduced species.

introduced crested wheatgrasses and desert wheatgrasses, and intermediate wheatgrasses, Idaho fescue, sheep fescue, Indian ricegrass, Sandberg bluegrass, Thurber needlegrass, bottlebrush squirreltail, and others.

A rich array of forbs also grow in the sagebrush-grasslands, including species of aster, lupine, locoweed or milkvetch , balsamroot, Agroseris, wild buckwheat, and goldenrod. Sagebrush species are the dominant and codominant species of over 40 described habitat types of the American West (Blaisdell and others 1982). Passey and others (1982) published a classic study on sagebrush habitats of the Intermountain West. Their statement of the importance of sagebrush:

> Opinions differ among plant scientists as to the place of sagebrush in plant communities on semiarid rangelands (Ellison 1960). Historical accounts of the amount and distribution of sagebrush are also often contradictory. As noted, the relative amount and distribution of sagebrush species or subspecies have been observed and evaluated on the several hundred tracts examined in this study. One or more species of sagebrush were present on every area examined except where there was unmistakable evidence of recent burning, tillage, or mechanical or chemical treatment. Many of these observations were made on rangelands where the plant community was judged to be in near-climax condition. Some areas, in fact, had no evidence of use or disturbance of any kind except by native fauna. On all study sites supporting subspecies of big sagebrush, annual growth rings of the largest stems were counted to determine the age of the plants and to establish the length of time during which there had been no fires. The oldest plants found were about 120 years old, and several locations supported plants at least 100 years old. Many of the older plants had split and nearly decayed stems on which the growth rings could not be accurately counted; so some plants may have been even older. With few exceptions, the oldest (not necessarily the largest) plants grew on stony or gravelly soils, and were of the Wyoming big sagebrush subspecies. On disturbed relic areas, subspecies of big sagebrush typically grew in open stands with individual plants or small clumps of plants uniformly distributed. Where it grew, big sagebrush made up five to 20 percent of the total annual production on the study site.

Woody *Artemisia*, called wormwood in North Africa and Eurasia, are principal components of the steppes of those regions. There (Larin 1956), as in North America (Blaisdell and others 1982; Laycock 1979; McArthur and Plummer 1978), many range managers regard them as a mixed blessing. They are aggressive and increase on overgrazed land; on the other hand, they provide much forage for wildlife and domestic animals. This group of plants (*Artemisia*) may number 400 species and is divided into four subgenera based on floral, anatomical, chemical, karyotypical, and distributional characteristics (McArthur 1979; McArthur 1983b; McArthur and others 1981; table 2). Rabbitbrushes are equally as widespread as sagebrush (= N. American *Tridentatae*) but are generally less dominant (McArthur and Meyer 1987). There are 17 rabbitbrush species with 40 subspecies divided into five sections (table 4).

Seed of most composite shrubs can be collected by hand stripping, beating into a container, and, in some cases, with vacuum harvesters (chapter 24). For seed to pass through most seeders, plumes and other flower parts need to be partially removed. This can be done by passing the seed through a barley debearder followed by screening and fanning. Seeds are rather brittle; consequently, care must be taken to ensure that they are not cracked or broken during cleaning and seeding. Seed of most composites can be stored no more than 1 to 3 years before seeding—otherwise, considerable viability will be lost (Stevens and others 1981a).

A principal trait of sagebrush and rabbitbrush is the ability to persist under heavy abuse and poor management, and yet, be able to recover with proper management. Few other shrubs can recover in a reasonable period without special management, including seeding. Most plants of this group can compete with weedy herbs, and many species occupy arid sites where few other shrubs persist.

Important characteristics of a number of composite shrubs are listed in the Introduction to section VII. Seeding recommendations for principal vegetative types and conditions are discussed in chapter 17. Composite shrubs adapted to these vegetative types and conditions are included in the seeding recommendations. Seed characteristics are found in chapters 24 and 26.

We include in this chapter a brief species description, ecological relationships, distribution, culture requirements, use, improved varieties, and management of each of the species appearing in the chapter contents list.

General Sagebrush Culture

Intermountain sagebrush species all have small seed (see chapter 24). The smallest seeds are those of fringed sage, with over 4.5 million seeds per lb (9.9 million per kg) (100 percent purity). Pygmy sagebrush has relatively large seeds with about 500,000 per lb (1.1 million per kg). In big sagebrush, seed size varies among subspecies. Basin big sagebrush has just over 2.5 million seeds per lb (5.5 million per kg), Wyoming big sagebrush just under 2.5 million (5.5 million per kg), and mountain big sagebrush has about 2 million (2.2 million/kg). Seed size, no doubt, influences the depth at which seeds should be planted. Seed of most sagebrush species should not be planted deeper than 1/16 inch (1.6 mm). Good results can be obtained when seeds are broadcast on top of disturbed soils and not covered.

Adequate covering usually occurs from natural soil sluff. Sagebrush seed can be placed on top of the seedbed using drills that have had their seed drops or tubes pulled out between the disk-furrow opener and placed behind. Seeds then drop on the soil disturbed by the disk furrow openers. Several effective methods of planting sagebrush seed include broadcasting (aerial or by ground rigs), and placing through a seed dribbler, thimble seeder, or browse seeder onto disturbed soil. Drill seeding is a low priority option.

Table 2—Taxonomic subgenera of *Artemisia* (McArthur and others 1979a).

Classical section[a]	Modern subgenera[b]	Distinguishing characteristics	Distribution	Species mentioned in this chapter
Absinthium	Artemisia	Pistillate ray flowers perfect disc flower, predominantly herbaceous, but a few are woody	Eurasia North Africa North America	*A. abrotanum* *A. absinthium* *A. frigida*
Abrotanum				*A. longifolia* *A. ludoviciana*
Drancunculus	Drancunculus	Pistillate ray flowers staminate disc flowers herbacious and woody.	Eurasia North America	*A. filifolia* *A. pedatifida* *A. spinescens*
Seriphidium	Seriphidium	Ray flowers lacking, perfect disc flowers; herbaceous and woody.	Eurasia, North Africa[d]	
	Tridentatae	Ray flowering lacking, perfect disc flowers, woody.[c]	North America	*A. arbuscula* *A. argillosa* *A. bigelovii* *A. cana* *A. longiloba* *A. nova* *A. pygmaea* *A. rigida* *A. rothrockii* *A. tridentata* *A. tripartita*

[a]De Candolle 1837; Hooker 1840; McArthur and Plummer 1978; McArthur 1979.
[b]Rydberg 1916; Beetle 1960; Polyakova 1961; McArthur 1979; McArthur and others 1981.
[c]The single exception, *A. bigelovii*, has zero to two pistillate ray flowers on otherwise discoid heads.
[d]Two anomalous American species have been referred to Seriphidium: *A. palmeri* of southern and Baja California and *A. mendozana* Argentina.

Seeding sagebrush with most ground equipment requires that the seed be cleaned to at least 60 percent purity. Most sagebrush seed is collected between 10 to 15 percent purity. To increase purity, the collected material is run through a hammermill or barley debearder followed by fanning and screening. Barley debearders are preferred (Booth and others 1997; Welch 1995). Hammermills tend to ball up the collected materials, rendering it almost impossible to seed mechanically.

As seed purity increases, volume of material decreases. Seed cleaned to more than 30 percent purity requires being mixed with a carrier such as rice hulls or screened sawdust. Range seeders and drills are not equipped to handle seed the size of sagebrush seed. Small seed size requires that volume of material be increased to help ensure proper seed metering. Plant materials and floral parts that are collected with sagebrush seed will not flow through and will plug most ground rig seeding devises.

Most sagebrush seed matures and is dispersed October through December. This is also the most ideal time to seed. We do not recommend spring seedings. Sagebrush seedlings are susceptible to frost damage and are intolerant of short drought. Many sagebrush seedlings that establish are located in, under, and next to downed and dead plant materials and next to rocks—all areas that provide some protection from adverse climatic conditions and grazing animals. When seeding sagebrush in a mixture with other species through ground equipment, we recommend that sagebrush seed be separated in the seeding device from seed of more competitive species (those with strong seedlings and fast rate of growth; most grasses fall in this group). Individual compartments in drill seed boxes can be constructed with cardboard partitions and duct tape. This will allow sagebrush and compatible species to be seeded separately but at the same time as seeding the noncompatible species another compartment. Seeding sagebrush aerially generally results in the seed of the various species in the mixture being separated so they are not in competition with each other.

When dried and stored in an open, untreated, uncooled warehouse, seed of most sagebrush species will retain good viability for up to 3 years following collection (Stevens and others 1981a).

Most sagebrushes transplant well. When standard bareroot and container stock handling, planting, site condition, requirements, principles, procedures, and methods are followed, excellent establishment success can be expected (Richardson and others 1986; Stevens and others 1981b).

A majority of sagebrush seed is hand collected by stripping or beating the seed into some type of container. Seed of some species can be collected with a mechanical seed stripper.

Artemisia abrotanum

Oldman Wormwood

Oldman wormwood, also called southernwood, is a shrub 1.5 to 6 ft (0.5 to 1.8 m) tall (Grieve 1931; Hall and Clements 1923; Plummer 1974b). Stems are much branched, erect or somewhat spreading, and form a rounded bush (fig. 1). The species has a pleasing aromatic fragrance and bright green, finely divided, pinnately dissected leaves giving the shrubs a feathery appearance. It has a deep and extensive root system allowing the plant to obtain nutrients and water from considerable distances (Plummer 1974b). This characteristic also allows the plant to establish in raw subsoils. Principal leaves are 3.0 to 6.1 cm long, two or three times pinnately dissected with revolute margins, glabrous or sparsely puberulent on upper surfaces, but lightly tomentulose on the lower surfaces (Hall and Clements 1923). The inflorescence is an elongated terminal panicle, leafy at the base, 6 to 15 inches (15.2 to 38.1 cm) long and 1.5 to 6 inches (3.8 to 15.2 cm) broad. Heads are heterogamous, short

Figure 1—Oldman wormwood plants growing from stem cuttings along Ephraim Canyon Road, Sanpete County, UT.

peduncled, and nodding, and are about 2.0 to 2.5 mm high, 2.5 to 3 mm broad. There are five to 15 ray flowers with 1.5 mm long corollas and 10 to 20 five-toothed disk flowers with campanulate corollas, 1.5 to 2 mm long. There are eight to 18 bracts. The receptacle is naked.

Ecological Relationships and Distribution

Oldman wormwood is native to the Mediterranean areas of Europe, Asia, and Africa (Hall and Clements 1923). Its alternate common name, southernwood, distinguishes it from common wormwood (*A. absinthium*). The latter is common and adapted in northern Europe including Great Britain, whereas oldman wormwood was recognized as an introduction in these areas (Grieve 1931). In Britain, oldman wormwood rarely flowers, perhaps because of the high latitude. In North America, the plant is occasionally adventive in the Eastern United States as a garden escape. In the Intermountain area, however, it occurs only where it has been planted. Few viable seeds are produced and only rarely are seedlings found (Plummer 1977). A dwarf form, var. *nana* 1 ft (30.5 cm) tall, and another regular sized ecotype have long been maintained by the USDA-ARS High Plains Research Station at Cheyenne, WY. Although seed production remains rare, a higher frequency of viable seed production has occurred with these additional plant genotypes growing in proximity to the formerly near sterile ecotype. This suggests that outcrossing facilitates seed production in oldman wormwood. It can be established by cuttings in many soil types including raw subsoils in various vegetation types big sagebrush to the subalpine, 5,000 to 10,500 ft (1,500 to 3,200 m) elevation, 12 to 40 inches (30.5 to 101.6 cm) precipitation (Plummer 1974b, 1976, 1977). It can tolerate moderately alkaline to moderately acidic soils (Plummer 1974b). Although this species is adapted to subsoils such as roadcuts it is not universally adapted to mine disturbances. Plants are apparently sensitive to heavy metals or other mine waste materials. Plants have not persisted more than 5 years on acidic soils of the Idaho Batholith (Monsen, unpublished).

Plant Culture

This species is, in essence, maintained vegetatively in the Intermountain area. It is easily propagated by stem cuttings. The process for establishing the plant in a nursery or in outplantings is the same. Place cuttings in the ground in spring when and where soil is moist. Plummer (1974b) gave instructions for cuttings. Stems 10 to 18 inches (25.4 to 45.7 cm) and up to 0.5 inch (12.7 mm) in diameter give good results. Smaller cuttings root well but are difficult to stick in the ground. For best results, leaves and small twigs should be removed from the cuttings. Sharpening the large end of the cutting will facilitate penetration of a hard soil surface and minimize damage to the cuttings. The cuttings perform best if planted within 48 hours after being taken. However, cuttings have rooted after 6 weeks in cold storage (32 to 40 °F; 0 to 4.4 °C). Cuttings should be kept moist and cool until planted. In general, roots are forming and new buds leafing out about 2 weeks after planting. Plants should be placed about every 2 to 4 ft (0.6 to 1.2 m) for good stands. Nursery plants remain vigorous and disease-free for years (Nelson and Krebill 1981).

Uses and Management

Oldman wormwood is useful for stabilizing subsoil sites (Plummer 1974b, 1977). Its deep extensive root system makes the plant especially useful for erosion control. Plants placed in staggered rows about 2 to 4 ft (0.6 to 1.2 m) apart make good ground cover. It is especially useful on steep sites such as roadcuts and fills. On such sites, new roots are produced on freshly covered stems with each earth movement, thus providing additional stabilization. This species is useful as a nurse crop in that it helps stabilize and modify raw soils so that natural invasion of plant materials from the surrounding areas can occur. Individual plants may persist for 15 to 25 years or more, but eventually they will go out without reproducing themselves. By that time, however, they have usually served their purpose. Plants are consumed by small animals (at times girdling the bark under snow) and insects, but are not often eaten by large animals. Plants do provide excellent cover for upland game species. Formerly the plant was much used in herbal medicine as a tonic, anthelmintic, emmenagogue, and antiseptic (Grieve 1931). It is also used in ornamental plantings (Hall and Clements 1923; Plummer 1974b).

This plant requires little management. Nurseries can be maintained as a source of cutting stock with only routine maintenance. Occasional weed control and supplemental water on dry sites is all that is required. At outplanting sites where the plant has been put in to help with soil stabilization no care is necessary. These sites, however, often provide additional cutting stock.

Varieties and Ecotypes

Two varieties exist, the common one (var. *abrotanum*) and a dwarf one (var. *nana*). We know of no plant improvement work or ecotype comparisons. The common variety is best, in most cases, for raw soil stabilization planting because of its more vigorous growth.

Artemisia arbuscula

Low Sagebrush

Low sagebrush (fig. 2) is a low spreading, irregularly branched shrub up to 20 inches (50.8 cm) high. The slender, erect twigs are densely canescent but may become nearly glabrous and thus darker green in late summer. The plant layers infrequently. Leaves are broadly cuneate, or fan shaped, 0.5 to 1.5 cm long, 0.3 to 1 cm wide, and are usually three-toothed (occasionally four to five in ephemeral leaves) or cleft at the apex (fig. 3). Leaves on the upper part of the flowering shoots may become entire. Flowerheads are grouped into elongated, narrow racemose panicles. The heads usually contain five to 11 disc flowers with corollas 3 to 4 mm long. The 10 to 15 involucral bracts are canescent. Flowering occurs August to September, depending upon strain and elevation. Seed ripens in October and November (McArthur and others 1979a).

Ecological Relationships and Distribution

Low sagebrush grows on dry, sterile, often rocky and alkaline, usually clay, soils between 2,300 and 11,500 ft (700 and 3,500 m) on approximately 39,112 mi^2 (101,300 km^2) in 11 Western States (Beetle 1960; McArthur and Plummer 1978; Ward 1953). In the warmer, drier parts of its range, particularly in southwestern Utah and Nevada, it may grow well into the mountains above 9,800 ft (3,000 m). In some areas, for example, east-central Idaho, low sagebrush occurs on disjunct low and high elevation bands (McArthur and others 1979a). Low sagebrush ranges from southern Colorado to western Montana and west throughout Utah and Idaho to northern California, Oregon, and Washington. Normally its sites are drier and more rocky than those on which big sagebrush occurs. It may grow in mosaics with big sagebrush where each is confined to a particular soil type. Low sagebrush and black sagebrush only rarely occur in intermixed stands, for example, Lost River-Lemhi Range area of Idaho (McArthur and others 1979a). In areas where the distribution of these two species overlap, low sagebrush is usually found in the more moist habitats or at slightly higher elevations than black sagebrush (Tisdale and Hironaka 1981; Ward 1953; Zamora and Tueller 1973).

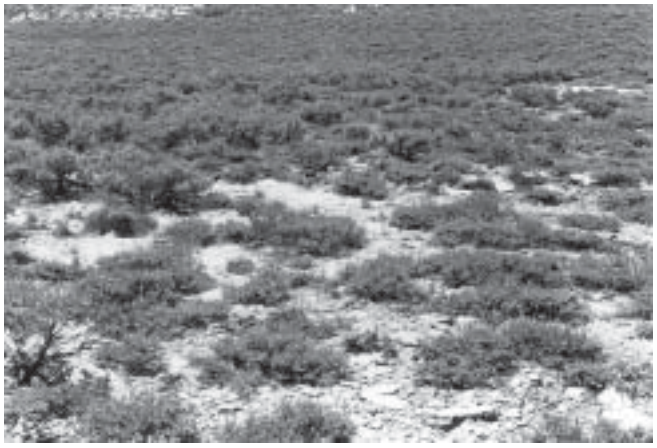


Figure 2—Low sagebrush growing on shallow, stony soil in Logan Canyon, Cache County, UT.

Figure 3—Two subspecies of low sagebrush: (A) *A. arbuscula* ssp. *arbuscula*; (B) *A. arbuscula* ssp. *thermopola* (Shultz 1986).

Plant Culture

Plants can be established on adapted sites by direct seeding, broadcasting, and drilling. Seeding should be conducted in the fall on disturbed soil. Care must be taken to ensure that seeds are not covered more than 1/16 inch (1.6 mm). Wildings of this species can be transplanted in the spring or fall. Experimental nursery plantings have successfully reproduced. Plants of low sagebrush established at the Snow Field Station were more vigorous than most other sagebrush plantings there (Nelson and Krebill 1981). Plants establish well by direct seeding. Seedlings emerge rapidly and grow quickly, although few attain large stature at first. Roots develop rapidly, and plants are able to survive dry surface conditions. Low

sagebrush recovers quickly after burning and other disturbances. It persists and invades sites seeded to perennial grasses. It expresses good seedling vigor and can be seeded with herbs. Seeds should be planted at a shallow depth with a firm seedbed. Seed lots of low sagebrush usually contain less inert or floral materials than processed seed lots of big sagebrush. Thus, seeds can be more easily planted. Seed of low sagebrush is more difficult to collect than the more robust big sagebrush. Seed prices are, thus, somewhat higher, and lower quality seed is often sold. Low sagebrush may often occur with little understory. When seeded with herbs, a mixed community normally develops, but the understory often weakens and recedes. The relationship with introduced and native herbs is not well understood.

Uses and Management

On winter ranges, and to a limited extent on summer ranges, low sagebrush is browsed by big game and livestock (Kufeld and others 1973; McArthur and others 1979a). Considerable variation exists in how animals browse it in different locations. In Nevada a gray-green form may be heavily browsed, while the green form is only lightly browsed (Brunner 1972). In addition to the direct browsing use of the plant, its communities are important as habitat for a wide range of domestic and wild animals (Dealy and others 1981). Low sagebrush grows on difficult sites and is, therefore, not often a candidate for manipulation. Because low sagebrush grows on exposed sites it is important to wintering animals. Few other shrubs are adapted to similar conditions. Consequently, maintenance of the species is often critical. Attempts to maintain low sagebrush on sites not similar to its origin have proven unsuccessful. Seedlings usually establish when planted "offsite," and plants may attain maturity. However, plants usually succumb after a few years with little or no regeneration.

Varieties and Ecotypes

We are not aware of any substantial plant improvement work on this species. There are numerous ecotypes (Brunner 1972; McArthur and others 1979a) and three subspecies (fig. 3a,b shows two of these subspecies). Low sagebrush can apparently hybridize with its *Tridentatae* relatives (McArthur and others 1979a). Beetle (1959, 1960) named a dwarf form hotsprings sagebrush. This form occurs in the Stanley Basin area of Idaho, Jackson Hole area of Wyoming, east-central Oregon, and perhaps other locations. Beetle speculated that this form arose as a result of hybridization between typical low sagebrush and threetip sagebrush. Another important low sagebrush is Lahonton low sagebrush (Winward and others 1986; Winward and McArthur 1995). This plant occurs in western Nevada. We believe that it is a stabilized hybrid between low and big sagebrush. The big sagebrush parent is probably Wyoming big sagebrush (Winward and McArthur 1995).

Artemisia bigelovii

Bigelow Sagebrush

Bigelow sagebrush is a low shrub 8 to 16 inches (20 to 40 cm) high with numerous spreading branches (fig. 4). It is also known as flat sagebrush (Hall and Clements 1923). The flowering stems are slender and erect and bear inflorescences that are long, narrow panicles with short, recurved branches (fig. 5). New growth is covered with a silvery-canescent pubescence. The leaves of vegetative branches are similar to those of big sagebrush. They are narrowly cuneate, 1 to 2 cm long, 2 to 5 mm wide, and normal tridentate, but may show various abnormal tips. The odor of crushed leaves is mild and pleasant. The heads are arranged into elongated, narrow panicles and normally contain one, but occasionally zero to two, ray flowers and one to three, usually two, disc flowers. The turbinate involucre consists of eight to 12 short, densely tomentose, bracts 2 to 4 mm long and 1.5 to 2.5 mm broad. Flowering occurs August to October. Bigelow sagebrush closely resembles, and is often mistaken for, low forms of big sagebrush produced by overgrazing. In contrast to big sagebrush, it has ray flowers. Furthermore, lobes of Bigelow sagebrush's vegetative leaves are always more shallow and more sharply dentate than those of big sagebrush (McArthur and others 1979a).

Figure 4—Bigelow sagebrush growing at the Snow Field Station. The ruler is 12 inches (30 cm) long.

Figure 5—Bigelow sagebrush (McArthur and others 1979a).

Ecological Relationships and Distribution

Bigelow sagebrush has a more southerly distribution than other sagebrushes. It is one of the most drought-resistant of the sagebrushes. It occurs over approximately 34,010 mi^2 (88,086 km^2) through western Texas, southern Colorado, New Mexico, Arizona, Utah, Nevada, and California in canyons, gravelly draws, and dry flats (fig. 6) from 3,000 to 7,900 ft (900 to 2,400 m) (Beetle 1960; Kearney and Peebles 1960; Ward 1953). This species is often found mixed with big sagebrush, black sagebrush, leafless green rabbitbrush, shadscale, and especially broom snakeweed. It is also characteristic in rocky soils of the southern portion of the pinyon-juniper woodlands (Hall and Clements 1923). Bigelow sagebrush is normally free of the common rust diseases and insect galls common on other *Tridentatae* taxa (Beetle 1960). However, in common with other *Tridentatae*, it is susceptible to a wilt disease (Nelson and Krebill 1981). Seedlings of Bigelow sagebrush spread well naturally. Seedlings grow rapidly and are robust and vigorous. Direct seeding of this shrub has been limited to experimental plantings. Where seeded, the shrub responds favorably and natural spread normally occurs around the parental plant. Plants appear to have good drought tolerance, even as young seedlings. Direct seeding should not be a handicap to the use of this species.

Plant Culture

Wildings can be successfully transplanted in the spring or fall. Nursery plantings successfully reproduce. Seedlings grow in the wild, suggesting that Bigelow sagebrush can be successfully direct seeded.

Uses and Management

Bigelow sagebrush is palatable to livestock and game in all areas where it occurs. Its twigs are less woody, the odor milder, and taste less bitter than most of the big sagebrush complex (Hall and Clements 1923). This species can withstand considerable browsing; generally more than other sagebrushes. However, the plants are usually scattered, and consequently, not an abundant forage source except for some large stands in the Four Corners area.

Varieties and Ecotypes

Ecotype variation has not been documented although it exists in chromosome races from 2x to 8x (McArthur and others 1981; McArthur and Sanderson 1999). Bigelow sagebrush occupies a taxonomic position between the true sagebrushes (subgenus *Tridentatae*) and the *Artemisia* (subgenus *Artemisia*) species. We have chosen to treat it as a member of the *Tridentatae* because of its characteristic growth habit, woody anatomy, leaf form, chromosomal karyotype, and RAPD molecular genetic markers (McArthur and others 1981; McArthur and others 1998a). The confusion arises because its flowers have zero to two ray flowers as well as the characteristic disc flowers of the *Tridentatae*.

Figure 6—Bigelow sagebrush, foreground, growing with fourwing saltbush in a gravelly draw near Bicknell, Wayne County, UT.

Artemisia cana

Silver Sagebrush

Silver sagebrush is an erect, freely branched, rounded shrub up to 5 ft (1.5 m) tall. Older branches have dark brown, fibrous bark while younger branches are covered with a dense white to yellowish-green tomentum. Leaves on the vegetative branches are 1 to 10 mm wide and 2 to 8 cm long, linear to linear-oblanceolate, entire or occasionally with one or two irregular teeth or lobes, silver-canescent becoming slightly viscid with age (fig. 7). Leaves on the flowering stems are similar, but they may be slightly smaller, especially on the upper parts of the stems. The foliage emits a mild to pungent aromatic odor when crushed. Numerous heads are arranged into dense, narrow, leafy panicles, sometimes reduced to a raceme or spikelike inflorescence. Stems layer when in contact with the soil, thus producing additional root systems. Each head contains four to 20 disc flowers. Ray flowers are lacking. Achenes are granuliferous. Blooming occurs during August and September. Seed ripens in October and November.

Figure 7—Mountain silver sagebrush on Targhee National Forest, Sublette County, WY, showing leaves and flower heads.

Ecological Relationships and Distribution

Aside from big sagebrush, silver sagebrush is the most widely distributed sagebrush. It occurs over approximately 53,221 mi^2 (137,842 km^2) in British Columbia and Saskatchewan in the north, south to Arizona and New Mexico, and west to Oregon and California (Beetle 1960; McArthur and Plummer 1978). It grows on soils that are less mature, with less phosphorus, potassium, nitrogen, organic matter, and lower cation exchange capabilities than do soils that support big sagebrush (Hazlett and Hoffman 1975). However, it may grow on a variety of soils (Morris and others 1976).

Plant Culture

Wildings of silver sagebrush can be transplanted in the spring or fall. Establishment by direct seeding has also been successful (Kelsey 1986), especially when done in the fall on the soil surface or at shallow depths (Wasser 1982). In most natural situations, however, few seedlings survive (Walton and others 1986). The species can also be propagated from hardwood cuttings. Harvey (1981) successfully rooted 87 percent of the cuttings of plains silver sagebrush. He used 6 inch (15.2 cm) cuttings with the basal, 1.5 inch (3.8 cm) stripped of leaves, dipped in "rootone" and placed in a misting propagation bench with a growth medium of 50 percent sand, 25 percent vermiculite, 15 percent peat, and 10 percent perlite. Monsen (personal communication) has had excellent success seeding silver sagebrush on mine disturbances on semiarid ranges in southern Idaho and Wyoming and under nursery conditions. Seedlings develop rapidly often attaining a larger stature than plants of basin big sagebrush. Seedlings respond dramatically to moist conditions and may reach 15 to 20 inches (38.1 to 50.8 cm) in 1 year. Plants are usually quite uniform in size and form. Young plants grow well with understory herbs. In undisturbed sites, conditions often support a diverse understory. Plants appear well adapted to harsh disturbances when artificially seeded, but initially are slow to invade raw sites.

Use and Management

Silver sagebrush is important through its range as a browse shrub and is used quite extensively by livestock and big game, particularly when other food is scare (Kufeld 1973; Kufeld and others 1973; Wasser 1982). Bolander silver sagebrush was among the most preferred of the sagebrush taxa offered to mule deer and sheep in winter and fall feeding trials (Sheehy and Winward 1981). Mountain silver sagebrush is grazed by sheep in the fall after grasses and forbs dry. In the Western Great Plains, silver sagebrush is an important antelope survival food. Like big sagebrush, this species has been used by white settlers and Native Americans for fuel (McArthur and others 1979a). Silver sagebrush is not as susceptible to fire as many other sagebrushes (Wright and others 1979; White and Currie 1983). In efforts to manage stand densities by prescribed burning, White and Currie (1983) reported that on both fall and spring burns fire intensity was directly related to plant mortality and

inversely related to subsequent growth. In general, fall burns are more effective, as a silver sagebrush control measure, than are spring burns. Internal water stress in silver sagebrush is greater as the season progresses and soils dry out, and that stress is compounded in thick stands where there is interplant competition (White and Currie 1984). An ecotype from the Sheridan, WY, area shows promise as a fire resistant competition to cheatgrass (Monsen, unpublished).

Varieties and Ecotypes

No plant improvement work has been pursued on silver sagebrush. The species, however, hybridizes with other sagebrushes (Beetle 1960; McArthur and others 1979a; Ward 1953). It is, in all likelihood, a parent along with mountain big sagebrush for spicate big sagebrush, which we believe to be a widely adapted stabilized hybrid in Intermountain areas (Goodrich and others 1985; McArthur and Goodrich 1986). It has also been proposed that silver sagebrush is one of the parents, along with early sagebrush, of the narrowly endemic coaltown sagebrush (Beetle 1960). Silver sagebrush is differentiated into three subspecies (fig. 8) separated from one another geographically, ecologically, and morphologically (Beetle 1960, 1977; Harvey 1981; McArthur and others 1979a; Shultz 1983; Walton and others 1986). RAPD genetic markers confirm both the relationship between and the integrity of subspecies (McArthur and others 1998a,c).

Plains silver sagebrush is an erect, round, canescent, freely branched shrub up to 5 ft (1.5 m) tall. It

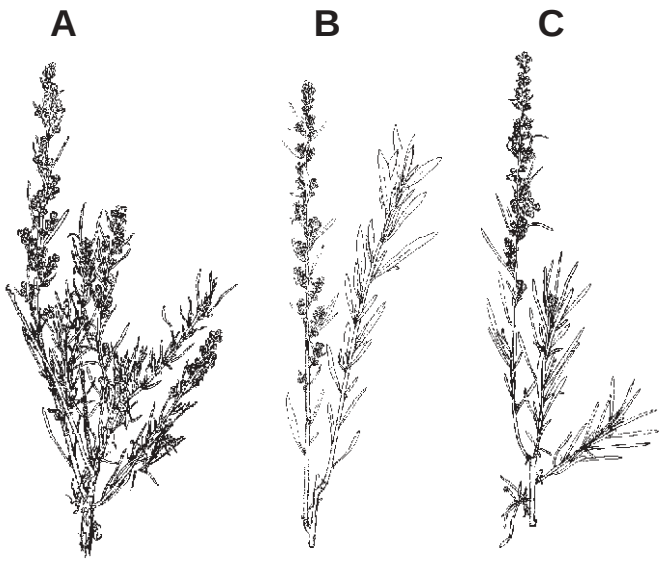


Figure 8—Silver sagebrush subspecies: (A) *A. cana* ssp. *cana*, (B) *A. cana* ssp. *bolanderi*, (C) *A. cana* ssp. *viscidula* (Shultz 1986).

layers whenever conditions are suitable. This subspecies may spread rapidly, particularly after burning, by rootsprouting and by rhizomes (Beetle 1960). Leaves of the vegetative branches are linear-oblanceolate, entire or rarely with one or two irregular teeth or lobes, 1 to 10 mm wide, 2 to 8 cm long, and are densely silky-canescent. Crushed foliage emits a pungent turpentine odor (Beetle 1960; Ward 1953). Flowerheads are usually arranged into dense, leafy panicles and may contain one to 20 disc flowers. Blooming occurs during September, and the seeds ripen during October and November. It is octoploid, 8x (McArthur and Sanderson 1999). Putative natural hybrids between plains silver sagebrush and big sagebrush subspecies have been found (Beetle 1960; Ward 1953). This subspecies has a more eastern distribution than the other two silver sagebrush subspecies. It occurs southern Canada southward, but mostly east of the Continental Divide, through Montana, the Dakotas, Wyoming, western Nebraska, and northern Colorado. It grows particularly well on the well watered, deep soils of the northern Great Plains, especially along stream bottoms and drainageways (Johnson 1978; McArthur and others 1979a; Walton and others 1986).

Mountain silver sagebrush (*A. cana* ssp. *viscidula*) is an erect shrub that readily layers. It usually is not more than 3.3 ft (1.0 m) tall. Leaves on the vegetative branches are 1 to 5 mm wide, up to 7 cm long, and are often crowded in dark green clusters. The leaves typically are simple and entire, but occasionally are variously toothed or lobed. This subspecies varies in appearance but is always darker green than mountain big sagebrush with which it is often growing (Beetle 1960). Mountain silver sagebrush is distinguished from plains silver sagebrush by its smaller, darker green leaves, its lower stature, and more western distribution. Flowerheads are arranged into dense, short racemes or spikelike inflorescences 1 to 3 cm long. Each head contains four to 15 disc flowers. Flowers bloom during August and September. Seed matures during October and November. Mountain silver sagebrush occurs in mountainous regions around 5,500 ft (1,800 m) and above. It is usually found in areas of heavy, lingering snowpack from the southwestern corner of Montana, south along the Continental Divide to New Mexico, and west to Arizona, Nevada, and Oregon (Beetle 1960, 1977; McArthur and others 1979a; Tisdale and Hironaka 1981; Winward 1980). It occurs as both diploid, 2x, and tetraploid, 4x, populations (McArthur and others 1981).

Bolander silver sagebrush (*A. cana* ssp. *bolanderi*) has narrow leaves like mountain silver sagebrush, but they are canescent like plains silver sagebrush. It is distributed in poorly drained, alkaline soils from central Oregon to eastern California (Beetle 1960; McArthur and others 1979a; Tisdale and Hironaka 1981; Winward 1980). It is known only as diploid, 2x (Ward 1953).

Artemisia filifolia

Sandsage or Oldman Sage

Sandsage is a round, freely branching shrub up to 5 ft (1.5 m) tall (fig. 9). Young branches are covered with a canescent pubescence while the older stems are covered by a dark-gray or blackish bark. Leaves are long, filiform, and silvery-white canescent; 3 to 8 cm long, less than 0.5 mm wide, entire or alternately divided into filiform divisions, and are often fascicled (fig. 10). Numerous, nodding heads containing two or three fertile, pistillate ray flowers and one to six perfect, but sterile, disc flowers are arranged into leafy, narrow panicles. Each head is subtended by five to nine canescent involucral bracts. Both the receptacle and achenes are glabrous. Flowers bloom during August and September. Seed ripens from October to December (McArthur and others 1979a). Other seed characteristics are given in tables in chapters 24 to 26.

Ecological Relationships and Distribution

Sandsage is an excellent indicator of sand. It is probably the most widespread shrub on sand dunes and sandhills the southern Black Hills of South Dakota southward to Texas and Chihuahua and westward to Arizona and Nevada (Hall and Clements 1923; McArthur and others 1979a; Rasmsussen and Brotherson 1986). In a study in southwestern Utah, Rasmussen and Brotherson (1986a) found that sandsage communities were floristically less diverse than adjacent plant communities, but that there was a higher density of plants in the sandsage communities. In the same study, they reported that despite the poor relative quality of the sandsage community soil profile, sandsage nutrient quality was not affected. Sandsage accumulates mineral nutrients well above levels found in the soils in which it grows. At the study locations, at least, sandsage is adapted to soils of low fertility.

Figure 9—Sandsage growing near Moccasin, Mohave County, AZ.

Figure 10—Sandsage (McArthur and others 1979a).

Plant Culture

Wildings can be transplanted in the spring or fall. Plants can be easily reared from seed. Seeds are smaller than those of most other sagebrushes but grow well once established. Plants mature quickly even when planted offsite. Survival is reduced, however, when the species is planted out of its natural range (Nelson and Krebill 1981). It grows well on infertile soils. It has been seeded alone in most plantings but appears to develop rapidly and can be seeded with herbs adapted to arid sandy sites. It has been easy to grow as bareroot stock and survives well when field planted. It does not require special media for rearing (Monsen n.d.).

Uses and Management

The browse value of sandsage depends on where it grows. It is seldom eaten in grasslands where other food is adequate, but in more arid, desert regions it is consumed by cattle, sheep, and big game. It is particularly important in dry years (Hall and Clements 1923; McArthur and others 1979a). Sandsage is habitat for some small nongame birds. This species helps prevent wind erosion by helping to stabilize light sandy soils. It is an important candidate for harsh sandy sites but often grows in such arid sites that seed production is quite low. It is particularly useful in blackbrush and pinyon-juniper sites where sandy outcrops occur.

Varieties and Ecotypes

No ecotypic differentiation has been documented, but it may well occur. It does have some cytological and chemical similarities with the true sagebrushes (subgenus *Tridentatae*) although it is assigned to the subgenus *Dracunculus* and differs from the *Tridentatae* in floral characteristics and wood anatomy (Kelsey and Shafizadeh 1979; McArthur and Pope 1979; Moss 1940).

Artemisia frigida

Fringed Sage

Fringed sage is a fragrant, aromatic, mat-forming perennial subshrub 8 to 24 inches (20.3 to 61.0 cm) tall (fig. 11). The lower woody stems are spreading and often much branched. Adventitious rooting may occur when stems contact the soil. The upper herbaceous stems are erect and leafy. The whole plant is densely silver-canescent. The numerous small, silky, canescent leaves are 6 to 12 mm long and are two or three times pinnately divided (fig. 12). This species has a deep perennial taproot with numerous extensive laterals that help it withstand drought. Numerous small flowerheads are borne in nodding racemes or open panicles. Small, densely hairy involucral bracts occur in several series around each flowerhead. Each head contains 10 to 17 outer, seed-producing, pistillate ray flowers and numerous (25 to 50) tubular, funnelform, perfect seed-producing disc flowers. Flower receptacles are densely villous. Fringed sage blooms from June at high elevations and latitudes, to November at lower elevations and latitudes. Seed matures between September and December (McArthur and others 1979a).

Ecological Relationships And Distribution

Fringed sage is probably, on a worldwide basis, the most widely distributed and abundant species of *Artemisia*. Its range extends from Mexico northward through most of the western United States and Western Canada into Alaska, then on to Siberia, Mongolia, and Kazakhstan (Harvey 1981; USDA Forest Service 1937). Fringed sage is a common plant of the high plains along the eastern slope of the Rocky Mountains, but also occurs in valleys and mountains. In the United States, it is most abundant in the eastern and northern parts of its range. This species ranges from low semidesert valleys to more than 11,000 ft (3,400 m) elevation throughout the Rocky Mountain, Intermountain, and adjacent plains regions. Fringed sage inhabits a wide variety of sites. Most typically, it grows in full sunlight in dry, coarse, shallow soils. On winter ranges in western Utah and eastern Nevada, fringed sage may occur in dense stands along shallow depressions that collect moisture from summer rains. In such areas, it is frequently associated with winterfat, shadscale, and rabbitbrushes. On plains, foothills, and mountain slopes, this species may be associated with a variety of grasses and forbs as well as with various shrubs such as big sagebrush, Bigelow sagebrush, sandsage, and especially in overgrazed areas, with broom snakeweed. It is a common understory plant in ponderosa pine in several Western States (McArthur and others 1979a).

Figure 11—Fringed sage growing at Black Mesa, Gunnison County, CO.

Plant Culture

Fringed sage can be established by seed or by transplanting young plants or segments of old plants. Surface seeding on disturbed soils is recommended (Wasser 1982). It produces an abundance of small seeds, approximately 1,000 seeds per inch (2.5 cm) of inflorescence (Harvey 1981). There are 4.5 million seeds per lb (9.9 million per kg) (see chapter 24). In a nursery, plants require little care and maintain reasonable vigor (Nelson and Krebill 1981). Individual plants are susceptible to overgrazing, but on a populational basis, fringed sage seems to be stimulated and increases plant numbers with heavy grazing pressure (Cooperrider and Bailey 1986).

Uses and Management

The forage value of fringed sage varies considerably with location and season (Dietz 1972). Its value as browse is highest in late fall, winter, and early spring on western ranges where it is eaten readily by big game and livestock (Cooperrider and Bailey 1986; Kufeld 1973; USDA Forest Service 1937; Wasser 1982). It is also important food for sage-grouse (Wallestad and others 1975). Nutritive quality is highest in the spring, but remains adequate for animals for much of the year (Cooperrider and Bailey 1986; Rauzi 1982). In other areas, such as the grasslands of the Northwest and Great Plains, fringed sage may be less palatable and occasionally invades deteriorated grasslands. However, on the Great Plains, fringed sage is an important winter antelope food and is used to a lesser extent the year round (McArthur and others 1979a).

It is well suited for growth with grasses and broadleaf herbs. Its seedlings are competitive and can be direct seeded into areas with herbaceous competition. It is adapted to mine disturbances, perhaps better than any other *Artemisia*. It can be used to control the rapid influx of weeds on large disturbances.

This species has strong reproductive qualities and is a good pioneer shrub for stabilizing disturbed areas. It is often used in seeding western strip mines, especially coal areas. It has excellent reproduction by seed, and young plants or segments of old plants are readily transplanted in early spring (McArthur and others 1979a). Its strong taproot and numerous lateral roots make it effective in stabilizing gullies and reducing soil erosion. These rooting characteristics make the species capable of withstanding considerable grazing and trampling use. Fringed sage has some value as a medicinal plant (Hall and Clements 1923). It can be controlled when it is too abundant (Alley 1972).

Varieties and Ecotypes

Undoubtedly, fringed sage, with its wide geographical and altitudinal distribution, has considerable genetic variation. However, no subspecific taxa are recognized and no plant improvement work is under way. Unlike several other widespread *Artemisia* species, fringed sage is known only at the diploid ($2n = 2x = 18$) chromosome level (McArthur and Pope 1979).

Figure 12—Fringed sage (McArthur and others 1979a).

Artemisia longiloba

Alkali Sagebrush

Alkali sagebrush has also been called early sagebrush and low sagebrush. Alkali sagebrush is a misnomer because it grows mostly on neutral rather than on alkaline soils (Passey and Hugie 1962b; Tisdale and Hironaka 1981). It, however, is adapted to drought conditions (Robertson and others 1966; Zamora and Tueller 1973).

Alkali sagebrush is a low shrub up to 18 inches (45.7 cm) tall (fig. 13). It has lax, spreading stems that frequently layer. The bark is dark brown to black on the older stems. The whole plant has a dark gray-green appearance (Beetle 1960). Leaves on the vegetative stems are broadly cuneate, up to 2 cm long, and are deeply three-lobed (fig. 14). Leaves of the flowering stems are similar but smaller. This species is

Figure 13—Alkali sagebrush growing at Wasatch Station, Summit County, UT. Note the abundant, large flower heads.

readily distinguished from other low statured sagebrushes by its large heads and early blooming (Beetle 1959). Its heads contains six to 11 disc flowers and are 3 to 5 mm broad as opposed to 3 mm or less for other short statured sagebrushes (low sagebrush and black sagebrush). It flowers during mid-June to early August and its seed ripens in August and September. Beetle (1960) points out that this species has in the past been confused with silver sagebrush because of its large heads; with big sagebrush because of its broadly cuneate, 3 lobed leaves; and with low sagebrush because of its dwarf size.

Ecological Relationships and Distributions

Alkali sagebrush characteristically grows in heavy, highly impermeable soils generally with dense "B" horizons (Passey and Hugie 1962b; Tisdale and Hironaka 1981). It is, however, also found on lighter soils (McArthur and others 1979a). It occurs at elevations from 6,000 to 8,000 ft (1,800 to 2,400 m) along foothills and in basins of the ranges forming the Continental Divide in southwestern Montana, south through Wyoming to northwestern Colorado, and scattered westward through northern Utah and Idaho to Nevada and Oregon (Beetle 1960; Winward 1980).

Plant Culture

Little is known except the plant can be transplanted. Natural seeding occurs rapidly following fires and other disturbances, yet mechanical tillage can limit seedling establishment if seeds are buried too deep or the seedbed is disrupted (Monsen and Shaw 1986).

Uses and Management

The habitat of some stands of alkali sagebrush, when in good condition, supports a mixed understory of perennial grasses and annual and perennial forbs providing forage and cover for sage-grouse, antelope, and other wildlife as well as livestock (Dealy and others 1981; Monsen and Shaw 1986). Other stands are quite depauperate of associated vegetation and provide little forage and habitat for animals. Alkali sagebrush itself provides, depending on the site, browse for sheep (often preferred), and habitat and food for small animals (Dealy and others 1981; McArthur and others 1979a). The plant should be useful in rehabilitation plantings, particularly on heavy, seasonally dry soils. It has been observed invading roadcuts in Echo Canyon, UT, and barrow pits near Kemmerer, WY, (McArthur and others 1979a). Monsen and Shaw (1986) reported that decadent stands can be rejuvenated by mechanical means. Sites that lack a satisfactory understory remain closed stands unless these shrubs are reduced in number by fire or mechanical means.

Varieties and Ecotypes

Alkali sagebrush has not been studied sufficiently enough to make substantial comments here. However, because of its relatively broad and scattered distribution and its differential use by animals, we suspect it harbors considerable genetic variation. Beetle (1960) considered it to be a parent to the restricted endemic coaltown sagebrush.

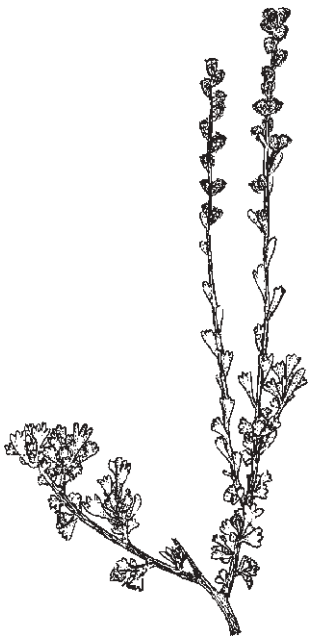


Figure 14—Alkali sagebrush (Shultz 1986).

Artemisia nova

Black Sagebrush

Black sagebrush is a small spreading, aromatic shrub 6 to 8 inches (15.2 to 20.3 cm) or occasionally to 30 inches (76.2 cm) tall with a dull grayish-tomentose vestiture that causes most populations to appear darker than big sagebrush and low sagebrush (fig. 15). However, some forms may be as light in color as those species (Beetle 1960; Brunner 1972). Numerous erect branches arise from a spreading base (fig. 16). This shrub had not been observed to layer or stump sprout (Beetle 1960; Tisdale and Hironaka 1981). However, some layering of black sagebrush on a roadcut near Kolob Reservoir, Washington County, UT, has been noted (McArthur and others 1979a). Typical leaves are evergreen, cuneate, viscid from a glandular pubescence, 0.5 to 2 cm long, 2 to 8 mm wide, and three-toothed at the apex. The uppermost leaves, particularly on the flowering stems, may be entire. Flowerheads are grouped into tall, narrow, spikelike panicles that extend above the herbage. The inflorescence stalks are red-brown and persistent. The heads usually contain three to five disc flowers with corollas 1.8 to 3 mm long. The eight to 12 involucral bracts are greenish-yellow and nearly glabrous. The principal difference between black sagebrush and low sagebrush is that low sagebrush has five to 11 flowers per head, 10 to 15 canescent involucral bracts, and is light in color. Also, the flower stalks of black sagebrush are denser, much darker, and more persistent than those of low sagebrush (McArthur and others 1979a; Ward 1953). Black sagebrush is characterized by the presence of leaf hairs readily visible at 10x magnification when compared to its relatives low sagebrush, alkali sagebrush, threetip sagebrush, and the subspecies of big sagebrush (Kelsey 1984). Three-fourths of a large sample (n = 152) of black sagebrush plants across the species range showed this characteristic conspicuously, whereas, no other taxa exceeded a 4 percent display (n = 1,849).

Figure 15—Black sagebrush, with dark flower stalks, and Wyoming big sagebrush growing at ecotone near Gabbs, Nye County, NV.

Figure 16—Black sagebrush (Shultz 1986).

Ecological Relationships and Distribution

Black sagebrush covers approximately 43,301 mi^2 (112,150 km^2) in the 11 Western States (Beetle 1960). It is most abundant at elevations from 4,900 to 7,900 ft (1,500 to 2,400 m) and normally grows on drier, more shallow stony soil than basin, mountain, or Wyoming big sagebrushes or low sagebrush (Beatley 1976; Tisdale and Hironaka 1981). Zamora and Tueller (1973) reported root restricting layers at depths of 11 to 27 inches (28.0 to 68.6 cm) in half of their black sagebrush study sites. Other soils in which black sagebrush commonly occurs are usually underlain by gravelly and sandy loam strata. Most, but not all, soils supporting black sagebrush are calcareous. Most black sagebrush stands do not burn because of their sparseness (Tisdale and Hironaka 1981). However, we have observed large burns of black sagebrush stands in central Utah. Insect galls are numerous on black sagebrush, but rust diseases are less common (Beetle 1960). Nelson and Krebill (1981) found black sagebrush to be less susceptible to a wilt disease than most other *Artemisia* taxa growing at the Snow Field

Station in Ephraim, UT. Clary (1986) reported that winter livestock grazing (principally sheep) has had a significant and often severe effect on black sagebrush. Some large areas in Nevada formerly occupied by black sagebrush have been invaded recently by Utah juniper and singleleaf pinyon pine.

Plant Culture

Black sagebrush has been successfully transplanted (Luke and Monsen 1984). Seed production in nurseries is often good. It should be seeded in fall or early winter. Seeds should be covered lightly up to 0.25 inch (6.4 mm) deep. Once established, black sagebrush can spread rapidly (Stevens 1986b).

Seeds of black sagebrush are larger than those of most sagebrushes (see chapters 20 and 24). Seeds tend to remain attached to the flower but can be processed easier than seeds of other sagebrush. Seedlings are vigorous, and young plants often grow rapidly. However, even under favorable conditions, young plants do not grow as rapidly as big sagebrush. Once established, small seedings persist well even under adverse conditions. Plants are able to establish amid rocky exposed surfaces. Under these conditions the shrub seedlings persist and usually exclude weedy annuals. Black sagebrush can be established when seeded on sites other than its origin. It grows well on areas normally occupied by big sagebrush and may persist and reproduce. Young stands grow well with seeded herbs, but as stands mature a reduction in understory herbs occurs. Black sagebrush establishes well from direct seeding. The larger seed is not as likely to be seeded too deep as smaller seeded species of sagebrush. Under favorable moisture conditions, mature plants produce abundant seed crops. Natural spread occurs quickly, consequently interseeding or other techniques can be used to establish a seed source and allow natural spread to populate large areas.

Use and Management

Black sagebrush is usually held in high regard as a palatable forage for wildlife and livestock, especially sheep, antelope, and deer (Clary 1986; McArthur and Plummer 1978). However, it, like big sagebrush, has populations that differ dramatically in mule deer preference (Behan and Welch 1985; Welch and others 1981). Welch and his colleagues (Behan and Welch 1985; Welch and others 1981) have shown that some accessions are not eaten whereas others are highly preferred—one accession had 60 percent of its current annual growth eaten in 1978 and 82 percent in 1982. Scholl and others (1977) also reported accessional differences of mule deer preference between black sagebrush accessions. In comparison with other sagebrushes, black sagebrush was preferred by mule deer (Nagy and Regelin 1977); however, Smith (1950) and Sheehy and Winward (1981) found no such preference. Striby and others (1982) reported that mule deer and elk preferred black sagebrush over basin big sagebrush, but not over Wyoming and mountain big sagebrushes. However, Wambolt (1996) found that elk and mule deer preferred black sagebrush least in comparison with mountain, basin, and Wyoming big sagebrush. In the preference tests it should be remembered that there are considerable intraspecific variations as well as interspecific ones being compared. Black sagebrush has good winter nutritive quality (Welch 1983b); not as good as big sagebrush, but the two are adapted to different habitats. Black sagebrush is a good conservation plant for dry, shallow, stony soils. The plant is an aggressive natural spreader from seed. Because it usually grows on dry rocky sites, it is usually not a candidate for plant control.

Varieties and Ecotypes

Welsh and Goodrich (1995) recently described a new variety, *A. nova* var. *duchesnicola* to go with the longstanding typical taxon, *A. nova* ssp. or var. *nova*. Typical black sagebrush occurs in two color morphs (Beetle 1960). The gray-green form is generally browsed more than the darker glossy-green form (Brunner 1972; Stevens and McArthur 1974; Winward 1980). Welch and others (1981) and Behan and Welch (1985) have shown that an accession Pine Valley Ridge in Millard County, UT, is a fine candidate for wider planting because of browsing animal preference. That accession has been transplanted and survived in several locations. It has been released as a germplasm (Welch and others 1994). Black sagebrush has many ecotypes that deserve additional attention. Black sagebrush may have had a role in the parentage of Wyoming big sagebrush (McArthur 1983a; Winward 1975). Beetle and Johnson (1982) reported that some forms of black sagebrush approach Wyoming big sagebrush in appearance. We have made similar observations on the Kaibab foothills in northern Arizona.

Artemisia pygmaea

Pygmy Sagebrush

Pygmy sagebrush (fig. 17) is a dwarf, depressed, evergreen, cushionlike shrub less than 8 inches (20.3 cm) tall. Bark on older stems becomes dark brown and fibrous. On young branches the bark is nearly white to straw-colored and somewhat puberulent. Leaves on the vegetative stems are green, nearly glabrous, viscidulous, 2 to 4 mm wide, 2 to 8 mm long, and are pinnatified with three to 11 lobes, or sometimes may be only toothed (fig. 18). Leaves on the flowering branches are usually reduced and may be

Figure 17—Pygmy sagebrush growing at the Snow Field Station, Sanpete County, UT.

entire. Heads with three to five disc flowers are arranged into spikelike inflorescences. Ray flowers are lacking. Twelve to 18 greenish-yellow bracts subtend each head. Achenes are glabrous. Flowers bloom in August and September, and seed matures in October. Seeds are large for *Artemisia* (McArthur and others 1979a; see chapter 24).

Pygmy sagebrush is limited to calcareous soils in desert areas over approximately 21 mi^2 (54 km^2) eastern Utah to western Nevada and northern Arizona (Beetle 1960; McArthur and Plummer 1978; Ward 1953). In Nevada, this species is often associated with halophytic threadleaf rubber rabbitbrush. Some fairly large stands occur with black sagebrush in Utah.

Because of its scarcity and small size, this species has little value as browse although it is eagerly taken when available. It does, however, provide important ground cover in the dry, alkaline areas where little else will grow. It establishes readily by transplanting divided plants. Although it spreads well from naturally dispersed seed, artificial planting of seed has not, as yet, been successful. This is due probably to poor quality seed and not the inability to establish by artificial planting. It is a good candidate to plant in heavy soils. It may be of considerable value for mine and roadway disturbances. Natural spreading has occurred when plants have been established in research plantings.

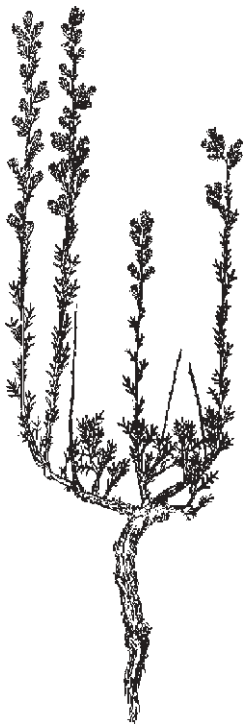


Figure 18—Pygmy sagebrush (Shultz 1986).

Artemisia rigida

Stiff or Scabland Sagebrush

Stiff sagebrush is a low, pungently aromatic shrub with thick, rigid, somewhat brittle branches up to 16 inches (40.6 cm) high (fig. 19). It is not known to resprout or layer. The wider deciduous, silvery-canescent, spatulate leaves are mostly 1 to 4 cm long and deeply divided into three to five narrowly linear lobes (fig. 20). Occasionally some leaves are linear and entire. The inflorescence is a leafy spike with heads sessile or in small clusters in the axils of their subtending leaves, which generally are all longer than the heads. The campanulate involucre is 4 to 5 mm long with numerous, canescent bracts. Each head consists of five to 16 perfect disc flowers. Flowering occurs from late August to early October; seeds ripen in October and November (see chapters 20 and 24). This species resembles threetip sagebrush somewhat in its small size, silvery pubescence, and the deeply, narrowly lobed leaves, but may be distinguished by the spikelike inflorescence, large leafy bracts that subtend the heads, and the deciduous leaves.

Stiff sagebrush occurs in dry rocky scablands in the Columbia and Snake River basins and spills over into the northern end of the Great Basin. It occurs primarily, if not exclusively, over basaltic bedrock (Daubenmire 1982; Tisdale and Hironaka 1981). It grows at elevations from 3,000 to 5,000 ft (910 to 1,500 m) in Idaho, central and eastern Oregon, and central and eastern Washington. Otherwise its ecological niche is similar to that of low sagebrush (Ward 1953). The report of this species growing in Montana are apparently in error (Morris and others 1976; McArthur and others 1979a).

Figure 19—Stiff sagebrush growing at the Snow Field Station, Sanpete County, UT. The ruler is 30 cm long.

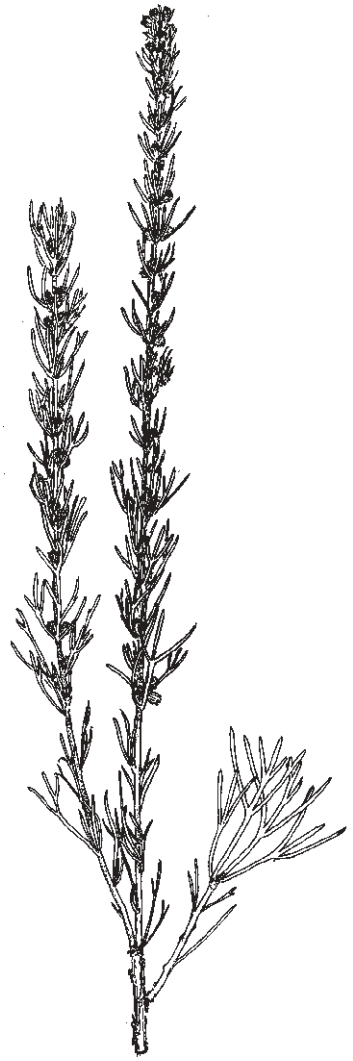


Figure 20—Stiff sagebrush (Shultz 1986).

Because of its scant foliage and stiff branches, stiff sagebrush has been considered of little value for browse, except for sheep (Hall and Clements 1923). It provides forage on the dry sites on which it grows in the midsummer when herbaceous plants are dry. This species provides cover on the poor rocky soils where it grows. It appears to have a wider range of adaptation than is indicated by its present natural range of occurrence, thus giving it potential use in reclamation of some harsh disturbed sites.

Seed production is normally quite low and seed quality is questionable (Monsen, unpublished). Attempts to seed and transplant this species in arid sagebrush ranges near Boise, ID, have not been successful. In most cases plantings were made on sites where cheatgrass and other annuals had invaded the shrublands. Stiff sagebrush seedlings were not able to compete with the weeds. Plants grow slowly and appear to require 2 to 4 years to establish and attain reasonable size. The invasion of cheatgrass undoubtedly limits the natural distribution and occurrence of this shrub. However, it is an important plant for harsh rocky sites. Plantings have successfully established on prepared seedbeds. It is able to seed naturally on harsh sites and has been able to survive wildfires.

Artemisia spinescens

Budsage

Budsage is a low, spinescent, pungently aromatic, rounded shrub 4 to 20 inches (10.2 to 50.8 cm) high (fig. 21). It is profusely branched from the base and has white-tomentose pubescence on young twigs and leaves. This pubescence is grayish and stiff on older branches. Leaves are small, mostly 2 cm or less in length, including the petiole. Leaves are three to five palmately parted, with the divisions again divided into three linear-spatulate lobes. Leaves are crowded on the short stems, with those near the apex being smaller and more entire (fig. 22). Unlike most species of *Artemisia*, budsage is deciduous, with the leaves falling by midsummer. Early in the spring, when budsage first shows signs of breaking dormancy, but before the buds elongate, the bark the last season's growth can easily be pulled off. At this developmental stage, budsage is sought out by big game and livestock. Sheepmen refer to this condition as "slipping." As early as February or March, new bright-green leaves are produced.

Budsage is well adapted to xeric conditions. It has an extensive root system that grows primarily in the top 6 to 22 inches (15.2 to 55.9 cm) of soil. Interxylary cork is formed annually over the last year's wood in both the roots and the stem. This layer of cork restricts

Figure 21—Budsage growing near Sevier Lake, Millard County, UT.

the upward movement of water to the narrow zone of wood formed by the current year's growth. The corky tissue develops during early summer and thus helps to prevent excessive water loss during the dormant season (Wood 1966). Many other xerically adapted woody *Artemisia* also have interxylary cork (Moss 1940). Budsage bears small flowerheads, 3 to 5 mm long, in glomerate racemes of one to three heads in leaf axils of the flower branches. Each head contains two to six fertile, pistillate ray flowers and five to 13 perfect, but sterile, disc flowers with aboritive ovaries. The loose flowerheads are held together by long, matted hairs that cover the corolla and especially the achenes. The heads often fall off the plant intact, without breaking apart to release the seed. However, some seeds are usually dispersed independently. In some instances, seeds germinate while still in the head (Wood 1966). Seeds mature by early June. Good seed production occurs infrequently. The flowers bloom so early in the spring that developing embryos frequently are frozen. Abundant reproduction occurs in years of plentiful seed and favorable moisture.

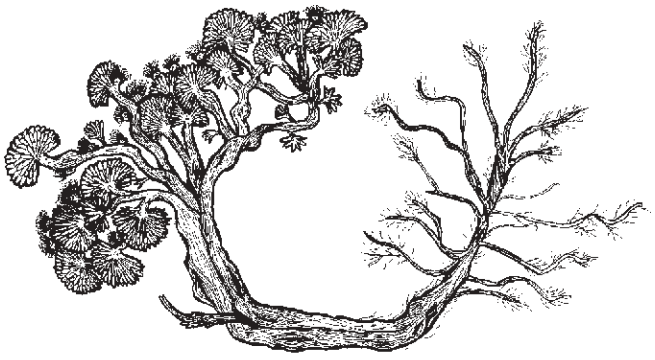


Figure 22—Budsage (McArthur and others 1979a).

Terminal and lateral buds of budsage generally expand and begin to elongate in late March and early April during the latter part of the "slipping" period. Blooming normally occurs the last week in April through the last week in May, although it has been found in bloom as early as late March and as late as mid-June (Wood 1966). Although budsage ordinarily begins growth early in the spring and then becomes dormant by early or midsummer, it occasionally may break dormancy in response to late summer storms. The plants then remain green all winter to provide succulent forage throughout the winter and spring.

Ecological Relationships and Distribution

Budsage is a drought-resistant shrub quite common in semiarid valley bottoms, benches, and foothills over much of the interior Western United States (Hall and Clements 1923; Wood and Brotherson 1986). It occurs from Wyoming through southwestern Montana, southern Idaho, and eastern Oregon south to northwestern New Mexico, northern Arizona, and southeastern California. It is often associated with shadscale, winterfat, and other salt-tolerant shrubs (McArthur and others 1979a; Wood and Brotherson 1986).

Plant Culture

Summer dormancy can be broken by supplemental water. Wood and Brotherson (1986) reported that supplemental water advanced the beginning of growth by 2 weeks, but did not increase total productivity by the time of the onset of cold weather. Seed quality is usually low, but during infrequent years, natural seeding occurs. Some sites have improved well through protection from livestock grazing. Blaisdell and Holmgren (1984) reported significant recovery of budsage on areas protected from spring grazing. Artificial seeding has been hampered by the use of low quality seed, not the inability of the plant to establish from direct seeding. Plants do not reach maturity quickly, but seedlings and young plants are competitive. They persist under adverse conditions where few other species exist. Plants grow well with winterfat and scattered amounts of grass. Disking is detrimental to the survival of budsage, but anchor chaining usually has little effect upon the shrub.

Uses and Management

Budsage is a palatable, nutritious forage plant for upland birds, small game, big game, and sheep in the winter. It is especially high in calcium, magnesium, phosphorus, and protein (Wood and Brotherson 1986). Generally, it is more palatable in the late winter than during the early winter (Holmgren and Hutchings 1972). During this time it is of tremendous value to the welfare of grazing animals, especially where there

is an abundance of dry grass. Care must be taken in grazing budsage in late winter and early spring. Even light grazing during this period is detrimental, and continual heavy grazing may eliminate budsage from areas (Holmgren and Hutchings 1972).

Varieties and Ecotypes

Despite its wide distribution and isolated population, little morphological variation has been described in budsage. However, polyploidy is known (McArthur and Pope 1979).

Artemisia tridentata

Big Sagebrush

Big sagebrush (*Artemisia tridentata*) is a highly polymorphic species with numerous ecotypes and biotypes (fig. 23). Three subspecies—basin, Wyoming, and mountain (*tridentata*, *wyomingensis*, and *vaseyana*) big sagebrush—are generally recognized (Beetle 1960; Beetle and Young 1965) (see chapter 21). Additional subspecies, spicate big sagebrush (*spiciformis*) and xeric big sagebrush (*xericensis*), have recently been proposed (Goodrich and others 1985; Rosentreter and Kelsey 1991). Subspecies will be discussed in the Varieties and Ecotypes section. Big sagebrush is composed of aromatic, evergreen shrubs ranging from dwarf to tall, arborescent forms up to 15 ft (4.6 m) tall (fig. 24). The lower forms generally have several main stems arising from the base, whereas the tall forms often have a single short trunk. Older branches are covered with a gray to brown to black shredded bark. Younger branches and leaves have a white to gray tomentum that gives the plants a silvery cast. Typical leaves are narrowly cuneate or oblanceolate and terminate with three blunt teeth at their truncate apexes. However, considerable variation occurs, ranging from linear, entire leaves with rounded to acute apexes (fig. 25) to broadly cuneate leaves with varying numbers of teeth or shallow lobes. The leaves also range in size from 2 mm to 2 cm broad and 1 cm to 6.5 cm long. Normally, leaves of vegetative shoots are more characteristic and less variable than those on flowering shoots. Also, persistent, that is overwintering, leaves are less variable than leaves of the spring growth flush (Miller and Shultz 1987; Winward 1970, 1980), which are shed by midsummer. Heads of this species contain three to eight disc flowers, (except spicate big sagebrush, which may have up to 12 flowers per head) and are arranged into leafy panicles with erect or sometimes drooping branches. In some forms, the inflorescence becomes spikate. Blooming occurs from July to October. Seeds mature in October, November, and December. Big sagebrush plants often live 70 to 100 years or more. Specimens from several sites were found to be more than 200 years old (Ferguson 1964). Usually, however, a high rate of individual plant turnover occurs within a 20 year period (Stevens 1986b). Characteristics of big sagebrush are detailed in table 3.

Figure 24—Large basin big sagebrush near Meeker, Rio Blanco County, CO.

Figure 23—Individual big sagebrush plants of basin, mountain, and Wyoming subspecies. Plants of each subspecies are randomly placed at the Gordon Creek Wildlife Management Area, Carbon County, UT. Plants are even aged.

Ecological Relationships and Distribution

Big sagebrush is the most widespread and common shrub of Western North America. It is especially common in the Great Basin. Beetle (1960) reports the species as covering approximately 226,374 mi^2 (586,309 km^2) in the 11 Western States. Beetle's estimate of coverage for this and other species is probably too high, because it includes areas where *Artemisia* are partial dominants (McArthur 1981, 1983b; McArthur and Ott 1996). Nevertheless, his figures show how extensively sagebrush is distributed and the relative abundance of each *Artemisia* species when compared to related species. Big sagebrush grows in a variety of soils on arid plains, valleys, and foothills to mountain slopes from 1,600 to 11,200 ft (490 to 3,400 m) and is frequently associated with such shrubs as shadscale, saltbush, rubber rabbitbrush, low rabbitbrush, fourwing saltbush, spiny hopsage, spiny horsebrush, winterfat, broom snakeweed, antelope bitterbrush, snowberry, and serviceberry. Although it is tolerant of quite alkaline as well as quite acidic soils, its optimum growth is in deep, fertile, alluvial loams (Sampson and Jesperson 1963).

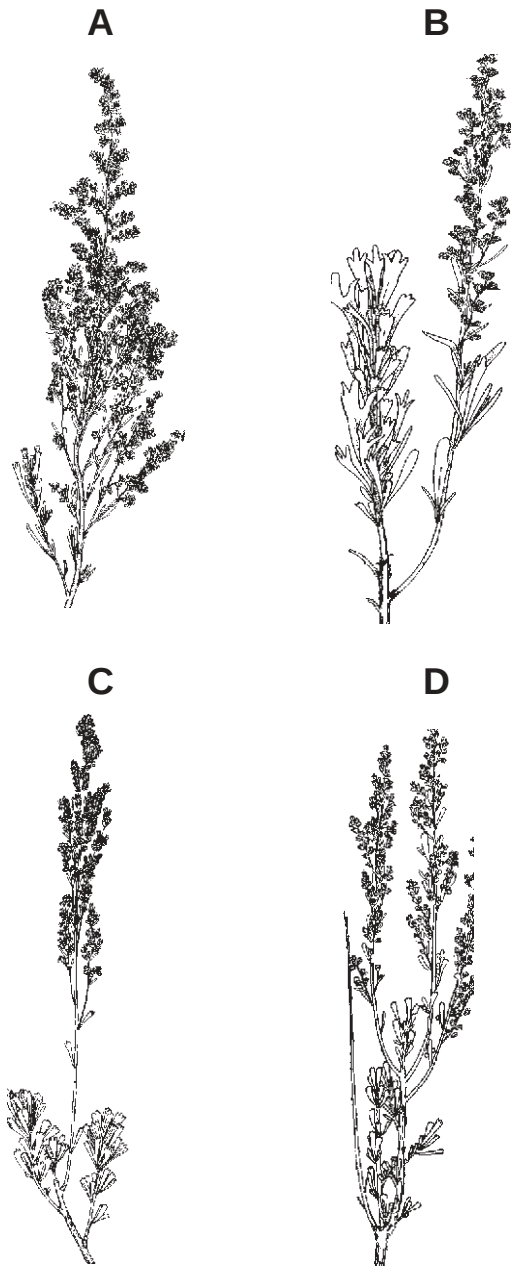


Figure 25—Four subspecies of big sagebrush: (A) *A. tridentata* ssp. *tridentata*, (B) *A. tridentata* ssp. *spiciformis*, (C) *A. tridentata* ssp. *vaseyana*, (D) *A. tridentata* ssp. *wyomingensis* (Shultz 1986).

Although big sagebrush has spread with settlement of the West (Cottam 1961; Christensen and Johnson 1964; Hull and Hull 1974), it was clearly an important and widespread plant before this settlement. Vale (1975), quoting early pioneer and explorer diaries, has shown it was a common Western plant prior to 1850. Johnson (1986) presented photographic evidence showing sagebrush as a widespread dominant in the 1870's. As early as the Pleistocene Epoch, sagebrush was already an important part of the Intermountain flora. Some 80,000 to 10,000 years ago, sagebrush dominated large tracts of land in areas where it is still found (Tidwell and others 1972; Van Devender 1977). Big sagebrush is an indicator of site quality (Kearney and others 1914; McArthur and Welch 1982; Passey and others 1982; Stevens and others 1974). Some populations, especially basin big sagebrush, have been taken out and the land they occupied put into agriculture.

Big sagebrush and its subgenus *Tridentatae* relatives are subject to insect and microbial pests and benefactors—most notably the sagebrush defoliator moth (*Aroga websteri*) (see chapter 21). Wide ranging and periodic outbreaks of this insect have caused extensive sagebrush mortality over much of the range of *A. tridentata* and its relatives (Hall 1965; Henry 1961; Hsiao 1986; McArthur and others 1979a). However, except on some critical winter game ranges, *Aroga websteri* is not believed to have serious, long-term effects. The moth is subject to insect parasites and predators and does not completely kill entire sagebrush stands (Hall 1965; Hsiao 1986). In time, sagebrush naturally reinvades its old sites that in the meantime have become more diverse plant communities. During drought, grasshoppers have been known to defoliate big sagebrush (Schlatterer, personal communication). Galls of many kinds of flies (*Diptera*) are found on sagebrush (Hall 1965; Jones 1971). The effect of the galls is not known. Sagebrush hosts many others insects of various orders (see Graham and others 1995; Messina and others 1996). Some of these may protect the plant disease vectors. Several microbial-induced diseases are known (Krebill 1972).

Table 3—Characteristics of subspecies of *Artemisia tridentata* (adapted from McArthur 1983b).

Characteristics	Subspecies				References
	tridentata	***vaseyana***	***wyomingensis***	***spiciformis***	
Habitat and range	Foothills and valley floors. 4,000 to 7,000 ft (1,220 to 2,135 m). British Columbia and Montana to Baja California and New Mexico.	Foothills and mountains. 3,000 to 19,000 ft (915 to 5,790 m). British Columbia and Alberta to California and New Mexico.	Foothills and valley floors. 2,500 to 7,000 ft (760 to 2,135 m). Montana, Washington to Arizona.	High mountain areas. 7,000 to 12,000 ft (2,135 to 3,660 m). Oregon and Montana to Nevada and Colorado.	Beetle and Young 1965; Morris and others 1976; Winward and Tisdale 1977; McArthur and Plummer 1978; McArthur and others 1979a; Dealy and others 1981; Winward 1980; Harvey 1981.
Smell	Biter pungent	Pleasant	Bitter pungent	Pungent, not bitter	McArthur and others 1974.
Essential oil	x = 1.4 percent	x = 2.2 percent	x = 1.1 percent	x = ?	Welch and McArthur 1981.
Leaf shape	narrowly cuneate	Cuneate to spatulate	Cuneate	Cuneate to narrowly cuneate	Marchand and others 1966; McArthur and others 1974; McDonough and others 1975; Winward and Tisdale 1977.
Common height ranges	3 to 13 ft (0.9 to 4 m)	2 to 5 ft (0.6 to 1.5 m)	1.5 to 3 ft (0.5 to 0.9 m)	2 to 5 ft (0.6 to 1.5 m)	McArthur and others 1979a; Winward 1980.
Sesquiterpenes compounds	4 to 7	3 to 6	2	5	Kelsey and others 1973.
Ultraviolet visible coumarins	Trace	Abundant	Trace, but often more than *tridentata*.	Abundant	Shafizdeh and Melinknoff 1970; Stevens and McArthur 1974; Brown and others 1975; McArthur and others 1981.
Tendency to layer	None	Mild	None	Very strong	Beetle and Young 1965; Winward 1980; Goodrich and others 1985.
Palatability to deer and sheep	Low	Usually highest	Highest for sheep sometimes high for deer.	High for sheep in late summer and fall. Sometimes under snow in season of use.	Hanks and others 1973; Sheehy and Winward 1981; Welch and others 1981; Striby and others 1982; Welch and McArthur 1986; unpublished; Welch and others 1987.
Protein content	High	Low	Low	?	Welch and McArthur 1979b.
Seed germination prior to stratification	High	Low	Intermediate	?	Harniss and McDonough 1976.
2*n* chromosome	Commonly 18, some 36	Commonly 18, some 36	Consistently 36	18, 36	Ward 1953; Taylor and others 1964; Winward and Tisdale 1977; Kelsey and others 1975; McArthur and others 1981; McArthur and Sanderson 1999
Flower and seed phenology	Late	Early	Late-intermediate	Early	Marchand and others 1966; Hanks and others 1973; Winward and Tisdale 1977.
Flower stalk to vegetative shoot length ratios	x = 1.8	x = 3.4	x = 2.2	x = 3.1	Winward and Tisdale 1977.
Flower per head	3 to 6	4 to 8	3 to 8	6 to 12	Beetle and Young 1965; Winward and Tisdale 1977; Goodrich and others 1985.
Effect of fire on seed germination	Negative	Positive	Neutral	Positive?	Chaplin and Winward 1982.
Leaf and stem water potential differences	Lower	Higher	Lower	Higher?	Miller and others 1982; Shumar 1984; McArthur and others 1998b
Shrub shape	Uneven topped	Even topped (usually)	Uneven topped	Even topped	Winward 1980; Goodrich and others 1985.
Position of flower stalks	Throughout crown	Above crown	Throughout crown	Above crown	Winward 1980; Goodrich and others 1985.
Seedling growth	Longest sustained root growth rate	Slowest root growth rate	Both above ground and root growth is initially more rapid than other ssp.	?	Welch and Jacobson 1988; Booth and others 1990.

Some of these are widespread and may be locally destructive; however, sagebrush populations are resilient and generally are not significantly affected in the long run. Nelson and Krebill (1981) isolated several fungal species of the genera *Gliocladium*, *Fusarium*, and *Rhizoctonia* from dying sagebrush in uniform gardens. Similar symptoms (dying desiccated plants) have been observed in natural populations (McArthur and others 1979a). Nelson and Sturges (1986; Sturges and Nelson 1986) reported that snowmold disease can be serious in mountain big sagebrush populations. Diseases induced by these fungi may be among the most serious sagebrush diseases. Some microbes are likely useful for the vigor and growth of sagebrush. Wallace and Romney (1972) found preliminary evidence that big sagebrush formed symbiotic relationships with microbial endophytes to fix atmospheric nitrogen. Williams and Aldon (1976) found endomycorrhizae within big sagebrush roots and abundant spores around the roots. Endomycorrhizae, in general, have a beneficial influence on plant growth by promoting nutrient absorption through infected roots (Williams and Aldon 1976). For sagebrush, the beneficial effect has recently been demonstrated (Allen 1984).

Plant Culture

Big sagebrush is one of few shrubs with potential for easy establishment by artificial seeding. Seedlings grow rapidly and compete well with herbaceous plants. The plant establishes well from broadcast planting on irregular but firm seedbeds. Consequently, plants can be established by broadcast seeding even when seeded in mixtures with herbs. Natural seeding often takes place amid established stands of seeded grasses. Because natural spread generally occurs, sagebrush can be planted at low rates and allowed to spread. This has been successful.

Sagebrush seed is difficult to separate from the chaff. Large stalks and debris are usually removed and seed is sold and seeded at a purity of 10 to 20 percent. Seeds are small and planting rates of 0.10 PLS (1 lb bulk per acre or 1.1 kg per ha) can produce adequate stands from broadcast or drill seeding. Seeds require minimal coverage but must be planted on a firm seedbed. Planting on a loose surface is not advised. Seeding should be delayed until early winter when soil surfaces are moist and firm. Seeds require afterripening and stratification to attain uniform germination. Small seedlings are not frost tolerant, and extensive losses occur from spring frosts.

Sagebrush often establishes better from broadcast seeding than drill seeding, as seed are placed too deep with conventional drills. Seedings using the cultipacker seeder are successful as seeds are not placed more than 0.25 inch (6.4 mm) deep and the soil surface is compacted or “firmed up” with this machine.

Although established stands of big sagebrush can reduce the productivity of associated herbs, young sagebrush plants do not diminish the density or vigor of developing herbs. Consequently, sagebrush can be directly seeded with herbs to provide a mixed composition of plants. Big sagebrush is also compatible with numerous shrubs, so mixed seedings can be done even though young sagebrush plants develop more rapidly than serviceberry, snowberry, Martin ceanothus, green ephreda, and Wyeth eriogonum.

Big sagebrush wildings can easily be transplanted into nurseries and field locations when they are relatively dormant and moisture conditions are right—fall and early spring. Wildings about 6 to 8 inches (15.2 to 20.3 cm) tall transplant best. McArthur and Plummer (1978) reported that of the 829 big sagebrush plants transplanted to the Snow Field Station in Ephraim, UT, in 1969 to 1970, 590 established (71.2 percent). Five years later 421 plants were vigorous and growing. Luke and Monsen (1984) reported high success in transplanting sagebrush on a Wyoming mine spoil site. Individual big sagebrush plants can be propagated by the rooting of stem cuttings (Alvarez-Cordero and McKell 1979). Tissue culture propagation is also possible (Neville and McArthur 1986).

Big sagebrush can be successfully drill (fig. 26, 27), or broadcast seeded (fig. 28). Care should be taken that seeds are not covered too deeply, 1/8 inch (3.2 mm) or less is preferred (Monsen and Richardson 1984; Richardson and others 1986; Young and Evans 1986b). Seeding should be done in the fall. Planting in subsoil substrates has had mixed success. Luke and Monsen (1984) and Monsen and Richardson (1984) were not successful, but Stevens and others (1981b) successfully seeded big sagebrush in subsoil scalps (fig. 29).

Figure 26—Drill seeded big sagebrush with grass mixture in southern Idaho. Sagebrush seed was separated from grass seed in seed boxes and drill rows.

Figure 27—Seeded big sagebrush in subsoil scalps in an intermediate wheatgrass seeding, Millard County, UT.

Figure 28—Plant establishment from aerial seeding of big sagebrush with crested wheatgrass, alfalfa, and Utah sweetvetch in south-central Utah.

Matching seed source with planting site habitat is important for emergence and survival of big sagebrush (Meyer and Monsen 1991). In general, regardless of subspecies, big sagebrush seed germination is adapted to climate of collection sites (Meyer and others 1990b). A wilt disease can be troublesome in nurseries (Nelson and Krebill 1981). Symptoms of this disease are present also in natural populations. Snowmold can also cause lack of vigor and death in sagebrush (Nelson and Sturgess 1986; Sturgess and Nelson 1986). During cold winters with little snow cover, winter injury and death has been documented for large stands of sagebrush (Nelson and Tiernan 1983).

Uses and Management

Big sagebrush is one of the more nutritious shrubs on Western winter livestock and game ranges. Basin big sagebrush has higher protein levels than the other subspecies (Welch and McArthur 1979b). Palatability of the different populations of this shrub to mule deer and other animals varies widely. For deer, basin big sagebrush is generally less palatable than Wyoming big sagebrush; both are generally less palatable than mountain big sagebrush (Hanks and others 1973; Scholl and others 1977; Sheehy and Winward 1981; Wambolt 1996; Welch and McArthur 1986; Welch and others 1981). However, Striby and others (1982) reported that Wyoming big sagebrush was most palatable to deer and elk at their Montana study site. Wyoming big sagebrush is generally most palatable to sheep (Welch and others 1987). Palatability of spicate big sagebrush has not been studied to any great extent. It is browsed by sheep in the late summer and early fall and by big game when available in winter. Palatability of xeric big sagebrush is good for mule deer and sheep. Sagebrush is important food and cover for upland birds. For example, sagebrush comprised 62 percent of the annual diet of sage-grouse in Montana (Wallestad and others 1975). Big sagebrush is an important component of antelope diet. Olsen and Hansen (1977) found sagebrush comprised 78 percent of the annual diet for antelope in Wyoming's Red Desert. Even though sagebrush is a valuable forage, it is generally a less preferred browse for deer and other

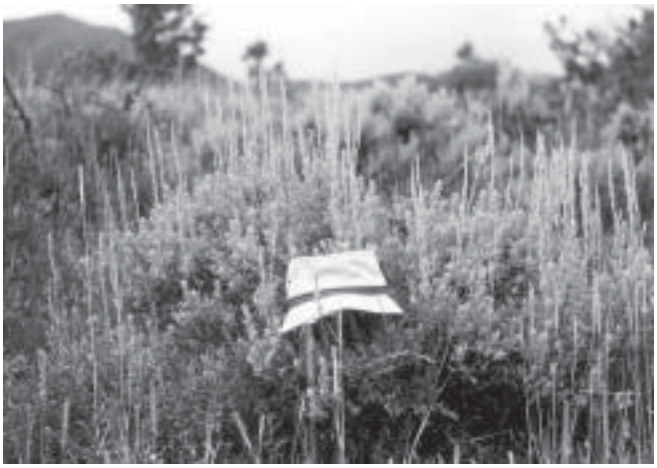


Figure 29—An even-topped mountain big sagebrush.

browsers than many rosaceous shrubs such as the mountain mahoganies, bitterbrush, and cliffrose (McArthur and others 1978b; Smith and Hubbard 1954; Smith and others 1965). Because of its widespread abundance, its ability to grow with associated grasses, forbs, and other shrubs and its nutritious nature, big sagebrush is the most important winter forage in foothill areas throughout much of the West for livestock and big game. Sustained heavy use can, however, result in loss of vigor and mortality of big sagebrush and other sagebrush species (Cook and Child 1971; McArthur and others 1988a; Smith 1949). It is one of the best shrubs available for use in revegetation of depleted winter game ranges in the Intermountain area (Plummer 1974a; Welch 1983a).

Meyer and colleagues showed that sagebrush seeds are site-adapted. Generally seeds from the area to be planted or a similar area will establish and perform better (Meyer 1994; Meyer and Monsen 1992; Meyer and others 1990b).

All forms of big sagebrush usually recover by naturally seeding sites that have been sprayed, burned, disked, or chained. Natural spread can be reduced if soils are plowed or deeply disked causing seeds to be deeply buried. Mountain big sagebrush recovers well even amid the presence of established herbs. However, mountain big sagebrush usually grows on sites that receive high amounts of summer moisture to sustain seedling growth. In addition, this sagebrush is able to produce good seed crops each year. Under more arid conditions, natural seed production is more erratic. Poor seed crops often occur and seed viability is diminished after 2 to 3 years of storage (Stevens and others 1981a).

Big sagebrush is aggressive and persistent and sometimes forms closed stands. These stands may require thinning and rejuvenation. These techniques are treated in chapter 17, and in Plummer and others (1955), Pechanec and others (1965), Laycock (1979), Utah State University (1979) (especially Keller's contribution), Marion and others (1986), and Whisenant (1986b). Big sagebrush stands are unexcelled in providing ground cover and forage when grazed to maintain a balance between the sagebrush and associated herbs and shrubs. Because big sagebrush has the potential to establish rapidly from both transplanting and direct seeding, it is useful for stabilizing washes, gullies, roadcuts, and other raw, exposed sites (Clary and Tiedemann 1984; McArthur and others 1979a; Monsen and Richardson 1984) and planting depleted game ranges (Plummer and others 1968). Big sagebrush, especially basin big sagebrush, has shown promise as a living snowfence (Laycock and Shoop 1986). Winward (1980, 1983) reported that associated species richness with each subspecies (see next section) varies greatly. Of the three common subspecies, the order and quantity of diversified associated species is *vaseyana* > *tridentata* > *wyomingensis*. This information should be kept in mind for carrying capacity and manipulative considerations.

Varieties and Ecotypes

Because of its plasticity and the apparent ease with which it hybridizes, there are good opportunities for developing improved forms of big sagebrush for different purposes (McArthur 1981; McArthur and others 1979a, 1985, 1988b; Noller and McArthur 1986; Welch and McArthur 1979a). One accession has been released as a named germplasm; 'Hobble Creek' is a vigorous mountain big sagebrush from near the mouth of Hobble Creek Canyon, UT. It is palatable to mule deer and sheep; it persists in relatively dry sites receiving from 13 to 14 inches (33.0 to 35.6 cm) of rain; and has good growth characteristics (Welch and others 1986). Other accessions also show promise and may qualify for later release.

Basin big sagebrush (*A. tridentata* ssp. *tridentata*) is an erect, heavily branched, unevenly topped shrub (fig. 24). Similar contrasting characteristics of basin and other big sagebrush subspecies are given in table 3. This subspecies has undivided or at least trunklike, main stems. Most shrubs range between 3 to 6.5 ft (0.9 to 2.0 m) in height. Some forms, however, may reach 15 ft (4.6 m) in suitable habitats. Mature shrubs of this subspecies are the largest members of the big sagebrush complex. The evergreen, vegetative leaves are narrowly lanceolate, up to 5 cm long by 5 mm wide, and typically three-toothed at the apex. The leaves of the flowering stems gradually become smaller and may be linear or oblanceolate and entire. Winward (1970) found the average length-to-width ratio of persistent leaves is 4.6 to 5.6. The gray-canescent foliage passes a strongly pungent, aromatic odor. Flowering stems arise through the uneven crown and bear numerous flowerheads in erect, leafy panicles. The heads contain three to six small yellowish or brownish, trumpet-shaped, perfect disc flowers. The narrowly campanulate involucre consists of canescent bracts 3 to 4 mm long and about 2 mm wide that form four to five overlapping series around each head. The outermost bracts are less than a fourth as long as the innermost bracts. Flowering occurs from late August to October. Seed matures, depending on site, from October to early December. Seed can be collected fairly easily by beating (see chapters 20 and 24). Basin big sagebrush is probably the most abundant shrub in Western North America on lowland ranges. It normally occurs on dry, deep, well-drained soils on plains, valleys, and foothills below 7,000 ft (2,100 m) elevation. Above this elevation subspecies *vaseyana* and *spiciformis*, and occasionally subspecies *wyomingensis* are

more prevalent. Vigorously growing basin big sagebrush is considered indicative of productive ranges because it often grows in deep, fertile soil. This subspecies has generally been regarded as intolerant of alkali, but there are ecotypes that grow in relatively high alkalinity in association with such alkali-tolerant plants as black greasewood, shadscale, and saltgrass. A similar taxa restricted to southern California is ssp. *parishii* distinguished by its exceptionally hairy achenes. Subspecies *parishii* may only be an ecotype of basin big sagebrush.

Mountain big sagebrush (*A. t.* ssp. *vaseyana*) is normally a smaller shrub than basin big sagebrush. Its main stems are usually divided at or near the ground, and it tends to have a spreading, evenly topped crown (fig. 29). Vegetative branches are usually less than 3 ft (91.4 cm) high and occasionally layer at the base. Some lower elevation ecotypes reach about 6 ft (1.8 m) in height. The persistent vegetative leaves are broadly cuneate to spatulate and are characteristically wider than those of both basin and Wyoming big sagebrushes. When looking down at shrubs of mountain big sagebrush, terminal leaves on each twig appear to be distinctly whorled. Basin big sagebrush does not show this trait, but Wyoming big sagebrush shows the trait to some extent. Mountain big sagebrush grows in slightly acidic to slightly alkaline soils (Welch and McArthur n.d.). Unlike ssp. *tridentata*, ssp. *vaseyana* is rarely associated with any of the saltbushes. Mountain big sagebrush has larger seeds than Wyoming and basin big sagebrushes. It usually comes better from direct seeding than the other two subspecies. There are two varieties of mountain big sagebrush. Each variety occurs in large distinct populations but also integrates into other populations. The most common variety outside of the Pacific Northwest is small-headed mountain big sagebrush (Goodrich and others 1985). This is the sagebrush that Ward (1953) referred to as that of "timbered or mountainous areas in which the plants are very uniform in size, usually about 2 ft (61.0 cm) in height, and of a rather spreading, flat-topped habit of growth, with the inflorescence extending upward like plumes above the rest of the bush." The small-headed form has four to six flowers per head. The other variety, var. *vaseyana*, has seven to 11 flowers per head and has a more restricted geographical range in the upper elevational sagebrush areas of Washington, Oregon, and Idaho with only occasional small patches occurring outside of that area (Goodrich and others 1985).

Rosentreter and Kelsey (1991), on Winward's (1970) suggestion maintained that xeric big sagebrush, (*A. t.* ssp. *xericensis*) be recognized as a distinct entity. This subspecies is apparently derived from hybridization between ssp. *tridentata* and *vaseyana* (McArthur and others 1979a; Rosentreter and Kelsey 1991). It is adapted to dry sites between 2,600 and 4,600 ft (790 to 1,400 m) in southern Idaho and surrounding areas. Its introgression with ssp. *tridentata* is apparent in that plants are large and ragged topped, but chromatographically, cytologically, and phenologically it most closely resembles ssp. *vaseyana*.

Wyoming big sagebrush (*A. t.* ssp. *wyomingensis*) is somewhat intermediate in distribution, ecology, and morphology between basin big sagebrush and mountain big sagebrush, but more diminutive than either (fig. 30). It is adapted to drier sites than other subspecies by virtue of its rapid and long root growth and early, but relatively small, aboveground growth (Booth and others 1990; Welch and Jacobson 1988). The accession 'Gordon Creek' has recently been released as a named germplasm (Welch and others 1992b). It combines wide adaptability, palatability, favorable growth characteristics, and drought tolerance. Occasionally, the subspecies *tridentata*, *vaseyana*, and *wyomingensis* may be found growing together. Whenever it is found associated with ssp. *tridentata*, ssp. *wyomingensis* is growing in the poorer, more shallow soils (Beetle and Young 1965). Subspecies *wyomingensis* is a low shrub usually less than 3 ft (91.4 cm) in height. It has an uneven to round top with flower stalks arising throughout the crown like ssp. *tridentata*. Its main stem branches at or near the ground level like ssp. *vaseyana*, but it does not layer. Leaves are 1 to 2 cm long, narrowly cuneate to cuneate, and have an average length-to-width ratio of about 3:1 for the persistent leaves (Winward 1970). Flowerheads contain three to eight disc flowers and are arranged into panicles narrower than the paniculate inflorescence of *tridentata*, and is wider than the spicate inflorescence of *vaseyana* (Beetle and Young 1965; Winward and Tisdale 1977). Flowering and seed ripening take

Figure 30—Wyoming big sagebrush growing near Daniel, Sublette County, WY.

place later than *vaseyana* and earlier than *tridentata*. Wyoming big sagebrush plants have an effective near surface root system (Sturges 1977). This may be one reason why relatively few plant species grow with it. This subspecies may have arisen from hybridization between ssp. *tridentata* and *vaseyana* (Beetle and Young 1965; Hanks and others 1973) or ssp. *tridentata* and *A. nova* (Winward 1975), or a combination of all three taxa (McArthur 1983b). Wyoming big sagebrush grows throughout the Intermountain region. It is particularly abundant east of the Continental Divide in Montana, Wyoming, and parts of Colorado in dry, shallow, gravelly soil; usually from 5,000 to 7,000 ft (1,500 to 2,100 m) (Beetle and Young 1965). In Idaho, this subspecies is found from 2,500 to 6,500 ft (760 to 2,000 m) in the hotter, drier portions of the state (Winward 1970).

Timberline big sagebrush (*A. t.*ssp. *spiciformis*) has been the subject of some taxonomic confusion (see *A. rothrockii* discussion in Goodrich and others 1985 and McArthur and others 1979a, 1981). This taxon is the widespread root sprouting big sagebrush of high elevations in the Intermountain area (Goodrich and others 1985; McArthur and Goodrich 1986). Its habitat is often in openings in aspen, spruce, or fir woods or where drifting snow accumulates (fig. 31). It had formerly been confounded with Rothrock sagebrush (*Artemisia rothrockii*), a similar taxon of the Sierra Nevada (Goodrich and others 1985; Shultz 1983; Ward 1953). Rothrock sagebrush differs from timberline sagebrush by its dark resinous leaves, restricted California distribution, and high polyploidy. Timberline big sagebrush is thought to be a stabilized hybrid between mountain big sagebrush and mountain silver sagebrush (Goodrich and others 1985). In growth form, timberline big sagebrush resembles mountain big sagebrush in stem and leaf characteristics, but mountain silver sagebrush in floral characteristics (fig. 32). It has 10 to 18 flowers per head. Timberline big sagebrush flowers in August and September in native habitats, but in early June when transplanted to low elevations (4,500 to 5,600 ft; 1,400 to 1,700 m). It is a palatable sagebrush often browsed heavily in the fall by sheep and mule deer. In winter it is usually unavailable under snow. It has shown potential as a low landscape hedge (McArthur and others 1979a). Although basin, Wyoming, and mountain big sagebrush occur in distinct sites, all three of these common subspecies express a wide range of adaptation. When planted throughout the big sagebrush, pinyon-juniper, and mountain brush communities all three subspecies demonstrate adaptiveness. Although sources from high elevations are not suited to arid circumstances, and sources collected from light textured soils are not adapted to heavy clay textured soils, most selections have established and persisted when planted over a wide range of sites.

Figure 31—Timberline big sagebrush growing near Minturn, Eagle County, CO. Note the large flower heads and flowering stalks.

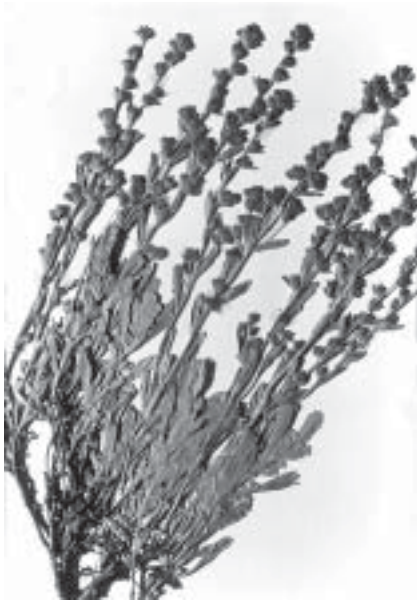


Figure 32—A specimen of timberline big sagebrush collected from Wolf Creek Summit, Wasatch County, UT.

The subspecies of big sagebrush as well as near relatives (=subgenus *Tridentatae*) hybridize at many of their contact points. In fact, hybridization is thought to have been a key mechanism in the evolution and speciation of the group (Beetle 1960; Hanks and others 1973; McArthur and others 1981, 1988; Ward 1953). Artificial hybridization may be useful in selecting and combining traits for management purposes such as fire tolerance and palatability (McArthur and others 1979a, 1988b,c, 1998a; Weber and others 1994). Some

current studies of big sagebrush zones of hybridization are yielding results in an effort to better understand the role of hybridization in nature and to help determine the importance of the permanence and function of hybrid zones. These studies have concentrated on morphological, chemical, physiological, cytological, ecological, edaphic, and entomological characteristics (Byrd 1997; Byrd and others 1999; Freeman and others 1991, 1995, 1999; Graham and others 1995; McArthur and others 1988b,c, 1998a, 1999b; McArthur and Sanderson 1999; Messina and others 1996; Wang 1996; Wang and others 1997, 1998, 1999).

Artemisia tripartita

Threetip Sagebrush

Threetip sagebrush is a round, evergreen shrub up to 6 ft (1.8 m) high. It may have a simple, trunklike main stem or several branches arising from the base. The bark on young branches is canescent but becomes shredded and grayish, light brown to dark brown or black on older stems. This species can layer, sometimes sprout back after a burn, and may sprout from the stump following herbicide treatment (Beetle 1960; Pechanec and others 1965; Schlatterer 1973; Winward 1980). Leaves of the vegetative branches are canescent, 0.5 to 4 cm long, and typically deeply divided into three linear or narrowly linear-lanceolate lobes, which in turn may be three-cleft (fig. 33). Some of the upper leaves are often entire. Crushed foliage emits a pungent odor. Flowerheads contain three to 11 disc flowers and are normally arranged into panicles. Ray flowers are lacking. Each head is subtended by eight to 12 canescent involucral bracts. Achenes are resinous-granuliferous. Blooming occurs from July to September and seed is collected from mid-October to mid-December.

Ecological Relationships and Distribution

Threetip sagebrush covers approximately 13,000 mi^2 (33,670 km^2) in the Northern Rocky Mountains and Great Basin States from British Columbia south through Montana and Wyoming to Colorado and west to Washington, Oregon, northern Nevada, and northern Utah at elevations between 3,000 to 9,000 ft (910 to 2,700 m) (Beetle 1960). In some places, particularly in Idaho, this species occurs between the lower, hot, dry sites dominated by Wyoming big sagebrush and the higher, cooler sites dominated by mountain big sagebrush (Schlatterer 1973). It usually grows on moderate to deep, well-drained, loamy and sandy loam soils (Winward 1980).

Figure 33—Threetip sagebrush (Shultz 1986): (A) *A. tripartita* ssp. *rupicola*; (B) *A. tripartita* ssp. *tripartita*.

Uses and Management

Threetip sagebrush is a vigorous seeder, but unfortunately some forms are not particularly palatable. However, Kufeld (1973) reported use by elk, and Kufeld and others (1973) reported use by deer. Beetle (1960) reported it was of low palatability for both livestock and game, and Brunner (1972) observed that it was never grazed in Nevada. However, a form near Salmon, ID, is palatable to deer. The form near Salmon may have been introgressed by a nearby population of Wyoming big sagebrush (McArthur and others 1979a). Stands of threetip sagebrush sometimes require thinning by mechanical and chemical means (Pechanec and others 1965).

Threetip sagebrush has not been difficult to establish by direct seeding, rearing, or transplanting. Usually a large amount of high quality seed is produced annually. Seeds can be harvested without difficulty from the upright bushes. Within its area of occurrence, threetip sagebrush establishes and performs well. Seedlings are able to persist within both a dense perennial and annual understory. But threetip sagebrush is not any more competitive with cheatgrass and other annuals than other species of sagebrush.

Plants grow quickly and can attain a mature stature in 3 to 5 years. The shrub frequently exists with a number of other shrubs and herbs. Seeding a mixture of species usually does not reduce the survival or productivity of this shrub.

Attempts to establish threetip sagebrush onto arid sites dominated by Wyoming big sagebrush have not been successful. Plants initially appear but fail to persist if reseeded. However, some ecotypes can be extended to drier sites.

Threetip sagebrush recovers well following extensive disturbances. However, hot summer fires can kill large stands and prevent resprouting and can significantly delay recovery by seeds.

Threetip sagebrush often grows intermixed, but as separate stands, with mountain big sagebrush, Wyoming big sagebrush, or alkali sagebrush. When disturbances have occurred in these areas, threetip sagebrush seedlings often invade into all circumstances. Natural sorting occurs, but rather slowly. Threetip sagebrush demonstrates good compatibility with many introduced and native grasses and broadleaf herbs. It survives and grows well with competitive grasses including mountain brome, slender wheatgrass, intermediate wheatgrass, and orchardgrass.

Varieties and Ecotypes

Wyoming threetip sagebrush (*Artemisia tripartita* ssp. *rupicola*) is a dwarf shrub with decumbent branches that rarely grows over 6 inches (15.2 cm) tall. It is frequently found layering and may have a crown of 12 to 20 inches (30.5 to 50.8 cm) (Beetle 1960). Leaves of the vegetative branches are often 3 cm long and deeply divided into linear lobes, each at least 1 mm wide (Beetle 1959, 1960). Flowerheads bear three to 11 disc flowers and are arranged into leafy, narrowly racemose panicles. Flowers bloom in late August and September. Seed ripens in October. Wyoming threetip sagebrush has a rather limited range. It occurs on rocky knolls from 7,000 to 9,000 ft (2,100 to 2,700 m) in elevation in central and southeastern Wyoming (Beetle 1960). Brunner (1972) reported this subspecies also occurs in southern Oregon, but had not yet been found in Nevada. It typically grows on sites adjacent to those of mountain big sagebrush.

Tall threetip sagebrush (*A. t.* ssp. *tripartita*) is a freely branching shrub up to 6 ft (1.8 m) high. It can layer easily when the conditions are right but is seldom found layering in the field. After burning, it may stump-sprout (Beetle 1960). Leaves of the vegetative branches are 1.5 to 4 cm long and deeply divided into three linear lobes less than 1 mm wide. The lobes may be further divided (Beetle 1959, 1960). Flowerheads bear four to eight disc flowers and are arranged into panicles that may sometimes be reduced to a spicate form. Flowers bloom in late August and September. Seeds ripen in October. This subspecies occurs in dry, well drained soils at 3,000 to 7,500 ft (910 to 2,300 m) elevation from British Columbia south through Washington to northern Nevada and eastward to northern Utah and western Montana.

Other Sagebrushes

Coaltown sagebrush (*Artemisia argillosa*) is a threetip form endemic to a small area in Jackson County, CO. This species is well adapted to heavy clay spoil material and may have some utility in reclamation activities (Beetle 1960; McArthur and others 1981).

Rothrock sagebrush (*A. rothrockii*) is similar in many respects to subalpine big sagebrush and would share the latter's uses. However, Rothrock sagebrush does not occur in the area of interest for this book. It is confined to the high country of California (Goodrich and others 1985; Shultz 1983).

Two other species—longleaf sage (*A. longifolia*) and birdsfoot sage (*A. pedatifida*)—are not true sagebrushes in that they don't belong to the subgenus *Tridentatae* (table 2). Both, however, may prove useful in revegetation efforts. Longleaf sage is the most robust and woody member of the mostly herbaceous Louisiana sage (*A. ludoviciana*) complex (see chapter 19 for treatment of the Louisiana sage or sagewort complex). Longleaf sage may grow up to 3 ft (91.4 cm) tall. It grows well on clay soils from Nebraska and Wyoming north to Canada (Hall and Clements 1923). Birdsfoot sage is a low perennial subshrub up to 6 inches (15.2 cm) tall with a tough woody root. It grows on alkaline flats in Wyoming and Idaho and could be used for rehabilitation of alkaline spoils (Hall and Clements 1923).

General Rabbitbrush Culture

Table 4 presents distribution and differentation of rabbitbrush taxa. Tueller and Payne (1987) and other papers in Johnson (1987) provide additional information on rabbitbrush culture, management, and use.

The fruit of rabbitbrush is a spindle shaped achene (seed). The terminal, or crown end, of each seed bears a ring or crown of hairs, known as the pappus. Seed can be wind and animal dispersed. Normally seed is produced annually. Seedlings naturally establish, especially on disturbed sites where competition is lacking or slight. Thousands of seedlings can be found in bare and disturbed soils, under and next to mature plants. Most do not, however, develop beyond the seedling stage. Seeds are relatively small (see chapter 20) with considerable variation in size between taxa. White rubber rabbitbrush seeds are among the smallest with about 700,000 per lb (1.5 million/kg) (100 percent purity). Mountain rubber rabbitbrush seeds are somewhat larger with just over 425,000 per lb (937,000 per kg).

Various rabbitbrush species have been successfully seeded. Seeding success, based on successful establishment, has ranged from 0.001 to 4.0 percent (Stevens and others 1986). The pappus has to be removed to facilitate seed being seeded aerially, broadcast, or drilled. Although seeding success theoretically could be

Table 4—Species of *Chrysothamnus* with distribution, notes, and subspecific differentiation (drawn from Anderson 1986a; McArthur and Meyer 1987; McArthur and others 1979a; and references cited therein).

Section and species	Distribution	Notes	Number of subspecies
Chrysothamnus			
C. albidus	Scattered in alkaline soils W Utah to EC California.	White-flowered very resinous	—
C. greenei[a]	Often in sandy soils SC Colorado and N New Mexico to W Nevada and E California.	Mature plants have brittle white shiny stems Involuvral bracts are acuminate and recurved.	1
C. humilis	Arid plains NW Nevada, NE California, SE Oregon, and isolated populations further N in Oregon and Washington	Blooms earlier than rabbitbrush.	—
C. linifolius	Dry arroyos and other moist, deep but usually alkaline soil sites S Montana to N Arizona and N New Mexico	Large statured like rubber rabbitbrush.	—
C. viscidiflorus	Broad distribution on dry open areas British Columbia and Montana S to New Mexico, Arizona, and E California; entire state of Utah.	Some populations have the only ray flowers in *Chrysothamnus*	5[b]
Gramini			
C. eremobius	Known from only three populations in upland S Nevada.	Related to genus *Petradoria*	—
C. gramineus	Grows in mountain canyons in S Nevada and adjacent California.	Related to genus *Petradoria*. As opposed to *C. eremobius* this species has longer involucres, unkeeled phyllaries, and glabrous achenes.	—
Nauseosi			
C. nauseosus	Broadly distributed in plains, foothills and mountains British Columbia to Saskatchewan S to Western Texas, Sonora, and Baja California.	Most common and widely distributed rabbitbrush with much diversity. Forms of ssp. *albicaulis*, *hololeucus*, and *salicifolius* are preferred by browsing animals.	22[c]
C. parryi	Dry open places in mountains and foothills Wyoming and Western Nebraska W to California and S to New Mexico and Arizona.	Shares stem tomentum character with *C. nauseosus* but has attenuate involucral bracts as opposed to acute bracts of *C. nauseosus*. Generally smaller and finer structured than *C. nauseosus*.	13[d]
Pulchelli			
C. depressus	Dry plains, hills, and rocky mountain slopes scattered over Western Colorado and New Mexico W to SE California and S Nevada.	Dwarf shrub with conspicuously keeled, sharply ranked involucral bracts. Perhaps the most palatable taxa to ruminants.	—
C. molestus	Occurs only in a few scattered populations in uplands of NC Arizona.	Rare species. Has glandular-hispid foliage.	—
C. pulchellus	An undershrub in SW desert savannas SE Utah and SW in Utah, Kansas, to W Texas and N Coahuila.	Has prominantly angled achenes.	—
C. vaseyi	Scattered populations in mountain valleys and foothills SE Wyoming to NC New Mexico W to high plateaus of Utah.	Resembles the more common *C. viscidiflorus*.	—
Punctati			
C. paniculatus	Arid often stony slopes especially in dry arroyos SW Utah and SW Nevada to SC California.	Striate stems and terete leaves.	—
C. teretifolius	Arid stony slopes in S Nevada and SE California.	Similar to *C. paniculatis* but more abundant. Has more strongly aligned involucral bracts	—

[a] Formerly ssp. *greenei* and *filifolius* were recognized, but McArthur and others (1978a, 1979a) and Anderson (1986a) see no consistent distinctive differences between the formerly recognized subspecies.

[b] A total of 25 have been named at various taxonomic ranks. Hall and Clements (1923) recognized nine; Anderson (1986a) recognized five subspecies: ssp. *axillaris*, *lanceolatus*, *planifolius*, *puberulus*, and *viscidiflorus*.

[c] A total of 62 have been named at various taxonomic ranks. Hall and Clements (1923) recognized 20; Anderson (1986a) recognized 22 subspecies: ssp. *albicaulis*, *arenarius*, *bernardinus*, *bigelovii*, *ceruminosos*, *graveolens*, *hololeucus*, *iridis*, *junceus*, *latisquameus*, *leiospermus*, *mohavensis*, *nanus*, *nauseosus*, *nitidus*, *psilocarpus*, *salicifolius*, *texensis*, *turbinatus*, *uintahensis*, and *wasinoensis*.

[d] A total of 16 have been named at various taxonomic ranks. Hall and Clements (1923) recognized 10; Anderson (1986a) recognized 12 subspecies: ssp. *affinis*, *attenuatus*, *asper, howardii*, *imulus*, *latior*, *monocephalus*, *montanum*, *nevadensis*, *parryi*, *salmonensis*, and *vulcanicus*.

enhanced where the pappus is not removed (Stevens and others 1986), there is presently no available equipment for seeding uncleaned seed.

Seeds are generally hand collected but can be harvested with various types of seed strippers, seed beaters, and vacuums. The pappus is removed by running the seed through a barley debearder or hammermill followed by screening and fanning. Seed is generally collected between 10 and 15 percent purity. Seed can be cleaned to 95 percent purity with persistent screening and fanning. Barley debearding is preferred over hammermilling. Seeds are somewhat brittle; hammermilling can result in seed breakage and cracking in the balling of the collected material. Balling hinders seeding.

Seed cleaned to less than 70 percent purity can only be seeded aerially, by hand, or through a thimble seeder. Seed cleaned to 70 percent or greater can be run through a drill, seed dribbler, or browse seeder. Where seeds are cleaned to high purities, they need to be diluted with rice hulls or screened sawdust to facilitate seeding. Seed of most rabbitbrush species should be surface seeded or covered not more than 1/32 inch (0.8 mm) deep. If drilled, seed drop tubes and hoses should be removed from between the disk furrow opener and placed behind them. Seed will then be deposited behind the disk furrow opener on a disturbed soil surface. Rabbitbrush seedlings are generally not competitive and may be suppressed by other species. If drilled, thimble, dribbler, or browse seeder seeded, rabbitbrush seed should be seeded individually or with less competitive species. Broadcasting results in substantially less competition between species. Late fall and early spring seeding are preferred. Rabbitbrush seed can be stored in an open, unheated, uncooled warehouse for up to 3 years following collection without too much loss of viability.

Chrysothamnus depressus

Dwarf Rabbitbrush

Dwarf rabbitbrush is a small, irregularly branched, depressed shrub or subshrub 1 ft (30.5 cm) high or less, with numerous short branches arising from decumbent lower stems (fig. 34). The branches are covered with a dense scabrid pubescence. The narrowly oblanceolate to spatulate leaves are 0.7 to 2 cm long, 1 to 4 mm wide, and finely puberulent or scabrous like the branches. The heads contain five disc flowers that are arranged into compact terminal cymes. Involucral bracts have mucromate to attenuate tips, are 10 to 13 mm long, and are arranged into five distinct vertical ranks. Achenes are 5 to 5.5 mm long and glabrous or obscurely pubescent toward their apex. The soft brownish-white pappus is slightly longer than the corolla. Blooming occurs from May to October; seed matures from October to December (see chapter 20).

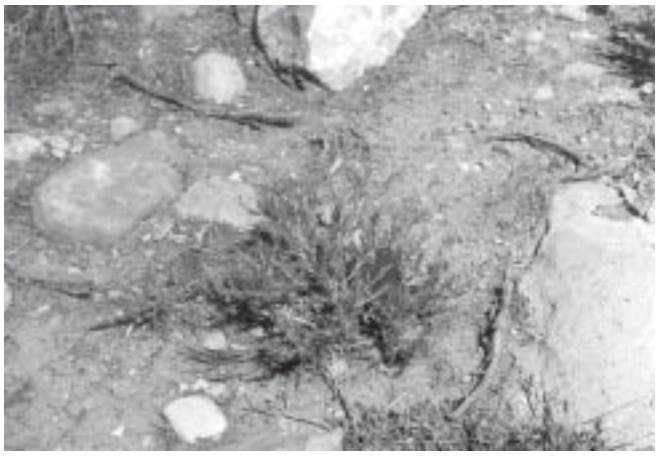


Figure 34—Dwarf rabbitbrush growing near the mouth of Ephraim Canyon, Sanpete County, UT.

This species occurs on dry plains, hills, and rocky mountain slopes from 3,300 to 6,900 ft (1,000 to 2,100 m) in elevations scattered over western Colorado, New Mexico, Utah, Nevada, Arizona, and southeastern California (Anderson 1986a).

Dwarf rabbitbrush is often heavily browsed by sheep, cattle, and wildlife (Hall and Clements 1923; Kufeld and others 1973). It transplants readily, can be seeded, and is useful for stabilizing depleted soils on which it readily grows. This handsome shrub is a source of protein when grasses and broadleaf herbs have dried (McArthur and others 1979a).

Chrysothamnus linifolius

Spreading Rabbitbrush

Spreading rabbitbrush is a tall, robust shrub up to 7 ft (2.1 m) high that spreads underground (fig. 35) by lateral roots that form adventitious shoots (Anderson 1964). Of all the rabbitbrushes only Parry rabbitbrush shares the underground spreading trait and then not nearly to the extent spreading rabbitbrush does. Leaves are large, flat, green, glabrous, lanceolate to oblong-lanceolate, 2 to 5 cm long, and 8 to 16 mm wide. Heads contain four to six, usually five, disc flowers and are arranged into broad, loose cymes. The involucral bracts have obtuse tips with thickened green spots similar to those of Vasey rabbitbrush. These spots, however, dry to a brown color. Achenes are covered with dense, long, soft hair. Blooming occurs during August and September with seed ripening from October to mid-December.

Spreading rabbitbrush occurs in Montana, Wyoming, Colorado, New Mexico, Utah, and Arizona. It is most abundant in alkaline soils along roadcuts, barrow pits, ditches, streams, and washes in the Upper Colorado River drainage.

Figure 35—Root sprouts, foreground, of spreading rabbitbrush at the Snow Field Station.

Figure 36—Large rubber rabbitbrush growing at Palmetto, Esmeralda County, NV. The specimen pictured is the *viridulus* form of ssp. *consimilis*.

The species has aggressive underground spreading characteristics coupled with an ability to spread by seed that make it a valuable stabilizer of disturbed alkaline soils (McArthur and others 1974; 1979a; Plummer 1977). It transplants readily. Laycock and Shoop (1986) found spreading rabbitbrush to be an excellent living snowfence for the central Great Plains. Spreading rabbitbrush receives little browsing use. It does, however, provide year round cover for upland game and small birds.

Chrysothamnus nauseosus

Rubber Rabbitbrush

Rubber rabbitbrush is a shrub usually 12 to 80 inches (0.3 to 2.0 m) high, but it varies from dwarf forms to types over 10 ft (3.0 m) high (fig. 36). Usually, several erect stems arise from the base and these branch to form rounded bushes. Branches are covered with a green, yellow-green, gray-green to white feltlike tomentum usually infiltrated with a resinous gum, making the plant somewhat sticky. This coating is often mistaken for part of the bark but can be discerned by scraping with a knife edge or a fingernail. Leaves are nearly filiform in some subspecies to broadly linear in others. Leaves vary from 18 to 63 mm long and are covered with a tomentose vestiture. They are not twisted or gland-dotted. The heads of this species are usually arranged into a cymose inflorescence. Each head bears 20 to 25 glabrous to densely tomentose involucral bracts arranged in up to five vertical rows. Rubber rabbitbrush blooms from August to October and are among the latest bloomers of the genus. Plants at higher elevations bloom earlier than those at lower elevations. Seeds mature, depending on location and subspecies, and are collected from mid-October until the end of the year with over 500,000 cleaned seeds per lb (1.1 million/kg) (see chapter 24). Rubber rabbitbrush is normally a heavy seed producer (fig. 37).

Ecological Relationships and Distribution

We have recently discovered that galls induced by tephritid flies are differentially distributed among the subspecies of rubber rabbitbrush (McArthur 1986; McArthur and others 1979b—See Varieties and Ecotypes section later in this section for subspecies descriptions). Over much of their range, the white-stemmed subspecies *albicaulis* and subspecies *hololeucus* are infested with a persistent round stem gall, 0.3 to 1.2 cm in diameter. This gall was found restricted to these white-stemmed subspecies in our observations. Green subspecies *consimilis*, *graveolens*,

Figure 37—Rubber rabbitbrush in seed, south-central Utah.

and *turbinatus*, on the other hand, have a less persistent, fluffy stem gall reminiscent of a ball of cotton about 0.7 to 1.4 cm in diameter. This gall is found also on ssp. *hololeucus* in southern areas near Kanab, UT, and Colorado City, AZ. The round gall is absent in these areas. In areas where these green-stemmed and white-stemmed rubber rabbitbrush subspecies occur together the galls are specific. We have observed only a few cases of cross gall inoculation and then only on putative hybrid plants. Wangberg (1981) independently observed some species and subspecies specificity of tephritid galls on rabbitbrush in Idaho. He found less specificity for the round gall in Idaho than we did in Utah. He identified the tephritid flies that induce the galls as two different species of *Aciurina*. Dodson and George (1986) confirmed the genetic and ecological integrity of the two *Aciurina* species.

Rubber rabbitbrush ranges from British Columbia to Saskatchewan south to western Texas, Sonora, Baja California, and eastern California (Anderson 1986a, c). It is a common plant on plains, valleys, and foothills. It grows best in openings with the sagebrush, juniper-pinyon, and ponderosa pine zones in sandy, gravelly, or clay-alkaline soils. This species grows at elevations ranging from 500 to 9,000 ft (150 to 2,700 m). Rubber rabbitbrush is a vigorous early invader of disturbed sites such as roadcuts and overgrazed rangelands. On ranges where big sagebrush has been destroyed by fire, insects, vehicular traffic, or continued heavy grazing, rabbitbrush will increase and often become the dominant vegetation (Evans and others 1973; Rosentreter 1986). Nevertheless, in most habitats, this species is not overly competitive with herbaceous species, and on some sites, it does not suppress grass. Production of herbaceous cover percentage have been notably greater (fig. 38) when rabbitbrush is present than when it is not present (Frischknecht 1963; Plummer 1959; Plummer and others 1968). We find it of interest that rubber rabbitbrush has a high photosynthetic rate, not unlike desert-adapted C4 photosynthetic pathway species (Davis and others 1985).

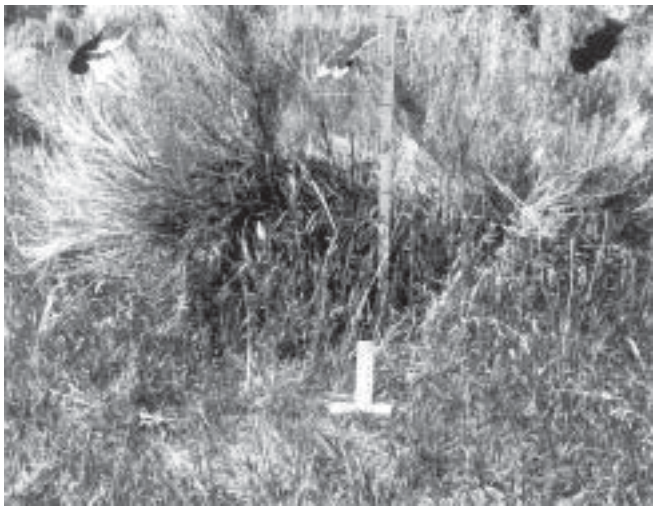


Figure 38—Rubber rabbitbrush growing in association with smooth brome, Sanpete County, UT. Note vigor of grass under shrub canopy.

Plant Culture

Rubber rabbitbrush can easily be transplanted in the fall or preferably in the spring to avoid frost heaving so long as the plants are physiologically inactive and moisture conditions are right and the transplants are small (10 inches tall; 25.4 cm or less). A less successful method—which, nevertheless, yields some results—is to divide dormant crowns (Hall and Clements 1923). Tissue culture techniques have been successfully employed to propagate rubber rabbitbrush (Upadhyaya and others 1985). Success was obtained from direct seeding, especially when seeds have been distributed on top of disturbed soil in the fall or early winter. Once established, natural spread can occur (Stevens 1986b).

Seed germination of rubber rabbitbrush is usually quite high. Seeds maintain high viability (65 percent) for 3 years under ordinary warehouse storage conditions (Stevens and others 1981a). With cool night (40.5 °F; 4.7 °C) and warm day temperatures, rubber rabbitbrush seed germinates in about 2 days (Weber and others 1985). However, under standardized single cool temperature germination conditions, seeds from lower elevations and latitudes germinate in about half the time (2 weeks) that it takes for seeds from higher elevations and more northerly areas to germinate (McArthur and others 1987a; Meyer and McArthur 1987; Meyer and others 1989). Stevens and others (1986) have shown that seeding rabbitbrush is more successful when the pappus is left on the achene (the fruit that holds rabbitbrush seed) and the achenes are placed upright at the soil surface. Achene size in rubber rabbitbrush subspecies appears to be correlated to habitat; subspecies adapted to sandy sites have larger achenes (Meyer 1997).

Uses and Management

Rubber rabbitbrush is an excellent plant for controlling erosion because of its deep roots, heavy litter, and ability to establish on severe sites (Aldon and Pase 1981; Luke and Monsen 1984; Monsen and Richardson 1984; Monsen and Stevens 1987; USDA Forest Service 1937). Once established, this species reproduces easily and spreads fast from its light, plumed, wind-disseminated achenes (Young and others 1984b). It also grows vigorously when transplanted. The value of

C. nauseosus as browse varies greatly between subspecies and ecotypes. The white to grayish subspecies such as *albicaulis*, *hololeucus*, and *salicifolius* are more palatable to livestock and big game than the green subspecies, *graveolens* and *consimilis* (fig. 39) (Hanks and others 1975; McArthur and others 1974). Throughout much of the summer range, game and livestock browse the plant lightly, if at all, except under unusual conditions. During late summer and fall when rubber rabbitbrush is in bloom, most livestock and game graze the flowers and occasionally a few leaves and the more tender stems. Rubber rabbitbrush is most heavily browsed on winter ranges (fig. 40). Rubber rabbitbrush was found in 48 percent of the deer stomachs examined on a portion of winter range in Owens Valley, Inyo County, CA; however, it never amounted to more than 6 percent of the total food ingested (Sampson and Jesperson 1963). Crude protein content ranged from 9 percent during the dormant months to 11.8 percent in the spring after new leaves had formed (Sampson and Jesperson 1963). Antelope also make extensive use of rubber rabbitbrush (Yoakum 1986). Bhat and others (1990) found a wide range of winter nutritive quality in rubber rabbitbrush accessions growing in a uniform garden. Rubber rabbitbrush is resilient to browsing. Severely browsed plants often obtain full regrowth by midsummer following heavy browsing. Rubber rabbitbrush also provides cover for small mammals and birds.

The potential for this species to produce rubber and other chemicals has long been recognized (Hall and Goodspeed 1919). There has been a recent revival of interest in this potential (Hegerhorst and others 1987; Ostler and others 1986; Weber and others 1985). Some accessions produce up to 6 percent stem rubber and 20 percent resin content. The plant also has other possible industrial and horticultural uses (Weber and others 1985).

Rubber rabbitbrush can become troublesome on ranges when it invades and occupies disturbed lands at high densities. It is a difficult plant to control because of its resistance to herbicides and its crown sprouting nature (Evans and others 1973; Whisenant 1986b, 1987; Young and others 1976a).

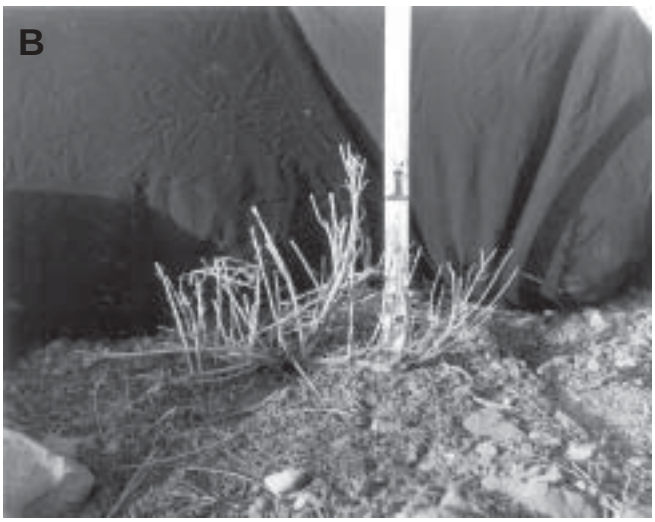


Figure 40—Heavy use of rubber rabbitbrush by deer in the winter at an experimental plot in Sanpete County, UT: (A) *C. nauseosus* spp. *salifolius* plant in the late fall; (B) The same plant after winter browsing. The stake in "A" is 1 ft tall; the mark on the stake in "B" is at 1 ft.

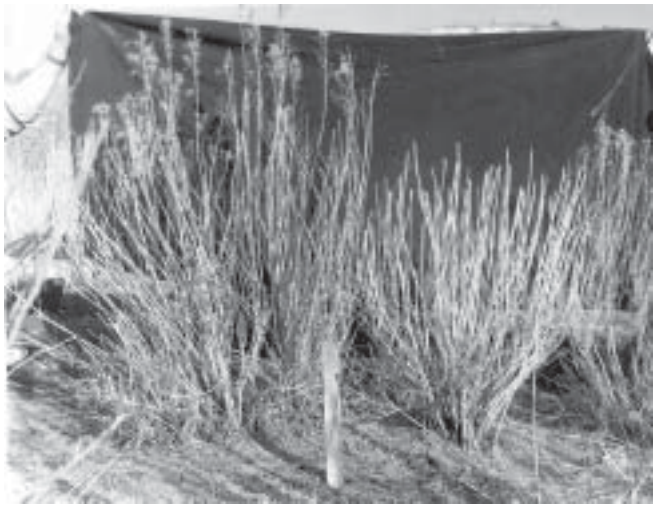


Figure 39—Differential winter-spring utilization of rubber rabbitbrush subspecies by deer in Sanpete County, UT. Left, *C. nauseosus* ssp. *consimilis* (10 percent use), right, *C. nauseosus* ssp. *hololeucus* (50 percent use).

Varieties and Ecotypes

Anderson (1986a,c) recognized some 22 subspecies of rubber rabbitbrush. Often, two or more subspecies will occur sympatrically. Each subspecies is essentially inbred and morphologically clean (Anderson 1986c; McArthur and Meyer 1987; McArthur and others 1978a). However, reproductive isolation occasionally breaks down, especially at the limits of subspecies geographical ranges, and intermediate morphological forms are found (Anderson 1986c; Hanks and others 1975; McArthur and others 1978a). Because of the mostly inbreeding, but potential for outbreeding, system of rubber rabbitbrush, many local reproductively isolated populations of rubber rabbitbrush occur. We agree with Hall and Clements (1923) that "improvement in any desired direction may be brought about by selection, or by hybridization or by both of these methods." To date, no artificial improvement has been made, but individual populations with desirable characteristics such as high rubber content, palatability, or growth form have been identified. We discuss below the more common subspecies of rubber rabbitbrush.

White stem rubber rabbitbrush—*C. nauseosus* ssp. *albicaulis* (mountain), and *hololeucus* (basin)—are shrubs from 2 to 6.5 ft (0.6 to 2.0 m) high with erect, leafy branches and leaves covered with a permanent, dense, white to grayish tomentum (fig. 41). The leaves are 2.5 to 4 cm long, 0.5 to 1.5 mm wide or sometimes to 3 mm wide in a few forms. The strongly keeled, acute involucral bracts are white, more or less tomentose, 8 to 10 mm long, and arranged into five distinct vertical ranks. The yellow corollas are 8 to 11 m long and terminate in lobes 1 to 2 mm long. The achenes are densely pubescent. The subspecies differ in the length of their corolla lobes (ssp. *albicaulis* 1 to 2 mm long, ssp. *hololeucus* 0.5 to 1 mm long) and style appendage lengths for which ssp. *albicaulis* has style appendages longer than stigmatic portions, but ssp. *hololeucus* does not (Anderson 1986a). These subspecies tend to overlap morphologically in their area of sympatry (northern Utah, northeastern and western Nevada, southwestern Idaho, and southeastern California; Anderson 1986a,c). In these areas of sympatry, subspecies *albicaulis* occurs at higher elevations (over 6,000 ft; 1,800 m) whereas ssp. *hololeucus* is confined to lower elevations. White rubber rabbitbrush subspecies are common and widespread and are found in open places in plains, foothills, and mountains from British Columbia, Alberta, and Montana southward to northwestern Colorado, Utah, Nevada, and southern California (Anderson 1986c). Subspecies *hololeucus* grows in the Great Basin area whereas ssp. *albicaulis* occurs on mountains and foothills, east, north, and west fringes of the Great Basin and beyond (Anderson 1986a,c; Hall and Clements 1923). Subspecies *hololeucus* is often intermixed with ssp. *graveolens* on foothill ranges and with subspecies *consimilis* in valleys and plains. The striking white forms of both subspecies have potential use as ornamentals (McArthur and others 1979a; Weber and others 1985). Another common white subspecies of the foothills and plains of Colorado, Wyoming, Montana, and the western Dakoatas is ssp. *nauseosus*. This subspecies is short statured, about 2 ft (61.0 cm) tall, and quite palatable to game and livestock.

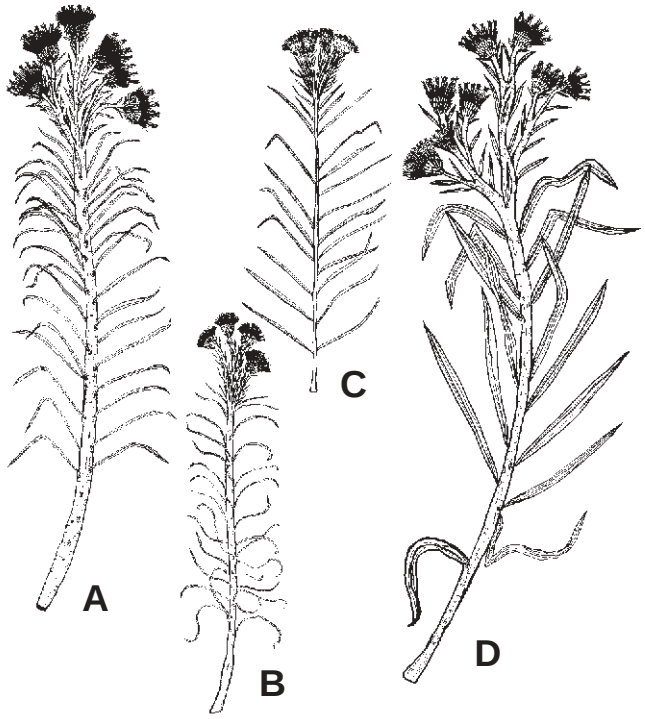


Figure 41—Four subspecies of rubber rabbitbrush: (A) *C. nauseosus* ssp. *albicaulis*; (B) *C. nauseosus consimilis;* (C) *C. nauseosus* ssp. *graveolens*; (D) *C. nauseosus* ssp. *salicifolius* (McArthur and others 1979a).

Threadleaf rubber rabbitbrush (*C. n.* ssp. *consimilis*) may reach 10 ft (3.0 m) in height when mature. It has leafy, erect branches covered with a green to yellow-green tomentum. The narrow threadlike (linear-filiform) leaves are less than 1 mm wide and 2.5 to 5 cm long (fig. 41). They are usually covered with a green to yellow-green tomentum and are somewhat resinous. The involucral bracts are acute, glabrous, and keeled and are arranged in fairly distinct vertical rows. The bracts are 6.5 to 8.5 mm long. The corollas are 7 to 9.5 mm long, with glabrous lobes 1 to 2.5 mm long. The achenes are densely pubescent, suggesting that this subspecies may be a connecting link between rubber rabbitbrush and low rabbitbrush. Subspecies *consimilis* is most common in alkaline valleys and plains of the Great Basin where it is often associated with

various saltbushes and black greasewood. In less alkaline areas, *consimilis* intermixes with ssp. *hololeucus* and *graveolens*. Threadleaf rubber rabbitbrush also occurs in alkaline soil outside the Great Basin from western Wyoming, Colorado, and New Mexico to northeastern Oregon and eastern California. A large ecotype, up to 12 ft (3.7 m) tall with treelike trunks, occurring principally in the western parts of its range, was formerly recognized as a separate subspecies (*viridulus*) (fig. 36). Perhaps ssp. *viridulus* should be maintained as it is higher in rubber content and in resins than ssp. *consimilis* (Ostler and others 1986). Another subspecies, *pinifolius*, has also been reduced to be synonymous with *consimilis* (Anderson 1986a). Plants formerly referred to as *pinifolius* grow in southern Colorado and New Mexico. Threadleaf rubber rabbitbrush is one of the least palatable of the *C. nauseosus* subspecies. It may, therefore, have value in revegetating disturbed sites such as roadcuts where attraction of browsing animals is not desired. This subspecies helps control erosion on open alkaline soils by providing ground cover and soil stabilization (McArthur and others 1979a).

Green rubber rabbitbrush (*C. n.* ssp. *graveolens*) ranges from 2 to 5 ft (0.6 to 1.5 m) high when mature. Its leafy, erect branches are yellow-green to green or sometimes gray-green and are covered with a compact tomentum (fig. 41). The linear leaves are 1 to 3 mm wide, 4 to 6 cm long, and only slightly pubescent. The involucral bracts are 6 to 8 mm long, glabrous at least on their backs, acute, keeled, and arranged in vertical rows. Achenes are densely pubescent. Green rubber rabbitbrush is widespread and sporadic from North Dakota to Idaho and southward to western Texas, New Mexico, and Arizona. It is most common on well-drained foothills but also extends up into the mountains and down into valleys and plains where it is often intermixed with ssp. *consimilis*. Green rubber rabbitbrush is generally less palatable than the white or gray subspecies, *hololeucus*, *albicaulis*, and *salicifolius*. Nevertheless, some forms of this subspecies have been found that are utilized to a moderate degree by livestock and mule deer.

Mountain rubber rabbitbrush (*C. n.* ssp. *salicifolius*) is a shrub from 1 to 6.5 ft (0.3 to 2.0 m) high. Its ascending to erect twigs are leafy and covered with a gray-green, fairly compact tomentum. The leaves are broadly linear, ranging from 4 to 8 cm long and 3 to 10 mm wide, which makes them the largest leaves of the species (fig. 41). The involucral bracts are 7 to 8 mm long, mostly obtuse, nearly glabrous, and arranged in rather obscure ranks. The yellow corollas are about 1 cm long and have a minutely pubescent throat. The achenes are densely pubescent. Hall and Clements (1923) reported that mountain rubber rabbitbrush is "apparently rare and confined to Utah." However, McArthur and others (1979a) found it to be fairly widespread at higher elevations in Utah and perhaps extending to Nevada as part of the lower subalpine vegetation. It extends down to the foothills in parts of its range where it may be found intermixed with ssp. *albicaulis*, *hololeucus*, and *graveolens* (Plummer 1977). Mountain rubber rabbitbrush appears to be the most palatable subspecies for both livestock and big game of the five common subspecies, *salicifolius*, *albicaulis*, *hololeucus*, *graveolens*, and *consimilis* in Utah, and it is often browsed heavily in the fall (McArthur and others 1979a).

Other less common subspecies with locally large populations include *arenarius*, *junceus*, *leiospermus*, and *turbinatus*. Subspecies *arenarius* is a striking white shrub adapted to sand dunes in the Four Corners area. It has large heads up to 20 mm long. Subspecies *junceus* is a nearly leafless, yellow-green form adapted to sandy areas in the Colorado River drainage. Subspecies *leiospermus* is a low shrub usually less than a meter in height. It has affinities to ssp. *consimilis*. It occurs mostly on arid, rocky sites in the southern half of the Intermountain area. A distinguishing feature of ssp. *leiospermus* is its glabrous or nearly glabrous achenes. Subspecies *turbinatus* is a yellow form adapted to sandy sites, mostly in western Utah. It has large floral heads. A few additional subspecies occur principally outside of the Intermountain area. These include *bigelovii* (mostly south and west of the Four Corners area), *nauseosus* (mostly on the western edge of the northern Great Plains), and *mohavensis* (southern California) (Anderson 1986a,c; McArthur and Meyer 1987; McArthur and others 1979a).

Chrysothamnus parryi

Parry Rabbitbrush

Parry rabbitbrush (*Chrysothamnus parryi*) is a shrubby species somewhat intermediate in height, stem and leaf tomentum, and growth habit between rubber rabbitbrush and low rabbitbrush. Parry rabbitbrush is a low, dense shrub similar in habit to certain forms of low rabbitbrush (fig. 42). It is usually from 8 to 24 inches (20.3 to 61.0 cm) in height with numerous spreading to erect flexible branches. Like rubber rabbitbrush, the branches of Parry rabbitbrush are covered with a feltlike white to green tomentum. The tomentum is neither as dense nor resinous as in rubber rabbitbrush. Paulsen and Miller (1968) and McArthur and others (1979a) observed that Parry rabbitbrush spread from underground roots. The glabrous to tomentose, somewhat viscid leaves are narrowly linear to elliptic and range in size from 0.5 to 8 mm wide and 1 to 8 cm long. Flowerheads usually are arranged in terminal leafy racemes that sometimes form panicles. The involucral bracts are 9 to 14 mm

Figure 42—Parry rabbitbrush (*C. parryi* ssp. *howardi*) growing at Current Creek, Duchesne County, UT.

high and terminate in acuminate to very attenuate herbaceous tips. The yellow, tubular to funnelform corollas are 8 to 11 mm long. Achenes are 5 to 6 mm long and are covered with long, shaggy, appressed hairs. Blooming occurs from July to September; seed matures in October and November.

Ecological Relationships and Distribution

Parry rabbitbrush occurs in dry, open places in mountains and foothills of Western North America from Wyoming and western Nebraska west to California and south to New Mexico and Arizona. Like other species of rabbitbrush, this species tends to increase on overgrazed and disturbed areas. Populations of Parry rabbitbrush are usually smaller and more scattered than those of the other common species (rubber and low rabbitbrushes) of rabbitbrush.

Varieties and Ecotypes

Parry rabbitbrush is a diverse widespread group, with 12 subspecies (Anderson 1986a; McArthur and Meyer 1987).

Chrysothamnus parryi ssp. *asper* is a low shrub 6 inches (15.2 cm) or more high with slightly spreading to erect branches. Its green leaves, roughened with short-stalked resin glands, are 2 to 5 cm long and 1 to 3 mm wide. The heads contain five to 10 disc flowers and are subtended by somewhat ranked involucral bracts with straight tips. This subspecies occurs on mountain sides bordering desert areas from 6,900 to 8,500 ft (2,100 to 2,600 m) in elevation in western Nevada and eastern California (Anderson 1986a; McArthur and others 1979a).

Chrysothamnus parryi ssp. *attenuatus* consists of low shrubs with mostly erect stems up to 2 ft (61.0 cm) high. It has green, slightly viscid, narrowly linear leaves, 2 to 4 mm long and about 1 mm wide. The leaves are erect but are not larger than the inflorescence. Heads contain five to seven disc flowers and are subtended by involucral bracts with slender, straight tips. The bracts are ranked into five vertical rows. Blooming occurs from August to October. Subspecies *attenuatus* is found in the sagebrush, pinyon-juniper, and yellow pine vegetation types in Utah and southwestern Colorado and northwestern New Mexico (Anderson 1986a; McArthur and others 1979a).

Chrysothamnus parryi ssp. *howardii* is a low shrub. Its spreading basal stems and erect branches are up to 2 ft (61.0 cm) high. The narrowly linear, tomentose leaves are 2 to 4 cm long, about 1 mm wide, and the upper ones usually extend beyond the uppermost heads of the inflorescence. Flowerheads contain five to seven pale yellow disc flowers. The heads are subtended by vertically ranked involucral bracts usually with spreading tips. Blooming occurs from July to September. The subspecies occurs on dry hills and mesas associated with sagebrush, pinyon-juniper, and ponderosa pine vegetational types in Utah, southern Wyoming, Colorado, New Mexico, and Nebraska (Anderson 1986a; McArthur and others 1979a).

Chrysothamnus parryi ssp. *monocephalus* is a low shrub from 4 to 24 inches (10.2 to 61.0 cm) high with rigid, spreading branches. Its viscid, somewhat tomentose leaves are linear-oblanceolate or spatulate, 1 to 3 cm long and 1.5 cm or less wide. The upper leaves usually extend beyond the inflorescence. The flowering heads occur singly or in pairs on the end of short, leafy branches. The heads contain five to six disc flowers and are subtended by obscurely ranked involucral bracts with straight, attenuate tips. This subspecies occurs in the high mountains of western Nevada and eastern California at elevations between 2,600 and 11,000 ft (790 and 3,400 m) (McArthur and others 1979a).

Nevada rabbitbrush (*Chrysothamnus parryi* ssp. *nevadensis*) consists of low shrubs with ascending to erect branches up to 2 ft (61.0 cm) high. The linear to linear-oblanceolate leaves are 1.5 to 4 cm long, 0.5 to 3 mm wide, and sometimes green to resinous, but usually gray-tomentose. The uppermost leaves rarely extend beyond the inflorescence. The flowering heads contain four to six yellow disc flowers and are subtended by ranked involucral bracts with slender recurved tips. *Chrysothamnus parryi* ssp. *nevadensis* occurs between 4,300 and 8,900 ft (1,300 and 2,700 m) in elevation on dry mountain sides from eastern California to eastern Nevada, southwestern Utah, and northern Arizona. It is most common along the eastern flank of the Sierra Nevada (Anderson 1986a; McArthur and others 1979a).

Chrysothamnus parryi ssp. *parryi* consists of low shrubs with erect branches 1 to 2.5 ft (30.5 to 76.2 cm) high. The uppermost leaves usually extend beyond the inflorescence. Flowering heads contain 10 to 20 disc flowers and are subtended by obscurely ranked involucral bracts with straight attenuate tips. It blooms during August and September. Subspecies *parryi* grows in dry plains, valleys, and hillsides in central Nevada, southern Utah, south-central Wyoming, western Colorado, and northern New Mexico (Anderson 1986a; McArthur and others 1979a).

A few other subspecies of *C. parryi*, such as *affinis*, *glandulosa*, *imulus*, and *vulcanicus*, occur outside of or only on the fringe of the Intermountain area and in small numbers (Anderson 1986a; Hall and Clements 1923). No efforts have been made to improve Parry rabbitbrush. The species contains abundant genetic variation. Its ssp. *howardii* is thought to be involved in the parentage of *C. nauseosus* ssp. *utahensis* (Anderson 1984).

Chrysothamnus vaseyi

Vasey Rabbitbrush

Vasey rabbitbrush is a low, rounded shrub with ascending to erect branches up to 1 ft (30.5 cm) high. The bark on the young branches is pale green to whitish and glabrous, becoming brown and fibrous with age. Leaves are linear to linear-oblanceolate, 1 to 2.5 cm long, 1 to 3 mm wide, and glabrous. Heads contain five to seven disc flowers each and are arranged into small, compact cymes. The obscurely ranked involucral bracts are 5 to 7 mm high, oblong, obtuse to rounded, and all but the innermost have a thickened greenish spot near the apex. The achenes are about 5 mm long, terete, longitudinally 10-striate, and glabrous. Blooming occurs from July to September; seed matures from October until mid-December (table 1).

Vasey rabbitbrush occurs scattered over plains, hillsides, and mountain valleys at altitudes of 5,600 to 8,500 ft (1,700 to 2,600 m) mostly in Utah and Colorado, but also in New Mexico and Wyoming (Anderson 1986a; Hall and Clements 1923).

This shrub is browsed by sheep but is small and so scattered that it provides little forage (McArthur and others 1979a).

Chrysothamnus viscidiflorus

Low Rabbitbrush

Low rabbitbrush varies in appearance and foliage characteristics. It is usually 1 to 3.5 ft (0.3 to 1.1 m) tall with many erect stems branching from a simple base (fig. 43). The brittle, erect twigs are glabrous or puberulent with pale green or white bark. Leaves are narrowly linear to oblong or lanceolate, 1 to 6 cm long and often twisted. Leaf vestiture is glabrous or pubescent and commonly viscidulous with usually scabrous margins. Degree of pubescence may vary tremendously in variants of this species. As Hall and Clements (1923) pointed out, sometimes the pubescence among the subspecies of low rabbitbrush "will occur as a fairly dense though minute puberlence in certain plants, while others almost exactly duplicating these in every other respect will be perfectly glabrous." Furthermore, L. C. Anderson (n.d.) has observed good correlation between plant stature and leaf size of ssp. *visicidiflorus* and *lanceolatus* with altitude and amount of precipitation. Flowerheads containing approximately five perfect, fertile disc flowers each are arranged in compact terminal cymes. Involucral bracts number about 15 per head and are arranged in poorly to well defined vertical ranks. The bracts of some subspecies have a greenish or brownish thickened spot near their apex (McArthur and others 1979a). Flowering occurs from August through October; seed matures from October to the end of December. Low rabbitbrush produces about 3.4 million seeds per lb (7.5 million/kg) of cleaned seed (see chapter 24). This species has strong basal sprouting tendencies, especially following top removal and injuries (Wasser 1982).

Ecological Relationships and Distribution

Low rabbitbrush is one of the most widely distributed shrubs on rangeland throughout Western North America (Anderson 1986a,b; McArthur and Meyer 1987). The species has great ecological amplitude. It occurs in dry, open areas from British Columbia and Montana, south to New Mexico, Arizona, and eastern

Figure 43—Low rabbitbrush growing at the Snow Field Station, Sanpete County, UT. This specimen is a mountain low rabbitbrush (*C. viscidiflorus* ssp. *lanceolatus*).

California at elevations between 2,600 and 11,000 ft (790 and 3,400 m). Low rabbitbrush is usually associated with sagebrush, snakeweed, and other species of rabbitbrush. Anderson (1986b) has shown that polyploid races in those subspecies where polyploidy occurs (ssp. *lanceolatus*, *puberulus*, *viscidiflorus*) are adapted to lower and drier sites than their diploid counterparts (Anderson 1986b).

Plant Culture

Low rabbitbrush can be transplanted in the fall and spring. When transplanting in the fall consideration needs to be given to frost heaving potential. Fall seeding is preferred; seed can be drilled or broadcast, and seed should not be covered more than 1/8 inch (3.2 mm). Seeds can be harvested by hand and by vacuum harvesting techniques.

Uses and Management

This shrub may provide an important supply of browse to both game and livestock, particularly during late fall and winter after more desirable forage has been consumed. Throughout the Great Basin, low rabbitbrush, especially the flowering shoots, provide good sheep feed. In California small amounts of low rabbitbrush were found in deer stomachs examined between October and January (Sampson and Jespersen 1963). Much variation exists in palatability among the different subspecies. Some may be heavily utilized, whereas others are consumed little if at all (McArthur and others 1974). Variety *stenophyllus* of ssp. *viscidiflorus* on rocky foothills is often heavily used, and sometimes destructively so, with animals preferring mature or partially mature plants to green immature ones. On a Utah winter range, this subspecies averaged to 11.31 percent by weight of the diet of sheep (Cook and Harris 1950; Cook and others 1954). On another Utah winter range, mule deer diets consisted of over 80 percent low rabbitbrush in December (Austin and Urness 1983). Substantial use of ssp. *lanceolatus* in widely scattered areas of Utah and Nevada has been observed (McArthur and others 1979a). Antelope, elk, and bighorn sheep, as well as deer and livestock, show varying preferences for low rabbitbrush, depending on season, locality, and subspecies (Kufeld 1973; Kufeld and others 1973). The species, like rubber rabbitbrush, increases rapidly and vigorously on otherwise disturbed sites. Some subspecies such as stickyleaf low rabbitbrush (ssp. *viscidiflorus*) and mountain low rabbitbrush (ssp. *lanceolatus*) adapt well to higher elevations, while other subspecies such as hairy low rabbitbrush (ssp. *puberlus*) do best in lower desert and foothill habitats. Low rabbitbrush is valuable for revegetating depleted rangelands and other disturbed sites such as strip mines and roadsides (Plummer 1977).

Varieties and Ecotypes

This species includes five subspecies and several ecotypes within subspecies (Anderson 1980, 1986b; McArthur and Meyer 1987). Most important among these in the Great Basin are two glabrous subspecies, *viscidiflorus* and *axillaris*, and two pubescent subspecies, *lanceolatus* and *puberulus*. Anderson (1980) reduced ssp. *stenophyllus* to varietal status under ssp. *viscidiflorus*. Hall and Clements (1923) believe numerous intergrades have been held together in one rather close species through interbreeding where their ranges meet or overlap. Abrams and Ferris (1960) describe *C. viscidiflorus* as a highly polymorphic species composed of several freely intergrading subspecies of overlapping distribution. Intermediates are invariably found in the field. We believe forms of low rabbitbrush may be improved for grazing and other uses through selection and breeding. Because each subspecies is self-fertilized and predominately self-pollinated, each maintains its identify despite occasional outcrossing (McArthur and others 1978a).

Mountain low rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *lanceolatus*) is a small shrub from 8 to 20 inches (20.3 to 50.8 cm) tall (fig. 43, 44). Its branches are straw colored or gray and are finely pubescent. Flowerheads are borne in small compact cypes with densely pubescent branches. Involucral bracts are 5.9 to 6.5 mm long, lanceolate to oblong, obtuse, and

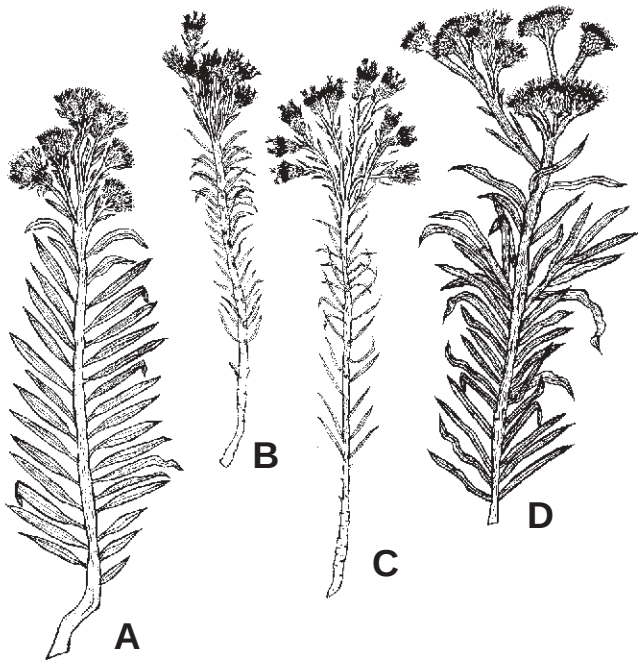


Figure 44—Three subspecies and a variety of low rabbitbrush: (A) *C. viscidiflorus* ssp. *lanceolatus*; (B) *C. viscidiflorus* ssp. *publerus*; (C) *C. viscidiflorus* ssp. *viscidiflorus* var. *stenophyllus*; (D) *C. viscidiflorus* ssp. *viscidiflorus*.

glabrous to pubescent. Achenes are densely strigose. On the basis of his systematic investigations in the genus *Chrysothamnus*, Anderson (1980) recommended placing the former ssp. *elegans* in synonymy with *C. viscidiflorus* ssp. *lanceolatus*. Chromatographic work by McArthur and others (1978a) supports this consolidation. Mountain low rabbitbrush is widespread and fairly common in dry foothill and mountainous habitats from 5,000 to 10,500 ft (1,500 to 3,200 m) ranging from British Columbia, east to Montana, and south to New Mexico, Utah, and Nevada. This subspecies may be found growing with such shrubs as big sagebrush, snakeweed, various subspecies of rubber rabbitbrush, Greene's rabbitbrush (*C. greenei*) and Parry rabbitbrush (*C. parryi*) (McArthur and others 1979a).

Hairy low rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *puberlus*) is a small shrub up to 20 inches (50.8 cm) high with yellowish to green, finely pubescent branches (fig. 44). Its linear-filiform to linear leaves are sparsely to densely pubescent with scabrid-ciliate margins and are usually twisted or revolute. The leaves are up to 2 mm wide and up to 3 cm long. Flowerheads are borne in small compact cymes with densely pubescent branches. Involucral bracts are about 5 to 6 mm long, lanceolate to oblong, acute to obtuse, and are usually marked with a thickened greenish spot near their tips. Hairy low rabbitbrush occurs on dry plains, valleys, and foothills, especially on poorer soils and disturbed areas. Its range is essentially the Great Basin area from southern Idaho and Oregon south through Utah and Nevada to eastern California and northern Arizona (Anderson 1986a). This subspecies is most abundant in the big sagebrush communities of western Utah, Nevada, and south-central Idaho. However, it has been found growing in one locality or another with most of the other subspecies of low rabbitbrush, shadscale, winterfat, halogeton, and occasionally with pinyon and juniper (McArthur and others 1979a).

Stickyleaf low rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *viscidiflorus*) is the largest subspecies of low rabbitbrush. Mature shrubs are usually more than 20 inches (50.8 cm) tall, whereas the other subspecies are normally under 20 inches (50.8 cm). Its branches, leaves, and inflorescences are glabrous but viscid (sticky). The broadly linear to narrowly lanceolate, bright green leaves are 1 to 5 mm wide, 2 to 5 cm long, and flat to twisted (fig. 44). Leaf margins are sometimes scabrid. Crushed foliage usually emits a pungent odor. Branches of the stems are glabrous. Involucral bracts are obtuse, oblong, not keeled, and 5 to 7 mm long. Stickyleaf low rabbitbrush is widely distributed on dry plains and hills from Washington, Idaho, Montana south to Colorado, Utah, Nevada, northern Arizona, and eastern California. It occurs primarily in sagebrush and pinyon-juniper communities at elevations between 5,000 and 8,500 ft (1,500 and 2,600 m). This subspecies often becomes dominant in cleared or overgrazed areas. At lower elevations stickyleaf low rabbitbrush may be associated with such halophytes as shadscale, winterfat, and halogeton. Other subspecies of low rabbitbrush are also often associated with it.

Anderson (1971) recommends placing the former ssp. *pumilis* in synonymy with *C. viscidiflorus* ssp. *viscidiflorus* because its specimens are "only environmentally modified variants of *C. v.* ssp. *viscidiflorus*." Chromatographic work (McArthur and others 1978a) supports Anderson's reduction of *pumilus* to synonymy. Because of its distribution from moist to arid sites, the species is well suited to a wide range of disturbed sites over the Western States (McArthur and others 1979a). Recently Anderson (1980) reduced ssp. *stenophyllus* to varietal status under ssp. *viscidiflorus*. This variety is known as narrowleaf low rabbitbrush (fig. 44). It is a low, glabrous shrub up to 12 inches (30.5 cm) high with white bark. Leaves are linear-filiform, often twisted, viscidulous, 1 mm or less wide, 1 to 3 cm long, and glabrous except for the usually scabrid and revolute margins. The branches of the small, compact cymes are glabrous. Involucral bracts are 4 to 6 cm long, not keeled, and lance-oblong.

Narrowleaf low rabbitbrush is rather common on many desert ranges, particularly in the northern Great Basin and adjacent areas (Anderson 1980, 1986c). On these ranges this variety is usually found in the sagebrush type on poorer soils and disturbed sites, but is also found growing with halophytes such as shadscale, fourwing saltbush, greasewood, and halogeton.

Anderson (1980, 1986a) recognized two other subspecies of low rabbitbrush. These are ssp. *axillaris* and *planifolius*. The former subspecies is morphologically quite similar to var. *stenophyllus*, but occurs mostly in the southern Great Basin and on the Colorado Plateau and appears by its somewhat attenuate bracts to be introgressed by Greene's rabbitbrush. It is quite abundant in certain locales. Subspecies *planifolius* is a local form with small heads and flat leaves endemic to Coconino County, AZ (Anderson 1986a).

Other Rabbitbrushes

Alkali rabbitbrush (*C. albidus*) and Greene's rabbitbrush (*C. greenei*) are two other relatively important species. Alakli rabbitbrush is a much branched, leafy shrub. It has erect, brittle, glabrous, very resinous, whitebarked branches up to 3 ft (91.4 cm) high. The glabrous, filiform leaves are 1.5 to 4 cm long, 0.5 to 2 mm wide, and the margins become revolute. Their

surface is covered with small pits and abundant resinous exudate. Heads with four to six white disc flowers each are arranged in small compact cymes. Each head is subtended by approximately 15 glabrous, resinous, involucral bracts. These are 7 to 9 mm long and terminate in attenuate to acuminate, usually curved tips. The pappus is abundant and longer than the corollas. Mature achenes are about 4 mm long and densely covered with long soft hairs. Blooming occurs from August to November. This species is a definite halophyte. It occurs most commonly along the western side of the Great Salt Lake desert but is also found across Nevada to eastern central California in alkaline soils. Alkali rabbitbrush may invade strongly alkaline areas as a pioneer plant. In less alkaline flats it may be associated with threadleaf rubber rabbitbrush, basin wildrye, and greasewood. This species has value as ground cover on alkaline soils (McArthur and others 1979a).

Greene's rabbitbrush is a small highly branched shrub only 4 to 14 inches (10.2 to 35.6 cm) high. Its glabrous brittle twigs are green at first but soon become white and shiny. Bark on the lower branches often peels off in sheets (Hall and Clements 1923). The nearly glabrous or slightly scabrous-ciliate leaves are narrow, linear, 1.2 cm or less wide, 1 to 3.5 cm long, and are more or less viscidulous. Flowerheads normally contain five disc flowers in rounded or flat topped cymes. The involucral bracts are 5 to 7 mm long, arranged in five poorly defined vertical ranks, and terminate in narrowly acuminate, greenish tips. The tubular to funnelform corollas may be whitish or yellow and 4 to 4.5 mm long. Achenes are about 3 mm long and are covered with dense, long, shaggy hairs. Greene's rabbitbrush has been divided into two subspecies, ssp. *greenei* and ssp. *filifolius* by some authors (Hall and Clements 1923; Harrington 1964; Kearney and Peebles 1960). These authors separate ssp. *filifolius* from *greenei* by its normally larger stature and shorter narrower leaves. McArthur and others (1978a) believe no subspecies should be recognized because the purported subspecies are (1) chromatographically similar and (2) often occur in mixed populations. The chromatographic data from McArthur and others (1978a) further suggest that *C. greenei* could be considered a subspecies of *C. viscidiflorus* rather than a separate species. *Chrysothamnus greenei* closely resembles *C. viscidiflorus*, particularly ssp. *axillaris* and ssp. *viscidiflorus* var. *stenophyllus*. All have a low bushy habit, whitebarked stems, and short narrow leaves. Furthermore, ssp. *axillaris* has involucral bracts with attenuate tips (Anderson 1964) that closely resemble those of *C. greenei*. We concur with Hall and Clements (1923) who felt the similarity between *C. greenei* and *C. viscidiflorus* indicated a close genetic relationship. Greene's rabbitbrush occurs on plains, valley, and foothills in Colorado, New Mexico, Nevada, and Utah. Overgrazing allows it to greatly increase, sometimes forming a subclimax community (Hall and Clements 1923). This species provides cover and emergency browse in areas where it is abundant.

There are several other rabbitbrush species (Anderson 1986a). These are all less common than the species discussed or are outside of the geographical area of concern for this treatment. These are *C. gramineus* and *C. eremobius* both related to the genus *Petradoria* and of limited distribution in uplands of southern Nevada (and for *C. gramineus*, adjacent California). *Chrysothamnus molestus* is a rare, distinctive species from Coconino County, AZ. Both *C. pulchellus* and *C. spatulatus* are distinctive species that occur southeast of the main distribution of the genus *Chrysothamnus*. *Chrysothamnus humilus* is similar in some respects to low rabbitbrush, but is distributed on the northwest fringe of the species distributional range. Both *C. paniculatus* and *C. teretifolius* are viscid hot desert southwest shrubs. The former is more common in gravelly washes whereas the latter occurs mostly on rocky slopes.

Other Composite Shrubs

Haplopappus species (goldenweed), *Tetradymia* species (horsebrush), *Gutierrezia* species (matchbrush or snakeweed), *Lepidospartum latisquamatum* (scalebroom)

Both goldenweed and snakeweed belong to the same tribe (Astereae) of Compositae that rabbitbrush does (McArthur and others 1978a). Horsebrush and scalebroom belong to the tribe Senecionieae. *Haplopappus* is a large genus that is mostly herbaceous. Its constituent species are widely distributed but usually scattered over Western rangelands (Hall 1928; USDA Forest Service 1937). The most notable shrubs are goldenweed rabbitbrush (*Haplopappus bloomeri*) and its near relatives (Anderson 1983). Goldenweeds are generally of little forage value, but they are of value in erosion control (USDA Forest Service 1937). Other shrubby goldenweeds include *H. macronema*, *H. suffruticosus*, *H. resinosus*, *H. greenei*, and *H. carthamoides* (Hitchcock and others 1955).

The genus *Tetradymia* consists of rather low, stiffly branched shrubs (fig. 45). The stems are uniformly canescent or have glabrous to woolly streaks running down the stem internodes from the primary leaves. The tomentum may be permanent or deciduous on both the stem and leaves. Spines may be present (fig. 46). *Tetradymia* bears primary and secondary leaves. Primary leaves develop alternately along

Figure 45—Gray horsebrush growing at Wasatch Station, Summit County, UT.

elongated shoots and are usually long-lived. Secondary leaves develop in fascicles in the axils of the primary leaves. They are generally short-lived and often dry up and fall away within a few weeks (Strother 1974). Horsebrush flowers are borne in heads located singly or in pairs in the upper primary leaf or spine axils or are clustered in short, dense racemes or corymbs at the tips of branches. Each head contains from four to nine yellow disc flowers. Ray flowers are lacking. Four to six equal involucral bracts with overlapping sides subtend each head. The pappus consists of numerous bristles or scales or may be lacking. The ovary of each flower develops into a glabrous to densely longhaired achene.

This genus blooms from April to August depending on elevation, climatic conditions, and species. Numerous small moths, bees, flies, and beetles visit the

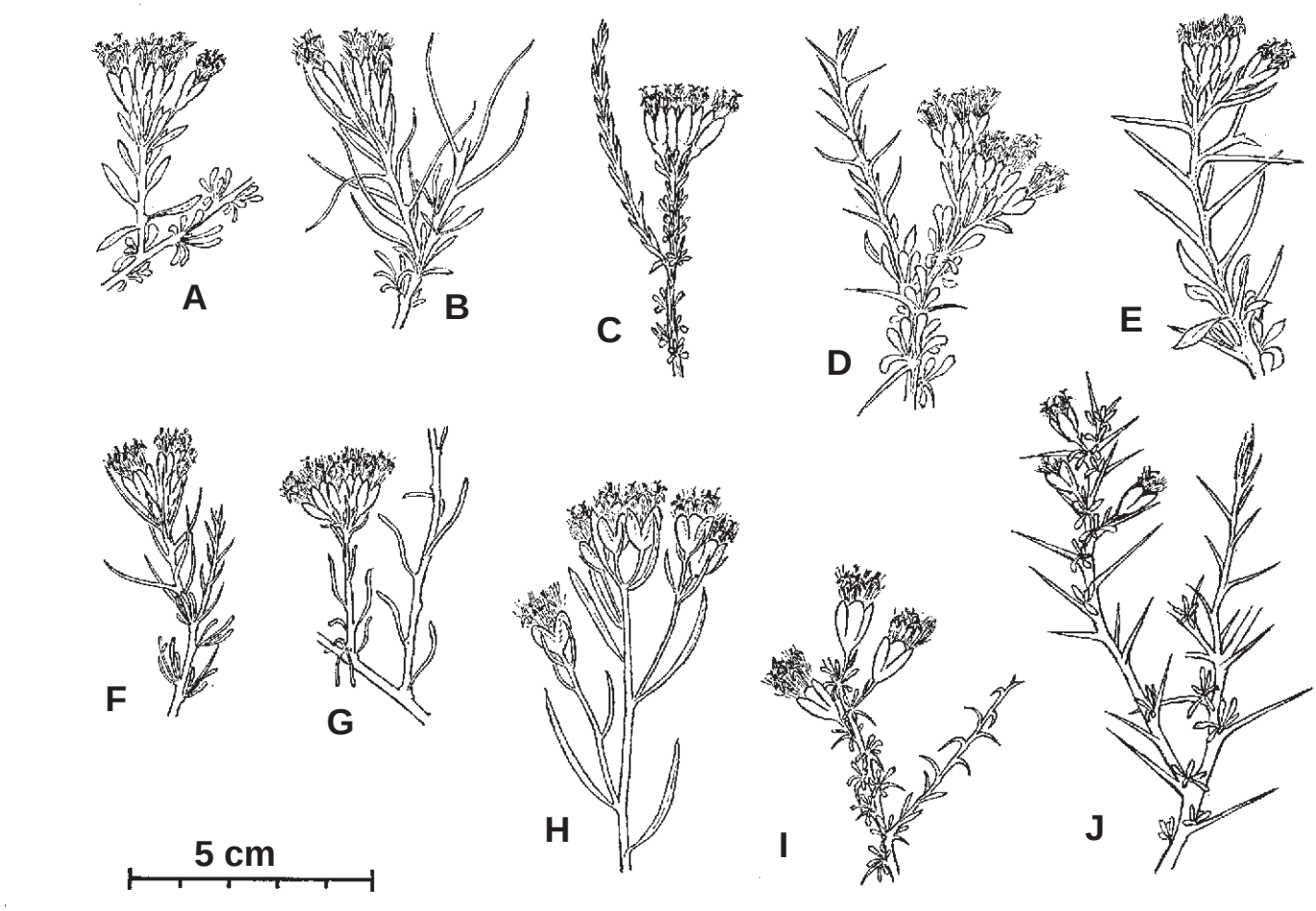


Figure 46—Horsebrush species (Strother 1974): (A) *Tetradymia canescens*, (B) *T. filifolia*, (C) *T. glabrata*, (D) *T. nuttallii*, (E) *T. stenolepis*, (F) *T. argyraea*, (G) *T. tetrameres*, (H) *T. comosa*, (I) *T. spinosa*, (J) *T. axillaris* var. *longispina*.

flowers. Although numerous potential pollinators are available and the flowers are highly fertile, seedlings are not commonly seen in nature. This is probably due to the harsh environment in which horsebrush is usually found (Strother 1974). However, young plants and sprouts may be found growing in burned-over areas (McArthur and others 1979a). Horsebrush provides some critically needed ground cover in the dry, sparsely vegetated desert ranges where it grows. Although several species are poisonous to sheep and have caused losses of thousands of animals in Utah and Nevada, horsebrush is browsed particularly heavily during winter and early spring on desert ranges and overgrazed areas where little else may be available this time of year. In fact, Zimmerman (1980) has built a successful winter range cattle operation in central Nevada on horsebrush and other desert shrub species that are often considered useless. Severe losses have occurred when hungry animals have been trailed from winter to summer ranges through stands of horsebrush without allowing the animals a chance to graze other plants (Kingsbury 1964). Considerable variation in toxicity within and between species of *Tetradymia* has been noted by Johnson (1974a,b), who believed ingesting black sagebrush and horsebrush under certain poorly understood conditions is responsible for toxicity. Four horsebrush species (*T. canescens*, *T. glabrata*, *T. nuttallii*, and *T. spinosa*) are quite common in the Intermountain area. The first two species are spineless, and the latter two are spiny (McArthur and others 1979a). *Tetradymia axillaris*, another spiny species, occurs on the edge of the Intermountain area in scattered populations from southwestern Utah to southern California. Two other species are found southwest of the Intermountain area: *T. argyraea* (southeastern California) and *T. comosa* (southern California and Baja California) (McArthur and others 1979a; Strother 1974).

The broom snakeweeds (*Gutierrezia* formerly *Xanthocephalum*) consist of mainly perennial herbs and low suffrutescent shrubs (subshrubs) with woody roots, crowns, and stem bases (fig. 47). A few species are annuals (Lane 1985). However, of these only, *G. sphaerocephala* occurs in the Intermountain area (in New Mexico). These perennials are ordinarily short-lived as well. Snakeweed leaves are entire, linear to narrowly oblanceolate, and usually sticky from resin exuded to the surfaces of both leaves and young stems. Numerous small heads form in loose or crowded terminal clusters. Resinous, imbricated involucral bracts within thin membranous margins and green tips subtend each head. A few yellow ray and disc flowers are both present (fig. 48). The ray flowers are usually pistillate and fertile, while the disc flowers are usually perfect and fertile or sometimes staminate. Pappi of several small scales or awns are

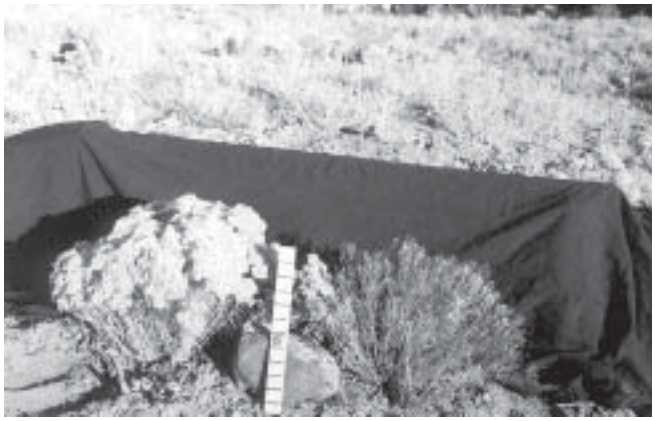


Figure 47—Broom snakeweed, right, growing next to hairy low rabbitbrush, left, near Ephraim, Sanpete County, UT.

generally pubescent. Blooming occurs from May to October. The numerous common names of this genus are perhaps indicative of its wide distribution. The genus consists of about 25 species scattered throughout western North and South America (Hitchcock and others 1955; Lane 1985). Only two of these species, *G. sarothrae* and *G. microcephala*, are of importance in the Intermountain area although there are two less common endemics, *G. petradoria* and *G. pomariensis* (Welsh and others 1987). Some additional North American species include *G. bracteata*, *G. californica*, and *G. serotina* (Lane 1985; McArthur and others 1979a; Solbrig 1971; . Snakeweed commonly invades depleted ranges and is considered an indicator of

Figure 48—Broom snakeweed, right, with its showy ray flowers, growing next to Parry rabbitbrush, left, in Salina Canyon, Sevier County, UT.

overgrazed rangelands. It does occur, usually in a low, but fluctuating density, in ranges in good to excellent condition. Species in this genus are generally unpalatable and seldom grazed. When eaten in quantity, this plant is more or less poisonous to sheep and goats (Benson and Darrow 1945; Kearney and Peebles 1960).

Scalebroom (*Lepidospartum latisquamatum*) is confined to sandy washes and gravelly plains in the Mojave Desert extending to the southwestern portion of the Intermountain area (Kay and others 1977e). This plant superficially resembles rubber rabbitbrush but is a member of the tribe Senecioneae and hence has diagnostic morphological as well as chemical differences from rabbitbrush (McArthur and others 1978a). Scalebroom has potential use as a revegetation plant in areas where it is adapted (Graves and others 1975; Kay and others 1977e). These authors demonstrated that seed should be planted less than 1 cm deep. Furthermore, seed viability is lost rapidly (in less than 2 years) if not stored in sealed containers.