Fourwing Saltbush (*Atriplex canescens*) Seed Transfer Zones

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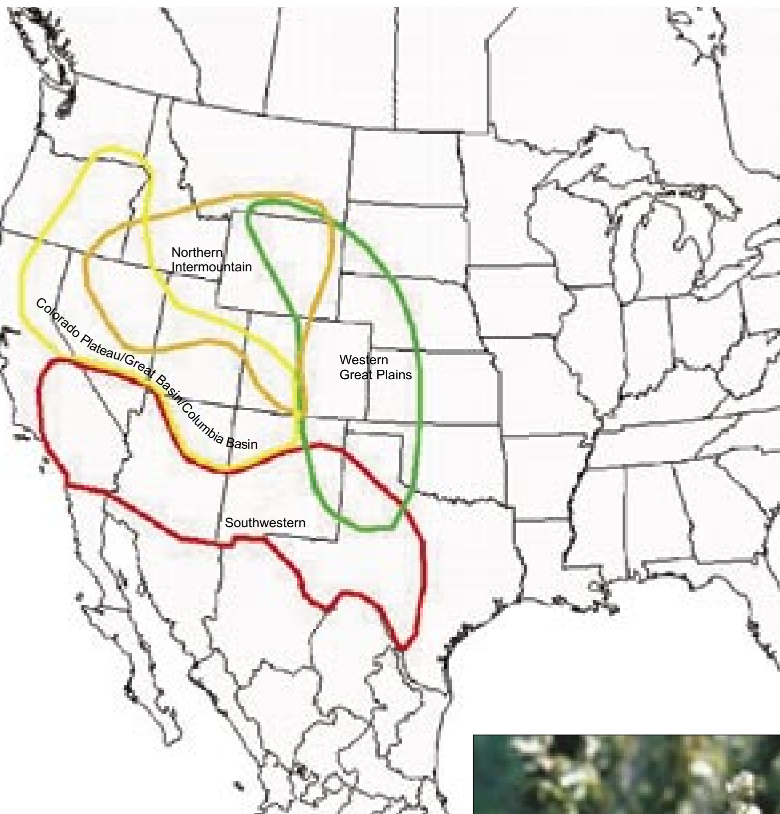

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Abstract

Atriplex canescens (Pursh.) Nutt. is the most widespread species of perennial *Atriplex* in North America. Throughout its distributional range, *A. canescens* shows considerable between-population variation. Some of this variation may be due to phenotypic plasticity but most of it appears to be genetic. Mutations, polyploidy, introgressive hybridization, and segregation from interspecific hybrids all appear to have contributed to its extensive heritable variation. Polyploidy is unusually common with numerous chromosome races (2x, 4x, 6x, 8x, 10x, 12x, 14x, 20x).

Fourwing saltbush is widely used for reclamation plantings. Proper identification is important to the utilization of fourwing saltbush in such plantings. While many of the races have been formally named as varieties, others have not. Even though differentiated by ploidy, chemical constituents, geographic distribution, and statistical distribution of morphological characters, races may lack sufficient diagnostic characters to allow facile identification, at least in the herbarium. Rather than combining unnamed races under those that do have a taxonomic name, it seems better at present not to use the formal infraspecific categories in treating the fourwing saltbushes, but to consider them all as races. Seed transfer should be within the geographical distribution limits of each race. The most common race, by far, is Occidentalis. We recommend four overlapping seed transfer zones for race Occidentalis in the United States: (1) Northern Intermountain, (2) Western Great Plains, (3) Colorado Plateau/Great Basin/Columbia Basin, and (4) Southwestern. Source seed populations from near the planting sites generally do well; and populations generally perform better when moved south and/or to lower elevations than when moved north and/or up in elevation.

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Acknowledgments

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Introduction

Fourwing saltbush, *Atriplex canescens* (Pursh.) Nutt., is an important shrub for revegetation plantings (Plummer and others 1966; Blauer and others 1976; Plummer 1984). Its uses include mine land rehabilitation (Aldon 1981), shrub-herb interplantings for animal forage (Pendery and Provenza 1987; Rumbaugh and others 1982), fire rehabilitation plantings (Ott and others 2003), rangeland improvement (Monsen and Shaw 1995), and stock for nutrient-poor soils (Glenn and others 1996, 1998). It is widespread in North America, being found from southern San Luis Potosi, Mexico, to southern Alberta and Saskatchewan, Canada, and from the Pacific Coast of California and Baja California to Texas, Oklahoma, Nebraska, Kansas, and the Dakotas (figures 1-5). It is a quality forage plant. Not only does it have fine nutritive quality but it is palatable to wild and domestic animals and tolerates browsing (Cibils and others 1998; Maywald and others 1998; Welch and Monsen 1981, 1984). It shows abundant variation in response to seasons and to rainfall, as well as genetic differentiation. This has resulted in increasing confusion, even by reputable authors (see for example Taylor and Wilkens 1993 who do not recognize the extent of subspecific variation). Fourwing saltbush is widely used for reclamation and restoration plantings. Over 100,000 pounds of seed is sold annually (McArthur and Young 1999). Last year, one seed company alone sold 70,000 pounds (McArthur and Sanderson, personal communication). With this much seed in commerce, land management agencies and seed vendors need guidance in planting. This paper is intended to meet that need.

The species has been planted successfully not only in restoration habitats, i.e., sites on which it naturally occurs, but also on sites in which it does not naturally

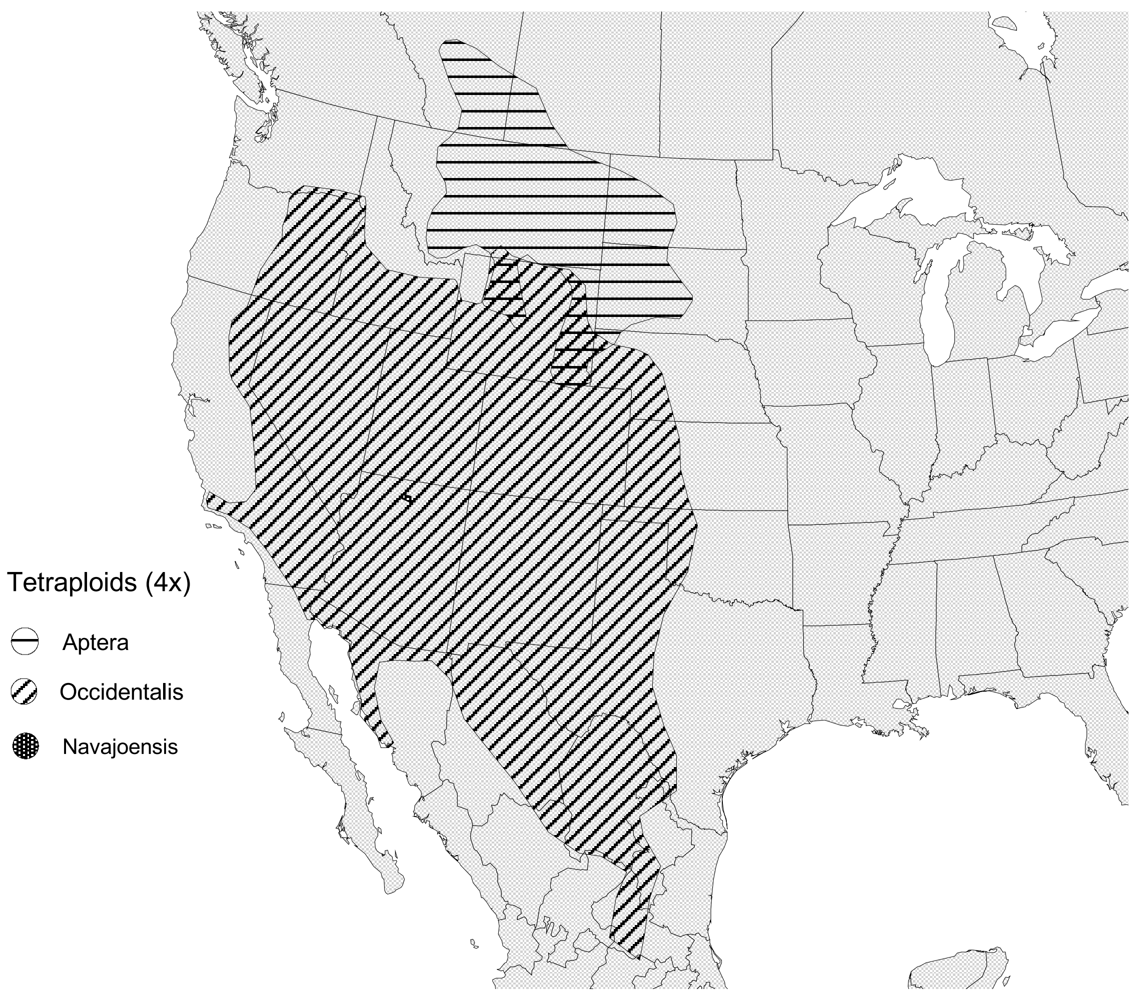

Figure 1. Distribution of tetraploid races of fourwing saltbush. Occidentalis and Aptera overlap extensively in Wyoming.

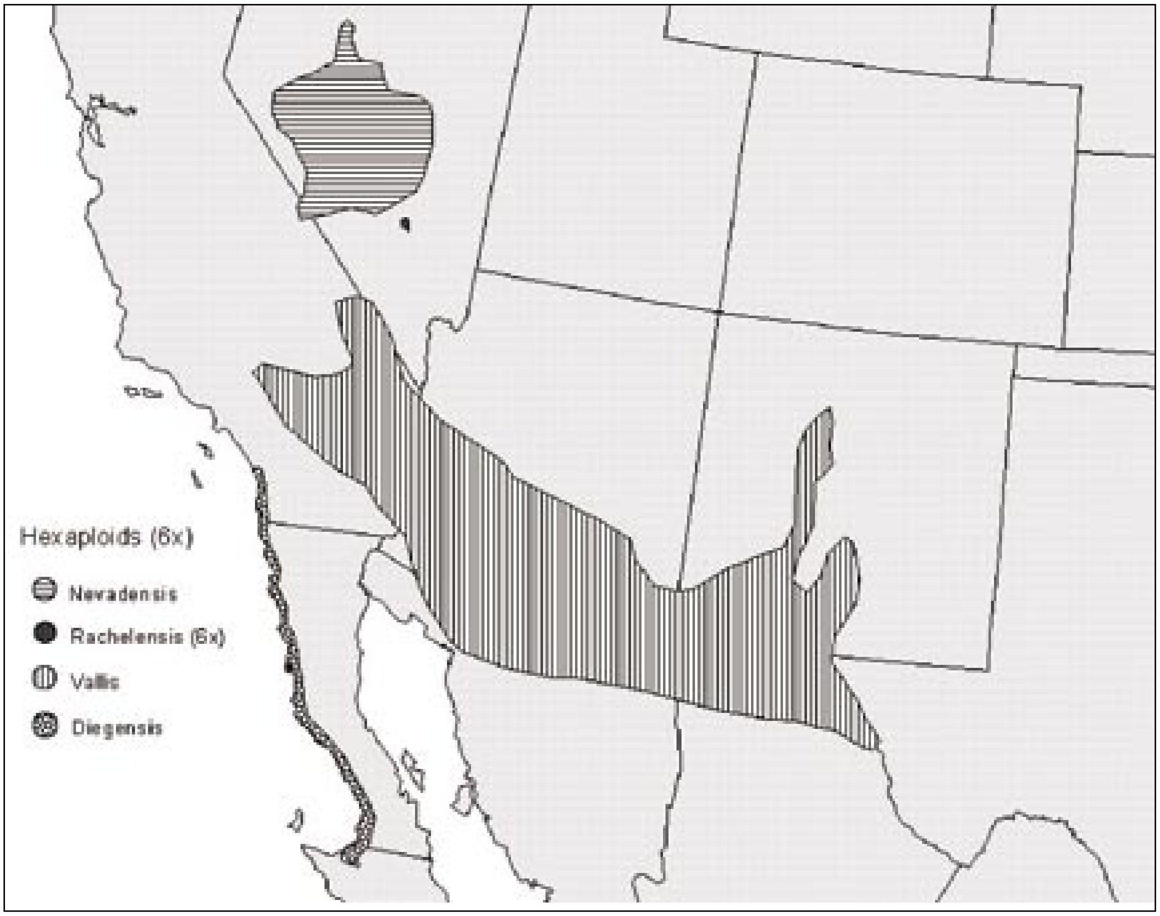

Figure 2. Distribution of hexaploid races of fourwing saltbush.

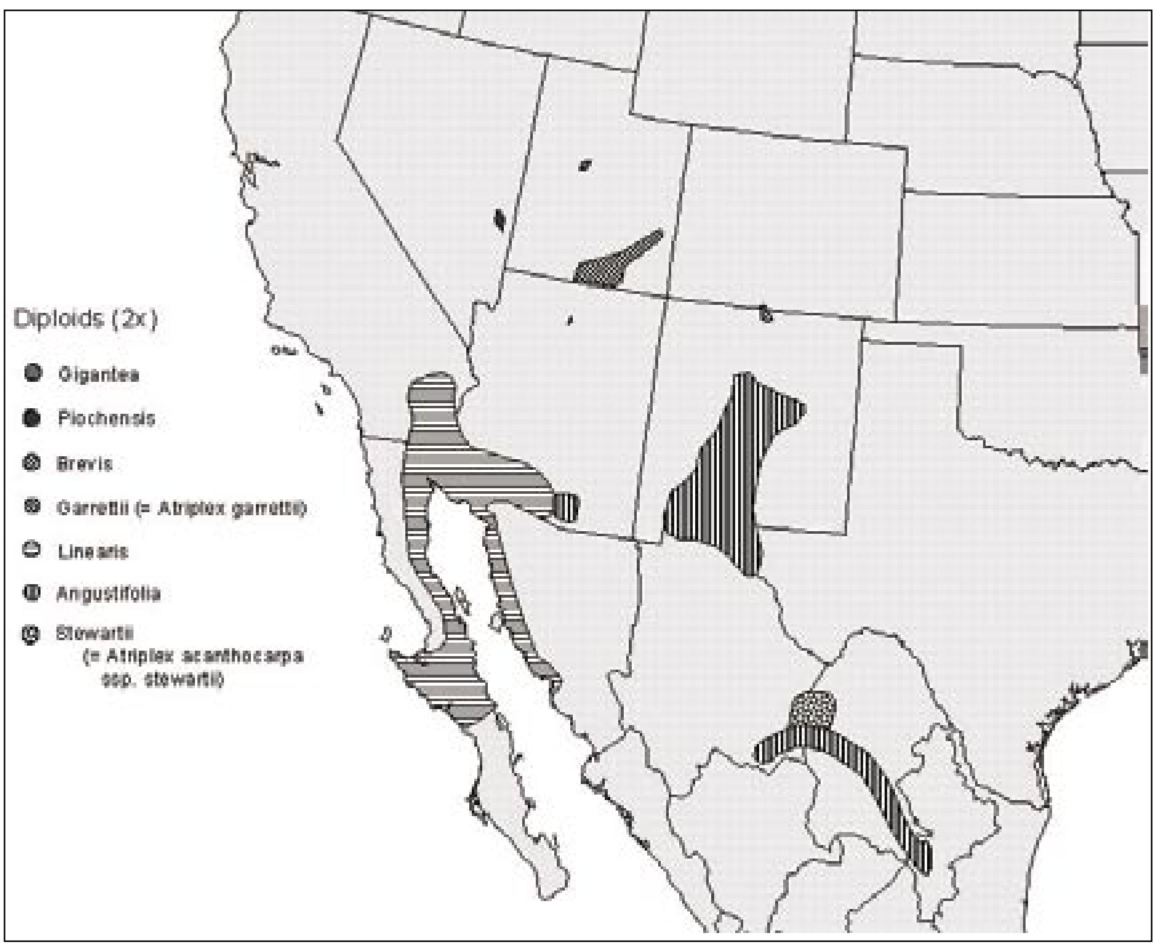

Figure 3. Distribution of diploid races of fourwing saltbush.

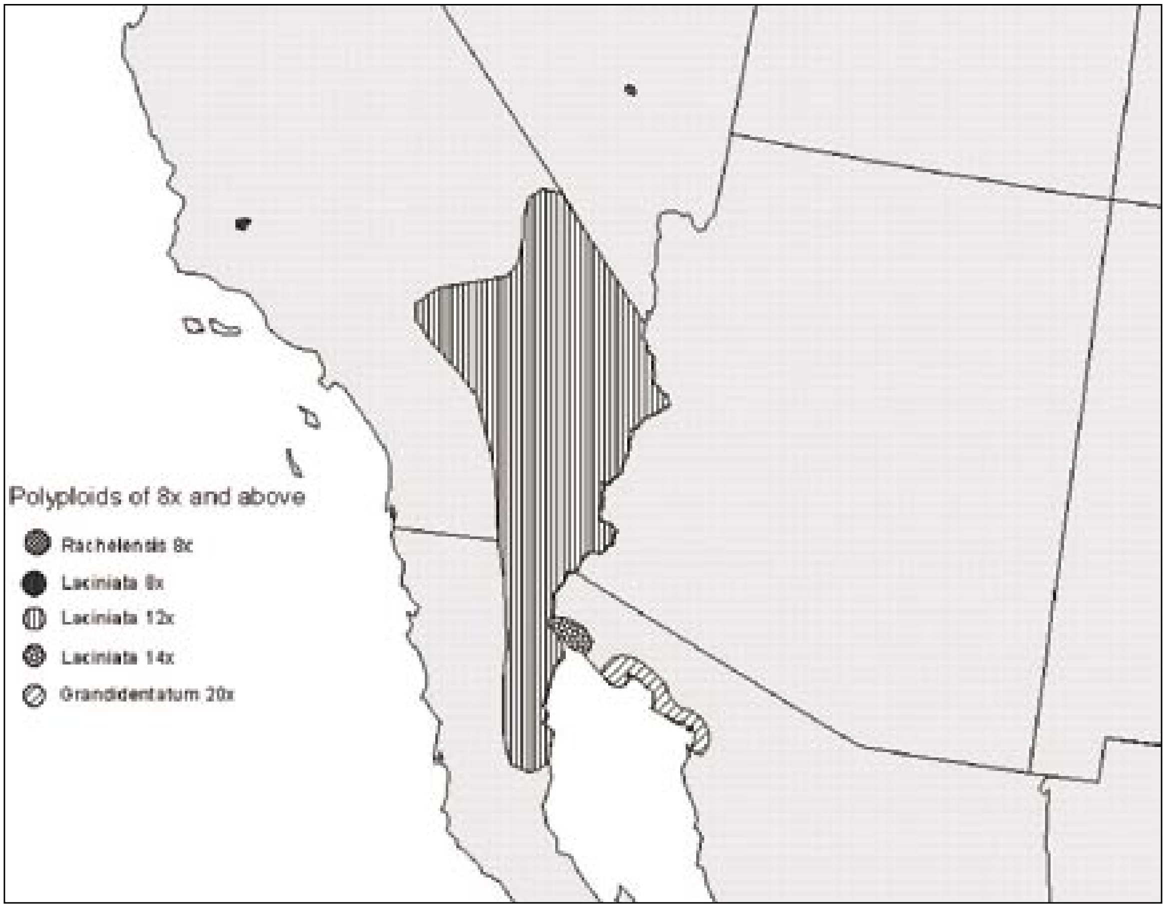

Figure 4. Distribution of races that are octoploid and higher in Nevada and in the Mojave and Sonoran deserts.

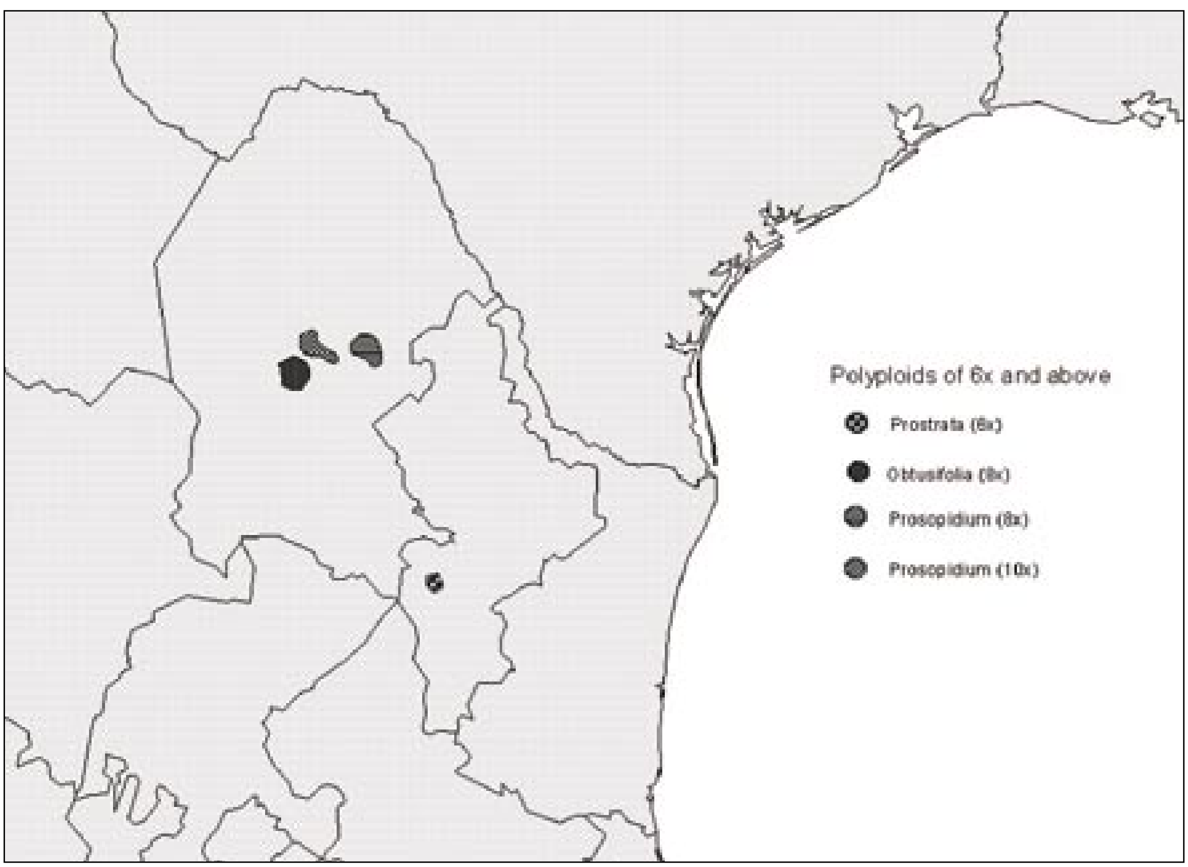

Figure 5. Distribution of races that are hexaploid and higher in the Mexican portion of the Chihuahuan Desert.

Table 1. Distinguishing characteristics of races of fourwing saltbush.

Race	Bush height	Leaves	Four-winged fruits	Habitat[a]
Angustifolia (2x)	3 to 6 ft	Narrow to very narrow, often long	Unusually large	Sand (U.S.), other soils (Mexico)
Aptera (4x)	1 to 4 ft	Moderately wide, with curving margins	Wings often small and irregular	Badlands and grasslands
Brevis (2x)	1 to 2 ft, a few 3 ft	Narrow to very narrow, shorter	Size normal to somewhat small	Grasslands on old lava flows
Diegensis (6x)	3 ft to as much as 6 ft	Moderately wide, often green colored	Normal size and shape	Sea coast, ravines, canyons
Garrettii (2x)	Usually 1 ft or less	Leaves roundish, often yellow-green	Normal	Shale slopes, often southwest facing
Gigantea (2x)	4 to 8 ft, often partly buried	Not very narrow, but often long	Unusually large	Active dunes
Grandidentatum (20x)	3 to 6 ft	Bluish colored, small to very large, ends often rounded	Strongly toothed, can be large near the beach	Sandy coastal areas
Laciniata (8x)	6 to 8 ft	Small to long and wide	Wings strongly toothed	Bottomlands
Laciniata (12x)	4 to 6 ft	Extremely small to large	Wings with many teeth and cuts	Sandy desert soils
Laciniata (14x)	4 to 6 ft	Short, or large and long. Bluish	Deeply toothed	Coastal dunes
Linearis (2x)	Usually 1 to 2 ft	Usually very narrow, bluish, the sides straight	Wings very small (1/8 in), the body may be swollen	Bottomlands, may be seasonally flooded
Navajoensis (4x)	One to 2 ft	Shortened and exceptionally wide	Normal	Red or blue shale
Nevadensis (6x)	1 to 4 ft, rarely more	Wider than 4x at the same season	Usually more toothed than 4x	Desert sands and slopes
Obtusifolia (8x)	1 to 2 ft	Egg-shaped with a blunt end, greenish gray	Wings small, toothed	Alkaline bottomlands
Occidentalis (4x)	2 to 6 ft	Small to large, narrower than 6x	May be toothed	Valleys and hills, sometimes on sand
Piochensis (2x)	1 to 6 ft	Narrow to very narrow	Normal in size to rather large	Hills, commonly with juniper
Prosopidium (8x)	1 to 4 ft	Short and wide, bluish	Wings small, toothed	Valleys
Prosopidium (10x)	1 to 4 ft	Short and wide, bluish	Wings small, toothed	Valleys
Prostrata (6x)	1 to several inches, flat topped	Moderately long	Normal	Alkaline valley bottoms
Rachelensis (6x)	1 to 5 ft high	Wider than 4x	Smallish, toothed	Valley
Rachelensis (8x)	1 to 2 ft high	Very gray	Smallish, toothed	Alkaline valley bottoms
Vallis (6x)	Usually 1 to 3 ft high, larger in West	Wider than 4x	Normal to smallish	Bottomlands

[a] These specific type sites need to be combined with the general race distribution as shown in figures 1-5.

occur, e.g., Wyoming big sagebrush habitats and pinyon-juniper habitats (Monsen and Shaw 1995; Ott and others 2003). It has also been used with success in the Mediterranean Basin and western and southern Asia (Belal and others 1993; Hyder 1981; Khalii and others 1986; Le Houérou 1992, 2000; Sankary and Goodin 1986; Thompson and others 1998).

Fourwing saltbush includes populations with different chromosome numbers that are distributed in distinct geographical patterns. Sanderson and Stutz (2001) described and characterized this variation as chromosome number or chromosomal races based on previously described formal taxonomic designations and geographical, morphological, chemical, and cytogenetic information that they presented (table 1). The racial names in fourwing saltbush are derived, for the most part, from previously applied formal specific or varietal names but some racial names come from geographical or morphological traits of races that had not been formally characterized prior to the description of chromosomal races by Sanderson and Stutz (2001). This chromosomal race knowledge is useful in clarifying the limits of the species and its subspecific and population variation. Chromosome number races range from 2x to 20x—2x, 4x, 6x, 8x, 10x, 12x, 14x, 20x (Dunford 1984, 1985; Sanderson and Stutz 1994, 2001; Stutz and others 1975; Stutz and Sanderson 1979)—and apparently account for much of the existing genetic differentiation. By far the most widespread of the races is the tetraploid Occidentalis (figures 1-5). Fourwing saltbush's dioecious or trioecious outbreeding fosters genetic variation and contributes to the species' successful occupation of diverse habitats (Freeman and others 1993; McArthur and others 1992). The reason the widespread race is called Occidentalis rather than "Canescens" is that the variety name *canescens* has to be given to plants from the type locality (site from which the species was first collected and described). The type locality for fourwing saltbush is a badland area along the banks of the Missouri River Big Bend in South Dakota, where the plant was collected by the explorers Lewis and Clark and described by Frederick Pursh. The type specimen, and plants growing there now, have relatively wide leaves and belong to race Aptera (4x), or perhaps to their own separate race because they show abundant sprouting from the roots (in figure 1 they are shown in the distribution map with Aptera).

Fourwing saltbush plants from different areas or belonging to different races have been found to vary in tolerance to environmental factors (Glenn and others 1994, 1996; McArthur and others 1983; Mikhiel and others 1992; Plummer and others 1968; Van Epps 1975). Especially important from the point of view of reclamation in cold desert settings is variation for tolerance to low temperatures (Van Epps 1975; Aberdeen Plant Materials Center staff 2002; USDA-NRCS and University of Idaho staff 2001).

Materials and Methods

Chromosome counts were accumulated over a period of 30 years in the laboratory of Howard C. Stutz, now professor emeritus, Brigham Young University in cooperation with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Shrub Sciences Laboratory. Recently, a ploidy analyzer instrument (Partec GmbH, Münster, Germany) has been obtained by the Shrub Sciences Laboratory, Provo, Utah, that facilitates the chromosome count work.

Meiotic chromosome counts were made from male flower buds preserved in the cold (-20° F) in vinegar or 5% acetic acid. Pollen mother cells were squashed on a microscope slide and stained with saturated acetocarmine dye (Sanderson and Stutz 1994). More recently, ploidy levels were also determined on the ploidy analyzer using a DAPI stain for DNA and plants of known ploidy for comparison (Koontz 2001).

Flavonoid chemistry was found to be useful in differentiating some races, due to presence or absence of 6-methoxy flavonols, 3-O methylated flavonols, and the flavone tricin. Flavonoid aglycones were obtained from glycosides by acid hydrolysis with 1 N HCl, separated by paper chromatography, and examined over a black light (longwave ultraviolet) both before and after treatment with 5% aqueous aluminum chloride solution (Sanderson and others 1999). We have also examined isozymes to characterize the genetic variation of fourwing saltbush populations (McArthur and others 1986).

We call on our experience and reports in the literature in planting, transplanting, and survival of fourwing saltbush seed source populations taken together with the genetic and chemical variation data cited in the previous paragraphs to make recommendations for seed transfer for revegetation plantings for this important reclamation species.

Application of Results

Knowledge of chromosome numbers and flavonoid chemistry proved invaluable in understanding the variation observed in fourwing saltbush. Previously described varieties were validated and new races were discovered.

Fourwing saltbush is adaptable to seasonal drought and the leaves vary in size from large to small depending on growth status and moisture availability. This is particularly true of the high polyploids. Plants of Grandidentatum (20x) normally have small leaves of a bluish color, but when we grew plants from seed in a barrel of sand, the juvenile plants had leaves about 3 inches long and 1 inch wide that looked somewhat like peach leaves. In spite of strong foliage variability, differences in leaf characters must often be relied upon in distinguishing the different races (table 1). There is a tendency for leaf width to increase with ploidy, at least at the lower ploidy levels. This is the most useful characteristic in distinguishing diploids from tetraploids. With the notable exception of race Garrettii (*A. garrettii*), diploids have very narrow leaves that are 10 times or more longer than broad, although they vary seasonally to some degree. With care, tetraploids can also be distinguished from hexaploids by leaf width alone, but plants have to be compared in the field and at the same time of year. Leaf color is also useful in some cases. The diploids, except for race Linearis with rather bluish gray-green leaves (sometimes blackish in herbarium specimens), all tend to have more yellowish foliage during dry seasons and winter due to chlorophyll loss, which has been found to prevent damage from excess light energy during times when the plant is not growing (Munné-Bosch and Alegre 2000). Yellowing may be seen slightly in tetraploid plants also, but not usually in higher polyploids. Like Linearis, several Mexican races of higher ploidy also have a bluish leaf color.

A problem with the identification of the diploids Angustifolia, Brevis, and Piochensis is the occurrence of hybrid intermediates between these and local plants of the tetraploid race Occidentalis. Hybrid intermediates are usually also tetraploid, and therefore interbreed with Occidentalis but not with their parental diploid. As a result the diploids remain unchanged and pure, but tetraploids can be somewhat mongrelized by the hybridization and begin to look more like diploids. Tetraploid plants in an area of past or present diploid occurrence are often sufficiently intermediate in form that it is difficult to tell from appearance alone where the diploid leaves off and the tetraploid begins. However, there are seasons when it is easier to distinguish them, and the tetraploids seldom become exactly like diploids in any characteristic. For instance, flavonoids, a kind of plant chemical, are different between diploids and the tetraploids of race Occidentalis (the latter produce 6-methoxy flavonols and the former do not). In many cases that have been examined, hybrid derivatives always produce these compounds too.

Planting Recommendations

Many of the races are relatively localized (figures 1 to 5). Many are also found in Mexico and have little ability to survive the winters of the temperate zone in the U.S. Therefore, they are not likely candidates for use in reclamation in this country. In localities where any of the distinctive less common races of fourwing saltbush are encountered, they alone should be used in reseeding. Ordinarily, however, it is the tetraploid Occidentalis, or sometimes Aptera, that are ordinarily used in reclamation or restoration plantings. When an appropriate seed source is chosen, the primary concerns are to seed each race in its own area of natural distribution and to be mindful of ecotypic variability of Occidentalis (see further discussion, below).

As might be expected, resistance to winter injury increases in a northward direction. Of the various *Atriplex* species and races from warm desert areas or Mexico (and some from Australia) that were planted in gardens at Provo, Utah, over the years, none survived for long and most died during their first winter (Stutz and Sanderson, personal observations). Van Epps (1975) reported on winter survival of fourwing saltbush plants from a number of sites in the Intermountain area. There was variability, but generally plants from southern Utah and areas farther south suffered high mortality when grown in central Utah, and the best survival for this planting area was in plants obtained from Bridger in southern Montana. The Aberdeen, Idaho, Plant Materials Center has recently announced the release of a cold-adapted strain of fourwing saltbush hardier than strains presently in use (Aberdeen Plant Materials Center staff 2002; USDA-NRCS and University of Idaho staff 2001). It should be especially useful in colder areas, such as northern Nevada, northern Utah, and southern Idaho.

The race Aptera, mainly found in Montana (figure 1), is also very cold hardy. Its native habitat is saline soils such as are found in badlands, in areas of generally greater annual precipitation (≥15 inches), especially summer rainfall, than is found over the general fourwing saltbush distributional range. Plants of Aptera from various locations were grown successfully for many years in gardens at Provo, Utah and at the Gordon Creek Wildlife Management Area near Price, Utah, where the annual rainfall is about 15 inches and 11.3 inches, respectively (Ashcroft and others 1992; McArthur and Welch 1982).

Plants from more northern areas generally perform well in areas to the south of their origin. On the other hand, plants from the south typically grow in northern areas with much vigor during summer but are eliminated during the cold season. Cold resistance probably

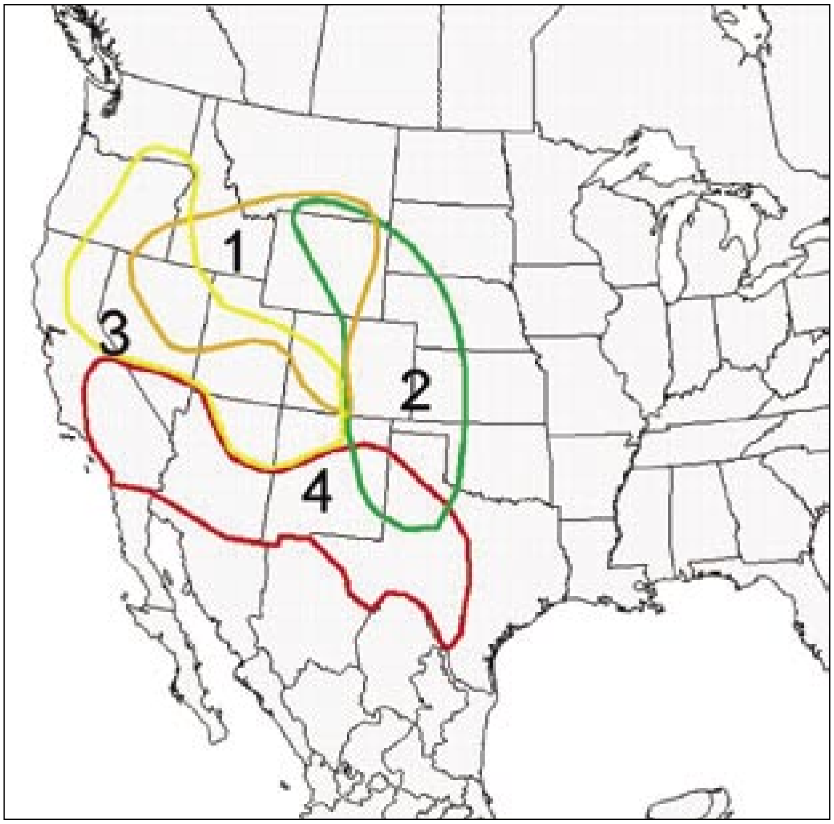

Figure 6. Recommended seed transfer zones for race Occidentalis: (1) Northern Intermountain, (2) Western Great Plains, (3) Colorado Plateau/Great Basin/Columbia Basin, and (4) Southwestern.

comes at a certain cost, and that is a reduced growth rate. Usually this is not an adaptive disadvantage. Long-term survival of seeded populations depends on successful recruitment by seeded plants. This may or may not happen depending of the site adaptation of the source population—it usually does not happen in off-site plantings, e.g., Wyoming big sagebrush sites (McArthur and Sanderson, personal observation). Seeded plants do produce viable seed in most locations (Noller and others 1984; Monsen and McArthur 1985; Sanderson and McArthur personal observations).

Our general recommendations for planting race Occidentalis are summarized in figure 6. Common garden plantings and revegetation plantings (Fitzsimmons and others 1998; Geist and Edgerton 1984; McArthur and others1983; Pendleton and others 1992; Peterson and others 1987; Plummer and others 1966; Van Epps 1975) point to a consensus that source populations should not be moved too far north or up in elevation. In general, source populations from near planting sites do well. So, we recommend that source populations not be obtained out of the general zones (figure 6) and not moved up in elevation more than 2,000 feet within their respective zones. The four zones are Northern Intermountain; Western Great Plains; Colorado Plateau/Great Basin/ Columbia Basin ; and Southwestern (figure 6).

Stutz and colleagues (Stutz 1982; Stutz and Estrada 1995) recommend that revegetation be by natural evolutionary processes by seeding mixes of compatible seed sources (sources of the same ploidy level), thus stimulating an evolutionary trajectory for the specific seeded site. Should this be the management choice for revegetation, we recommend that the seed mix chosen include source populations from the zone to be rehabilitated.

Selected Germplasms

Five germplasms of fourwing saltbush have been released for reclamation plantings (Davis and others 2002). Germplasm releases are plant materials that have been identified and depending on class (source identified, selected, tested, source identified, cultivar—see Young 1995 and Young and others 1995 for criteria), evaluated for performance and made available for seed increase. Whereas there is a substantive continuing demand for fourwing saltbush seed for rehabilitation plantings (McArthur and Young 1999), most of this need is met by wildland collected seed. McArthur and others (1978) made an economic analysis on the potential profitability for growing fourwing saltbush in seed orchards. However, the ready availability of wildland-collected seed has dampened the demand for more expensive field-grown seed. Some commercial production, however, is available. The best way to determine if seed is available is to contact state Crop Improvement Associations or the plant materials specialists of the U. S. Department of Agriculture, Natural Resources Conservation Service.

The released germplasms are 'Marana,' 'Rincon,' 'Santa Rita,' "Snake River Plains," and 'Wytana' (Davis and others 2002). All but "Snake River Plains" were released as cultivars, implying that the indigenous population sources underwent selection for specific trait(s) and were tested in comparisons with other fourwing saltbush source populations. "Snake River Plains" is a tested plant material comprising a synthetic composite of four populations. The released plant materials are all of race Occidentalis except 'Wytana' which is of race Aptera. Both 'Marana' (originally collected from El Cajon, San Diego County, California at an elevation of 600 feet) and 'Santa Rita' (originally from south of Tucson, Pima County, Arizona at an elevation of 2400 feet) are from southern locations at relatively low altitudes and are best adapted to the Mojave and Sonoran Deserts, respectively (Davis and others 2002; Cable 1972; United States Department of Agriculture Soil Conservation Service and others 1980). The source population for 'Rincon' is at Rincon Blanco, Rio Arriba County, New Mexico, at 7,800 feet. This release was a result of selection and testing over a wide geographical area (McArthur and others 1984). The source high elevation site (ponderosa pine, pinyon-juniper, and big sagebrush community) preadapted this release to more northern habitats (as far north as central Utah and Nevada) than might be expected. The "Snake River Plains" tested germplasm was selected for its tolerance to the colder, windier northern conditions of Snake River Plain and Northern Great Basin areas (USDA-NRCS and University of Idaho staff, 2001). 'Wytana' is adapted not only to the Aptera geographical area (Fig. 1) but also to somewhat more southern areas (Sanderson and McArthur, personal observations).

We believe that each of the released plant materials should be considered for use in revegetation areas to which they are adapted but that wildland collected materials should be used prudently within their zones of adaptation (our recommendations are in Fig. 6). As a general rule, close habitat and geographical proximity are preferred. And, when greater movement from source sites occurs, down slope and south is better than upslope and north.

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