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Chapter 20

Chenopod Shrubs

Chenopod plants (Family Chenopodiaceae) are distributed worldwide but are especially prominent in some wet and dry saline or alkaline situations. Chenopods are both herbaceous and woody. The relative proportions of life-forms in the family is demonstrated by data from the important center of chenopod diversity in south-central Asia, where n = 341 species: 76 percent are herbaceous (mostly annual), 23 percent are shrubs or subshrubs, and 1 percent is arborescent (McArthur and Sanderson 1984; Shishkin 1936). Chenopod shrubs grow over wide expanses of Intermountain rangelands as well as on large saline and alkaline tracts on all continents, except Antarctica. In the Intermountain area, seven genera (table 1) with 28 species make important contributions to the landscapes or to revegetation needs.

As a group the chenopod shrubs exhibit the ability to grow in low fertility, salt-bearing soils as well as on more favorable sites. Their presence is essential for maintaining a stable soil in many xeric environments where soil is too salty or dry for most other classes of plants to live (Blauer and others 1976; Goodall 1982; Sanderson and Stutz 1994b; Wilkins and Klopatek 1984). Chenopod shrubs grow well in high concentrations of calcium and potassium salts and can endure considerable concentrations of

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sodium salts (Gates and others 1956; McNulty 1969; Moore and others 1972). Certain ones grow through a much wider range of alkalinity than others (table 2). A few tolerate such high salt concentrations that they are the only plant life. As a group they are especially suited for planting on depleted salt desert shrub type range areas as well as on construction scars, mine spoils, and roadcuts (McArthur and others 1978b; Plummer 1977).

Within species, large differences exist between ecotypes in morphological and physiological traits. The smaller ecotypes are usually from dry, severe sites, whereas the larger ones are from more favorable areas. Size of the shrubs is, to a large extent, genetically controlled as demonstrated by maintenance of ecotypic form in accessions grown together in uniform gardens (McArthur and others 1983a). Furthermore, Stutz and Sanderson (1983) have shown in shadscale that the smallest ecotypes growing on the most severe sites are higher polyploids, whereas lower ploidy levels occur on more favorable mesic sites. The gigas form of fourwing saltbush reported by Stutz and others (1975) is a diploid. Dunford (1985) reported consistent morphological differences among the chromosome races of fourwing saltbush. Even though genetic factors are important, moisture does, of course, markedly affect luxuriance and growth. Wallace and others (1974) reported that 40 percent of the biomass of fourwing saltbush is in the root system.

Shrubby chenopods have a chromosome number based on x = 9. Polyploids occur in most genera (Blauer and others 1976; McArthur and Sanderson 1984). They are wind pollinated, occur in sympatric distributions, are monoecious, dioecious, or even trioecious—factors that lead to common interspecific hybridization (McArthur 1989). Woody chenopods show remarkable capability to hybridize both naturally (Sanderson and Stutz 1994b; Stutz 1978, 1984) and under controlled conditions (Blauer and others 1976; Drobnick and Plummer 1966; Stutz 1982). Most of the hybridization occurs within *Atriplex*, although some possible intergeneric hybrids have been reported (Blauer and others 1976).

Hybridization allows opportunity to create new gene combinations to fill new niches—for example, those in newly created mine spoils. Stutz (1982),

Table 1—Shrubby chenopods in Western America useful or potentially useful for restoration and revegetation (adapted and expanded from McArthur and others 1978b).

Scientific name	Common name
Allenrolfea occidentalis	Iodine bush or inkbush
Atriplex aptera	Wingless saltbush
Atriplex bonnevillensis	Bonneville saltbush
Atriplex canescens	Fourwing saltbush
Atriplex confertifolia	Shadscale
Atriplex corrugata	Mat saltbush
Atriplex cuneata	Castle Valley clover saltbush or cuneate saltbush
Atriplex falcata	Falcate saltbush
Atriplex gardneri	Gardner saltbush
Atriplex hymenelytra	Desert holly saltbush
Atriplex lentiformis	Big saltbush or quailbush
Atriplex navajoensis	Navajo saltbush
Atriplex obovata	Broadscale saltbush
Atriplex polycarpa	Cattle saltbush or allscale saltbush
Atriplex robusta	Robust saltbush
Atriplex semibaccata[a]	Australian saltbush
Atriplex tridentata	Trident saltbush
Camphosoma monspeliaca[a]	Mediterranean camphorfume
Ceratoides lanata	Winterfat
Ceratoides latens[a]	Pamirian winterfat
Grayia brandegei	Spineless hopsage
Grayia spinosa	Spiny hopsage
Kochia americana	Gray molly
Kochia prostrata[a]	Forage kochia
Sarcobatus vermiculatus	Black greasewood
Sarcobatus baileyi	Bailey greasewood
Suaeda suffrutescens	Desert sumpbush
Zuckia arizonica	Arizona zuckia

[a]Introduced species.

Ferguson and Frischknecht (1985), and Stutz and Estrada (1995) found that several hybrid combinations within *Atriplex* performed well on mine spoils in Utah and New Mexico. Blauer and others (1976), Carlson (1984), Stutz (1983, 1984), and Stutz and Carlson (1985) showed that there is ample opportunity to: (1) make selections from natural populations, (2) locate natural hybrids, and (3) make artificial hybrids. All three plant classes can be useful in providing plant materials to rehabilitate harsh disturbed landscapes. Sanderson and colleagues (Sanderson and Stutz 1984, 1994a; Sanderson and others 1988, 1990) have identified flavonoid compounds that are useful genetic markers in population biology and hybridization studies.

Woody chenopods show remarkable ability to grow through a wide climatic variation. Some grow in the coldest parts of the northern desert shrublands and adjacent grasslands to warmer desert ranges in the Southwestern United States and Mexico (fig. 1). Three examples are Gardner saltbush, black greasewood, and winterfat. Several chenopods readily establish, grow, and produce in areas of severe aridity or where the average annual precipitation may be less than 5 inches (12.7 cm). Important among these are winterfat, shadscale, and falcate saltbush. However, they can also quickly take advantage of three to four times this precipitation to make luxuriant growth. While the shrubby chenopods are most characteristic of the salt desert shrub type in Western North America, some grow well in limey soils on mountain ranges in association with ponderosa pine, Utah juniper, pinyon pine, Saskatoon serviceberry, and Utah serviceberry. Winterfat, fourwing saltbush, and spiny hopsage grow best in these areas. However, on

Table 2—Physical dimensions and tolerance to alkalinity of some chenopod shrub taxa (from McArthur and others 1978b).

Species	Height/crown	Adaptation to alkalinity	
		Optimum	Range
	Inches (cm)		
Atriplex canescens (Fourwing saltbush)	12-78/12-178 (30-200/30-450)	Low	Low-medium
Atriplex confertifolia (Shadscale)	6-47/6-30 (15-120/15-75)	High	Low-high
Atriplex corrugata (Mat saltbush)	1-8/8-40 (2-20/20-100)	Medium	Medium-high
Grayia spinosa (Spiny hopsage)	12-47/12-70 (30-120/30-180)	Low	Low
Ceratoides lanata (Winterfat)	2-47/6-30 (6-120/15-75)	Low	Low-medium
Allenrolfea occidentalis (Iodine bush)	6-47/12-70 (15-120/30-180)	High	High
Sarcobatus vermiculatus (Black greasewood)	40-118/40-78 (100-300/100-200)	Medium	Low-high

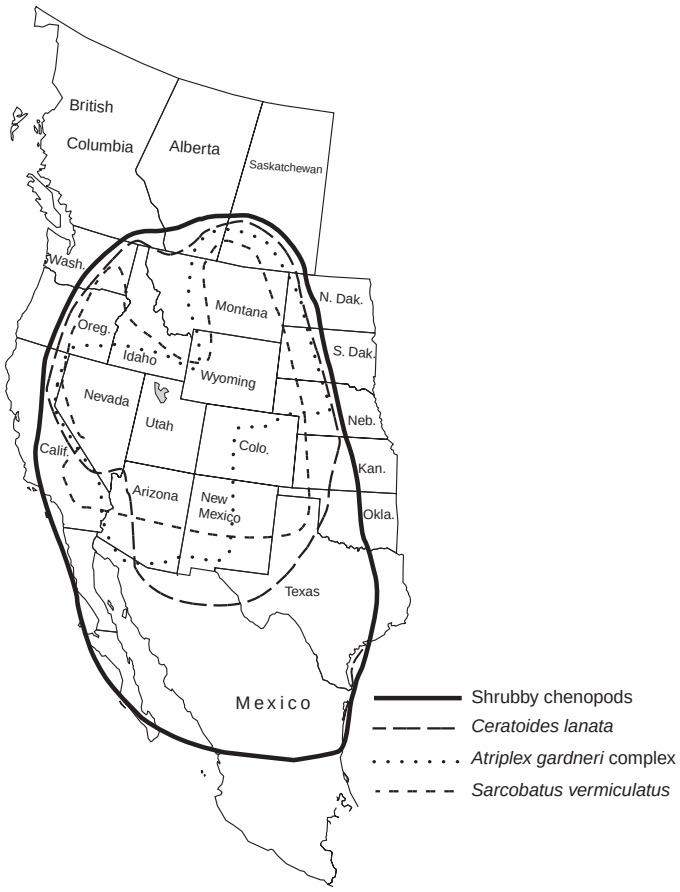

Figure 1—Distribution of shrubby chenopods in general and winterfat, greasewood, and the Gardner saltbush complex in particular. Distributions from Hall and Clements (1923), Branson (1966), and McArthur and others (1978b).

highly alkaline extrusions in these higher elevations are precipitation areas on mountain ranges where shrubby chenopods may grow to the virtual exclusion of other species (McArthur and others 1978b).

All shrubby chenopods bear a carpellate, loculed one-celled fruit known as a utricle, within which is a single seed. Actual seeds are small, usually no larger than an alfalfa seed. The utricle wall may be quite thin and easily removed from the seed, as in winterfat; or may be hard, as found in shadscale and some accessions of fourwing saltbush. Production of fruits varies widely among plants and from season to season as does percentage fill (Crofts 1977; Gamrath 1972; McArthur and others 1978b; Monsen and McArthur 1985; Springfield 1970b). To a considerable degree this relates to how favorable the growing season may be. Unless seed coats are restrictive, germination takes place quickly in a favorable environment of temperature and moisture. Utricles having indurated walls, such as in some ecotypes of fourwing saltbush and shadscale, may lay a year or more in the ground before germination. This may provide some survival value for the species because it ensures that some seeds remain in the ground to germinate and establish when temperature and moisture are most favorable. Apparently, saltbush seeds are not highly palatable to small rodents (Everett and others 1978) so they are retained in the soil. Some buildup occurs in the ground of fruits that have a tendency for delayed germination. Consequently, in favorable years many seedlings become established. Young seedlings, however, are particularly susceptible to rodent depredation (Nord and Green 1977; Young and others 1984e).

Shrubby chenopods express a number of traits that aid in artificial revegetation. The appendages attached to the utricles can be removed from most species. Except for winterfat, all seeds can be cleaned to a form that is easily handled and planted with conventional equipment (chapter 19). Cleaned seeds are of a size and shape that different seeding rates can be employed. Within a specific collection, seed germination features are uniform. However, seed germination is not so specific to a particular set of climatic conditions that all seeds germinate at any one time. An extended period of germination often assures the survival of a satisfactory number of plants. However, seed germination of winterfat is usually confined to a short duration. Seedlings and young plants are quite vigorous and are able to compete well with herbs (Giunta and others 1975).

The growth rate of nearly all shrubs is excellent. Even under adverse conditions plants grow remarkably well, often exceeding most herbs. Plants are well adapted to infertile soils and can be used to restore vegetation throughout variable, but harsh, situations. Young plantings withstand heavy browsing by game, livestock, and rodents. Individual plants normally reach maturity within 3 to 5 years, and natural spread can be expected thereafter. Once established, young plants persist under adverse climatic conditions. In addition, established plants provide high yields even when grown with a dense understory.

Chenopod shrubs frequently grow with a sparse understory but persist and grow well when seeded with numerous other plants. These shrubs normally occur throughout some principal sites or vegetative conditions important to both livestock and wildlife. The plants can be increased in density or seeded with a combination of herbaceous plants to improve forage or habitat. Many other shrubs exist within specific site conditions and do not grow well when moved to adjacent locations. Some ecotypes of many chenopod shrubs also exhibit specific site adaptation requirements, but others can be extended to additional sites (see McArthur and others 1983a).

Most shrubby chenopods are highly nutritious. They have higher protein content than most plants, particularly in the winter (Chatterton and others 1971; Esplin and others 1937; Tiedemann and others 1984a; Welch and Monsen 1981). On several species and

accessions, leaves persist and remain green well through winter. These are preferred by grazing animals during the winter and provide an important source of protein, which is vital to the well being of browsing animals on desert ranges of the West.

Without doubt, the shrubby chenopods have an important future for development of cover and forage on the generally basic soils of arid ranges worldwide. They are widely used in land rehabilitation programs (Aldon and Oakes 1982; Plummer 1984; Tiedemann and others 1984b).

Recently, Nechaeva and others (1977), Rumbaugh and others (1981, 1982), and Ostyina and others (1984) showed that most shrubs, especially some chenopods, provide complementary forage to grasses in mixed stands on semiarid ranges. Forage quality is enhanced in the mixed stands and the effective season of grazing is expanded. In addition, the forage resource is made less susceptible to attack from insects and diseases than are monocultures (Moore and others 1982).

Nord and Green (1977) identified several chenopod shrubs with potential to reduce the hazards of fire in the California chaparral. Among these were North American fourwing saltbush, Castle Valley clover saltbush, Gardner saltbush, allscale saltbush, and three Australian saltbush species.

From 1985 through 1988 a significant die-off of chenopod (and some other families) shrubs occurred in the Intermountain area (McArthur and others 1990b; Nelson and others 1989; Wallace and Nelson 1990). This die-off was particularly serious for shadscale. The die-off was not unique in time, but it was large in scale; and recovery will be complicated by the recent large-scale invasion of exotic annuals into chenopod shrublands.

Important characteristics of a number of chenopod shrubs follow. Seeding recommendation for principal vegetative types and conditions are discussed in chapter 17. Chenopod shrubs adapted to these vegetative types and conditions are included in the seeding recommendations. Seed characteristics are found in chapters 24 and 26.

Included in the remainder of this chapter are a brief species description, ecological relationship, distribution, culture requirements, use, improved varieties, and management of each of the species appearing in the chapter contents list.

Atriplex canescens

Fourwing saltbush

Fourwing saltbush is an upright shrub (fig. 2). Its height may vary from 1 ft (0.3 m) to 6.7 ft (2.04 m), depending on site conditions and genotype. It branches freely from the base. Its mature branches are quite brittle. Both young leaves and twigs are gray-green because of the white, scurfy vestiture. The linear to oblanceolate or spatulate evergreen leaves are 1 to 4 cm long and 2 to 6 mm wide. Fourwing saltbush is usually dioecious with a low frequency of monoecy. Pistillate (female) flowers are small and inconspicuous with no flower parts except pistils. Each pistil is enclosed by a pair of small bracts that are united along their edges to form winglike expansions. In addition, each bract of the pair has a wing down the middle; so the utricle (fruit) has, at maturity, a varying prominence of four wings (fig. 3, 4). The yellow to red to brown staminate flowers are more or less naked anthers (only a few bracts are present) borne in glomerules 2 to 3 mm wide (Blauer and others 1976; McArthur and others 1978c). Sex expression in fourwing saltbush is apparently a dioecious system for the only diploid population known in Utah (Freeman and McArthur 1989; McArthur and Freeman 1982; Stutz and others 1975). Barrow (1987) has shown that diploid New Mexico and Texas populations may contain rare monoecious plants. At the higher and more common (tetraploid, hexaploid) ploidy levels, fourwing

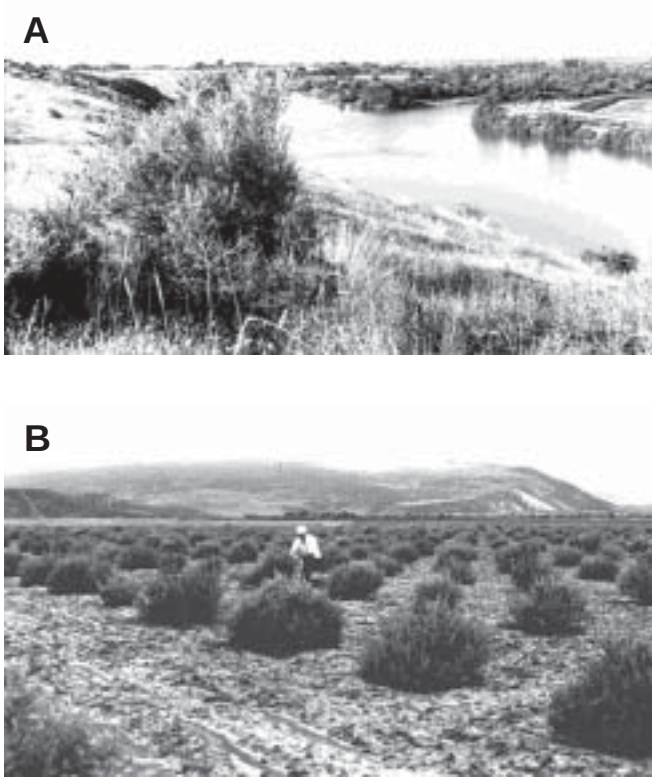

Figure 2—Fourwing saltbush is an upright shrub. (A) A large plant along the Snake River, Payette County, ID, opposite Nyssa, OR. (B) A 'Rincon' fourwing saltbush orchard at the Upper Colorado Environmental Plant Center, Meeker, CO.

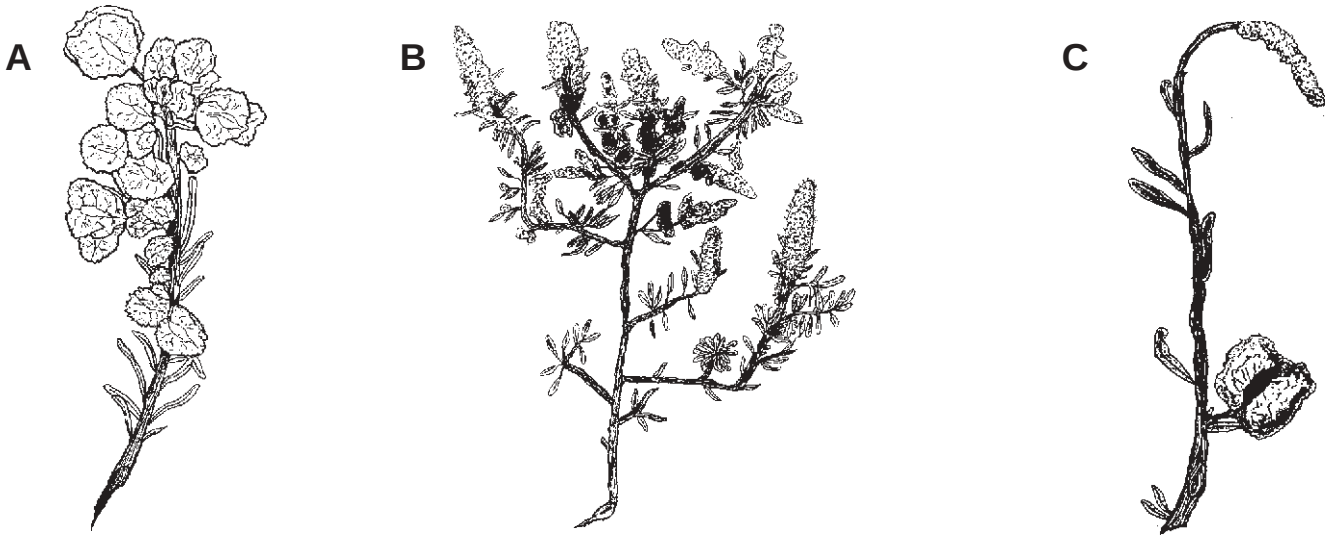

Figure 3—Flowers and fruits of fourwing saltbush (A) A pistillate (female) plant in fruit (McArthur 722, seeded near Mountain Home, Elmore County, ID, from seed collected near Panaca, Lincoln County, NV; 0.65x). (B) A staminate (male) plant in flower (McArthur 378, St. George, Washington County, UT; 0.87x). (C) A monoecious plant (McArthur 723, Payette County, ID; 0.56x).

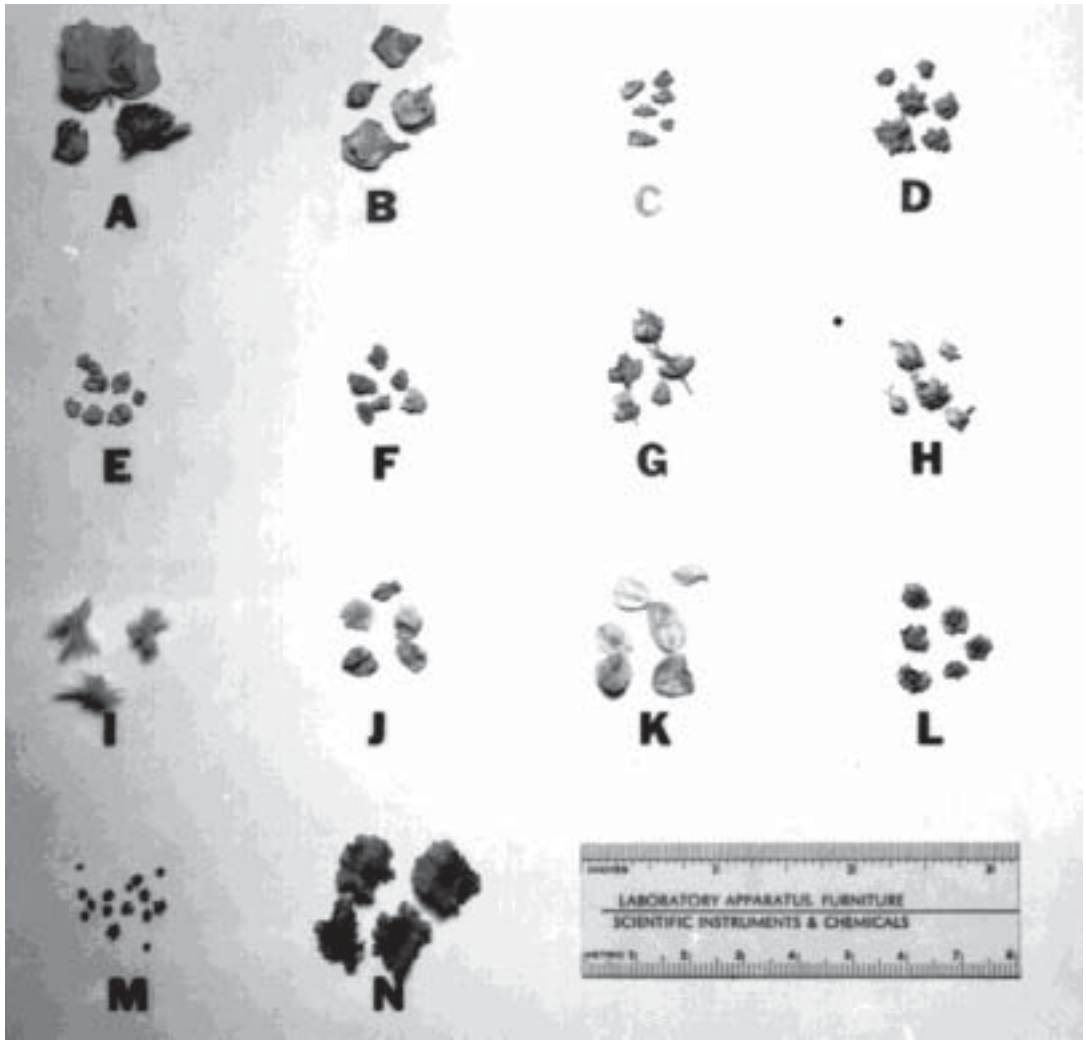

Figure 4—Fruits (utricles) of various chenopod species. (A) Fourwing saltbush. (B) Shadscale. (C) Mat saltbush. (D) Castle Valley clover saltbush. (E) Trident saltbush. (F) Broadscale saltbush. (G) Hybrid of fourwing saltbush x shadscale. (H) Fourwing saltbush x trident saltbush. (I) Winterfat. (J) Spineless hopsage. (K) Spiny hopsage. (L) Gray molly. (M) Forage kochia. (N) Black greasewood. (After Blauer and others 1976).

saltbush is trioecious (three sexual states). In the trioecious condition, some plants are lifetime constant females, others lifetime constant males, and some plants are apparently able to avoid stressful situations by switching away from the physiologically taxing female state (Barrow 1987; Freeman and McArthur 1989; Freeman and others 1984; McArthur 1977; McArthur and Freeman 1982; McArthur and others 1992; Noller and others 1984). Gender differences appear to be adaptive and allow fuller exploitation of habitats (Freeman and others 1993, 1997; Pendleton and others 1992). Dr. Daniel J. Fairbanks and his students at Brigham Young University have made progress toward understanding the molecular genetics basis of sex expression in woody *Atriplex* (Freeman and others 1993, 1997; Randell 1997; Ruas 1997).

Ecological Relationships and Distribution

The species grows in a variety of soil types from the Great Plains to Pacific Coast ranges and from Canada to Mexico (fig. 1); it occurs from elevations below sea level to about 8,000 ft (2,400 m). This shrub is well suited to deep, well-drained sandy soil, sand dunes, gravelly washes, mesas, ridges, and slopes; vigorous plants have been found in heavy clays. Ecotypes of the species may grow in widely different soil types and plant communities (Dunford 1985; McArthur and others 1978b; Richardson and McKell 1980). Fourwing saltbush is frequently found intermixed with black greasewood, shadscale, Castle Valley clover saltbush, basin big sagebrush, and occasionally black sagebrush and pinyon-juniper. In many Western regions it is the main shrub over extensive grassland areas. Important grasses on these tracts are galleta grass and blue grama. It is not unusual to find it growing in association with spring-growing grasses such as bluebunch wheatgrass and Sandberg bluegrass.

Plant Culture

This species may be propagated by direct seeding, transplanting nursery or container stock, or by rooted stem cuttings (Hennessey 1985; Kay and others 1977b; McArthur and others 1978c; Richardson and others 1979; nine papers in the revegetation section of Tiedemann and others 1984b). Shaw and Monsen (1984) give information on growing fourwing saltbush and other chenopod shrubs in a nursery setting to provide suitable bare root transplant stock. Ferguson (1980) recommended a growth medium of 50 percent sphagnum peat moss, 30 percent arcillite aggregate, and 20 percent vermiculite for growing Bonneville saltbush and other plant species native to semiarid alkaline soils. Use has been made of rooted stem cuttings (McArthur and others 1984a) to establish seed orchards that combine desired vegetative and floral traits together for seed production (Briggs 1984; McArthur and others 1978c; Noller and others 1984; Van Epps and Benson 1979). Such orchards may not only provide superior seed but may also provide income from marginal agricultural land.

Most wildland stands of fourwing saltbush produce a harvestable seed crop at least 3 out of every 5 years. Production and seed quality vary among sites, but fourwing saltbush is an abundant seed producer. Seed is collected by hand stripping or beating, although some vacuum and reel-type harvestors have been modified for this purpose (Monsen 1978; Monsen and others 1985b; Van Epps 1978). Seed is reasonably easy to harvest and process. Consequently, seed costs are not excessive. Seed is harvested in late fall and early winter, and seed can be cleaned immediately after collection. Various commercial growers have recently established seed orchards of fourwing saltbush. Seed yields from these centers appear to be more reliable than wildland stands. Seed quality differences may be better as well (Briggs 1984; McArthur and others 1978c; Noller and others 1984; Van Epps and Benson 1979).

The wings are removed from the utricles using hammermills, flail-type beaters, Dybvigs or cylinder grinders (chapter 24). If correctly operated, these cleaners can be used to fracture the utricle to aid seed germination. Removal of the wings greatly reduces the bulk and allows the utricles to be planted with most seeding equipment.

Only about 50 percent of the utricles contain a full viable seed. Seed "fill" can be increased by cultivation and culture of nursery plantings. Seed fill from wildland collections may vary from a low of 10 to 20 percent to as high as 80 percent (Crofts 1977; Gamrath 1972; Gerard 1978; Springfield 1970b). Seeds should be carefully inspected prior to harvest to ensure the acquisition of high quality seed. Acceptable fill is about 40 percent. Seeds can be stored for a number of years (up to 7) in an open warehouse without loss of viability. Even after 15 years storage, viability is acceptable (Stevens and others 1981a).

Seeds of fourwing saltbush normally require 20 to 30 days of stratification to initiate and assure uniform germination. Thick impermeable utricles often require much longer periods before water and oxygen can gain entry. Springfield (1966) and Potter and others (1986) found temperatures required for germination varied among ecotypes, but the optimum range was 15 to 18 °C (59.0 to 64.4 °F). Potter and others (1986) reported seeds are able to germinate at low media osmotic potential if optimum temperatures are maintained. However, ecotypes differed in their tolerance to moisture stress. Seeds germinate early in the spring, and if fall seeded, high mortality

to spring frost can occur. Consequently, spring plantings are sometimes recommended. However, seeds must be planted early enough to facilitate stratification. If this is not possible or if seeds with impermeable seedcoats or long-term stratification period requirements are to be planted, fall seeding should be conducted. Where the climate permits, fall or winter planting is preferred.

Seed should not be covered more than 0.5 inch (1.2 cm) deep. Broadcast seeding followed by chaining has produced excellent stands. Satisfactory stands have also developed from drill and interseeding. Plants can also establish when seeded in separate rows with herbs using a conventional rangeland drill. However, fourwing saltbush seedlings are not able to compete with herbs if drilled together in a single row. Separating seeds of different species and reducing herb seedling density by broadcast seeding is beneficial to shrub establishment. Most satisfactory stands have been achieved when fourwing saltbush was seeded at 1 to 2 lb PLS/acre (1.2 to 2.2 kg/ha) or between 2 to 4 lb (2.2 to 4.5 kg) bulk or cleaned utricles. Between 0.3 and 4.67 percent of all viable seed planted ultimately emerge and develop into mature plants (Richardson and others 1986).

Fourwing saltbush is well adapted to interseeding. Plants can be established in strips or furrows separate from herbs (Giunta and others 1975; Ostyina and others 1984; Rumbaugh and others 1982; Stevens and others 1981b). Interseeding is a useful means of seeding the shrub into established stands of perennial herbs. Narrow furrows or strips approximately 28 to 30 inches (71.1 to 76.2 cm) in width can be created using various interseeders (Giunta and others 1975; Stevens and others 1981b). Herbicides have also been used for this purpose (Petersen and others 1990). Shrub seeds are placed in the clearing. Furrows can be interspaced at desired intervals, usually 10 to 12 ft (3.0 to 3.7 m) apart. Fourwing saltbush grows profusely and quickly produces a dense overstory. Fourwing saltbush grows well with understory herbs and other shrubs. When grown in association with other species, herbage production of the fourwing saltbush plants and the understory herbs remains quite high (Rumbaugh and others 1981, 1982).

Fourwing saltbush is naturally susceptible to basal decay disease in both plantation and natural populations (Nelson and Welch 1984). This is not usually a serious problem. Insects can be troublesome to fourwing saltbush plants and populations, especially when plants occur at heavy densities (Haws and others 1984; Moore and Stevens 1984). In seed orchards the case-bearing moth can be devastating if not controlled. Malathion will effectively control this pest (Moore and Stevens 1984).

Uses and Management

Fourwing saltbush is one of the most valuable forage shrubs in arid rangelands because of its abundance, accessibility, palatability, size, evergreen habit, nutritive value, rate of growth, and large volume of foliage (McArthur and others 1978; Petersen and others 1987). Its leaves, stems, and utricles provide browse in all seasons. Sanderson and others (1987) have shown that saponin content may be important in the palatability of fourwing saltbush. In addition to providing forage and cover, this species is one of the most important shrubs for use in rehabilitation of depleted rangelands and in soil stabilization projects in Western desert areas (Blaisdell and Holmgren 1984; Blauer and others 1976; Plummer 1984; Plummer and others 1966b). Stutz (1982) and Stutz and Carlson (1985) have shown that fourwing saltbush hybridized with other saltbush species can be effective in an *in situ* selection process in revegetation efforts. Many lines of potentially adaptive plants are established under this technique. Additional onsite hybridization and rapid natural selection allow sustained establishment of adapted plant materials.

Fourwing saltbush is widely planted in revegetation projects. When the seedings are carefully planted they are usually successful. Evidence shows that fourwing saltbush increases the value of otherwise herbaceous pastures (Ostyina and others 1984; Rumbaugh and others 1982; Ueckert and others 1990). Giunta and others (1975) demonstrated the value of interplanting fourwing saltbush in cheatgrass-dominated ranges. Sometimes, however, stands do not persist, perhaps because of planting in sites that will not support the species or because the source planted is not adapted to the site. The species is a secondary or facultative selenium absorber and thus may be mildly poisonous where selenium occurs in the soil (Davis 1972; Kingsbury 1964). Minor losses have occurred when livestock had little or nothing else to eat (Hitchcock and others 1964).

In propagating fourwing saltbush, it is especially important to be sure that the strain being planted is adapted to the site. If possible, seed should be from a source growing in a climate similar to that of the site being seeded unless other tested strains are known to have similar or better adaptation. Strains adapted to the mountain brush types, where soils tend to be neutral, mature rapidly; but in deeper soils of this type, the life span has often been not more than 10 years. On drier sites having higher alkaline content, life span of the same types has been much longer. However, persistence of different accessions has been quite erratic. Various biological and climatic influences apparently affect persistence. Plants established from seed collected in the blackbrush-mesquite belt in

southern Utah have not persisted in colder parts of the State. Seed collected from colder areas have persisted well on warmer sites (Plummer and others 1966, 1968).

Varieties and Ecotypes

Fourwing saltbush probably has the greatest potential among the woody chenopods for reclaiming arid ranges. It is one of the most widespread and adaptable western shrubs. Fourwing saltbush is the center of a large species complex. It hybridizes widely with other woody saltbushes (Blauer and others 1976; Sanderson and Stutz 1994b; Stutz 1978, 1984). Several subsidiary species have been recognized. These species are all fourwinged and likely have *A. canescens* in their ancestry or are directly derived from that species. Five of the allies of fourwing saltbush (*A. aptera*, *A. bonnevillensis*, *A. garrettii*, *A. navajohensis*, and *A.* "*robusta*") are listed in table 3. Each species has a habitat requirement different from *A. canescens*, and consequently would be useful for restoration and revegetation of particular kinds of sites (table 3).

Fourwing saltbush proper is composed of widely occurring polyploid races (x = 9). Diploids are mostly restricted to the southern portion of the species range—New Mexico and Texas and south (Dunford 1984; Stutz and Sanderson 1979). Hexaploids, too, are restricted mostly to the west Texas and New Mexico area. Other high polyploids (up to 20x), usually restricted endemics, occur in the southern portions of the species range (Sanderson and Stutz 1994a; Stutz and Sanderson 1979). Tetraploids (4x = 2n = 36) are the common plants of the Intermountain areas.

Fourwing saltbush, with its outcrossing habit and common polyploidy, exhibits both allo- and autopolyploidy (Stutz 1978, 1984). Many of the common tetraploids of the Intermountain area appear to be autotetraploids (McArthur and others 1986).

Differences have been demonstrated among several accessions in winter protein content (Welch and Monsen 1981, 1984) and in both growth performance and survival (Geist and Edgerton 1984; McArthur and others 1983a; Shaw and others 1984; Young and others 1984e). In planting fourwing saltbush, either a proven accession or accessions obtained from nearby or from higher latitudes or higher elevations than the planting site should be used (McArthur and others 1983a; Van Epps 1975).

Three releases of fourwing saltbush of proven quality and adaptability have been made (Carlson 1984). Additional work is under way to provide more plant material with known characteristics by identifying and testing promising accessions and through hybridization and selection procedures (Carlson 1984; Stutz and Carlson 1985).

The three releases are 'Rincon', 'Marana', and 'Wytana'. 'Rincon' is well adapted to a wide range of

Table 3—Other fourwing saltbushes in addition to *Atriplex canescens*.

Species	Postulated origin	Habitat	Distribution	Distinguishing characteristics	References
Atriplex aptera	*A. canescens* x *A. gardneri*	Clay hill badlands	Upper Missouri River Drainage, Montana, Wyoming, the Dakotas	Diminutive (or lacking) utricle wings. Small 24 inches (60 cm) plants	Brown 1956; Stutz 1978; Stutz and others 1979.
Atriplex bonnevillensis	*A. canescens*	Alkaline playas	Eastern and Central Great Basin, Utah and Nevada	Small 30 inches (75 cm) highly variable plants	Hanson 1962; Frischknecht and Ferguson 1979.
Atriplex garretti	—	Rocky, sandy soils; in canyons	Colorado River and tributary canyons, southern Utah, northern Arizona	Early flowering, succulent, yellow-green leaves. Small 16 inches (40 cm)	Brown 1956; Hanson 1962; Blauer and others 1976.
Atriplex navajoensis	—	Rocky, sandy soils	Vicinity of Navajo Bridge, Coconino County, AZ	Woody, yellow-green leaves. Up to 40 inches (100 cm) tall	Hanson 1962.
Atriplex "robusta"[a]	*A. canescens* x *A. tridentata*	Highway disturbances in salt flats	East of Wendover, Tooele County, UT	Rapid growth rate, utricles rarely winged but with variously shaped protuberances	Stutz and others 1979.

[a]This taxa has not been formally named.

soil textures: sandy areas, gravely washes, loamy soils, heavy clay soils, and moderately saline soils. This strain is best adapted to big sagebrush and pinyon-juniper zones, but it also does well in the more mesic portions of the salt desert shrub area. It appears to have tolerance to salt similar to that of other fourwing saltbush ecotypes. Because of its high elevation origin, 'Rincon' has shown an adaptability to more northern climates than might be expected, considering its origin in northern New Mexico. It has performed well at 3,000 to 8,000 ft (910 to 2,400 m) elevation where the average annual precipitation ranges from 9 to 23 inches (22.9 to 58.4 cm) (McArthur and others 1984b). 'Rincon' is being grown in seed orchards for commercial seed production (fig. 2b). The recommended design and early orchard performance characteristics of 'Rincon' are given by Noller and others (1984).

'Marana' is recommended for Mediterranean type climates below 4,000 ft (1,200 m) in elevations with minimum temperatures of 10 °F (–10 °C) generally in California and adjacent areas (Carlson 1984; Hassell 1982; McArthur and others 1984b). 'Wytana' is closely related to *A. aptera* (table 3), and is adapted to eastern Montana and Wyoming (Carlson 1984; McArthur and others 1984b).

Several other accessions may have utility for widespread planting although they haven't been formally released (McArthur and others 1983a; Petersen and others 1987; Shaw and others 1984; Young and others 1984e). One particular accession with a proven performance record is the gigas diploid (up to 10 ft [3 m] tall) that grows naturally only in Utah's Little Sahara Sand Dunes (Stutz and others 1975). This giant form layers readily and appears to have an important place in the stabilization of dunes or other sandy areas. In trials since the 1980's, the giant form has grown well on clay, as well as sandy soils.

Several other Utah accessions perform well in pinyon-juniper and big sagebrush communities and on mine disturbances throughout the Intermountain region (McArthur and others 1983a). Some selections or ecotypes are nearly evergreen; that is, they retain a high percentage of their leaves on a year-round basis. Ecotypes that have this feature occur in both the warmer and cooler portions of the plant's natural range. Consequently, the feature is not restricted to limited areas. Among ecotypes considerable differences exist in seed size, utricle thickness, and germination patterns (Monsen and McArthur 1985; Springfield 1970b). Similar variation also occurs among seeds collected from a single bush. However, germination traits are distinct with different ecotypes, and the features can be used to increase stand establishment. Small utricles normally germinate more rapidly and uniformly than large utricles. Large, thick utricles must be mechanically fractured to attain uniform germination (Monsen and McArthur 1985).

Atriplex confertifolia

Shadscale

Shadscale is a compact spinescent shrub, growing typically in dense clumps from 0.5 to 4 ft high (15.2 to 121.9 cm) and 1 to 5.5 ft (30.5 to 167.6 cm) wide (fig. 5). The rigid, brittle branches are scruffy when young but become smooth and spiny with age. The leaves are nearly circular to elliptic, oval, or oblong, 9 to 25 mm long, 4 to 20 mm wide. They are scruffy and gray especially at maturity (Blauer and others 1976).

Flowers of shadscale are similar to those of fourwing saltbush except in the nature of the bracts enclosing the seed. The bracts of shadscale are foliose, 5 to 12 mm long, broadly oval to almost round, united at the base, and have entire, free, somewhat spreading margins (fig. 5). Shadscale blooms from late March in the southern portion of its ranges to mid-June in the northern portion (Hanson 1962). Utricles mature about 15 weeks after blooming. They are fairly persistent through the winter months (Blauer and others 1976).

Although sex expression in shadscale has not been studied in the detail accorded fourwing saltbush, it shares some of the characteristics of that species. For example, shadscale populations may exhibit biased sex ratios and include monoecious as well as pistillate and staminate individuals, and individual plants of different genders behave different physiologically (Freeman and Harper 1980; Freeman and McArthur 1982, 1984).

Figure 5—Shadscale growing near Elberta, Utah County, UT.

Ecological Relationships and Distribution

Shadscale is widely distributed in the Western United States from Chihuahua to northern Montana and from North Dakota and Texas to California and Oregon (Branson and others 1967; Hall and Clements 1923; Sanderson and others 1990; Stutz and Sanderson 1983). In broadness of distribution among the woody chenopods it ranks next to fourwing saltbush and winterfat and frequently grows in association with both. It grows at elevations from 1,500 to 7,000 ft (460 to 2,100 m) usually on fine textured alkaline soils but also on coarser, sandier soils (Blaisdell and Holmgren 1984; Branson 1966; McArthur and others 1978b).

It occurs in nearly pure stands and in mixtures with winterfat, budsage, big sagebrush, black sagebrush, rabbitbrush, spiny hopsage, black greasewood, gray molly, horsebrush, juniper, other saltbushes, and several species of grass. It endures alkaline soils better than most of these associates and can be found growing with such halophytes as glasswort (Hall and Clements 1923). West, Caldwell, and their colleagues, (Caldwell and others 1977; Moore and others 1972; West 1985; West and Gasto 1978) showed how the synecological and physiological relationships of shadscale and winterfat growing in a mixed stand give insight on why subtle environmental differences are important in the distribution patterns of these and other desert shrubs. A number of ecotypes grow on a wide range of sites including highly alkaline soils. Shadscale has a relatively short life span and can be killed by drought and high water (Blaisdell and Holmgren 1984; McArthur and others 1978b).

Plant Culture

Although shadscale readily spreads naturally from seed, it is difficult to establish from seed. Only under the most favorable climatic conditions do stands become established from artificial seeding (McArthur and others 1978b; Monsen and Richardson 1984). It can be successfully transplanted when moisture conditions are right in the spring or fall (Luke and Monsen 1984). Fruit remains on the ground 1 year or more before germinating and establishing. Understanding the riddles in shadscale germination and stand establishment requires more research. Warren and Kay (1984) demonstrated that dormancy in shadscale is difficult to overcome by traditional mechanical and chemical methods. Young and others (1984e), following a Stutz (1978) and Stutz and Sanderson (1983), scenario of shadscale's evolution in a pluvial lake regime, suggested that a great deal of ecotypic variation in shadscale germination should occur. Oaks, Stutz, and Sanderson (unpublished) have found ecotypic germination variation to be common. Garvin and others (1996) using eight shadscale accessions concluded that the species germinates in a long-term temporally staggered fashion, suggesting the operation of multiple dormancy mechanisms. A few populations lack the species' characteristic seed dormancy. Insects can cause severe damage to shadscale (Haws and others 1984; Hutchings 1952).

Low seed fill often compounds low seed germination problems. Seed is usually acquired from wildland stands growing under arid conditions. Seed quality varies from year to year and even among bushes. Most commercial lots of seed are collected from upland foothill ranges that receive higher amounts of precipitation. Harvested seed crops are produced about every 3 to 5 years, yet some sites are more reliable than others.

Seed or utricles are normally hand collected but can be efficiently harvested with vacuum, rill, or strip-type machinery (see discussion under fourwing saltbush). Seed usually ripens in late fall or early winter. Utricles must be dry before they detach from the bush. Early winter storms can interfere with seed harvesting. Once harvested, the wings are usually removed from the utricle with a hammermill or flail-type beater. Seeds can be stored for a number of years without loss of viability. However, unless stored in cold chambers and treated with an insecticide, seed borne insects can destroy stored lots. Good quality seed has between 40 to 50 percent "filled" utricles. However, a considerable amount of lower quality seed is sold. Seed viability should be retested if stored over 1 year.

Because seed germination is often erratic and varies among ecotypes, fall seeding is recommended to aid in overcoming natural dormancy and breakdown of the utricle. Seed must be placed 0.25 to 0.5 inch (6.4 to 12.7 mm) deep to ensure germination and seedling establishment. Shadscale is often planted on heavy-textured salty soils. Soil particles may be flocculated, which creates a rough surface that aids in seed burial. However, soils may crust easily, and shadscale seedlings may not be able to emerge through the surface crust. Shadscale seedlings grow slowly and are not able to compete with herbs, particularly cheatgrass. Consequently, planting sites must be cleared of weeds, and the shrub should be seeded alone in separate rows from other species. Once seedlings reach 2 years old, losses to competition are low. The plant has done well on barren mine wastes, particularly infertile soils (Ferguson and Frischknecht 1985).

Broadcast seeding with no followup measure to cover the seed has not been very successful. Either direct drilling or interseeding is recommended. Seed should be planted at approximately 2 to 4 lb PLS/acre (2.2 to 4.5 kg PLS/ha). Most conventional seeders can

be used to seed this shrub. Dewinged seeds are relatively small and flow freely through most seeding devices. Seeds are relatively heavy and can be used in seed mixtures to facilitate the planting of more fluffy or trashy seeds through the seeder (Monsen, unpublished). Seeding rates can be easily regulated. Seed germination may begin quite early in the spring and continue until early summer.

Natural spread of shadscale occurs erratically, although large stands frequently develop. New seedlings normally require 3 to 8 years to attain a mature status. Some ecotypes, however, from north-central Nevada and northeastern Wyoming grow fast. Undoubtedly other collections have similar traits.

Transplants of shadscale can be successfully reared as container or bare root stock. Even under favorable conditions, shadscale seedings grow rather slowly. The 1 year old stock usually are 3 to 7 inches (7.6 to 17.8 cm) in height but have a moderately diverse root system.

Seedlings do not survive field planting well unless extra care is given in handling and planting. Seedlings must be dormant when planted. Because some leaves tend to remain on the plant, it is difficult to determine if plants are clearly dormant. Seedlings also require a growth medium that is similar to the original soil. Bare root seedlings are particularly sensitive to overwatering. Maintaining plants as 2-0 stock result in much larger materials, but has not improved field survival. Transplants do not survive if planted amid herbaceous competition. Clearings of 30 inches (76.2 cm) in diameter are required to reduce competition sufficiently. Field survival of 60 to 80 percent is considered normal for large-scale plantings. Much lower survival results if plants are planted offsite. Shadscale does not establish or persist long when planted on unadapted sites. Neither transplants nor direct-seeded seedlings persist if planted offsite. Care should be taken to assure seeding of adapted ecotypes. Unlike fourwing saltbush, shadscale seedlings and young plants are not selectively sought and grazed by rodents, rabbits, or livestock.

Uses and Management

Despite its spiny character, shadscale is grazed by livestock and game. Persistence of leaves varies greatly over shadscale habitat. Forage value improves with persistence of leaves. Spines save this species from heavier grazing than it would otherwise receive, and the spines are likely a factor in its common widespread distribution. Seeds are a preferred and nutritious part of the plant (USDA Forest Service 1937). According to Sampson and Jespersen (1963), as the leaves and fruits drop in the autumn, they often accumulate around the parent shrubs. Livestock readily seek this accumulation. In some areas shadscale is an increaser and becomes dominant as more palatable species such as budsage and black sagebrush are killed by grazing (Blaisdell and Holmgren 1984). Because shadscale is generally more salt-tolerant than fourwing saltbush and several other shrubby chenopods, it may be used to better advantage on the more salty areas for range rehabilitation and soil stabilization (McArthur and others 1978b). Existing stands of shadscale should be managed rather than mechanically manipulated because the species usually occurs on areas that are difficult to manipulate (Bleak and others 1965; Plummer 1966). This is because shadscale normally grows in semiarid conditions, often occupying sites that receive less than 10 inches (25.4 cm) annual moisture. When disturbed these areas are usually invaded by cheatgrass or other weeds. The competition must be controlled to allow survival of naturally or artificially seeded shadscale. Large extensive areas can be direct seeded if no competition exists. Otherwise, some means of site preparation is required to reduce competition.

Shadscale often occurs as near pure stands void of most other shrubs. Plants from these pure stands do not grow in mixtures with many other shrubs. Consequently, they are usually planted alone. Ecotypes that extend into pinyon-juniper woodlands and big sagebrush communities have been more successfully seeded in diverse habitats. These ecotypes, the diploid races (see Varieties and Ecotypes section), when seeded compete favorably with other species but are best adapted to sites similar to those from where they have been collected. Ecotypes collected from more arid salt desert conditions, the higher polyploids, are less adapted to foothill upland communities but appear more drought tolerant.

Varieties and Ecotypes

Shadscale comprise chromosome races ranging from diploid (2n = 18) to decaploid (2n = 90). The chromosome races are distributed, in general, with the high ploidy levels occurring in uniform stands on valley floors and lower ploidy forms progressively larger and more morphologically variable and occurring in more diverse communities (Sanderson and others 1990; Stutz and Sanderson 1983). Little attention has been paid to differential adaptation of these forms for revegetation purposes. However, the most robust erect forms produce more seed and have generally been used more for seeding. More attention should be paid to this feature because some of the higher polyploids are narrow genetically and adaptively. Consequently, these are poorly adapted to many sites for which the more diverse diploids and tetraploids are adapted (Stutz 1982; Stutz and Sanderson 1983).

Atriplex corrugata

Mat Saltbush

Mat saltbush is a low shrub that forms dense, extremely prostrate (6 inches [15.2 cm] tall) nearly white mats five to 20 times wider than they are tall (fig. 6). The prostrate branches often produce adventitious roots where they contact the soil. The bark is soft, spongy, and white. The evergreen sessile leaves are opposite on the lower parts of the stems, and alternate above. The blades are densely scurfy and measure 7 to 18 mm wide (Blauer and others 1976; McArthur and others 1978b). Bushes are commonly dioecious, but some are monoecious. The sexual system appears to operate much like that of fourwing and shadscale (Freeman and McArthur 1984; Pope 1976). The yellow to light-brown staminate flowers are borne of glomerules 3 to 6 mm wide on nearly naked spikes. The pairs of fruiting bracts that enclose the pistils of the female flowers are sessile or subsessile, 3 to 5 mm long, 4 to 6 mm wide, united along seven-tenths of their length and usually densely tuberculate on the lower one-third. Mat saltbush flowers from April to June, and the fruit ripens 6 to 10 weeks later.

Ecological Relationships and Distribution

Mat saltbush is distributed mainly on soils derived from the Mancos shale formation in eastern Utah, southwestern Wyoming, western Colorado, and northwestern New Mexico at elevations from 4,000 to 7,000 ft (1,200 to 2,100 m). It tolerates up to 13,000 ppm soluble salts and is often the only perennial plant present where such high concentrations of salt occur (Hanson 1962). Mat saltbush is probably the most halophytic shrub in the genus, but it is frequently found in areas where the salt concentration is not so high. In these areas, it may be associated with shrubs such as winterfat, cuneate saltbush, shadscale, fourwing saltbush, black greasewood, budsage, and gray molly. Young plants have been successfully transplanted into a former greasewood type in the Great Basin (Blauer and others 1976).

Figure 6—Male mat saltbush (left) and female Castle Valley clover saltbush (right) growing along highway near Fremont Junction, Emery County, UT.

Plant Culture

The seed or utricle does not require hammermilling. The seed is usually screened with a fanning mill to remove debris, and then seeded with most conventional equipment. Cleaned seed can be stored for several years without serious loss in viability. Most native stands produce between 40 to 60 percent filled utricles.

Seed production is often quite low, yet even during serious drought and prolonged use, some shrubs produce seed. Seed fill or quality is usually low. Some stands, particularly those in south-central Wyoming, produce unusually abundant crops yearly. Large fields are machine harvested and sold each year. Hand collection is quite slow, yet field combines are able to harvest seed easily.

Uses and Management

The plant is important as a winter forage. It often grows interspaced with other plant communities at mid to high elevations. Under these circumstances it is encountered on exposed shaley outcrops with few other plants. These sites are often windblown slopes that are accessible to winter grazing. The shrub withstands heavy use, even under unstable soil conditions. Plants may be heavily browsed and seriously trampled. Big game animals often concentrate on these exposed sites during periods of deep snow accumulation. The shrubs are able to recover from serious abuse without noticeable loss of vigor.

Fall seeding is normally recommended. Where possible, midwinter planting is successful. Seedlings are susceptible to early spring frosts. If serious frosts are expected, spring seeding can be used. Seeds should be planted near the soil surface or not more than 0.5 inch (1.3 cm) deep. Seeding is usually done on sites that once supported the shrub. These areas usually are not infested with annual weeds, consequently, direct seeding without other preparatory measures is all that is necessary.

Seedlings usually emerge rapidly and grow rather vigorously the first year. If moisture remains available, seedlings normally continue growth all summer. Mat saltbush has been seeded with selected grasses including Russian wildrye, tall wheatgrass, and crested wheatgrass. Although these herbs may improve the

forage production, they usually do not persist in dense stands throughout the site. Young grass seedlings and mature plants do suppress shrub establishment. However, grasses interseeded into established shrub stands do not decrease shrub density or vigor.

Mat saltbush can be broadcast seeded and covered with a drag or harrow if planted alone. When seeded with herbs, the shrub seeds should be planted in separate rows or spots. Between 2 to 4 lb PLS/acre (2.2 to 4.5 kg PLS/ha) is recommended. However, satisfactory stands have developed from lower rates. When seeding on the heavy clay soils that normally support this shrub, care must be taken to avoid surface compaction and crusting.

Transplanting either nursery-grown bare root stock, wildings, or container materials is successful. Wildings can be dug from native stands and transplanted directly on disturbances. Wildings and bare root stock survive abusive treatment, but should not be unnecessarily mistreated. Transplants should not be allowed to "heat up," and roots must be placed in a moist soil. When transplanted on unstable and seemly infertile soils, the transplants survive remarkably well. Natural enlargement of the crown occurs soon after planting, providing excellent soil protection even under adverse conditions.

Mat saltbush has performed well from either direct seeding or transplanting disturbed sites. It is particularly useful as a shrub for seeding mine disturbances, road construction sites, and similar areas where heavy textured soils and substrata are exposed. It has established, persisted, and grown well when planted on pinyon-juniper and big sagebrush sites if soils are quite basic and heavy.

Small seedlings normally are not destroyed by grazing or insect attack. The shrub should be seeded in areas where remnant plants remain. Attempting to convert mat saltbush communities to fourwing saltbush, winterfat, or blackbrush is not advised. Although these and other shrubs may be more palatable, converted communities usually do not remain.

Varieties and Ecotypes

Little study has been accomplished in this area. Hanson (1962) and Pope (1976) have demonstrated some populational differences. Mat saltbush will hybridize with other saltbush species (Blauer and others 1976; Stutz 1978, 1984).

Atriplex cuneata

Castle Valley Clover or Cuneate Saltbush

Castle Valley clover saltbush is a low shrub 0.3 to 1.5 ft tall (9.1 to 45.7 cm) with a more or less prostrate, woody, much-branched base and erect branches (fig. 6). The light grey-green, spatulate to broadly elliptic evergreen leaves are 2 to 6 cm long and 0.5 to 2.5 cm wide (Hall and Clements 1923). In common with some other woody saltbush species, this species is apparently trioecious (Freeman and McArthur 1984). Its yellow to brown staminate flowers are borne in glomerules arranged in panicles. The pistillate flowers are borne in axillary clusters and consist of pistils enclosed by wingless bracts. At maturity, the bracts are 5 to 9 mm wide, irregularly toothed along their margins, and have numerous, flattened, crestlike tubercles on their sides (fig. 4d). Blooming occurs from mid-April to July, depending on elevation and climatic conditions. Ripening of the fruit follows about 7 weeks later (Hanson 1962).

Ecological Relationships and Distribution

The species occurs in high to moderately alkaline soils in eastern Utah, southwestern Colorado, and northern New Mexico. In these areas, Castle Valley clover saltbush is often dominant or is codominant with shadscale and mat saltbush.

Plant Culture

Seed production of Castle Valley clover saltbush is similar to that of other woody saltbushes. Annual yields are erratic, and only about 50 percent of all utricles produce viable seeds. Seed germination is also erratic and varies among ecotypes. Seeds or utricles are relatively small and can be planted with most equipment. Seedlings are quite vigorous and grow moderately rapidly. Young plants are competitive but can be suppressed by perennial grasses and annual weeds. Plants invade open disturbances, yet success from artificial seeding is not consistent. The plant should not be seeded directly with herbaceous plants but is able to compete favorably when seeded with fourwing saltbush, big sagebrush, green ephedra, and spiny hopsage.

The shrub should not be seeded on areas other than sites naturally occupied by this shrub. The species is not well adapted to the big sagebrush and upland communities, but can be used throughout most salt desert shrublands. Like other woody saltbushes, the shrub does well on fresh disturbances and can be used to treat exposed substrata created from mining, road construction, and so forth.

Uses and Management

Castle Valley clover saltbush, so named by stockmen because of the high livestock preference in all seasons, remains green and succulent throughout the winter. The shrub shows particular promise in artificial restoration of certain winter game ranges and on disturbed sites having saline-alkaline soils.

It grows through a wide range of salinity and may be associated with any of the other shrubby chenopods and many of the sagebrush species. It grows well with a variety of desert grasses and forbs. Its protein content helps to provide a balanced diet for livestock and game, particularly in the winter when much of the associated vegetation is dry (McArthur and others 1978b).

Varieties and Ecotypes

Castle Valley clover saltbush hybridizes readily with a number of the saltbushes, but particularly so with fourwing saltbush, both naturally and artificially (Blauer and others 1976; Stutz 1984). A stabilized hybrid of these could be a boon to our winter ranges. Such a plant would be taller than Castle Valley clover saltbush and retain more green foliage than fourwing. A stabilized, widely adapted hybrid might be found in nature.

Atriplex gardneri

Gardner Saltbush

Gardner saltbush is a low subshrub, usually less than 12 inches (30.5 cm) (fig. 7). The lower one-fourth to three-fourths of the plant is slightly woody and the rest is herbaceous. Its habit varies from decumbent creeping forms to rounded forms three to five times broader than they are high. The spineless decumbent branches usually produce adventitious roots where they contact the soil. The lightly scurfy leaves are evergreen spatulate to oblaceolate to obovate 15 to 55 mm long, and 5 to 12 mm wide. Plants of this species are dioecious or sometimes monoecious (Hanson 1962; Pope 1976). The brown staminate flowers are borne in glomerules 3 to 5 mm wide on nearly naked one-branched terminal panicles. The pistillate flowers are borne on leafy spikes. Fruiting bracts that enclose the female flowers are 3 to 6 mm long, 2.5 to 5.0 mm wide, and are sessile. Their surfaces range from smooth and free of tubercles to densely tuberculate. The apex of the bract ends in an oval terminal tooth subtended by two slightly smaller lateral teeth. Gardner saltbush flowers from mid-May to the first of July and intermittently following heavy rains. The fruit ripens about 7 weeks after flowering.

Figure 7—Gardner saltbush (right) growing with budsage (left) in the Red Desert, Sweetwater County, WY.

Ecological Relationships and Distribution

Gardner saltbush is abundant throughout much of Wyoming and Montana on clay and occasionally sandy soils. It is tetraploid, 2n = 36 (Stutz and others 1979). It is useful year-around forage for big game and livestock (McArthur and others 1978b).

Plant Culture

Field establishment may be difficult because of low seedling vigor (Ansley and Abernethy 1984a,b). Ansley and Abernethy (1984b) demonstrated that plants are best established in a field situation when seeds are scarified and stratified.

For production fields and commercial harvest, Carlson and others (1984) recommend direct seeding on a firm weed-free seedbed with 36 inch (91.4 cm) rows in the fall at a rate of 20 pure live seed per foot (66 per m). Once the plants are established and producing seed, the plants can be cut by hayswather, windrowed, and the utricles collected by conventional grain combine.

Uses and Management

Gardner saltbush can be successfully seeded on mine disturbances and rangelands. Although initial establishment is often erratic, a slow but general improvement normally results. When seeded in areas free of weedy competition, seedling survival is usually adequate. Shrub seedlings grow quite favorably and are able to survive normal grazing pressure.

Gardner Saltbush Relatives

Atriplex buxifolia, *Atriplex falcata*, *Atriplex tridentata*

Much of the literature dealing with Gardner saltbush is confusing in that there are several related species considered as a species complex. The taxonomic complexity has not been completely unraveled. The species complex has been alternatively treated

as the *A. gardneri* or the *A. nuttallii* complex. These suffrutescent shrubs exhibit population variability, hybridization between populations of the same and different taxa, and polyploid chromosome races (Stutz 1978; Sanderson and Stutz 1994b). *Atriplex nuttallii* is a name that has recently been lectotypified from the northern Great Plains (Saskatchewan) by Bassett and others (1983); that name (*A. nuttallii*) had been without standing prior to then (Fosberg 1941; Stutz and others 1979). We believe the plants of the Intermountain area including *A. buxifolia*, *A. falcata* (falcate saltbush), and *A. tridentata* (tridentate saltbush) are best referred to as part of the *A. gardneri* complex reserving *A. nuttallii* for plants of the northern Great Plains. Drs. Howard Stutz and Stewart Sanderson (n.d.) are actively working on this group of plants from a cytogenetic and morphological standpoint. They propose the name of *A. canadensis* as an alternative name for *A. nuttallii*.

Atriplex buxifolia is similar to *A. gardneri* in habitat preference (heavy clay soils) and in morphology (Hanson 1962; McArthur and others 1978b). Stutz (personal communication) believes that there is no good reason to maintain the two as separate species but to refer both to *A. gardneri*. Plants that have been referred to as *A. buxifolia* were larger than *A. gardneri* (up to 50 cm; 19.7 inches) and distributed more to the north and east (northern Nebraska to southern Saskatchewan) (Hanson 1962; McArthur and others 1978b).

Both *A. tridentata* and *A. falcata* are generally larger statured than *A. gardneri*. *Atriplex tridentata* plants may be from 4 inches to 3 ft tall (10.2 to 91.4 cm). They root sprout profusely (fig. 8). This is the plant referred to as *A. gardneri* by Nord and others (1969) (see Stutz and others 1979). *Atriplex tridentata* can tolerate salt concentrations of over 30,000 ppm and grows with iodine bush and inland saltgrass (Hanson 1962). It is distributed mostly in the Lake Bonneville Basin of western Utah, eastern Nevada, and southern Idaho, but also in eastern Utah and southern Wyoming (Hanson 1962; Stutz and others 1979). *Atriplex falcata* grows up to 20 inches (50.8 cm) tall. It is distributed through the northern Great Basin extending northward to eastern Idaho and eastern Oregon. It grows in soils with 9 to 50 percent sand often between or in association with shadscale, Wyoming big sagebrush, and winterfat communities (Hanson 1962; Yensen and Smith 1984). *Atriplex tridentata* is mostly hexaploid, but tetraploids are also known (Stutz 1978; Stutz and others 1979). All the saltbushes treated in this section are useful year-around forages as is *A. gardneri* itself. They may prove useful in rehabilitation of disturbed saline sites. The edaphic adaption of each taxa should be borne in mind in rehabilitation efforts.

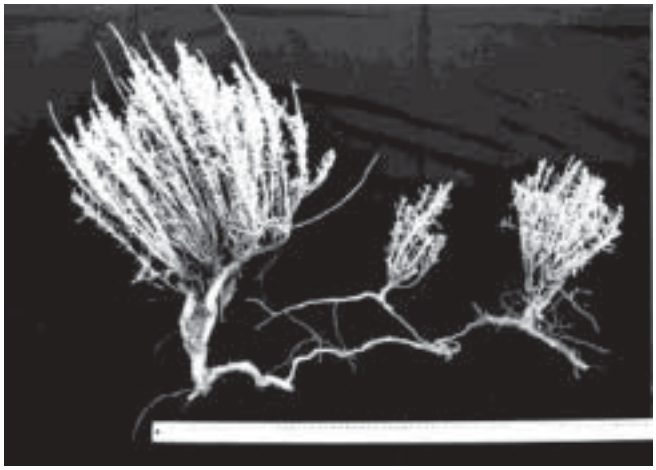

Figure 8—Example of root sprouting in trident saltbush from west Sanpete Valley near Ephraim, Sanpete County, UT.

Research with *A. tridentata* and *A. falcata* have been hampered by poor seed production. Although both species are capable of good seed yields, concentrated efforts have not been developed to acquire adequate samples. Both species have been successfully established by fall seeding. The shrubs appear capable of growing over a wide range of sites, including areas naturally occupied by fourwing saltbush.

The erect growth habit of *A. tridentata* and *A. falcata* can be grown as bare root or container transplant stock. They survive field planting quite well. Individual plants grow well under nursery conditions and may require pruning to reduce plant size.

Atriplex tridentata and *A. falcata* often lack a herbaceous understory. This is often due to heavy grazing. Both shrubs persist under intense use, although seed production is reduced. Both shrubs are capable of growing with a diverse understory. These shrubs have the unique ability to persist with various forage species, and yet remain quite productive themselves.

Other Saltbushes

Atriplex lentiformis (quailbush), *Atriplex obovata* (broadscale saltbush), *Atriplex polycarpa* (allscale saltbush), *Atriplex hymenelytra* (desert holly saltbush)

Some other saltbush species occur in parts of the Intermountain area—especially in the southern parts. Quailbush (*Atriplex lentiformis*) is a large shrub up to 11.5 ft (3.5 m) tall and 24.5 ft wide (7.5 m) (fig. 9). Its leaves are evergreen, alternate, gray-green, scurfy. The distinctive utricles are small flat discs about 3 to 4 mm in diameter. The similar species,

Figure 9—A large quailbush saltbush near St. George, Washington County, UT.

Torrey saltbush differs by being smaller, up to 10 ft (3.0 m) tall and 16 ft (4.9 m) wide, and in having anled stems (versus terete for quailbush). Both species occur in the St. George area of Utah and in other southern and western margins of the Intermountain area (Brown 1956; Hanson 1962). One selection, 'Casa', of quailbush has been released for upland game use and erosion control (Carlson 1984). In contrast to some other *Atriplex* species, quailbush utricles require burial for effective plant establishment (Young and others 1980).

Three other southern saltbush species are broadscale saltbush, allscale saltbush, and desert holly saltbush. Broadscale saltbush is a subshrub 0.6 to 1.5 ft (0.15 to 0.45 m) in height with a woody, spreading base that produces numerous ascending to erect branches (fig. 10). The silvery, scurfy, deciduous leaves

Figure 10—Broadscale saltbush growing in Hamblin Wash, Coconino County, AZ. Ruler is 12 inches (30 cm) long.

are elliptical to obovate, 1 to 3.5 cm long, 1 to 2 cm wide, with a short petiole. This species has yellow staminate flowers borne in small glomerules and arranged 500 to 5,000 to a panicle. The fruiting bracts are broadly cuneate or obovate, 4 to 5 mm long, 5 to 9 mm broad, with smooth or sometimes slightly tuberculed surfaces (Blauer and others 1976). Broadscale saltbush tolerates salinity from 165 to 4,900 ppm soluble salts (Hanson 1962). It is commonly associated with such halophytes as black greasewood, seepweed, and alkali sacaton, and other saltbushes (McArthur and others 1978b; Wagner and Aldon 1978).

Broadscale saltbush is an important browse plant in alkaline areas (Edgar and Springield 1977; Hall and Clements 1923). It grows rapidly and is most succulent in the spring. Within areas of adaptation, this species should be useful for stabilizing disturbed sites. Frischknecht and Ferguson (1984) reported that broadscale saltbush was the most successful of seven chenopod shrubs transplanted into a processed oil shale matrix in eastern Utah. After 6 years, over 80 percent of the shrubs survived in both irrigated and nonirrigated plots. Broadscale saltbush seed germinates best following an after-ripening period (Edgar and Springfield 1977). It has been observed to invade the disturbed margins of newly constructed highways.

Allscale saltbush is an intricately branched, rounded shrub to 5 ft (1.5 m) tall. Its twigs are delicate, even approaching spininess. Leaves are obovate to linearly obovate. It occurs in the Sonoran and Mohave Deserts and in drier portions of the San Juaquin and Owens Valleys of California. This species has value as browse and as upland game habitat (Brown 1956; Chatterton and others 1971; Hall and Clements 1923; Sankary and Barbour 1972). Chatterton and others (1971) reported that allscale saltbush is an excellent nutrient source for browsing animals especially late in the year. Graves and others (1975) reported that allscale saltbush was useful for revegetating Mohave Desert land. For successful reseedings, they suggested that allscale saltbush be drill seeded in the early winter. Sankary and Barbour (1972) reported that November is the time of natural seed dispersal and seedling establishment for allscale saltbush. Mixing activated carbon directly with utricles in the seedbox enhances germination by inactivating inhibitory substances found in the utricles (Graves and others 1975).

Desert holly saltbush is a compactly branching, rounded shrub to 3 ft (91.4 cm) tall. The twigs are brittle but not spiny. Its leaves are obicular in outline, but leaf margins are irregularly undulate or coarsely toothed and as long as 1.6 inches (4 cm). Desert holly is distributed on dry alkaline alluvial fans and hills from Owens Valley, California, to southwestern Utah and south to Mexico (Brown 1956).

Ceratoides lanata

Winterfat

Winterfat is an erect or spreading subshrub that shows wide variation in stature from dwarf forms less than 8 inches (20.3 cm) in height to larger forms to 4 ft (1.2 m) (fig. 11). The dwarf forms are herbaceous above a woody base. Taller forms tend to be woody throughout. Branches and leaves are covered with a dense coating of stellate and simple hairs that are white when young but become rust colored with age. The leaves are alternate, linear, 5 to 50 mm long, with entire, strongly revolute margins. Winterfat is predominately monoecious, but dioecious plants also may occur. The flowers are borne in dense paniculate clusters along the upper portion of the branches. The pistillate flowers are below the staminate flowers on monoecious plants. Staminate flowers lack bracts and petals. They have four sepals and four stamens borne opposite the sepals. Pistillate flowers lack both sepals and petals. Pistils are enclosed by a pair of bracts that are united more than half their length. The bracts are covered and often obscured by long, silky hairs (fig. 4i). These long hairs distinguish winterfat from species of *Atriplex*. Site and climate permitting, winterfat blooms between May and August. The fruit ripens from September to November and is dispersed by wind in late fall and winter. Seed production is extremely variable. A scant crop is produced in most years under arid circumstances. Sources from foothill ranges usually produce an adequate crop each year. A heavy seed crop can be produced in years of good summer storms coupled with the absence of summer grazing. Such productive crops on dry desert ranges may occur but once in a decade (Blauer and others 1976).

Figure 11—'Hatch' winterfat growing at Bell Rapids, Gooding County, ID.

Ecological Relationships and Distribution

Winterfat is remarkably resistant to drought, and even on dry sites will produce seed in the third and fourth years after establishment. On favorable sites, plants have produced some seed in their first year of growth. The species has a deep taproot and numerous extensive lateral roots. The plant may appear dead after unusually dry years, but it normally recovers after rain. It exhibits strong reproductive qualities; however, establishment from artificial seeding is hindered because seedlings are highly sensitive to frost damage (Stevens and others 1977a).

Winterfat stands often attain old ages. For example, in southern Idaho a stand of winterfat had plants thought to be an average of 72 years old, whereas the corresponding figure for falcate saltbush was 24 years (Yensen and Smith 1984). Determining the ages of chenopod shrubs is difficult and imprecise (Stewart and others 1940; Yensen and Smith 1984).

Winterfat is most abundant on lower foothills, plains, and valleys with dry subalkaline soils in Utah, Nevada, Wyoming, Arizona, and New Mexico (Riedl and others 1964; Stevens and others 1977). In the Great Basin, it often occurs in pure stands over thousands of acres (Benson and Darrow 1945) and is an important component over millions of acres of the salt desert shrub type. It also grows intermixed with basin big sagebrush, pinyon-juniper, and ponderosa pine. The ecotypes for these upland communities have been used to seed areas often lacking this shrub. Winterfat ranges from Canada through the Great Basin and Rocky Mountain States to Mexico, from California and eastward to Texas and North Dakota (Branson 1966; fig. 1). It also grows over a wide range of altitudes. In Utah, it occurs from the lower Sonoran zone to the alpine ridges. Dwarf forms usually occur on desert floors, on areas of high salt concentration, and on high mountain tops. The larger forms occur on alluvial fans, foothills, and mesas on ponderosa pine and juniper-pinyon sites.

Plant Culture

Winterfat can be established in seed production fields. To do so requires a firm, weed-free seedbed. Carlson and others (1984) recommended direct seeding at a depth of 0.12 inch (3.2 mm) in 36 inch (91.4 cm) rows. Fields require cultivation or hoeing and may require irrigation. Seeds can be combine harvested, usually from late October to mid-November. See chapter 24 for additional information on seed harvest.

Seed is often hammermilled to remove the fluffy utricles (Carlson and others 1984). Booth (1982), however, reported better establishment by seeding whole fruits on the soil surface. Hammermilling also damages many fruits. However, a problem with not

hammermilling is that fruits may be difficult to separate from stems, leaves, and litter collected in the field. Seed should be cleaned using a barley debearder to detach separate utricles from the flower head, and then processed with a fanning mill to separate utricles from debris.

Winterfat can be successfully seeded and transplanted in rehabilitation plantings (Clary and Tiedemann 1984; Frischknecht and Ferguson 1984; Luke and Monsen 1984; Plummer 1977; Shaw and Monsen 1984; Stevens and others 1981b). When seeded alone, winterfat seed does not flow through a drill or other seeding equipment. If mixed with heavier seed or a carrier, the winterfat seed is forced through the machinery. Even when mixed with heavier seeds, winterfat debris can cause bridging and clogging. Seed must be carefully cleaned to facilitate seeding. Sticks and other debris should be removed by screening. Chopping or hammermilling leaves a considerable amount of material that restricts seeding operation. Pelleting the seed has improved seeding without reducing seed germination. The heavy coated seed can also be broadcast seeded with less chance of drift. However, coated or pelleted seed must be properly cleaned prior to treatment, or sticks and leaves can still impede seeding.

Winterfat seed maintains viability only for relatively short periods (6 months to 4 years) without special treatment (Kay and others 1977d; Stevens and others 1977, 1981a). Special treatments—such as use of desiccants, sealed containers, and cold storage—can prolong viability up to 8 years (Kay and others 1977d; Springfield 1974). Winterfat seed requires an after-ripening period for maximum germination and germinates best at warm temperatures (77 to 80 °F [25.0 to 26.7 °C]) (Springfield 1968, 1972b; Young and others 1984a). Current research seeks ways to better establish winterfat by seeding because seedlings are generally vulnerable to spring frosts (Stevens and others 1977a).

Winterfat seed is usually cleaned to a purity of between 20 to 50 percent. Seed viability normally ranges between 20 to 50 percent. Approximately 1 lb (PLS) per acre (1.1 k/ha) is recommended for drill seeding. Seeds can be successfully established by broadcast seeding, if lightly covered with a drag, harrow, or pipe harrow. Seeds should be covered with not more than 0.25 inch (6.4 mm) of soil. Some seedlings establish from surface seeding, but failure to cover the seed is a major reason for poor stands on semiarid sites. Because spring frosts seriously weaken young seedlings, spring plantings are recommended in areas where spring frosts are expected.

Winterfat germinates quickly and seedlings grow rapidly. These traits, coupled with early germination, cause the plant to be highly competitive with herbs. Seedlings of few other shrubs survive and grow as well as winterfat amid competition. However, seedlings can be weakened by competition, and weedy annuals and established perennials can and do reduce seeding survival. Winterfat can be established by broadcast seeding directly with herbs and other shrubs. When drill seeded it is best to plant winterfat in separate furrows from the herbs to reduce competition and to set the furrower depth for proper seed placement. Winterfat establishes well when seeded with a cultipacker seeder. Although seeds need only shallow coverage, planting in a firm seedbed is recommended. Young plantings are extremely persistent and are able to withstand heavy grazing, trampling, and drought.

Winterfat is unusually well-adapted to mixed seedings, particularly when planted in pinyon-juniper communities. Although desert types normally grow alone, the tall robust ecotypes do well when seeded in mixtures. However, to encourage spread, openings must be created to allow seedling survival.

Winterfat is easily grown as container or bare root nursery stock. Seedlings are susceptible to damping off organisms, and entire plantings can be eliminated in a few days. Maintaining clean, disease-free conditions is the best control measure, although soil drenches and fumigation can be helpful. Young seedlings transplant well. Plants are difficult to “harden-off” prior to field planting. Transplants that are not hardened are susceptible to stress by drought and freezing. Spring planting is usually recommended, yet transplants are extremely hardy and survive even midsummer planting. The stems of young seedlings become quite brittle and can be easily broken off during lifting and transplanting.

Uses and Management

Winterfat is a superior nutritious winter browse for livestock and big game. Sheep, cattle, antelope, elk, deer, and rabbits consume it. Except for the woody base and larger stems, the plant is edible (McArthur and others 1978b; Riedl and others 1964). Overgrazing has greatly reduced and even eliminated winterfat in some areas, even though it is relatively tolerant to grazing (Stevens and others 1977a). Rasmussen and Brotherson (1986b) demonstrated that late winter grazing of winterfat by cattle reduces the vigor of winterfat stands and opens those stands to less desirable forage species. Winterfat is potentially one of the most useful shrubs for planting to increase cover and forage on alkaline soils of desert ranges in Utah and adjacent States where the average annual precipitation is less than 10 inches (25.4 cm). It is one of a few shrubs that can be reliably seeded under arid circumstances. A great deal of winterfat is planted on Western ranges. Plummer (1984) estimated that 20,000 lb

(9,100 kg) of seed were sold annually. Winterfat ecotypes from upland communities have proven useful for improving deteriorated pinyon-juniper game winter ranges.

Sampson and Jespersen (1963) give winterfat a browse rating of excellent to good for cattle and sheep, excellent to fair for goats, good to fair for deer, and fair for horses. Shaw and others (1984) showed that some winterfat ecotypes have potential as upland game cover. Ostyina and others (1984) reported that winterfat is useful in increasing range productivity for fall and winter use of grass pastures. The species is a good natural increaser and should be highly useful for stabilization in areas where it naturally occurs. Some good stands have resulted from broadcasting utricles on such areas (McArthur and others 1978b).

Varieties and Ecotypes

The different ecotypes of winterfat not only show wide variation in stature but also in seed production, seed size, seedling germination and vigor, pubescence on fruit and seed, and tolerance to varying pH in soils. These ecotypes maintain character differences when planted in uniform gardens (Riedl and others 1964; Stevens and others 1977a). A more woody, somewhat spinescent form of winterfat (*C. lanata* ssp. *subspinosa*) referred to as foothills winterfat occurs on rocky hills in southern Utah, Arizona, California, and Mexico. It apparently is the only form present in southern Arizona. This subspecies shows intergradation in all characteristics with typical winterfat (Kearney and Peebles 1960). Six other species of *Ceratoides* are confined to the old world (McArthur and Sanderson 1984).

Some controversy still exists as to whether the long standing name of *Eurotia* retains its validity in Eurasia and in North America (Committee for Spermatophyta 1978; Howell 1971; Reveal and Holmgren 1972; Robertson 1982). There is also some discussion that the proper generic name is *Krascheninnikova*. Robertson (1982) suggested that south-central Asian winterfat, also known as Pamirian winterfat (*Ceratoides latens* or *Eurotia ceratoides*) has value as a forage plant on North American ranges.

'Hatch' winterfat is a recently released selection that is suitable for its ability to establish, persist, and provide forage in sagebrush and pinyon-juniper communities (Monsen and others 1985a; Stevens and Monsen 1988). 'Hatch' is a large ecotype capable of providing winter forage available above the snow (fig. 11). This selection also has potential for upland game habitat (Shaw and others 1984).

Grayia brandegei

Spineless Hopsage

Grayia, like *Atriplex*, has staminate flowers of four or five sepals, four or five stamens, and pistillate flowers that lack both sepals and petals but have pistils enclosed by pairs of bracts. The margins of each pair of bracts are united from base to apex except for a minute apical opening. Pendleton and others (1988) have shown that spineless hopsage has the unusual monoecious floral system of heterodochogamy. In that system protandrous ("male" first) and protogynous ("female" first) plants are synchronized and reciprocal ensuring cross fertilization. On the basis of a morphological, embryological, and chromatographic study, Collotzi (1966) recommended that *Grayia* be reclassified as *Atriplex*. Welsh (1984) made an alternate suggestion that *G. brandegei* be transferred to *Zuckia* as *Z. brandegei* var. *brandegei*. We favor retaining *Grayia* as a genus including both the species *G. brandegei* and *G. spinosa*. McArthur (unpublished) analyzed Collotzi's (1966) chromatographic data, which shows *G. brandegei* and *G. spinosa* to be most similar among the 10 chenopod taxa. *Zuckia* was not included in Collotzi's (1966) study. More work is required to resolve the *Grayia-Atriplex-Zuckia* taxonomic question.

Spineless hopsage is a subshrub to 3.5 ft (1.1 m) tall (fig. 12) with linear-oblanceolate to obovate leaf blades 1.5 to 4.5 cm long (Collotzi 1966; fig. 13). The flowering period varies between mid-June and mid-August. Seed matures in late September through early October. Utricles persist on the plants until January and some may last through the winter. These are often removed by small mammals and birds.

Ecological Relationships and Distribution

Spineless hopsage is generally restricted to shale formations of the Upper Colorado River Drainage (Stutz and others 1987) in southwestern Wyoming, western Colorado, northwestern New Mexico, northeastern Arizona, and eastern Utah. Other populations occur in central Utah. It favors silty clay loam soil derived from shales. It grows on tough sites that few other plants occupy (Pendleton 1986; Pendleton and others 1988). Collotzi (1966) noted it occurred under mildly alkaline (pH 7.4 to 7.7) conditions.

Plant Culture

Seed viability and production is similar to saltbush species. Low viability is often encountered due to the arid conditions at the native sites. It germinates and produces seedlings readily, but unless protected, these are quickly taken by rodents and rabbits.

Figure 12—Spineless hopsage growing in Antelope Valley, Sanpete County, UT.

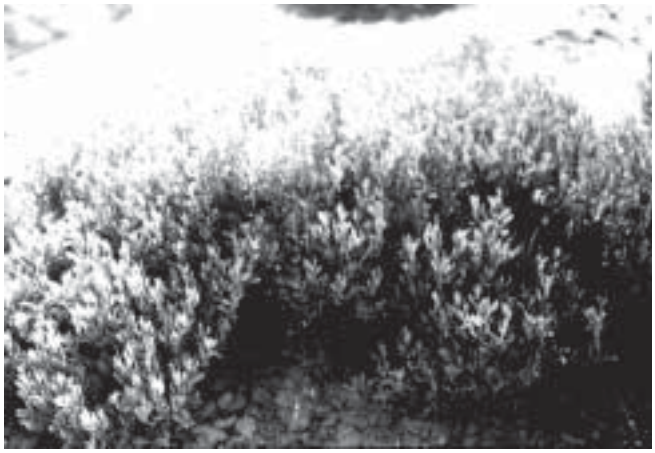

Figure 13—Spineless hopsage growing in Antelope Valley, Sanpete County, UT.

Uses and Management

This species may be used as browse by livestock and big game. Small mammals have shown a high preference for seedlings established at several locations. The shrub should be particularly useful for stabilizing disturbed shaley soils. It provides forage for livestock and game, especially in the spring when it is full leaf (McArthur and others 1978c). Kingsbury (1964) listed spineless hopsage as possible secondary or facultative selenium absorber. As such, it could be mildly poisonous in areas where the soil contains selenium. Some ecotypes demonstrate the ability to grow on heavy soils within pinyon-juniper and basin big sagebrush communities. Stands establish best from fall plantings. To date the shrub has not grown well with other herbs or shrubs. However, it is well suited to harsh situations. Seedlings grow quickly and can be reared as transplant stock quite easily.

Varieties and Ecotypes

Stutz and others (1987) showed that diploid (2x = 2n = 18) and tetraploid (2n = 36) populations differ in phenotype and distribution. In general, the diploids are restricted to the more central portion of the species range, are smaller (x = 13 inches tall and 29 inches wide; 33.0 by 73.7 cm) than tetraploids (x = 16 inches tall and 37 inches wide; 40.6 to 94.0 cm) and have narrower leaves (x = 3.8 mm versus x = 11.2 mm) than tetraploids (Stutz and others 1987).

Grayia spinosa

Spiny Hopsage

Spiny hopsage differs markedly from spineless hopsage in many respects, but the fruits and flowers are similar. It has small, inconspicuous, unisexual flowers. The sexual system appears to be temporally monoecious to allow the species to more efficiently occupy stressful, heterogeneous, patchy environments (McArthur and Sanderson 1984). Spiny hopsage is an erect, diffusely branched, spinescent shrub from 1 ft (30.5 cm) to 4 ft (121.9 cm) high. Its leaves are fleshy in the spring but usually dry before midsummer. Fruits (fig. 4k) generally mature just before leaf fall (Ackerman and others 1980). Unusual ecotypes in northeastern Utah and southwestern Idaho retain a considerable percentage of their leaves throughout the growing season (Blauer and others 1976).

Ecological Relationships and Distribution

Spiny hopsage occupies plains, desert valleys, and foothills over much of the Western United States (eastern Washington south to southern California and east to western Wyoming and northwestern New Mexico) at elevations ranging from 2,500 to 6,900 ft (760 to 2,100 m) (Blauer and others 1976; Collotzi 1966; Shaw 1992). It generally grows on well-drained soils of loamy to rocky or gravelly textures, but it may occasionally be found on clay soils. Soils usually range from neutral to alkaline; its adaptation to salinity may vary ecotypically (McArthur and others 1978b; Shaw1992; Stark 1966). It often grows in soils high in calcium (McArthur and others 1978b).

Spiny hopsage may occur in pure stands but more often is a component of communities dominated by other shrub species (Shaw 1992). It occurs in both sagebrush and salt desert shrub communities in association with Wyoming and basin big sagebrush, blackbrush, black greasewood, shadscale, winterfat, and pinyon and juniper species (Sampson and Jespersen 1963; Welsh 1984).

Plant Culture

Seed production is highly variable between years, populations, and individual plants. During favorable moisture years some shrubs produce large quantities of fruits, but during dry years few flowers or fruits are produced (Shaw 1992). Under warehouse conditions seed maintains viability up to 6 years (Shaw 1992; Smith 1974a). Kay and others (1984) demonstrated that seed life can be extended by drying seed at 35 °C (95.0 °F) for 6 days and storing them in glass jars with a desiccant at room temperature. This procedure has maintained full seed viability for over 9 years.

Viable seeds germinate rapidly. For field establishment late fall seeding is best because moisture levels are high (Shaw and others 1994). Bracts of spiny hopsage are probably important for seed dispersal and seedling establishment (Shaw and others 1996). In some cases, however, removal of the bracts may be preferred for seeding depending on the equipment used. Most drills are unable to seed the large fruits unless seeded alone.

Young seedlings grow quite rapidly but become dominant during the early summer. The plant often grows without an understory of herbs, and the shrub seedlings are not highly competitive with herbs. To be successful, seedlings must be made in prepared seedbeds free of competition. Small seedlings are vulnerable to weedy annuals.

Broadcast seedings have erratic success. Natural seeding is episodic; success depends on the availability of soil water (Shaw and others 1994). When hand seeded in pits or favorable sites and covered with soil, moderate success has been achieved. Rodents appear to forage upon young seedlings, but the extent of their damage is not fully understood. When seeded with herbs, small seedlings emerge and survive until about midsummer. Seedlings then appear to become dormant, yet few recover the following season.

Field grown transplants also demonstrate early summer dormancy even when irrigated. However, greenhouse reared stock do not senesce prematurely. Field survival of bare root transplants have been satisfactory when planted on mine disturbances and native sites. Neither container or bare root stock do well when planted offsite.

Uses and Management

Spiny hopsage is a valuable forage for livestock and game from early May to midsummer while foliage persists. It receives little use during its dormant period (McArthur and others 1978b; Sampson and Jespersen 1963; Welsh 1984). Spiny hopsage furnishes good cover for upland game in all seasons. The plant has potential for use in revegetation but has received little use in that capacity. Glazebrook (1941), Wood and others (1976), and Kay and others (1977c) have all recommended its use for rehabilitation plantings. However, additional work on site requirements is needed to better assure artificial seeding success.

Varieties and Ecotypes

No improved varieties have been developed. Spiny hopsage is, however, composed of numerous ecotypes. Use of these for various management purposes and genetic improvement should both be possible. The species is known only at the tetraploid (4x) level (Sanderson and Stutz 1994b).

Kochia americana _____

Gray Molly

Gray molly is a small, woody-based subshrub to 20 inches tall (50.8 cm) (fig. 14). Its numerous, annual, erect branches and leaves are covered with long, silky hairs. The linear, fleshy, more or less terete leaves are 5 to 30 mm long. Hairy perfect or pistillate flowers are borne singly or in small clusters in the axils of leaves along almost the full length of the branches. At anthesis, the hooded calyx lobes are about 1.5 mm long and closely cover the ovary. At maturity, the fruit is largely concealed in the persistent calyx, which develops conspicuous, horizontal, fanlike papery wings to 3 mm long. This species blooms from June to August (Blauer and others 1976).

Gray molly usually occurs in saline or alkaline clay on plains and foothills between 4,500 to 6,000 ft (1,400 to 1,800 m). Its range extends from southern Montana and eastern Oregon to New Mexico and California. Gray molly summer cypress is quite widely

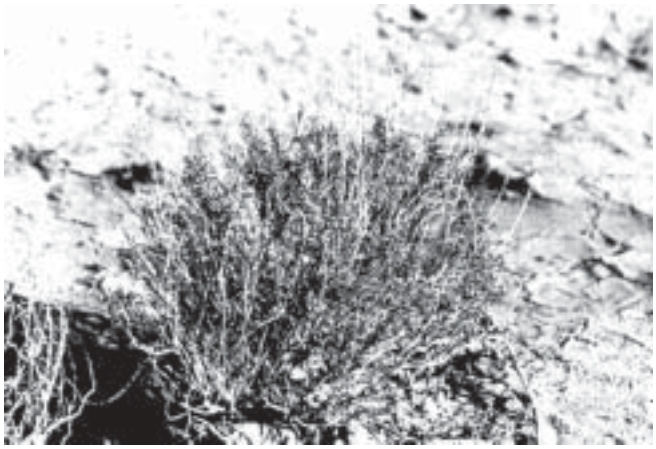

Figure 14—Gray molly growing near Faust, Tooele County, UT.

used as winter forage by livestock when it is sufficiently abundant (Blauer and others 1976). It appears to have usefulness in revegetation of areas with a high salt concentration.

Varieties and Ecotypes

Both diploid (2x) and tetraploid (4x) populations are known to exist but their characteristic differences, if any, are poorly understood (Sanderson and McArthur, n.d.; Sanderson and Stutz 1994b).

Kochia prostrata

Forage Kochia

Forage kochia is generally a long-lived, highly variable, woody-based subshrub (fig. 15). However, some ecotypes may be definite upright shrubs. It ranges from less than 12 inches to over 40 inches (30.5 to 101.6 cm) in height. Ascending branches are covered with short to long woolly hairs. Leaves are flat, linear to filiform, and hairy. Flowers are borne in small clusters (glomerules) in the axils of slightly reduced leaves on the upper part of the stem. As the fruit develops, the calyx forms dorsal appendages around it that are rounded, flat, and tuberclelike, or oblong and winglike (Shishkin 1936). Blooming occurs from July to September (Blauer and others 1976).

Ecological Relationships and Distribution

Forage kochia is native to arid and semiarid regions of central Eurasia extending to the Mediterranean basin and northeastern China. It grows on alkaline, stony, and sandy steppes and plains (Francois 1976; Shishkin 1936). Forage kochia tends to be evergreen. Seeds of accessions from several types including both subspecies of forage kochia were introduced into the United States during the 1960's (Keller and Bleak 1974). The species is well adapted to the climate and soils of the Intermountain area. This is especially so for the pinyon-juniper, sagebrush, and salt desert shrub communities (Blauer and others 1976; Keller and Bleak 1974; McArthur and others 1974; Stevens and others 1985a). It grows at elevations in its native range from 0 to 8,000 ft (0 to 2,400 m) (Balyan 1972; McArthur and others 1974).

Figure 15—Forage kochia growing on a roadcut near the mouth of Salina Canyon, Sevier County, UT.

Plant Culture

Seed, under uncontrolled storage conditions, loses viability rapidly in about 6 months (Balyan 1972; Jorgensen and Davis 1984). Seed viability can be maintained up to 4 years by drying seed to 7 to 9 percent moisture levels and storing in airtight containers (Balyan 1972; Jorgensen and Davis 1984; Young and others 1981c).

In seeding forage kochia, best results occur when the seed is surface sown and not covered (Stevens and Van Epps 1984). Aerial seedings have been successful. Seeding at a rate of 0.25 lb (PLS) per acre (0.28 k/ha) is usually sufficient. If drilled, seeds should be no deeper than 1⁄16 inch (1.6 mm) (Stevens and others 1985a). The species can be transplanted with good results in spring or fall when the ground is moist. Once established forage kochia is a good natural spreader. In concentrated stands, forage kochia attracts large populations of lygus bugs, but such concentrations do not occur in mixed plant communities (Moore and others 1982).

Uses and Management

In its native habitat, forage kochia is a drought-resistant, salt-tolerant species and is highly valued as a forage plant (Nechaeva and others 1977). The plant has high nutritive value with a high protein and carotene content (Balyan 1972; Davis 1979; Welch and Davis 1984). Forage kochia has its highest nutritive content in midsummer through fall when its crude protein and carotene levels are high (Davis 1979; Davis and Welch 1984). Frischknecht and Ferguson (1979), McKell and others (1979), and Ferguson and Frischknecht (1985) have shown forage kochia to be an effective mine spoil stabilizing plant. Sheep, goats, camels, and horses all consume it (Shishkin 1936). In Utah this species is sought out by mule deer. Davis and Welch (1985) showed some accessions are more palatable to mule deer than others. Forage kochia readily establishes from seed and grows rapidly, and under favorable conditions, reaches sexual maturity in 1 year (McArthur and others 1974). It spreads well, naturally, from seed. It is a useful component in shrub-grass pastures (Otsynia and others 1984). Once

established, forage kochia will compete with annuals such as halogeton and cheatgrass (McArthur and others 1990a; Monsen and Turnipseed 1990; Stevens and McArthur 1990; Stevens and others 1985a). One desirable characteristic for competing with cheatgrass is its fire tolerance (McArthur and others 1990a).

Forage kochia shows considerable potential for becoming a valuable forage and cover plant on arid Western ranges. In arid shrublands, it is among the most desired species to seed. Concern over possible poisonous properties is unnecessary (Davis 1979; Williams 1980). Russian workers have been seeding forage kochia on ranges since 1921 (Balyan 1972).

Ecotypes and Varieties

Although forage kochia is not native to North America, it is well adapted to many areas in Western North America (McArthur and Stevens 1983; Stevens and others 1985a). A near relative, *Kochia americana*, is widespread but less robust and aggressive than *K. prostrata* (Blackwell and others 1978; Blauer and others 1976).

Forage kochia comprises two subspecies and two varieties with separate habitat preferences (Balyan 1972):

Clay habitats; *Kochia prostrata*	ssp. *virescens* (green)
Sandy habitats; *Kochia prostrata*	ssp. *grisea* (grey) var. *canescens* (densely pubescent)
Solonetzes (salty clay soils)	var. *villosocansa* (white-villous)

Each of the above taxa has a relatively wide tolerance to soil types; however, in general, the green subspecies (ssp. *virescens*) grows best in clay soils. It has both mountain and lowland ecotypes (Balyan 1972). Variety *canescens* of the grey subspecies (ssp. *grisea*) is adapted best to sandy habitats, whereas variety *villosocansa* is best adapted to salty clay soils (Balyan 1972).

The species is a polyploid complex based on x = 9 with diploid, tetraploid, and hexaploid populations (Davis and Welch 1985; Herbel and others 1981; Pope and McArthur 1977). One selection, 'Immigrant', has been released (Stevens and others 1985a). This selection (ssp. *virescens*), originally from Stavrapol Botanical Gardens in Russia, has shown superior performance in longevity, forage production and quality, palatability, and competitiveness with annuals. It is adapted to sandy loam to heavy clay soils with best adaptation to heavier soils. 'Immigrant' has demonstrated its adaptability to the pinyon-juniper, basin and Wyoming big sagebrush, and greasewood-shadscale shrub vegetative types. McArthur and others (1996) recently confirmed the outstanding performance of 'Immigrant' forage kochia in an adaptation and performance test across an environmental gradient. Another accession (ssp. *grisea*) also performed well.

Sarcobatus vermiculatus

Black Greasewood

Black greasewood is an erect, spiny-branched shrub up to 10 ft (3.0 m) tall (fig. 16). The deciduous, bright-green leaves 1 to 4 cm long are usually narrowly linear and often semi-terete. The shrub is usually monoecious.

Black greasewood had traditionally been considered as a member of the chenopod family. However, recent studies on chloroplast DNA and sieve element plastids provide evidence that it should be separated from that family (Behnke 1997; Downie and others 1997). Behnke (1997) reviews the taxonomic history of *Sarcobatus* and concludes that this genus is distinct enough to merit its own family, Sarobataceae. We have included it here because of its traditional place in the Chenopodiaceae.

Ecological Relationship and Distribution

Black greasewood grows from Alberta south into Mexico with stands occurring in all the Western States. A smaller species, Bailey greasewood (*Sarcobatus baileyi*), occurs in western Nevada in association with shadscale and other desert shrubs. Shadscale often grows with black greasewood as well. In the more saline areas of its range, black greasewood may be found in nearly pure stands. On such sites, minor components of shadscale, Castle Valley clover saltbush, and Gardner saltbush may occur. In less saline areas, it may grow with threadleaf and whitestem

Figure 16—Black greasewood growing near Tuba City, Coconino County, AZ.

rubber rabbitbrushes, spiny hopsage, basin big sagebrush, fourwing saltbush, winterfat, black sagebrush, and broom snakeweed. Greasewood often occurs in valley bottoms where subsoil moisture is high. Often inland saltgrass, alkali sacaton, Nuttall alkaligrass, alkali muhly, and basin wildrye grow with black greasewood, they may form grassy understories. Russian wildrye, tall wheatgrass, and quackgrass have been successfully planted into black greasewood stands to make these stands more versatile grazing areas (McArthur and others 1978b).

Plant Culture

Like other chenopod shrubs, black greasewood produces erratic seed crops that usually have low viability. Seed is more difficult to collect because of the spiny, brittle nature of the stems. Poor seed quality has decreased planting success. Seeds ripen in the fall and respond best to fall or winter seeding. Establishment by natural or artificial seeding is unpredictable. Seeding with grasses is not recommended unless the shrub can be seeded in separate rows.

Black greasewood often exists on sites with clay-textured surface soils. Soils compact and crust easily, often reducing seedling survival. Black greasewood has done well when seeded or transplanted on mine disturbances. Under these conditions it establishes well on fresh exposures and infertile soils. It competes well with herbs under these circumstances unless the sites are fertilized heavily.

Uses and Management

Black greasewood contains soluble oxalates that will sicken and kill hungry livestock that consume large amounts of the foliage (Kingsbury 1964). However, where there is a good assortment of other species, this danger is negligible. It is often eaten by livestock (sheep and cattle) and wildlife in the spring. It is usually not regarded as an important forage plant although it furnishes cover and habitat. It is especially important on sites that flood, and it forms an important zone within various riparian habitats. It is highly important as cover to upland game birds and big game animals. Sites that are burned, disked, or plowed and seeded to herbs receive heavy use. When seeded on mine and related disturbances, the shrub is often heavily grazed.

Varieties and Ecotypes

Black greasewood exhibits considerable variation both in natural stands and plantations. Roos (1984), in a study involving 18 populations, concluded that *Sarcobatus vermiculatus* was rich in genetic variation. Sanderson and others (1999) have documented an interesting distribution of chromosome races in *Sarcobatus*. *Sarcobatus vermiculatus*, black greasewood, is widely distributed in Western North America (fig. 1). Tetraploid (x = 9, 4x populations) occur only on the periphery of the distributional range to the north (southern Alberta, southern Manitoba, northern Montana, eastern North Dakota), to the west (northeastern and east-central California and south-central Oregon), and to the south (southern Arizona and northwestern Sonora). Throughout the rest of the species vast range including the central portion of that range, *S. vermiculatus* is octoploid (8x). It is apparently an old plant; no diploids are known (Sanderson and Stutz 1994b; Sanderson and others 1999). *Sarcobatus baileyi* is dodecapoid (12x) throughout its more limited range (western and south-central Nevada) (Sanderson and Stutz 1994b; Sanderson and others 1999).

Other Chenopod Shrubs

Allenrolfea occidentalis (iodine bush), *Camphorosoma monspeliaca* (Mediterranean camphorfume), *Suaeda torreyana* (desert sumpbush or desert blite)

Iodine bush and desert sumpbush are two species that grow in areas where salt concentrations are so high that they are the only forms of higher plant life that survive (McArthur and others 1978b). In so doing, they provide a valuable soil-binding service. Perhaps these species could be used more for rehabilitation work. Another species, an introduction from Eurasia, Mediterranean camphorfume, has been shown to be useful in rehabilitating mine spoil materials (Ferguson and Frischknecht 1985). This species is similar in growth habit to forage kochia, and like forage kochia, it is a useful forage plant in south-central Asia (Nechaeva and others 1977).