

PACIFIC SOUTHWEST Forest and Range Experiment Station

FOREST SERVICE
DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

Low-volume and Slow-burning Vegetation for Planting on Clearings in California Chaparral

Eamor C. Nord

Lisle R. Green



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The Authors

The late **EAMOR C. NORD** was a range scientist assigned to research on low volume vegetation, with headquarters at the Station's Forest Fire Laboratory, Riverside, Calif. He attended the University of Idaho, where he earned a bachelor's degree in forestry (1940), and Texas A&M University, where he earned master's (1953) and Ph.D. (1956) degrees in range science. **LISLE R. GREEN** is a range scientist with the chaparral management research unit, with headquarters at Riverside, Calif. He was formerly in charge of the Station's research on fuel hazard reduction. He earned bachelor's (1940) and master's (1948) degrees in range management at Utah State University. He has been on the Station's research staff since 1948, except for 5 years when he taught range management and soil science at California State Polytechnic College.

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SUMMARY

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One means of reducing size and damage from wildfires in California has been fuel modification—replacement of hazardous fuels, primarily chaparral, with vegetation of lower fuel volume or flammability, or both. Unless suitable plants are established, when chaparral is cleared, flammable annual grasses and forbs dominate the site.

A search for suitable plants has been carried out intermittently during the past 35 years. In 1963, research was intensified at the Pacific Southwest Forest and Range Experiment Station. Results of this work show there are several shrubs, mostly low-growing species, and a few perennial grasses that can be established and grown satisfactorily under wildland conditions. Subsidiary studies carried out concurrent with test and field plantings at several locations showed that shrubs with high mineral (or ash) content held and retained considerably higher fuel moisture throughout the year, and thus were not as flammable as most chaparral and other species tested which had low mineral or ash content.

Some 50 or more shrub species or taxa and numerous grasses were tested. About 20 shrubs and an equal number of grasses showed promise for planting on fuelbreaks or other brush-cleared areas. The list included 11 low-growing, 2 semiprostrate, and 3 upright shrubs. Within each of these categories were a

few species that had a rather wide range of soil and elevational adaptability. Creeping sage fit more requirements than other shrub species tested for planting on fuelbreak sites. This plant, only a few inches high, provided a relatively dense cover that tended to inhibit growth of most other plants and proved it could slow down the rate of fire spread, especially within annual vegetation. The lavendercottons, Descanso rockrose, and some saltbushes were likewise adapted to many different sites. Several other shrubs and some grasses were suitable but only for a limited set of conditions. Creeping sage and a few saltbush species were successfully established by drill seedings upon properly prepared seedbeds along fuelbreaks.

In this report, characteristics of the individual species and their usefulness for planting are described; and directions are given for collecting or treating seed to improve germination, propagating plants from cuttings, and establishing these plants on wildland sites. The role of perennial grasses and trees, particularly to reduce fire hazards from brushlands near urban situations, is discussed. A number of the species described could serve not only to reduce fire hazards but for soil stabilization and improving wildlife habitat, and are attractive for landscape use near homes as well as for planting over more extensive areas.

An average of more than 11,000 wildfires a year burned in California during the 5 years ending in 1975.¹ Less than 2 percent of these fire starts became the extensive and damaging fires called conflagrations, yet in 1970 about half a million acres were blackened. There has been at least one fire exceeding 10,000 acres in extent in every year but one since 1960.

These periodic large wildfires cause staggering losses in structures burned, watershed blackened, postfire erosion, and floods.

One means for reducing spread and damages from wildfire is to replace hazardous fuels with vegetation that has low fuel volume or low flammability, or both. Such fuel modification is needed especially on fuelbreaks, along roads, near structures, and under powerlines. Areas that do not burn over rapidly, nor with great heat output, can provide firefighters safe access into brushfields, and a place to begin fire suppression action. Protection of structures is also easier if surrounding fuel is modified.

Herbaceous annual plants, especially grasses, usually dominate following clearing of chaparral. They are very flammable when dry, and fire spreads rapidly in such fuel. To replace the annuals, plants are needed that will grow on wildland sites with little or no maintenance, and burn less readily than the annuals, with less heat output than the chaparral. Extensive efforts have been made to identify such plants. Acceptable vegetation for planting on fuelbreak and related wildland sites will possess some of the following characteristics:

1. *Low volume*—Because heat output from burning fuel tends to be proportional to the quantity of fuel—the fuel volume—low-volume plants are preferred on fuelbreaks or other control lines. Some relatively tall plants can be considered in this group, but these generally have a high mineral content which, with associated high moisture content, tends to make the plants slow to ignite and burn.

2. *Low growth form*—Low prostrate shrubs that creep along and cover the ground are most desirable.

Some spreading grasses and forbs are also useful, although they are more apt to become dry and flammable during the summer.

3. *Wide adaptability*—Plants of interest must be adaptable to dry chaparral sites, and preferably to a moderately broad range of elevations, exposures, temperatures, and soils if they are to be useful.

4. *Reproducibility*—Species or varieties which reproduce vegetatively by adventitious roots, rhizomes, or stem layering, as well as by seed, have an advantage under dryland conditions. These characteristics allow plants to establish themselves or spread when seed will not germinate and grow. It gives them added power to recuperate after injury, as by drought or grazing.

5. *Widespreading, deep root systems*—Plants with much branched, deep, and fast-growing root systems are preferred because they make best use of available nutrients and soil moisture. They are less susceptible to frost heaving than plants with a deep tap root.

6. *Relatively low flammability*—Plants that retain high moisture content into the summer ignite and burn less readily than plants of lower fuel moisture. High summer moisture content is frequently correlated with high mineral or ash content. Any plant called “greasewood,” such as chamise and other plants that contain large amounts of tars, resins, or other flammable, volatile products, burns readily and is undesirable.

7. *Palatability to animals*—Palatable plants such as the saltbushes and ceanothus are subject to destruction during the establishment stage, or in sparse stands. Grazing or browsing of mature plants is desirable, however, because it reduces accumulation of dead and live fuel.

The search for plants that do not burn as readily nor supply as great fuel volume as native fuels began in 1928, when the Forest Service started test plantings of ice plant (*Mesembryanthemum* spp.), woody spurges (*Euphorbia* spp.), other succulents, and some saltbushes (*Atriplex* spp.) in southern California forest and nursery tests. These plantings succumbed to browsing, summer drought, or low winter temperatures (Ilch 1952). The effort diminished during the late 1930's and 1940's, but during the 1950's, personnel at the Los Angeles County Arboretum and

¹ California Department of Conservation, Division of Forestry. 1976. *California Wildfire Summary—1975*. 1 p.

Angeles National Forest started looking for slow-burning plants that would grow under southern California watershed conditions (Green 1965). The Pacific Southwest Forest and Range Experiment Station assigned a scientist, the senior author, to work full time on low-growing shrub research in 1963. The California Department of Forestry and the Los Angeles County Fire Department were interested and have participated in much of the work. Joint studies are in progress.

This paper summarizes findings of the Pacific Southwest Forest and Range Experiment Station, and some experience of cooperators. The brief section on

grasses that may be planted on fuelbreak sites consists of recommendations based on research that antedates or, for a few species, parallels the shrub studies. The shrub work has not been reported previously.

The reports of test results consist of tables showing relative performance of species, followed by descriptions of those species found most suitable. The descriptions cover plant origins, general characteristics, and other details pertinent to establishment of the species in fuel modification projects. Selection and management of vegetation to minimize fire hazard around homes is covered briefly in the Appendix.

SPECIES PERFORMANCE TESTING METHODS

Before 1965, species tested for chaparral areas were primarily grasses and forbs intended to provide herbage for domestic livestock. Grasses have been test planted on burned or mechanically cleared chaparral areas for more than 35 years (Jones and Love 1945, Bentley and Talbot 1949). The University of California, the California Agricultural Extension Service, the Forest Service (Pacific Southwest Forest and Range Experiment Station and California Region), and the Agricultural Research Service have tested promising grass and forb species throughout the State, frequently in joint studies (Bentley and others 1956). The Soil Conservation Service tested grasses and forbs for wildland plantings, and maintained facilities to produce seed for testing of promising strains or species. Edmunson and Cornelius (1961) and Green and others (1963) reported on tests aimed particularly at developing recommendations for fuelbreak planting in southern California. For grasses recommended as a result of these tests, cultural methods and site requirements are known, and seed is commercially available.

Since 1965, our program has aimed at developing low-volume shrubs for fuelbreak planting, although some attention has been given to tall-growing shrubs that may burn less readily than most chaparral species. The need is for shrubs that grow no taller than 1 foot (0.3 m), that are prostrate in growth habit, and that spread outward with dense enough foliage to suppress annuals. Suitable plant materials have been selected from domestic and foreign sources, and methods have been developed for propagating plants from seed or vegetative material. Greenhouse and field plot tests have been conducted, and some species are currently under test in large plot

field plantings. Still to come is the development of seed supplies of most shrubs, and management guidelines for shrub stands established on wildland sites.

Initial field tests were made from 1964 to 1973 at 11 sites (*table 1*), as suitable shrubs came to our attention. The primary test sites were on or near the North Mountain Experimental Area, near Banning in Riverside County, at 3600 (1097 m) and 5000 (1524 m) feet elevation. Others were elsewhere in Riverside County and in Los Angeles and San Diego Counties.

At all sites, chaparral vegetation was cleared and the ground prepared for planting by disking or rototilling, which reduced competition from annuals. Rooted transplants grown in asphalt or milkboard pots, generally 2 to 3 inches (5 to 7.6 cm) square by 8 to 12 inches (20 to 30 cm) deep, were used in initial tests. In only a few instances, and then only for 2 to 3 weeks after planting, was there any supplemental watering of the plants. Some of the plantings at the Nixon site in the North Mountain Experimental Area were protected from both grazing animals and rabbits by an enclosure fence. No protection from animals was provided for other plantings except that a few plants were initially protected by means of wire domes or cages, primarily against rabbit clipping, at a few locations.

More than 40 woody plant species and varieties were installed at one or more of the study sites during the past 10 years. Some were planted at several locations to determine their range of adaptability; plantings were installed in different years at the same site to compare annual variability; and species were either seeded or transplanted by various techniques to determine feasible means of establishment.

Table 1—Location and general characteristics of sites in southern California where low-volume/slow-burning shrubs were tested between 1964 and 1973

Site	Location and management unit	Elevation	Annual precipitation	Soil
		Feet (m)	Inches (cm)	
Primary test sites:				
Nixon	North Mountain Experimental Area (Bur. Land Manage.), Riverside Co.	3600 (1097)	21 to 23 (53 to 58)	Very sandy loam to loamy sand; pH 5.8 to 7.0.
Vista Grande	San Bernardino National Forest, Riverside Co.	5000 (1524)	30 to 32 (76 to 81)	Deep, loamy sand; pH 5.3 to 6.0.
Other test sites:				
Wolfskill	North Mountain Experimental Area (Bur. Land Manage.), Riverside Co.	2600 (792)	15 to 18 (38 to 46)	Moderately deep, fine sandy loam; pH 5.6 to 7.3.
Mill Creek Summit	Angeles National Forest, Los Angeles Co.	5200 (1585)	28 to 30 (71 to 76)	Moderately deep sandy loam; pH 6.2 to 6.8.
Upper Big Tujunga (Lynx Gulch)	do.	3400 (1036)	15 to 18 (38 to 46)	Very deep, loamy sand to sandy loam; pH 6.4 to 7.0.
Mill Canyon	do.	3000 (914)	18 to 20 (46 to 51)	Moderately deep, loam to heavy sandy loam; pH 6.5 to 7.0.
Alder Gulch	do.	4500 (1372)	20 to 24 (51 to 61)	Moderately deep, gravelly sandy loam; pH 6.2 to 7.0.
Sierra Saddle	Angeles National Forest, Los Angeles Co.	2500 (762)	15 to 18 (38 to 46)	[Data not available.]
Malibu Nursery	Los Angeles Co., Forestry Division, Los Angeles Co.	Below 2000 (610)	15 to 25 (38 to 64)	Deep, sandy clay loam; pH 7.0 to 7.6.
Jamul Ranch	Daley Ranch, San Diego Co.	1000 (305)	14 to 18 (36 to 46)	Deep sandy loam to sandy clay loam; pH 6.2 to 6.6.
Manzanita	Manzanita Indian Reservation, San Diego Co.	4000 (1219)	11 to 23 (28 to 58)	Moderately deep, loamy coarse sand; pH 6.0 to 7.2.

The number of plants used depended to some extent upon the supply available. At least 10 and usually 50 or more plants were installed at 1- to 4-foot (0.3- to 1.2-m) intervals along rows 3 feet (0.9 m) apart at each site (fig. 1).

The evaluation of relative performance of species tested took into account emergence and establishment of seedlings, plant survival, growth habit—especially by vegetative means (stem layering or root sprouting)—rate of growth, susceptibility to animal damage—especially by rabbits—and other plant responses.

Several species were evaluated in the Riverside nursery, and in limited numbers at a few other places, then were dropped from further consideration. These species are included in the tabulation of results with other plants found unsatisfactory.

Records of plant survival and growth were taken two or three times during the first year, and annually thereafter. Representative plants of a few species were excavated to determine the nature and extent of their rooting systems during the first year or two after establishment on field sites (fig. 2).

Concurrent studies or tests were conducted to determine means of improving germination (Nord and others 1971), methods for propagating plants from cuttings (Nord and Goodin 1970), and direct seedings to develop better methods for producing and establishing shrub plants. This included studies on time and depth of saltbush seedings (Nord and others 1971), and current work still in progress on prostrate ceanothus or squawcarpet (*Ceanothus prostratus* Benth.) and creeping sage (*Salvia sonomensis* Greene.).

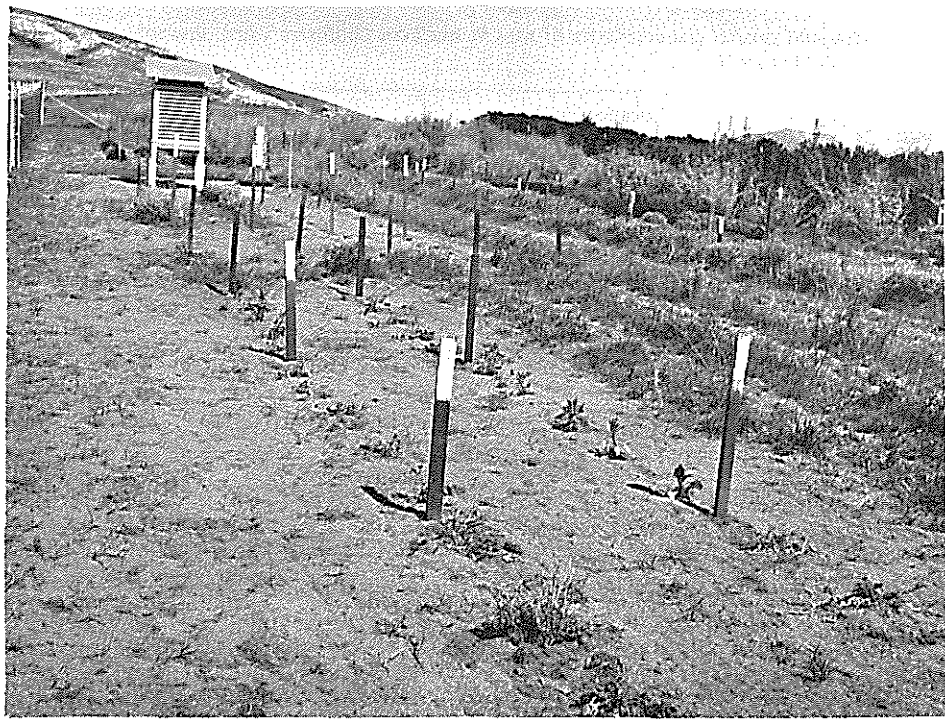


Figure 1—Nixon enclosure, North Mountain Experimental Area, Riverside County, California. Here, at 3500 feet elevation in the San Jacinto Mountain range, low-profile or slow-burning shrubs are tested for adaptability.

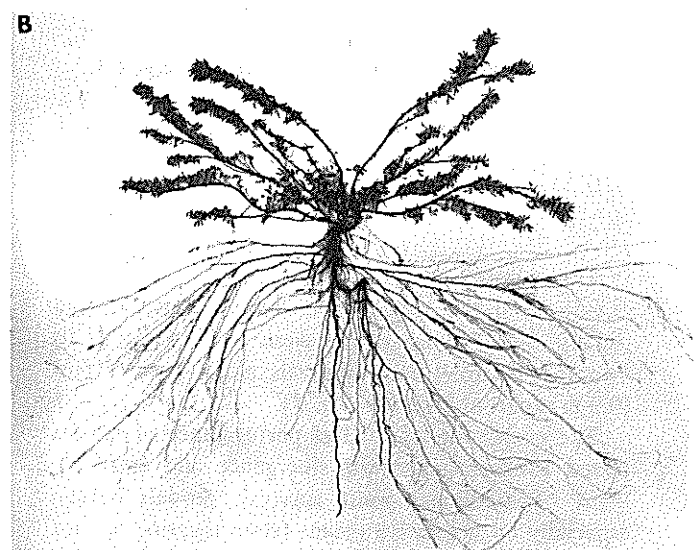
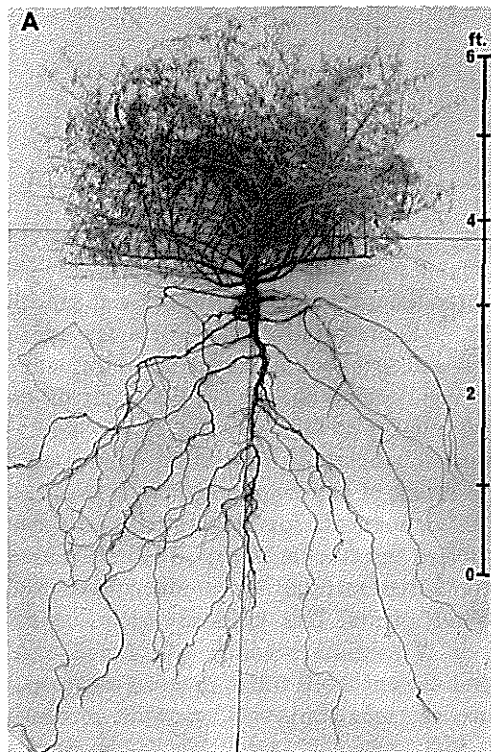


Figure 2—Representative low-profile or slow-burning shrubs were excavated to determine the nature and extent of root systems during the first year or two after establishment: *A*, 2-year-old creeping sage grown from fresh stem cutting; *B*, 1-year-old fourwing saltbush grown from seed planted on the Nixon test plot, North Mountain Experimental Area, Riverside County, California.

USEFUL GRASSES

Perennial Grasses

Perennial grasses have been recommended ground cover for fuelbreak sites, where they are adapted, for many years (fig. 3). There are several reasons:

- Viable seed of most recommended species is commercially available, and methods of establishment are well known. This is a tremendous advantage of perennial grasses over many shrub species whose seed must be hand collected, treated to break dormancy, and planted when we do not know much about the planting conditions needed, or when they must be reproduced from vegetative cuttings.
- They usually have deep, spreading root systems that enable them to draw on moisture not available to most annuals, and they stay green later into the summer. This makes them less flammable than annuals during part of the summer, and in the fall when they green up again.
- Successfully established in near solid stands, they provide a barrier that usually prevents reinvasion by woody vegetation.
- Once established, they provide herbage for grazing animals.

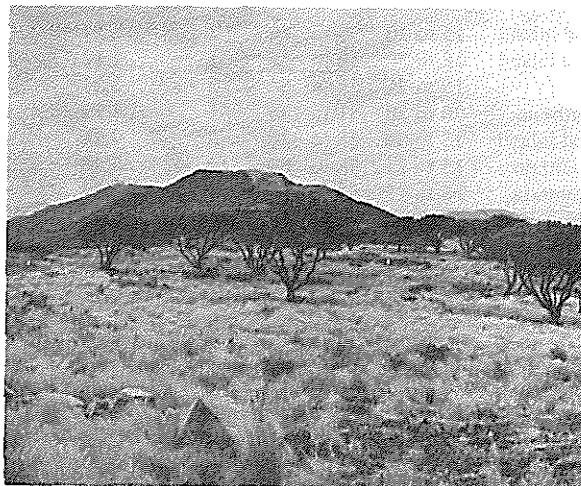


Figure 3—Perennial grasses, where adapted, make excellent fuelbreak ground cover. Seed is available, excellent forage is provided, and a solid grass cover provides a barrier to reinvasion of brush.



Figure 4—Intermediate and pubescent wheatgrasses (left) spread from underground stems (rhizomes). Bunchgrasses, such as tall wheatgrass or crested wheatgrass (right), depend predominantly on seed, an undependable method of reproduction for perennial grasses on dry or weedy sites.

There are limitations to use of perennial grasses, however. One is that in the chaparral zone they need a soil that can store 3 inches (7.6 cm) or more of available moisture in the surface 3 feet (0.9 m). Fine sandy loam, loam, or clay loam soils more than 2 feet (0.6 m) deep meet this requirement. Annual rainfall of at least 15 inches (38 cm) is needed on fine-textured soils, and 20 inches (50 cm) on sandy loams.

Another limitation is that perennial grasses need to be grazed once they are established. This prevents undesirable fuel accumulation, and it encourages “stooling out,” resulting in better ground cover and reduced height growth. Attracting livestock in sufficient numbers to fuelbreak situations has not always been possible. Contracting and paying for grazing by bands of sheep may be a solution.

Several perennial grasses are useful as low-volume ground cover:

Two wheatgrasses, intermediate (*Agropyron intermedium* [Host] Beauv.) and pubescent (*A. trichophorum* [Link] Richt.), are highly recommended. Both are introductions from eastern Europe or central Asia. Both are palatable to livestock. They become established readily from seed, and spread to form a loose sod from short rhizomes (fig. 4). Under dryland conditions, seed stalks grow 1 to 1½ feet (30 to 45 cm) tall, but on good site and with adequate moisture, they may be twice as tall. Pubescent wheat-

grass is somewhat more drought resistant than intermediate, and is recommended in the California brushfields above 2000 feet (610 m) elevation wherever rainfall is 15 inches (38 cm) or more (table 2). Intermediate wheatgrass needs a little more moisture—20 inches (50 cm) or more—and does best at elevations above 3000 feet (914 m) in southern California.

Tall wheatgrass (*A. elongatum* [Host] Beauv.) grows very well in the chaparral belt, but is not as well suited to fuelbreak situations as pubescent and intermediate wheatgrasses. It does not spread from the original bunches, grows taller and coarser, and is less palatable than pubescent or intermediate wheatgrass, and produces more fuel.

Hardinggrass (*Phalaris tuberosa* L. var. *stenoptera* [Hack.] Hitchc.) is a long-lived grass, planted more widely than any other perennial on low-elevation rangeland in California. It does best with 15 to 25 inches (38 to 64 cm) of precipitation, between 500 and 3500 feet (150 and 1067 m) elevation. On good sites, it produces an abundance of palatable herbage that is closely cropped by livestock. After maturing, stems frequently remain green near the base.

Several other perennial grasses should not be the dominant part of a planting mixture, but may be useful. Smilograss (*Oryzopsis miliacea* [L.] Benth.) is a palatable, long-lived grass adapted to 16 inches (40 cm) or more rainfall, and elevations to 3000 feet (914 m). It could be a valuable plant for fuelbreak use because the stems stay green into the summer, except that seeding success has been poor. This is because the extremely small seed—about 880,000 per pound or 1940 per gram—can easily be planted too deep (below 1/4 inch, 6 mm); the tiny seedlings often do not emerge through crusted soil, do not survive drought, or do not compete well with weeds; and the seed has a hard outer coat. Germination can be improved by soaking seed for 20 to 40 minutes in 70 percent sulfuric acid (Koller and Negbi 1959), or for 1 hour in household bleach (Love and others 1952). The ash formed in burning of woody fuels has a similar effect, and good stands have developed on recent brush burns. Smilograss is a good candidate to include in any perennial grass mixture at lower elevations.

Perennial veldtgrass (*Ehrharta calycina* Sm.) is a

Table 2—Grass species recommended for fuelbreak sites in California¹

Species	Elevation		Seeding zone	Rainfall		Recommended sowing rate	
	Feet	Meters		Inches	Cm	Lb/acre	Kg/ha
Hardinggrass	To 4000	To 1220	Coastal and inland	15 to 30	38 to 76	2	2.24
Smilograss	To 4000	To 1220	Coastal and inland	15 to 30	38 to 76	1	1.12
Veldtgrass	To 4000	To 1220	Coastal	15 to 25	38 to 64	2	2.24
	To 4000	To 1220	Inland southern	20 to 30	51 to 76	1	1.12
Pubescent wheatgrass	To 4000	To 1220	Coastal and inland	15 to 30	38 to 76	2	2.24
	3500 to 6500	1067 to 1980	Inland mountain	15 to 25	38 to 64	4	4.48
	3500 to 6500	1067 to 1980	Inland mountain	25 to 45	64 to 114	2	2.24
	3000 to 8000	914 to 2438	Desert side, mountain	15 to 25	38 to 64	2	2.24
Intermediate wheatgrass	To 4000	To 1220	Coastal	20 to 30	51 to 76	1	1.12
	3500 to 6500	1067 to 1980	Inland mountain	15 to 25	38 to 64	2	2.24
	3500 to 6500	1067 to 1980	Inland mountain	25 to 45	64 to 114	3	3.36
	3000 to 8000	914 to 2438	Desert side, mountain	15 to 25	38 to 64	2	2.24
Goar's tall fescue	To 4000	To 1220	Coastal	20 to 30	51 to 76	1	1.12
	3500 to 6500	1067 to 1980	Inland mountain	25 to 45	64 to 114	1	1.12
Sherman big bluegrass	To 4000	To 1220	Inland central	20 to 30	51 to 76	1	1.12
	3500 to 6500	1067 to 1980	Inland mountain	15 to 45	38 to 114	1	1.12
	3000 to 8000	914 to 2438	Desert side, mountain	15 to 25	38 to 64	1	1.12
Orchardgrass	3500 to 6500	1067 to 1980	Mountain	25 to 45	64 to 114	1	1.12
Crested wheatgrass	3000 to 8000	914 to 2438	Desert side, mountain	15 to 25	38 to 64	2	2.24
Blando brome (annual)	To 4000	To 1220	Coastal	15 to 30	38 to 76	¼ to ½	0.28 to 0.56
			Inland	20 to 30	51 to 76	¼ to ½	0.28 to 0.56

¹ Adapted from Green and others 1963, and Bentley 1967.

short-lived perennial that reseeds itself on sandy or sandy loam soils in the central and south coast regions of California. It also did well in the San Gabriel Mountains above Glendora, California at 4000 feet (1220 m) elevation.

Sherman big bluegrass (*Poa ampla* Merr.) is native to northern California, although the Sherman strain was collected in eastern Oregon. It is a short bunchgrass whose greatest usefulness is above 3500 feet (1067 m) elevation.

Less thoroughly tested are sandhill grass and buffelgrass. Sandhill grass (*Brachiaria ciliatissima* [Buckl.] Chase), is native to sandy ground in the Texas-Arkansas gulf coast area. It produces seed, but also long leafy stolons that root at the nodes. It is moderately frost tolerant; sandhill grass and creeping sage were the only two survivors of nine species planted on a roadside cut above Pasadena, California at 2500 feet (760 m) elevation. Plantings near Jamul, 20 miles (32 km) east of San Diego, were doing well in June 1973. Seed is not available commercially, but can be readily collected.

Buffelgrass (*Pennisetum ciliare* [L.] Link) was introduced from south Africa into our southern states, and from there into the warm western states. It has grown better than most other species on infertile sandy soils. It is a heavy seeder; the seed is fuzzy and difficult to harvest, but commercially available. A seeding on the Jamul Ranch in San Diego County in 1972 appeared promising. A variety known as "Higgins" buffelgrass grows from rhizomes; it has also been planted with some success in San Diego County.

Fountaingrass (*P. setaceum* [Forsk.] Chiov.), also from Africa and originally used in this country for ornamental plantings, has been successfully established and good stands have developed from seedlings on disturbed sites, especially along road cut or fill slopes in Los Angeles, Orange, Riverside, and San Diego Counties at elevations below about 1500 feet

(460 m). This grass is somewhat taller but in most other respects is quite similar in appearance to buffelgrass. Seed is also commercially available.

Annual Grasses

When woody fuels are cleared from wildland sites by wild or prescribed fire or with mechanical tools, a replacement cover of herbaceous annuals develops rapidly. This comes from viable seed present before burning or clearing, and from seed carried or blown into the cleared area. It consists of mostly nongrassy plants—forbs—following hot fire and, after the first year, annual grasses as well. Sprouts from woody plant crowns and brush seedlings also appear. Annual ryegrass (*Lolium multiflorum* Lam.) or bland brome (*Bromus mollis* L.) may be introduced artificially during the first year.

The herbaceous cover reverts to brushland in a few years, unless woody vegetation is controlled. If brush is controlled, the annual cover is usually an ecologically unstable mixture of annual grasses and forbs that is soon invaded by biennial or perennial herbs and subshrubs such as *Penstemon*, deerweed (*Lotus scoparius* [Nutt. in T. & G.] Ottley), and California buckwheat (*Eriogonum fasciculatum* Benth.).

Such a plant mixture has a reputation among firefighters of rapid fire spread and intense heat when it burns during the summer and fall months. Nevertheless, it does have a low flammable fuel volume—1/2 to 3 tons per acre (0.45 to 2.7 M.T.)—as opposed to 5 to 40 tons (4.5 to 36.3 M.T.) found in brushfields or conifer forests.

On sites with shallow soils, low rainfall, or other undesirable characteristics, the cover of annual grasses and forbs may be the best low-volume cover the site will support. To date, planting improved or specialized vegetation has not been successful under these conditions.

SHRUBS

About one-fourth of the species and varieties tested, including two to four each of low-volume, semiprostrate, and taller shrub classes, were promising (tables 3, 4). These plants could all be readily established—some by direct seeding as well as by transplanting; survival was uniformly high, usually 50 percent or higher; and growth was satisfactory over a relatively wide range of conditions commonly present in brushland areas. Nearly half of the species made at least fair growth, indicating they would be useful on

some brushland sites. Twenty-two species were unsatisfactory for one or more reasons (table 5).

None of the species tested grew throughout the range of chaparral site conditions, but creeping sage comes as close as any. The promising low-growing group included the two santolinas or lavendercottons (*Santolina chamaecyparissus* L. and *S. virens*). These were established from rooted transplants. Among the semiprostrate and upstanding shrubs that had good performance were rockrose (*Cistus crispus* L., *C.*

Table 3—Relative performance of low-growing¹ shrub species for plantings to reduce fire hazards in southern California brushland clearings

Species and native source	Elevation range of adaptability			How established			Growth rate			Remarks
	<2000 ft (<610 m)	2000 to 4000 ft	>4000 ft (>1220 m)	Direct seeding	Stem cuttings	Rooted transplant	Fast	Med.	Slow	
<u>Good performance</u>										
<i>Salvia sonomensis</i> Creeping or Sonoma sage, California	X	X	X	X	X	X	X			Good in most respects. Stem layers.
<i>Santolina chamaecyparissus</i> ² Gray santolina or gray lavendercotton, Mediterranean region	X	X	X	O	O	X	X			Lower in height and denser than <i>S. virens</i> ; stem layers.
<i>S. virens</i> ² Green santolina or green lavendercotton, Mediterranean region	X	X	X	O	O	X	X			Has fine, porous foliage; quite flammable.
<u>Fair performance</u>										
<i>Artemisia caucasica</i> ² Caucasian artemisia, USSR	X	X	X	O	³	X		X		Attractive, aromatic; stem layers; seed is sterile.
<i>Atriplex cuneata</i> Castlevalley saltbush, central Utah	O	X	X	³	³	X		X		Very fire retardant; high in mineral content. Very susceptible to rabbit damage.
<i>A. gardneri</i> Gardner's saltbush, Utah	O	X	X	X	³	X		X		As above. Produces root sprouts.
<i>A. mulleri</i> ² Muller's saltbush, Australia	X	O	O	X	³	X	X			Low in frost tolerance. Prolific seeder.
<i>A. semibaccata</i> ² Australian saltbush, Australia (Nat. U.S.)	X	O	O	X	O	X	X			Short lived; low in frost tolerance; naturalized.
<i>Baccharis pilularis</i> Prostrate or dwarf baccharis, California	X	X	O	O	X ³	X		X		Adapted to moist or irrigated sites.

Table 3—Relative performance of low-growing¹ shrub species for plantings to reduce fire hazards in southern California brushland clearings—Continued

Species and native source	Elevation range of adaptability			How established			Growth rate			Remarks
	<2000 ft (<610 m)	2000 to 4000 ft	>4000 ft (>1220 m)	Direct seeding	Stem cuttings	Rooted transplant	Fast	Med.	Slow	
<i>Atriplex falcata</i> "Falcata" saltbush, Great Basin region	O	O	?	X	O	X			X	Poorly adapted; low survival and poor vigor and cover.
<i>A. inflata</i> ² Flat-topped saltbush, Australia	X	O	O	X	O	X	X			Short-lived; sensitive to frost.
<i>A. nuttallii</i> Nuttall's saltbush, Great Basin region	O	O	X	X	O	X			X	Poorly adapted; low survival and poor vigor; stem layers.
<i>Ceanothus griseus</i> var. <i>horizontalis</i> Carmel creeper ceanothus, California	O	X	X	O	O	X			X	Poorly adapted except on very moist or irrigated sites; very susceptible to rabbits.
<i>Ceanothus prostratus</i> Prostrate ceanothus or squawcarpet, Sierra-Nevada, Cascade, Calif.	O	O	X	X	O	X		X		Attractive. Excellent on moist sites above 5000 ft. Stem layers.
<i>Galenia pubescens</i> ² Green galenia, South Africa (Nat. Australia)	X	O	O	X	O	X	X			Prolific seeder; sensitive to frosts. Possibly toxic to livestock.
<i>Myoporum parvifolium</i> ² Myoporum; "Horshum" cultivar, Australia	O	X	O	O	X ³	X		X		Adapted to moist or irrigated sites; stem layers.
	<u>Poor performance</u>									
<i>Arctostaphylos uva-ursi</i> Bearberry; Kinnikinnick, North America, Europe, and Asia	O	O	X	O	O	X			X	Very difficult to root; plantings all failed.
<i>C. gloriosus</i> Pt. Reyes ceanothus, California	X	X	O	O	O	X		X		As above.

Table 3—Relative performance of low-growing¹ shrub species for plantings to reduce fire hazards in southern California brushland clearings—Continued

Species and native source	Elevation range of adaptability			How established			Growth rate			Remarks
	<2000 ft (<610 m)	2000 to 4000 ft	>4000 ft (>1220 m)	Direct seeding	Stem cuttings	Rooted transplant	Fast	Med.	Slow	
<i>C. maritimus</i> Maritimus ceanothus, California	O	X	X	O	O	X			X	Drought hardy, but very slow in growth.
<i>Ceratoides lanata</i> Winterfat, Western United States	O	X	O	X	O	X			X	Poorly adapted; low in survival and poor in vigor; has fine porous foliage. Poor cover plant.
<i>Chamaebatia foliolosa</i> Sierra mountain miser, California	O	X	O	O	O	X			X	Very slow in growth; has fine porous foliage; quite flammable.
<i>Genista lydia</i> ² Genista, Greece	O	X	O	O	O	X			X	Very slow in growth; has sparse open foliage.
<i>Lippia canescens</i> var. <i>repens</i> Creeping lippia, United States	O	X	O	O	O	X			X	Very slow in growth; has sparse open foliage.
<i>Nama lobbbii</i> Woolly nama, California	O	X	X	O	O	X	X			Produces root sprouts; aggressive on disturbed sites; susceptible to gopher damage.
<i>N. rothrockii</i> Rothrock nama, California	O	O	O	O	O	X				Poorly adapted; all plantings failed.
<i>Osteospermum fruticosum</i> ² Trailing south African daisy, South Africa	X	O	O	O	O	X		X		Probably suited to moist or irrigated sites; susceptible to frost damage.
<i>O. pachypteris</i> ² Osteospermum, South Africa	X	O	O	O	O	X		X		As above.

¹ Generally less than 1 foot tall.

² Exotic species, including some naturalized in California.

³ Cuttings with layered rootlets.

Table 4—Semiprostrate and tall shrub species useful for plantings in southern California brushland clearings

Species and native source	Elevation range of adaptability			How established			Growth rate			Remarks
	<2000 ft (<610 m)	2000 to 4000 ft	>4000 ft (>1220 m)	Direct seeding	Stem cuttings	Rooted transplant	Fast	Med.	Slow	
Semiprostrate shrubs¹										
				<u>Good performance</u>						
<i>Cistus crispus</i> Descanso rockrose, Mediterranean region	X	X	?	O	O	X		X		Dense foliage; stem layers; attractive flowers.
				<u>Fair performance</u>						
<i>Arctostaphylos myrtifolia</i> Ione manzanita, California	O	X	X	O	O	X			X	Slow growth.
<i>Arctostaphylos confertifolia</i> Shadscale salt- bush, Western United States	O	X	X	O	O	X		X		High mineral content; best on basic soils.
<i>Ceanothus masonii</i> Mason's ceanothus, California	O	?	X	O	O	X		X		Has sparse open foliage; stem layers.
Tall shrubs¹										
				<u>Fair performance</u>						
<i>Atriplex canescens</i> Fourwing salt- bush or chamiza, Western North America	X	X	?	X	O	X	X			Excellent shrub for many uses; high mineral and moisture content, easily estab- lished by seeding.
<i>Atriplex polycarpa</i> Allscale or desert saltbush, California and Arizona	O	X	?	X	O	X	X			do.
<i>Cistus villosus</i> Purple rock- rose, Medi- terranean region	X	X	X	O	X	X	X			Three to 5 feet tall, moderately drought and frost tolerant, flammable when foliage dries, showy flowers.

¹ Semiprostrate shrubs are usually 1 to 3 feet (0.3 to 0.9 m) tall; tall shrubs are usually more than 3 feet tall.

Table 5—Plants not considered suitable for use to reduce fire hazards

Species and native source	Reasons why plants are not suitable
<i>Artemisia aucheri</i> Iran	Foliage too fine and porous, numerous small twigs, growing to 2 feet high. Appears to be equally as flammable as our native <i>Artemisias</i> .
<i>Artemisia herba-alba</i> Iran	As above.
<i>Artemisia cana</i> var. <i>bolanderi</i> Western United States	Poor survival, fine porous foliage that probably is very flammable.
<i>Atriplex elegans</i> Wheelscale saltbush, Western United States	Medium-sized shrub to 3 feet tall; short-lived perennial or annual; poor seedling establishment.
<i>Atriplex halimus</i> Mediterranean saltbush, Mediterranean region	Plants too massive and fuel volume too great; up to 8 feet high with crown at least that wide; numerous relatively small twigs that when dry are likely to burn with high intensity and heat output; not tolerant to low temperature.
<i>Atriplex hymenelytra</i> Desert holly, California	Not adapted except on saline to alkaline soils; grows to 3 feet tall, but otherwise acceptable.
<i>Atriplex lentiformis</i> Big or quailbush saltbush, California	Large shrub to 8 feet tall; high fuel volume.
<i>Atriplex lentiformis</i> var. <i>Breweri</i> Brewer's saltbush, California	Less cold tolerant, otherwise similar to <i>A. lentiformis</i> .
<i>Atriplex leucoclada</i> var. <i>turcomanica</i> Turcoman saltbush, Western Australia (Israel selection)	Frost sensitive, survives only below 2000 feet (610 m); fine foliage, probably quite flammable.
<i>Atriplex nummularia</i> Oldman wormwood, Australia	Somewhat larger but otherwise similar to <i>A. halimus</i> ; plants are massive and produce very high fuel volume.
<i>Atriplex Torreyi</i> Torrey's saltbush, California	More cold tolerant, otherwise similar to <i>A. lentiformis</i> .
<i>Atriplex verucifera</i> Iran	Fine foliage and numerous small twigs on upstanding shrub 2 to 3 feet (.6 to .9 m) tall. The growth form resembles Russian thistle (<i>Salsola kali</i> L. var. <i>tenuifolia</i>) tumbleweed and when dry may be equally as flammable.
<i>Cistus ladaniferus</i> Gum rockrose, Mediterranean region	Very tall upstanding plant; drought tolerant but quite flammable in late summer and fall; attractive flowers.
<i>Cistus salvaefolius</i> French Morocco	Relatively large, 3 to 4 feet (.9 to 1.2 m) high with fine foliage and numerous small twigs; probably equally or more flammable than <i>C. villosus</i> , but seems to have fewer advantages.
<i>Kochia prostrata</i> Prostrate summer cypress or "golden plant of Russia," Iran	Foliage too fine, numerous erect small stems up to 1½ feet (46 cm) tall; potential flash-fire fuel when dry in late summer. May become as flashy as annual grasslands. Is palatable so could be grazed.
<i>Lavandula stoechas</i> French lavender, French Morocco	Plants somewhat too tall—up to 3 feet (.9 m). The rather sparse upstanding branches have relatively fine foliage resembling that of California buckwheat (<i>Eriogonum fasciculatum</i>). This plant was grown from seed inadvertently included with another species sent from French Morocco. Species is used primarily for preparing perfume from its flowers.
<i>Opuntia ficus-indica</i> Mission cactus, Mexico	Too susceptible to damage by many agents including temperatures less than 25° F, and damage by small mammals and domestic livestock; has limited adaptability and suitability for use in reducing fire hazards.
<i>Opuntia serpentina</i> x <i>O. prolifera</i> Cholla, Western United States	Much too spiny, very slow growth and relatively weak or poor cover plant. High safety hazard to fire control personnel.

Table 5—Plants not considered suitable for use to reduce fire hazards (Continued)

Species and native source	Reasons why plants are not suitable
<i>Purshia glandulosa</i> Desert bitterbrush, California to Utah	Mature plants quite flammable; primary use as browse and as cover on disturbed sites; very drought tolerant.
<i>Purshia tridentata</i> Antelope bitterbrush, Western United States	More cold but less drought tolerant than <i>P. glandulosa</i> ; excellent browse and cover for disturbed sites.
<i>Rosmarinus officinalis</i> Rosemary, Mediterranean region	Drought tolerant; very flammable; aromatic.
<i>Tamarix aphylla</i> Athel tree, Mediterranean region	Too high volume and much fine foliage. It is susceptible to freezing and tops kill back at 20 to 25° F (–7 to –4° C) on young plants grown from cuttings.

Table 6—Silica-free ash and crude fat content of foliage (leaves and current year's stem leaders) of shrub species considered for plantings to reduce fire hazards on wildland areas in southern California

Species	Silica-free ash ¹	Crude fat ¹
Chamise (<i>Adenostoma fasciculatum</i>)	2.8 to 5.3	5.1
Caucasian artemisia (<i>Artemisia caucasica</i>)	8.3	3.5
Sweet sagebrush (<i>Artemisia ludoviciana</i> var. <i>incompta</i>)	11.9	5.2
Fourwing saltbush (<i>Atriplex canescens</i>)	12.4 to 19.1	0.9
Castlevalley saltbush (<i>A. cuneata</i>)	18.0	2.3
Shadscale saltbush (<i>A. confertifolia</i>)	21.6 to 27.5	2.0 to 2.9 ²
Gardner's saltbush (<i>A. gardneri</i>)	23.5 to 25.3	2.2 to 2.5
Muller's saltbush (<i>A. mulleri</i>)	21.1	2.9
Allscale or desert saltbush (<i>A. polycarpa</i>)	11.3 to 20.5	1.5 to 3.5 ³
Silver or sweet saltbush (<i>A. rhagodioides</i>)	12.8	1.7
Australian or creeping saltbush (<i>A. semibaccata</i>)	13.4 to 19.1	0.7 to 2.3 ⁴
Descanso rockrose (<i>Cistus crispus</i>)	3.9 to 8.8	2.6
Gum rockrose (<i>C. ladaniferus</i>)	5.0 to 10.4	—
Purple rockrose (<i>C. villosus</i>)	4.7 to 9.0	—
Green galenia (<i>Galenia pubescens</i>)	18.3	4.3
Rosemary (<i>Rosmarinus officinalis</i>)	5.5 to 7.2	—
Creeping or Sonoma sage (<i>Salvia sonomensis</i>)	4.7 to 7.1	10.1
Cypress lavendercotton (<i>Santolina chamaecyparissus</i>)	5.3 to 9.0	—
Green lavendercotton (<i>S. virens</i>)	6.0 to 7.9	—

¹ Where no range is given, a single sample was used. Other entries represent a range that is mainly seasonal. Except as otherwise cited, analyses were made at Northern or Riverside Forest Fire Laboratory.

² Cook and others 1954.

³ Chatterton 1970.

⁴ Russell 1946.

ladaniferus L., and *C. villosus* L.), saltbush (*Atriplex canescens* [Pursh] Nutt. and *A. polycarpa* [Torr.] Wats.), and rosemary (*Rosmarinus officinalis*). The saltbushes and creeping sage were the only ones within these groups that were readily established over a wide range of conditions from direct seedings as well as transplants; however, saltbush species were quite susceptible to damage by rabbits clipping the plants, especially during the first year.

The following sections describe most of the shrubs we are testing for planting in cleared brushland areas in southern California. The comments insofar as possible describe the plant's characteristics, denote the locale of its normal occurrence, state its usefulness for wildland plantings, and include directions for establishing the plant. For some species, the silica-free ash and crude fat contents were analyzed (table 6). Completeness of these comments varies because we have been able to study some species more thoroughly or over a longer time than others.

Sources for seed for many species will have to be developed or enlarged before extensive seedings can be made. Only a few of these plants are normally available at nurseries; therefore it is advisable to make arrangements at least 1 year ahead so that the seed can be obtained and plants propagated and ready when needed.

Low-growing Shrubs

Widely Adapted

Creeping or Sonoma sage (*Salvia sonomensis* Greene.)—Creeping or Sonoma sage is an aromatic, semiprostrate suffrutescent plant found in the chaparral zone along the Sierra Nevada and the Coastal ranges in California at elevations below 6000 feet (1830 m). It grows on relatively shallow, moderately acid-to-neutral soils, where annual precipitation averages 15 to 40 inches (38 to 100 cm) and temperatures range from about 15° to over 100° F (-10° to 38° C). It can withstand some frost, and, once it is established, considerable drought; it does not tolerate saline or alkaline soils (Pratt and others 1971).

This plant gives excellent protection to the soil, and is valuable for fire abatement. Fire burned through creeping sage stands only one-fifth as fast as through dry annual grass and weeds, and produced less heat (Phillips and others 1972). It crowds out most of the flash fuel plants. Plants form mats, often several feet across, with low, dense foliage not more than 8 to 10 inches (20 to 25 cm) tall (fig. 5). Creeping sage is not grazed or clipped to any extent by animals, and therefore has a distinct advantage

over more palatable shrub species. It is adaptable to many site conditions throughout the chaparral zone.

Creeping sage has been established successfully by direct seedings, fresh stem cuttings, and transplants. Once established, it spreads primarily by layering (rooting) along the prostrate branches.

Seedling establishment under natural conditions is very poor, but satisfactory stands have resulted from planting in clean seedbeds. The best stands developed from seed treated with gibberellic acid to break dormancy (Nord and others 1971) and planted at 1/2- to 1-inch (1.3- to 2.5-cm) depth during the late winter to early spring where there was sufficient moisture present in the soil for the plants to become established.

Survival of plants grown from seed or stem cuttings and planted in propagating tubes has consistently been high. For field plantings where watering is not feasible, the minimum recommended tube size is 2¼ by 2¼ by 8 inches (5.7 by 5.7 by 20 cm) with open bottoms so roots may readily grow into the soil below. Bare-rooted transplants can be grown in the nursery, or wildlings suitable for this purpose may occasionally be found, especially on areas where fire has burned through creeping sage stands. The Corte Madera area in San Diego County burned in 1970, and subsequently produced several thousand creeping sage seedlings per acre, many of which were lifted and used for plantings throughout southern California in 1973. Bare root transplants should have roots 8 to 12 inches (20 to 30 cm) long and should be planted in moist soil during the early spring before the plants leaf out to any extent.

Plants are easily propagated from stem cuttings taken at almost any season of the year without benefit of hormone treatment (Nord and Goodin 1970), although best rooting has developed from "hardened" stem or branch sections taken during the late winter. When planted in the field, cuttings with or without attached naturally formed rootlets should be at least 15 inches (38 cm) long and set almost as deep, with soil firmly tamped around the base. Early spring is the time for planting cuttings. The soil is warm enough to induce rooting while there is still adequate soil moisture.

The seed—of which there are about one-half million per pound (1100 per g)—is currently available only by collecting from natural stands. As it matures in mid-May or early June, the spikes can be gathered and spread to dry thoroughly. Later the seed can be readily separated, cleaned and graded by means of threshers, hammermills, and ordinary fanning mills equipped with proper sieves. Seed retains high via-



Figure 5—Creeping sage, a prostrate shrub native to California, forms a dense mat which tends to exclude most annual plants. Its blue flower stalks beautify the landscape in the spring: Here, a single row at Vista Grande (A) has spread to form mats up to 12 feet wide in 6 years; a creeping sage planting made 6 years previously at the Nixon enclosure (B) has spread several feet laterally and has inhibited annual grass growth shown in the foreground.



bility for 4 years and probably much longer when stored in airtight containers at refrigerator temperatures (35° F, 2° C), with or without the recommended gibberellic acid treatment to break seed dormancy.

Creeping sage does have some shortcomings. It does not resprout from either roots or stems following burns; however, new stands may develop from seedlings that appear following fires. It is highly susceptible to weed killers and thus would need to be reestablished should it be sprayed with herbicides, as has happened along fuelbreaks and roadways in some

areas. Moisture content of foliage goes below 60 percent during the late summer and early fall, and foliage will then burn if there is much dead litter to carry the fire.

Gray and green lavendercotton (*Santolina chamaecyparissus* L. and *S. virens*)—Gray and green lavendercotton, native to the Mediterranean Region, are frequently grown in gardens and have occasionally become locally established in parts of central and southern California (Munz and Keck 1959). Both species are low to semierect, compact, aromatic evergreen subshrubs with numerous small erect to semi-

decumbent branches and fine, porous foliage (*fig. 6*). They have a fibrous root system that penetrates quite deeply and widely into the soil. Green lavendercotton plants, up to 30 inches (76 cm) high and 4 to 5 feet (1.2 to 1.5 m) wide, are considerably larger than gray lavendercotton, which may grow to be 18 inches (45 cm) high and up to 3 feet (90 cm) across the foliar crown in good growth situations. Both species are smaller, commonly about 1 foot (30 cm), on dry sites.

Both lavendercottons provide good protection to soil; they spread to form dense cover that crowds out most annuals. Plants are not known to be grazed or clipped to any great extent by animals. Both species, but particularly gray lavendercotton, are drought tolerant, hardy, and versatile, and can be grown successfully in the low desert (Mathias and others 1961 and 1968) and throughout most of the chaparral zone in southern California. Once established, they persist under relatively harsh conditions. In the field, they spread slowly by layering along the decumbent branches, but initial establishment has been only by transplants grown from stem cuttings under intermittent mist. We know of no instances where either lavendercotton has been established on field sites by

direct seedings, nor have we observed any natural seedlings.

Rooted plants grown from stem cuttings have consistently survived and made satisfactory growth on a variety of cleared brushland and highway cut-fill sites in the coastal, San Gabriel, and San Jacinto Mountains up to 5000 feet (1524 m) elevations. When planted where weedy competition was removed immediately preceding planting, 75 percent or more of the potted lavendercotton plants were growing actively 2 years after planting without supplemental irrigation. Growth, recorded in 1969 after 2 years, was as follows:

	<u>Gray lavendercotton</u>	<u>Green lavendercotton</u>
Site and elevation:		
Nixon (3500 feet):		
Survival, percent	85	95
Height, inches	12	20
Crown diameter, inches	20	30
Vista Grande (5000 feet):		
Survival, percent	100	95
Height, inches	11	21
Crown diameter, inches	28	44



Figure 6—Lavendercottons or santolinas are shown here growing at 3500 feet elevation in southern California. Where planted to reduce fire hazards, the gray lavendercotton (*right or foreground*) is preferred because of its lower growth habit and lower fuel volume than green lavendercotton (*left or background*).

These plantings remain healthy in 1975; however, in Los Angeles County, some stands have faded out within 5 years (pers. commun., Arthur Arndt).

Flowering heads were formed by both species beginning the first year, but no viable seed developed. Stem layering that developed during the second year was frequently observed on gray lavendercotton but only rarely on green lavendercotton plants.

The mineral or ash content and fuel moisture in mixed old and new growth green leaves and twigs to 1/8 inch (3.2 mm) diameter varies considerably according to the season and to a lesser extent between the two species. The following analysis is of samples taken from 2- and 3-year-old plants at Nixon plot in 1971 and 1972:

	<i>Gray</i>		<i>Green</i>	
	<i>lavendercotton</i>		<i>lavendercotton</i>	
	<i>Moisture</i>	<i>Ash</i>	<i>Moisture</i>	<i>Ash</i>
	—— Percent of dry weight ——			
Sampling date:				
Late May 1971	271	9.0	327	7.9
Mid-July 1971	44	5.8	44	5.8
Early October 1971	47	7.7	78	7.0
Early April 1972	398	10.9	500	12.0
Mid-July 1972	83	7.6	92	6.3
Late September 1972	67	5.3	59	6.0

The foliage dries out enough to make these plants susceptible to burning. The fine foliage provides a porous fuel bed that somewhat resembles grassland fuels. Wildland fire will most likely burn rapidly through the foliage when fuel moisture is low as was recorded in 1971, particularly if there is dead fuel to carry the fire.

The chief value of these two lavendercottons is their ability to grow in dry situations, and their usually low fuel volume. Gray lavendercotton is preferred over the green.

Restricted in Adaptability or Usefulness

Caucasian artemisia (*Artemisia caucasica* Willd.)—Caucasian artemisia, native to plains and foothills of the Black Sea and Caucasus areas, USSR,² is a low-growing suffrutescent subshrub of the composite family. It is an attractive silver-colored plant that forms a thick turflike evergreen cover. It usually grows about 4 inches (10 cm) high, except for the nonpersistent erect flower stalks which reach 12 inches (30 cm). The prostrate branches root as they

spread and plants form huge mats, especially when grown in full sunlight. It tolerates some shade, but is not as thrifty nor foliage as dense as when growing in sunny situations. Plants grow satisfactorily on a wide variety of sites, particularly with irrigation from hot, low elevations up to 5000 feet (1524 m) or higher, in several parts of California and other western States (Idaho, Utah, and Washington). It is adapted to a wide variety of soils, and a pH range of 6.0 to 8.0.

Plants in this country originated from a single clone, developed from seed obtained from USSR in 1966 (PI #314-441; UCD #66-1178), and propagated by the University of California at Davis in a cooperative program with the Forest Service. The plants flower abundantly, but no viable seed has been obtained from any plantings. Apparently this particular ecotype or clone strain, like certain other *Artemisias*, is self-sterile.

Plants can be readily rooted from cuttings 3 to 4 inches (8 to 10 cm) long containing about 2 inches (5 cm) of hardened stem sections, in sand or sponge rock under occasional intermittent mist. Cuttings are susceptible to damping-off fungus and therefore care must be used to avoid excessively damp conditions in mist chambers. Also, crown masses from established plants can be sectioned and planted in much the same manner commonly used with "plugging" turf plants such as dichondra or bermudagrass.

Plants produced from stem cuttings or divisions or sections of stem having roots formed naturally from stem layers can be transplanted either in pots or bare rooted between late fall or early spring when the ground is still wet. Survival is high and growth rapid under irrigation, even without fertilizing throughout southern California. Spaced at 3-foot (0.9-m) intervals, plants spread up to 2 feet (0.6 m) outward per year, and cover the ground within a 2-year period (fig. 7).

Under dryland situations, survival and growth is considerably less than under irrigation. Plantings made at the Nixon and Vista Grande sites in southern California had 5 and 35 percent survival and crown diameters were 3 and 9 inches (8 and 23 cm) respectively, during a 2-year period when precipitation was about 15 inches (38 cm) annually.

Most of the mortality to Caucasian artemisia plants has been caused by gophers digging under and cutting off roots below the crowns rather than by dry soil conditions. Rabbits are also known to clip the foliage. Occasionally, dense stands may be damaged by fungus organisms, especially if plants are kept very moist from too frequent sprinkling or during prolonged humid conditions.

² *Flora URSS* (Flora Unionis Rerumpublicarum Socialisticarum Sovieticarum) XXVI. Editio Academiae Scientiarum URSS. Moscua, Leningrad. p. 492-493. (Trans. by Patrick Harlan, U.C., Riverside, Jan. 29, 1973.)



Figure 7—Caucasian artemisia is a recent introduction from the Soviet Union. It shows promise as a low-growing, drought- and cold-tolerant plant useful to reduce fire hazards, for erosion control, and as ornamental ground cover. Plants spread up to 2 feet outward per year under irrigation and spaced at 3-foot intervals cover the ground within 2 years.

One might suspect that when this plant becomes dry it would burn as do most other *Artemisia* (sagebrush) species. Its ash content, about 8 percent, and crude fat content, 4 percent (table 6), is intermediate between that in known flammable and slow-burning species. However, because of its very low growth habit and small fuel volume, any fires that might develop would be of low intensity and heat output; therefore, to have it occupy a site could reduce the fire hazard significantly.

Caucasian artemisia can then be recommended as a low-volume ground cover that is admirable for ornamental landscape use throughout a wide range of site conditions.

Castlevalley saltbush (*Atriplex cuneata* A. Nels.)—This saltbush is native to western Colorado, central Utah, and southward. It grows on alkaline soils, but in our tests tolerated soils of neutral or slightly acid reaction. It is low-growing—up to 1 foot (30 cm) tall—and 2 to 3 feet (60 to 90 cm) across the coarse textured, dense crown that spreads to a moderate extent by means of stem layers along decumbent branches. It is one of the most fire resistant plants existing anywhere. It has unusually high mineral con-

tent, with 20 to 25 percent of the foliage dry weight being ash constituents. The foliage is succulent; the moisture content is well above 100 percent much of the year. It is extremely palatable and nutritious for livestock, and where it grows is regarded as equal to alfalfa hay as feed. For us this palatability is a liability, however, as the plant is very susceptible to rabbit clipping and damage. Seed production is less than for many other saltbushes, and harder to collect. Consequently, there is no commercial seed supply, but seed can be collected. Seed orchards should be established to supply seed. Plants are easily propagated from stem cuttings, and this has been the main source of planting stock for our tests.

Gardner's saltbush (*Atriplex gardneri* [Moq.] D. Dietr.)—Gardner's saltbush is a low-growing shrub native to the Great Basin section of Western United States. It is woody at the base, seldom over a foot (30 cm) tall. It tends to develop nearly pure stands or colonies, sometimes many feet across. Unlike most shrubs, Gardner's saltbush reproduces by root sprouts (Nord and others 1969). Numerous buds and shoots originate from lateral roots which are 2 to 9 feet (0.6 to 2.7 m) long, lying about a foot below the surface.

These root sprouts can be dug up and used as planting stock. The plant can also be produced from seed, although the seed is harder to collect and lower in germination percentage than fourwing saltbush seed. In southern California, seeding results at 3500 feet (1067 m) elevation were much better than at 5000 feet (1524 m), 1/2 inch (1.3 cm) seeding depth was better than 1 inch (2.5 cm), and mid- to late-spring when soil temperatures were 60° to 65° F (15° to 18° C) and soil moisture was still adequate was the best time for seeding Gardner's saltbush (Nord and others 1971).

Muller's saltbush (*Atriplex mulleri* Benth.)

Muller's saltbush is a semiprostrate, suffrutescent shrub with light green foliage that grows about a foot (30 cm) high and 2 to 3 feet (0.6 to 0.9 m) in diameter. It is considered an annual in its native Australia (Black 1963), but has maintained a biennial or perennial habit in southern California. Plants are drought resistant, surviving with as little as 10 inches (25 cm) of rainfall, but freeze at temperatures around 20° F (-7° C). It appears adapted to diverse soil textures, but needs a pH range of 6.0 to 8.0. In most respects, its adaptability is similar to that of Australian saltbush (*A. semibaccata*). Muller's saltbush is

a good ground cover plant and, within its natural range, is considered a useful forage plant for grazing. Its forage potential in this country has not been determined; however, we observed one instance where horses avidly grazed most of this saltbush on a planting in San Diego County.

Chemical analysis of Muller's saltbush foliage showed a relatively high ash content, about 20 percent. In other saltbushes, high mineral content is usually associated with relatively high fuel moisture throughout much of the year.

The seed develops from small inconspicuous flowers on monocious plants, and ripens between July and late fall. The ripe seed loosens and may be harvested quite readily, either directly from the plant by suction harvesters (fig. 8), or by combines. Threshers can also be used after plants are cut and dried. There are about 115,000 generally well-filled seed per pound (254 per g). Numerous seedlings develop around established plants, especially where there has been some soil disturbance.

Seed yield from plants on irrigated plots was greater when harvesting was in the fall than during late summer, averaging 82 grams per plant compared to 38 grams for a July harvest. However, germination was somewhat lower—13 percent, and 20 percent for



Figure 8—Seed of Muller's saltbush can be harvested with a suction collector as here at the Forest Fire Laboratory nursery, Riverside, California, July 1973.

seed collected in July. This unexplained difference was statistically significant. Moist seed starts to germinate within 2 to 3 days and continues for about 3 to 4 weeks. The germination percentage is increased at least three times, and about half the germination time is required, if the seed coat is removed. The seed coat evidently contains an inhibitor similar to that found in other *Atriplex* seeds (Gerard 1965; Koller 1957; Nord and Van Atta 1960; Springfield 1970). The seed is readily loosened by a hammermill equipped with 1/16-inch diameter sieve, and then can be separated from the coats in a clipper mill.

Seed should be planted shallowly—1/4 to 1 inch (0.6 to 2.5 cm) deep—as for most other *Atriplex* species (Nord and others 1971), during late winter to midspring while soil moisture is available and the soil is warm. On weed-free seedbeds, 6 pounds of seed per acre (6.7 kg/ha) should be adequate where this species is sown alone. Where rabbits or other small mammals are likely to damage plantings, some protection will be needed. With irrigation, stands containing 5000 Muller's saltbush plants per acre (12,350 per ha) might produce 600 to 700 pounds (272 to 318 kg) of seed. Greatest seed harvest would result from a July suctioning, and a fall combining.

Desirable characteristics of Muller's saltbush include its low growth habit, abundant seed production, ease of establishment by direct seeding, rapid growth, and high mineral content. For these reasons, it appears to be a desirable plant on adapted sites for fire hazard reduction, and grazing by domestic and wild animals. However, we can only recommend it on a test basis at present. We do not yet know how durable stands will be in competition with native vegetation. Establishment may be a problem because of injury or destruction by rodents, and seed is not readily available. Should a demand develop, however, large amounts of this seed could be produced within a year or two, and mechanical harvesting is feasible.

Australian saltbush (*Atriplex semibaccata* R. Br.)—Australian saltbush, a native of Australia, was introduced experimentally about 1877 (Hall and Clements 1923; University of California Agriculture Experiment Station [n.d.]³) and naturalized in Cali-

fornia, Arizona, and New Mexico. It is a light green prostrate plant growing a few inches high and in mats up to 4 feet (1.2 m) across. It occurs along roads or other disturbed sites, mostly on saline soils below 3000 feet (914 m) elevations where temperatures do not drop much below 20° F (−7° C) (McKee 1919). It withstands considerable drought and hot weather. Almost from its introduction, Australian saltbush was acclaimed, particularly for grazing use, but the high hopes regarding its value were not realized in most areas. It does, however, provide some forage where it has naturalized and when planted to provide cover on disturbed areas (Sampson and Jespersen 1963).

This plant grows strong and vigorous the first year, but within a few years the stand weakens and often thins out or disappears, except where the ground is disturbed in some manner. Disturbance stimulates germination and establishment of new seedlings. Otherwise, stands are generally replaced by other plants—mostly herbaceous species—as the saltbush declines.

Australian saltbush is monocious, unlike many *Atriplex*. It produces an abundance of red, fleshy fruit that compresses and turns brown to black as it ripens, usually over a period of several weeks during late summer and fall. The seed ripens unevenly, and cannot be effectively collected directly from the plant. Instead, it is usually gathered from the ground by means of suction collectors designed for this purpose. The 120,000 seed per pound (265 per g) usually are filled and germinate within a few days when growing conditions are favorable without special treatment. Seed should be planted shallowly, not more than 1/4 inch (0.6 cm) deep, during late winter or very early spring while the soil is moist but after it has warmed. Three to four pounds of seed per acre (3.4 to 4.5 kg/ha) is generally sufficient when sown alone. This seed is available and currently costs about \$7.50 per pound (\$16.52 per kg) from commercial seed dealers.

Australian saltbush has a relatively high mineral content—up to 20 percent ash in the foliage—and retains a high fuel moisture content throughout most of the year. Its high salt and fuel moisture contents and low growing habit make it desirable for reducing fire hazard. However, this benefit generally does not hold for more than a few years because of its short life span.

Like many saltbushes, this one is very susceptible to damage by rabbits, squirrels, and other small mammals that clip off the plants before they can become established. No effective means of preventing depredation by these agents has been developed. The

³University of California Agriculture Experiment Station. [n.d.]. *Early history of Australian saltbushes (Atriplex sp.) and other halophytes introduced into the United States, 1877 to 1901*. A consolidation of California Experiment Station reports between 1877 to 1901 pertaining to plantings primarily for grazing use. (Copy on file at Forest Fire Laboratory, Pacific Southwest Forest and Range Exp. Stn., Riverside, Calif.)

species is also known to be a host plant for *Eutettix tenella*, the insect that carries curly-top disease of sugar beets, and thus it should not be introduced or planted in areas where it may affect this crop (Severin and Basinger 1922).

Dwarf baccharis or dwarf coyote brush (*Baccharis pilularis* DC.)—Dwarf baccharis is an attractive low-growing evergreen shrub, usually no more than 1 foot (30 cm) high. It spreads by means of root sprouts and stem layers along the prostrate branches to form dense mats that may be 10 feet (3.0 m) across on favorable sites. Its deeply penetrating root system and dense foliage make it valuable for erosion control, especially along cut and fill slopes. Sprouting following fire is quite common (Sampson and Jespersen 1963).

The plant is native to central California coastal areas, and is only moderately tolerant of drought or cold. Therefore, its use is limited to about 3500 feet (1067 m) elevation, and to sites near the coast unless supplemental irrigation is provided. Its sensitivity to herbicides such as 2,4-D (Leonard and Harvey 1965) may also limit its use.

The foliage has about 8 percent ash content, about the same reported for other baccharis species. This is somewhat higher than that of most chaparral species, but is less than that of many halophytes and most *Atriplex* species. When considerable dead wood is mixed with living branches, and fuel moisture is low, dwarf baccharis is probably as susceptible to burning as other baccharis species known to burn fiercely (Horton 1949), but it burns with less heat output.

Seed germinates well without pretreatment; however, direct seedlings are not used to any extent for either landscaping or field site plantings. Practically all plantings are from cuttings from male plants in order to maintain particularly desirable horticultural forms and to eliminate the objectionable feathery pappus found on the seed. Where large numbers of seedlings are needed, the most satisfactory method is to seed in flats or nursery beds. Tip cuttings about 1/16 inch (1.6 mm) in diameter, or slightly larger, taken between late fall and early spring, will root without need of hormone treatment when kept under intermittent mist (Everett 1957).

Rooted cuttings, preferably in pots, or rooted "wildling" plants formed naturally from either root sprouts or stem layers, can be transplanted during late winter or very early spring when the ground is still wet and preferably before new growth commences. Plants should retain as much of the root as possible and must be wrapped in wet toweling or burlap to

keep them moist while they are collected and until they are replanted in the ground.

Dwarf baccharis is seldom grazed or browsed; however, young plants are occasionally damaged or destroyed by small animals. About one-third of plants set out in early spring during one southern California test were damaged by rabbits, and a few plants were destroyed by gophers during the first year. No observable effects from animal use occurred thereafter or until all plants died from drought 2 years later.

Seedlings and stem cuttings are quite susceptible to damping-off fungus, and mildew may form to kill back portions of the older plants (Robinson 1961).

Survival of potted stock at Nixon plot, North Mountain Experimental Area, after 1 year was 53 percent. Plants averaged about 6 inches (15 cm) across the foliar crown during the first year, but less than 5 percent survived after the second year at this site. Very good first-year survival, usually 80 percent or higher, has been the experience with several other dwarf baccharis plantings made by the Los Angeles County Fire Department. These were mostly at lower elevations on sites situated near the coast and generally within the influence of marine climate.

Dwarf baccharis is an excellent landscaping shrub but, except near the coast, will generally require irrigation if it is to thrive.

Plants can be propagated from stem cuttings treated with hormone and kept under intermittent mist. This may be the only way to obtain the low-growing variety. Plants from seed have grown taller, and we believe the low-growing horticultural variety probably originated from a clonal section from Marin County. Neither the plants nor seed are currently available, but they could probably be obtained through special arrangements with nurseries or seed dealers. Seed dormancy can probably be overcome by cold stratification or chemicals such as gibberellic acid.

Prostrate ceanothus, squawcarpet (*Ceanothus prostratus* Benth.)—Prostrate ceanothus, native to the Sierra Nevada, and the Cascade and Coastal ranges in California and adjoining states, is an attractive, evergreen shrub, usually only a few inches high, that spreads to form dense mats up to 8 feet (2.4 m) across (fig. 9). The underside of many branches are lined with stem-layered roots which form new plants. The holly-shaped leaves are dull to glossy light green and the white-to-multihued-blue blossoms, borne in the leaf axils during late spring and early summer, often permeate the air with a sweet lavender fragrance.

This plant is generally found in the pine or fir

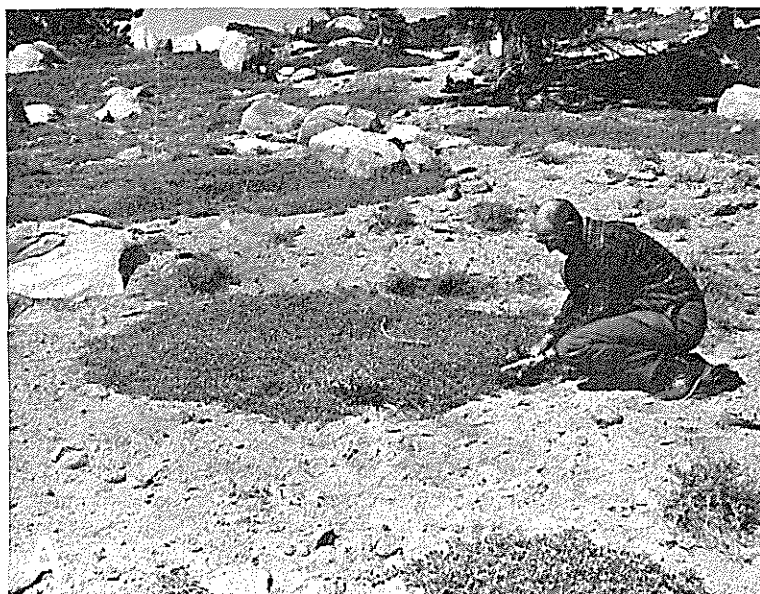


Figure 9—Prostrate ceanothus or squawcarpet is an attractive evergreen shrub that spreads to form dense mats often many feet wide. This plant is best suited to higher elevations, generally 5000 feet or higher, and prefers moister sites in southern California. (A) Shown here is a natural stand between Reno and Lake Tahoe, Nevada; and a 6-year old planting (B) at Vista Grande test site, San Bernardino National Forest, Riverside County, California.

forests at elevations between 2100 and 7000 feet (640 and 2134 m), on neutral to moderately acid soils. It withstands subzero temperatures but is only moderately drought tolerant. It grows vigorously even on infertile soils, perhaps partly because it supports nitrogen-fixing bacteria (Stewart 1967). Plantings made in southern California have not survived where soil pH was much above 7.5. It is a nonsprouter but reproduces from seed following burns.

Seed ripens during July or August, depending on the elevation and the year, and is quickly cast from the plants. When mature and dry, the fruit capsules

split open and scatter the seed, which is sought after by rodents and birds. The seed must be collected by plucking fruit capsules before they are fully ripened (about the time seed is in the hard dough stage) and then placing them in a warm, well-ventilated place to dry. Seed not released from collected capsules can be run through a seed scarifier or hammermill and separated out by a fanning mill.

There are about 41,000 prostrate ceanothus seed per pound (90 per g) (Reed 1974). This seed is dormant and requires treatment to germinate readily. The best method we have found is to place the seed in

water preheated to 170° to 180° F (77° to 82° C), allow it to soak for about 3 to 4 hours in the gradually cooling water, drain overnight or longer, then soak for about 48 hours, preferably under constant agitation, in 500 p/m gibberellic acid solution. The solution should then be drained off and, without rinsing, the seed dried thoroughly before it is planted or stored. This treatment remains effective for at least a year if seed is stored in a tightly sealed container in a refrigerator. The gibberellic acid treatment is relatively easily applied and our results show that it is at least as effective as stratification for 60 to 90 days or as other means previously recommended for breaking dormancy (Frolich 1967).

In tests at widely separated locations in the western states, prostrate ceanothus has made its best growth on soils derived from granitic parent materials. These were loose, coarse textured, well aerated, and well drained (Brown and others 1971).

Rooted plants grown from seed or stem cuttings in propagating tubes have shown fair to good survival and made rapid growth in southern California when they were planted at not less than 5000 feet (1524 m) elevation. At lower elevations, plantings either did not establish or grew poorly. A fair stand developed from seed treated with gibberellic acid to break dormancy and planted at 1-inch (2.5-cm) depth during February at the Nixon plot, but similar seedlings made about a month later at the Vista Grande plot failed to produce a stand of any consequence. Prostrate ceanothus should probably be seeded sometime during the late fall or winter when soil within the seed zone remains moist throughout the germination period.

Seed as well as young plants are quite susceptible to small rodent or rabbit damage. Seedling emergence was 35 times greater from spot plantings protected with wire mesh domes than from unprotected spots at the Nixon plot. Rodents mined out and removed practically all seed, including a portion that had been treated with a 0.5 percent Endrin solution intended to be a rodent repellent (Radwin and others 1970). More than 75 percent of the plants grown from seed at the Nixon plot were destroyed during the first growing season and plants not killed were badly stunted from severe clipping.

Plants are readily propagated from stem cuttings taken during late summer or fall, treated with a hormone powder dip (Brown and others 1971), and kept under intermittent mist. They can also be grown from seed and put into propagating pots; 2 by 2 by 8 inches (5 by 5 by 20 cm) is a good pot size for planting on field sites. Potted stock is commercially available, with plants costing about \$1.00 each at the nursery. Seed,

generally of good quality, is also available from a few dealers specializing in wildland seed; prices quoted range up to \$50 per pound. There appears to be good potential for growing this plant to produce seed that can be harvested. For example, we collected over 4 pounds (1.8 kg) of prostrate ceanothus seed from 56 plants established between 1965 and 1967 that now cover about 1200 square feet (112 m²) at the Vista Grande plot. About 2 man-hours were expended per pound (4 man-hours per kg) of seed collected.

Prostrate ceanothus in many respects is the ideal plant for reduction of fire hazard, and it is a very attractive ground cover as well. Unfortunately, we can only recommend it for higher elevations.

Green galenia (*Galenia pubescens* [Eckl. & Zeyh.] Druce (1917))—Green galenia, a member of the carpetweed family (Aizoaceae), is a native of South Africa but naturalized in coastal regions of Australia. It is a dense, spreading, suffrutescent perennial, usually about 1 to 2 feet (30 to 60 cm) high and several feet across. Foliage is dark green with innumerable small, inconspicuous white flowers. Stems are mostly prostrate and succulent except near the roots where they tend to be woody. They occasionally stem layer to form new plants. This plant species will require 15 inches (38 cm) of rainfall in the coastal zone, and 20 inches (50 cm) in inland southern California—about the same as perennial grasses. It does well in moderately acid to slightly basic soils. It does not appear to withstand temperatures less than about 20° F (−7° C). At 25° F (−4° C) we found frost damage, but plants survived; all plants were killed when temperatures dropped to 18° F (−8° C).⁴

Galenia plants grow very rapidly; in the nursery they spread outward at a rate of about 5 feet (1.5 m) (fig. 10) per year, and on dryland sites from 2 to 3 feet (0.6 to 0.9 m). Galenia and swamp saltbush (*Atriplex rhagodioides*) seedlings transplanted onto a Santa Monica Mountain road cut at 1800 feet (550 m) elevation grew fastest among 11 different species, mostly low-growing shrubs, planted at the site. Within 2 months, plants of both these species increased up to four times in size.⁴

Green galenia bears seed in great abundance, beginning the first year. It is very tiny, about 1,700,000 per pound (3800 per gram), and of good quality. Germination in petri dish tests averaged 74 percent,

⁴Radtko, Klaus. 1973. *Low fuel volume plants study report 1972-73*. U.S. Forest Serv. Coop. Agree. No. 21-235. 27 p. (Rep. on file at Forest Fire Laboratory, Pacific Southwest Forest and Range Exp. Stn., Riverside, Calif.)

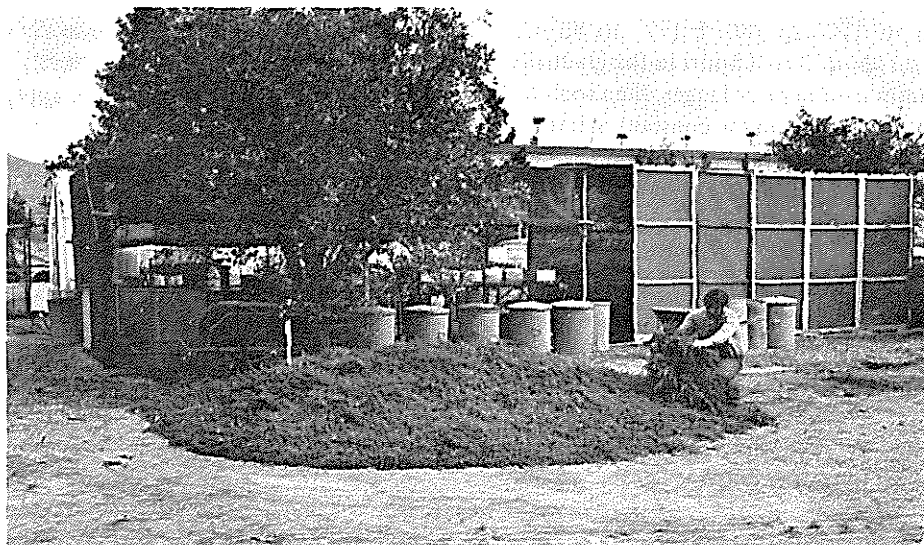


Figure 10—Green galenia can be used to slow down wildfires, but because of its prolific seed production and ability to naturalize, especially on disturbed sites, it might become a troublesome weed if grown near croplands. Here, a single wildling plant growing at edge of nursery passageway under good site conditions has spread to be 20 feet diameter in 4 years.

reaching a peak in 5 days and practically all completed within a 10-day period. We collected three-fourths pound (340 g) of seed from a pair of 2-year-old plants which covered an area of 120 square feet (11.1 m^2), about 20,000 seed per square foot (30 cm^2) of foliage. The plant flowers all summer and fall, but the greatest abundance of seed ripens in early fall and should be harvested soon thereafter. Clumps of foliage can be cut and placed on plastic or other suitable surface to dry before seed is separated by such means as threshing, scarifying, or hammermilling. If seed can be harvested from larger stands, an acre or more, the green forage harvester could be used to gather galenia seed in the same manner used to harvest certain legumes and several grasses (Harmond and others 1961). After the seed matures, the harvester cuts, chops, and blows the foliage into a trailing hopper wagon. After curing or drying, seed can be threshed by a combine.

Plants can be propagated readily from stem cuttings rooted under intermittent mist or from seed that germinates readily without special treatment. Wildlings that often develop in abundance where this plant has been established and grown for 2 years or longer can also be transplanted either bare root or potted. A satisfactory stand was established from seedlings made in March 1973 by Los Angeles County Fire Department on a brush-cleared hillside area adjoining the Malibu nursery. Plants were up to 2 feet (60 cm) diameter at the end of the first growing season.

Plantings of galenia should be made early in the year, but after there is little likelihood of frosts. As for other small seeds, a shallow planting depth not to exceed $1/2$ inch (13 mm) is indicated. One-fourth pound galenia seed per acre (280 g per ha) provides about 10 seed per square foot (100 per m^2). Mixing the seed with 8 gallons of rice hulls per acre (75 l per ha) facilitates sowing and allows for good seed distribution whether planted by drill or broadcast seeded. The seed is not commercially available, but can be produced and harvested quite readily and at a reasonable cost.

Besides its susceptibility to frost, galenia has a serious limitation that may not only restrict but prevent its use in this country. Reports from South Africa⁵ mention that galenia causes a disease known as "waterpens" in sheep and goats, but no positive conclusions have been made from any tests to date. Analysis of galenia foliage by the Agricultural Research Service Poison Plant Research Laboratory show that this plant contains from about 3 to 6 percent oxalate and may be toxic to animals. Tests are still continuing, however, to determine whether galenia is safe for planting in this country.

Normally in South Africa and Australia, galenia is grazed by sheep and goats only when there is nothing else to eat. Test plantings in this country have been

⁵ Personal communication, Dr. Bernard de Winter, Director, Botanical Res. Inst., Pretoria, Republic of South Africa, April 25, 1974.

avidly eaten by deer, however, and in some places have been heavily clipped by rabbits. Because of its aggressive growth and prolific seed production, green galenia might possibly become a weed pest, but in Australia it has not been regarded as either noxious or especially troublesome.⁶ We have considered that galenia plants may build up sizeable amounts of foliage over a period of years, and that it may burn intensely when dry. However, reports from Australia, where galenia is recommended and used for plantings intended to reduce fire hazards, claim "it burns with the greatest reluctance even in the dried state, in the manner of wool" (Waddington 1970). The high—18 percent—silica-free ash content that we found in the foliage is probably responsible to a large extent for the high moisture content and low flammability of this plant.

Until more definite information is available regarding toxicity, we cannot recommend that green galenia be planted in this country except in areas where it may be controlled or if necessary completely eradicated.

Semiprostrate Shrubs

Semiprostrate shrubs are usually 1 to 3 feet (30 to 90 cm) tall.

Generally Good Performance

Rockrose (*Cistus* L.)—The rockroses, all endemic to the Mediterranean Region, have been acclaimed to be "fire resistant" or to have "fire retardant" characteristics, and consequently have been suggested for plantings that would reduce hazard from wildfire (Martin and Juhren 1954; Laure and others 1961; Ching and Stewart 1962; Juhren 1966; Montgomery and Cheo 1969 and 1971).

Unfortunately, however, the evidence is not conclusive. Foresters from Europe have told us that *Cistus* burns readily in its native habitat (Green 1965). Juhren (1966) suggested that *Cistus ladaniferus* L. was more flammable than most other *Cistus* species because of its gum-resin content: it has an ether extractive content of 19 to 21 percent dry weight compared to only 6 to 9 percent in *Cistus albidus* and other nonresinous species (pers. commun., Kenneth R. Montgomery 1975). However, Montgomery and Cheo (1971) found that the relatively thick leaves (low surface area-to-volume ratio) of *C. ladaniferus*

ignited less readily in muffle furnace tests than leaves of other *Cistus* and chaparral shrubs tested. The foliage moisture content of other *Cistus* species during the July–November fire season was near that of chamise, a shrub notorious for its flammability (Olsen 1960).

Members of the *Cistus* genus do have one characteristic of great interest—their ability to grow on wildland sites in southern California. Several have done well in test plantings, even when native shrub plantings failed (Juhren 1956 and 1972). Plantings by the authors in southern California confirm the ability of *Cistus* to grow well on dry sites.

The rockroses are drought resistant, have deep, extensive root systems, and their period of dormancy is adjusted to our winter rains and summer drought.

Most rockroses are relatively upright growing shrubs, typically 4 or 5 feet (1.2 to 1.5 m) tall, but ranging up to 8 feet (2.4 m). Thus they are not "low-growing." However, *Cistus villosus* L., the shortest of the *Cistus* species previously planted in southern California, may have some use for wildland watershed or ornamental planting. Descanso rockrose (*C. crispus*) does not grow as tall, and should have a place in our low-growing plant program.

Descanso rockrose (*Cistus crispus* L.)—A rockrose, morphologically very similar to *C. crispus*, was introduced into the United States during the late 1940's and planted at the University of Washington Arboretum (Mulligan 1953). Similar plant material, probably derived from that planted at the University of Washington, was planted at the Descanso Gardens, Los Angeles County, in 1966. Plant descendants of this material, known as "Descanso rockrose" and believed to be *Cistus crispus*, are described in this report.

This is an attractive aromatic, evergreen semiprostrate shrub usually 1½ to 2 feet (45 to 60 cm) tall. It spreads by means of stem layers along the decumbent branches to form a crown several feet wide. The light green, compact foliage provides a dense cover that excludes most herbaceous plants from developing below the crown. During the late spring and early summer, plants have numerous attractive bright rose-lavender flowers.

The Descanso rockrose is relatively drought tolerant, being able to grow satisfactorily with as little as 15 inches (38 cm) annual precipitation. It is well adapted to a wide range of soils varying from moderately coarse to medium textures between pH 5.5 to 7.7.

Plants propagated from cuttings that probably originated from a single clone at the Descanso Gar-

⁶ Personal correspondence, D. E. Symon, Dep. Agron., Waite Agric. Inst., Univ. Adelaide, South Australia, August 17, 1971.

dens have failed to produce viable seed. Most likely this clone strain (or genotype) may be self-sterile. However, viable seed have been produced and collected from the original plantings, which were apparently grown from seed representing different progenies. Plantings from this single progeny source have made satisfactory growth throughout a wide range of sites extending from near the coast to 5000 feet (1524 m) elevation, under different soil and climate conditions in southern California. Under favorable conditions, plants rooted in bands grew from 6 to 10 inches (15 to 25 cm) the first year and thereafter spread outward about 1 foot (30 cm) per year. These plants are low in palatability to livestock and rabbits, and therefore have an advantage over many other shrub species that are susceptible to these agents.

Seed ripens during late summer when the capsules or seed heads can be stripped off the plants and dried, and the seed separated and cleaned. There are about 605,000 seeds per pound or 1330 per gram, and it has high viability. Seed collected from the original plantings at Descanso Gardens had 85 percent fill. Much of the seed is dormant and will not germinate readily unless it is treated in some manner. Tests by Kenneth R. Montgomery (pers. commun., 1975) showed that treating this seed for 2 minutes in dry heat at either 150° or 185° F (65° or 85° C), or for the same period in boiling water, yielded over 80 percent germination as compared to about 30 percent for untreated seed. A 2-hour soak in 200 p/m gibberellic acid was not quite as effective as the dry heat or boiling water treatments to break dormancy and improve germination.

Descanso rockrose can probably be established by direct seedings if the seed is treated, if care is exercised in selecting sites, and if good agronomic practices are utilized in such plantings. Sufficient seed has not been available heretofore for this purpose. However, several hundred seedling plants originating from the rockrose plants at Descanso Gardens were planted in spring 1975 at the North Mountain Experimental Area to test their suitability, and also to provide a more adequate source of this seed.

The foliage of Descanso rockrose contains from 6.4 to 8.8 percent ash (table 6). Moisture content of the foliage drops below 70 percent during the late summer and fall; consequently, mature plants are susceptible to burning. However, the plant should burn with less intensity and heat output than most chaparral vegetation because of the lower growth habit and fuel volume. This plant could reduce fire hazards as well as serve other useful purposes throughout a wide range of sites in the Southwest.

Fair Performance

Ione manzanita (*Arctostaphylos myrtifolia* Parry)

—Ione manzanita is a compact, semiprostrate shrub up to 3 feet (0.9 m) tall with dense evergreen foliage (fig. 11). It is native to the Ione region along the Sierra Nevada foothills at 1000 to 1500 feet (305 to 457 m) elevations. Its native occurrence is limited to strongly acid soils—pH 2.9 to 4.0—derived from outcrops or sediments from the Ione formation (Gankin and Major 1964). It is a nonsprouter, so plants are eliminated by severe fires. New plants are occasionally formed from stem layers along decumbent branches and seedlings generally develop naturally on recently disturbed areas, but rarely in competition with older plants. Reproduction on burned stands is dependent upon soil-stored seed or seed transported onto the area from adjoining stands.

The only southern California site out of several from 1500 to 5000 feet (457 to 1524 m) elevations where Ione manzanita has shown any promise was at the Vista Grande plot at 5000 feet in the San Jacinto range. Soil reaction was pH 6.0 to 6.8. Survival over a 6-year period from plantings made in 1966 and 1967 of potted wildling seedlings was 100 and 30 percent, respectively, and plants averaged about 1 foot (30 cm) high and 1 to 2 feet (30 to 60 cm) across the crowns at the end of the period. Similar plantings made at other sites were unsatisfactory; practically all plants died, usually during the first or second year. One difficulty in establishing the shrub is its slow growth, both above and below the ground surface. Not uncommonly, plants grew only 2 to 3 inches (5 to 8 cm) higher or wider each year, and roots extended only about a foot into the ground during the first growing season. This plant seems poorly adapted to coarse-textured soils like sandy loam or loamy sand, presumably because of the low water-holding capacity and rapid moisture depletion.

Ione manzanita is not well adapted and cannot be recommended for plantings intended to reduce fire hazards in most of southern California. It could be used to a limited extent as an ornamental, preferably in combination with other low-growing plants such as creeping sage or prostrate ceanothus. It is attractive because of its warm bark color, dense evergreen foliage, and symmetrical form. It could be useful for planting on brush-cleared areas in a semi-urban situation above 4000 feet (1200 m) elevation in southern California.

Mason's ceanothus (*Ceanothus masonii* McMinn.)

—Mason's ceanothus, native to Marin County, California, is a semiprostrate shrub usually 1 to 2 feet (0.3



Figure 11—lone manzanita is an attractive low-growing shrub that would have limited use in plantings to reduce fire hazards. These plants at the Vista Grande site were about 1 foot tall and 2 feet wide when 9 years old. Prostrate ceanothus (*foreground*) was planted at the same time and has spread into and under the crowns of the lone manzanita to completely carpet the area.

to 0.6 m) high and up to 6 feet (1.8 m) across the crown. Plants are moderately compact with divaricate, decumbent branches that occasionally stem layer to form new plants where in contact with the ground. This species is moderately drought tolerant and withstands temperatures down to about 15° F (10° C). Like most other ceanothus species we have tested, Mason's ceanothus is not well adapted to basic soils, and survived for only about 2 years under irrigation when soil pH was 7.5 to 8.2.

This species was successfully established and plants made satisfactory growth at the 5000 foot (1524 m) elevation Vista Grande plot. Plantings were grown in paper pots from stem cuttings treated with growth hormone to stimulate rooting. Nearly half have survived and grown to be 1 foot (30 cm) high and 5 feet (1.5 m) wide over a 6-year period. However, similar plantings at Nixon (3500 feet, 1067 m), and Wolfskill (2600 feet, 792 m) plots were not successful. Only a few plants survived for more than a year or two and these grew very slowly, spreading to no more than 3 feet (0.9 m) across during the same 6-year period.

Until more is known about the adaptability of Mason's ceanothus, plantings should probably be limited to elevations above 4000 feet (1220 m) or on moister sites elsewhere.

Promising, But Not Fully Tested

There are other species that, based on limited tests, are potentially valuable for some situations. Included are two semiprostrate native species—sweet sagebrush (*Artemisia ludoviciana* var. *incompta*) and Newberry's penstemon (*Penstemon newberryi*) from Utah and California, respectively—and a semiprostrate to somewhat erect plant, silver or swamp saltbush from Western Australia. These two species have effectively stabilized raw banks and road cuts in plantings made at a number of higher elevation sites in California, Idaho, and Utah. Silver saltbush is good forage; it grows rapidly and spreads aggressively by stem layers, thus providing cover for raw, disturbed areas. We believe these species merit additional study to determine their suitability and adaptability to different southern California conditions.



Figure 12—Sweet sagebrush is a native, low-growing, deciduous semishrub suited mostly to higher elevations. It spreads primarily by abundant root sprouts and occasionally by stem layers formed along the prostrate branches.

Sweet sagebrush (*Artemisia ludoviciana* Nutt. var. *incompta* [Nutt.] Keck.—Sweet sagebrush is a low-growing, aromatic plant native to Utah and surrounding area, usually on calcareous soils at 5000 to 9000 feet (1524 to 2743 m) elevations. It forms dense mats, generally less than a foot (30 cm) high, with individual plants up to 6 feet (1.8 m) across the crowns. Although the tops die back each winter, plants grow rapidly and aggressively from root sprouts as well as from occasional stem layers (fig. 12). It was one of the most satisfactory plants tested for stabilizing and protecting logging road cut fill slopes in southern Idaho.⁷ There are nodules on the roots and probably endotropic mycorrhizae as well, and both may add nitrogen to the soil (Farnsworth and Clawson 1972).

Plantings made at Nixon and Vista Grande plots had good survival and plants averaged over 1 foot (30 cm) diameter after the first season. Gophers, unfortunately, damaged or destroyed about one-third of our test plants by nipping off the succulent roots below the crown. Plants do not appear to be affected adversely by grazing animals or other pests in other

areas where this species has been grown.

Direct seedings have not been made because sweet sagebrush seed has not been available. However, plants were readily propagated from root sections and rooted from stem cuttings kept under intermittent mist. A single plant grown in the nursery can produce enough root stock sections for 100 or more plants in a single year. Root masses obtained during late winter from either native or nursery-grown plants and placed in flats in a heated greenhouse usually develop new shoots within 2 to 3 weeks. The root sections with attached stem can be transplanted into propagating pots for later use, or directly to field sites. This plant is probably best suited for plantings at higher elevations, generally above 5000 feet (1524 m) in mountain areas in the West. It should be useful around such mountain communities as Idyllwild, Lake Arrowhead, or elsewhere, if native conifers do well.

Newberry's penstemon (*Penstemon newberryi* A. Gray)—Newberry's penstemon or mountain pride, native in the Cascade range and Sierra Nevada in California and adjoining states, is an attractive, mostly evergreen plant with dense foliage 6 to 12 inches (15 to 30 cm), or sometimes to 18 inches (45 cm) tall. It spreads by means of stem layers along the

⁷Monsen, S. B. 1973. Personal communication. Intermountain Forest and Range Exp. Stn., Boise, Idaho.

semierect branches. It occurs at elevations of 4500 to 10,000 feet (1372 to 3048 m), mostly on neutral to moderately acid soils formed from granitic or in some instances volcanic materials. Its ability to reproduce vegetatively makes the plant useful in many places. The conspicuous crimson blossoms in late spring and early summer add to its attractiveness. It has done exceptionally well when planted on cut and fill slopes in the central Sierra Nevada in tests made by the Department of Environmental Horticulture, University of California, Davis (pers. commun., A. T. Leiser 1973). The plant has done poorly, most plants dying within a year, when grown in the Riverside, California, nursery on soils with pH 7.5 to 8.0. This fact suggests it is not well adapted to basic soils and perhaps not to lower elevations. Until more is known, plantings could well be restricted to soils that are moderately acid to neutral, pH 5.5 to 7.5.

No direct seedings have been attempted because seed of this penstemon has not been available. Presumably the seed will require cold stratification (Everett 1957) or other treatment to germinate satisfactorily.

Tip cuttings taken in the fall or early winter and kept under intermittent mist are readily rooted. The rooted cuttings, preferably held in pots, or "wildling"

plants formed naturally from stem layers, can be transplanted while the ground is still moist in early spring. This shrub deserves additional study so that we can determine its range of adaptability and learn how to produce stands from direct seedings.

Silver or swamp saltbush (*Atriplex rhagodioides*)—

Silver saltbush, introduced into this country from Australia about 5 years ago, has grown satisfactorily in the nursery at Riverside and at two field test sites near Malibu, Los Angeles County, and Laguna Beach, Orange County, California. This plant is a very palatable "ice cream" forage plant in its homeland. It is dioecious; it usually grows rapidly to 3 or 4 feet (0.9 or 1.2 m) tall, and spreads considerably wider. New plants are formed along the decumbent branches (fig. 13). Foliage is dense. Like most other saltbushes, it has a high mineral content, usually over 10 percent, and maintains higher levels of fuel moisture throughout the greater part of the year than most chaparral species. It is not tolerant to frost. Test plantings of this species grew satisfactorily during the first season at the Nixon plot but none survived the following winter when minimum temperatures dropped to about 20° F (-7° C). The plant seems suited to about the same climatic range where Australian saltbush



Figure 13—Silver or swamp saltbush, introduced from Australia, grows rapidly. Plants are 3 to 4 feet tall and spread much wider as the decumbent branches layer readily upon the ground. It is regarded as an "ice cream" forage plant in its homeland; the foliage has a relatively high mineral content and thus could help to slow down the spread of wildfires.

(*A. semibaccata*) has been naturalized, generally below 2000 feet (610 m) elevation in California.

Plants at the Riverside nursery produced seed which cutting tests showed to have less than 25 percent fill during the second year. The seed ripens in late August to early September, but persists on the plant so it can be collected for a few weeks. It germinates readily without special treatment, or plants can be propagated from tip cuttings under intermittent mist. It can probably also be established by transplanting "wildlings" formed naturally from stem layers. Sufficient seed has not been available for direct seeding tests.

The plant has dense foliage, high mineral content, aggressive spreading habits, and high palatability, suggesting that fuel or forage volume can be regulated to a large extent by grazing animals. We believe silver saltbush has good potential for planting to reduce fire hazards, as well as to improve habitat for grazing animals where it may be adapted in California.

Taller Shrubs

Most tall shrubs were eliminated because of excessive fuel volume, but three shrubs—fourwing saltbush, allscale saltbush, and purple rockrose—were tested extensively because of desirable characteristics.

Fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.)—Fourwing saltbush is widely distributed on dry plains and hillsides throughout much of the Western United States and Mexico. It is common in the desert and semidesert areas of southern California from near the coast to inland elevations up to 7000 feet (234 m). It grows on a variety of soils where pH ranges from 6.0 to 7.4 or higher. It is both drought tolerant and relatively cold tolerant. It is excellent browse for livestock and big game and habitat for upland game birds, and a good choice for stabilizing roadsides and other disturbed sites within its range.

Depending on the site, fourwing saltbush grows 2 to 6 feet (0.6 to 1.8 m) tall, and to 10 feet (3 m) across the crown, but some semiprostrate ecotypes exist. It establishes a deep and widely spreading root system that makes it drought resistant, and also desirable for stabilizing disturbed soils. It may also be important in soil fertility because nitrogen-fixing endotrophic mycorrhizae occur on the roots (Williams and others 1974).

The foliage of fourwing saltbush has from 10 to 15 percent mineral content, it is low in fat or volatile oil (table 4), and moisture content of small green twigs

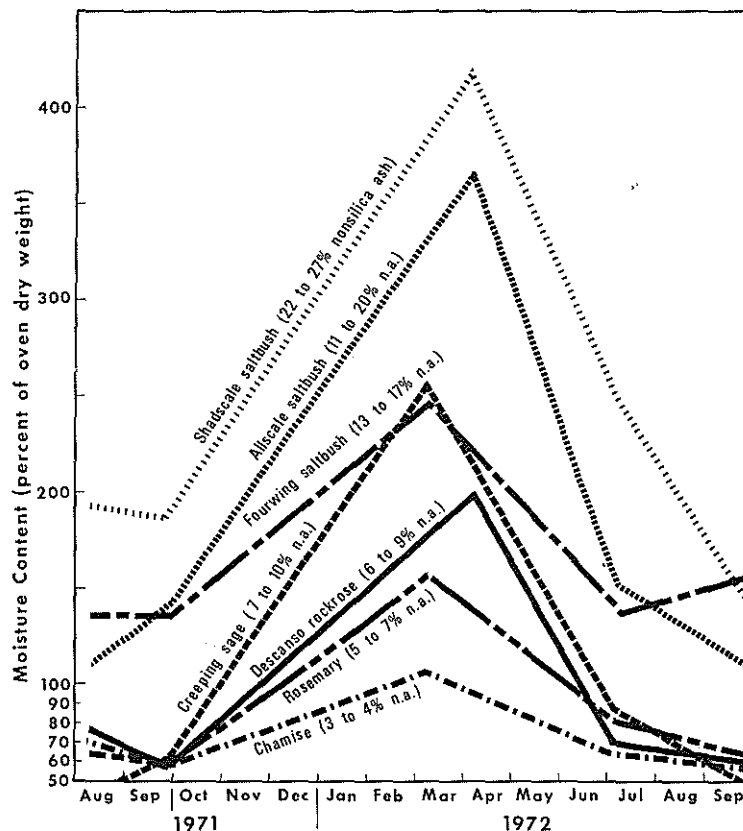
rarely drops below 100 percent (fig. 14). These characteristics make it less flammable than most chaparral plants. We have observed singed or partially burned plants following wildfire in southern California when other vegetation was more nearly consumed, and young regrowth, along roadsides was scarcely affected by the wildfires. The plant will burn, however, if dry fuel accumulates during drought or as a stand matures and becomes decadent. The plants generally sprout profusely from lower stems following burns, browsing, or mowing. Management should provide for this periodically, to maintain a healthy, fire-resistant stand.

Fourwing saltbush can be readily established by direct seeding or from potted transplants. The best time for planting in southern California is in late winter or early spring, usually late January to mid-March depending on elevation and exposure. Warm moist soil in the seed zone is essential for both germination and seedling establishment (Nord and others 1971). Seed should be sown about 1/2 inch (1.3 cm) deep except that up to 1 inch (2.5 cm) depth may sometimes be advisable to reach moist soil. Best stands can be expected from plantings made on well prepared, firm seedbeds where competition from other plants has been removed just prior to or simultaneous with seeding. Soil above the planted seed should be firmed with press wheels, a cultipacker or, when broadcast as on steep roadsides and other disturbed places, with a drag-chain or harrow. During the first year, plants may grow to be 1 to 2 feet (30 to 60 cm) tall and almost as wide with a root system up to 6 feet (1.8 m) deep and 10 feet (3 m) in diameter.

Seeding of 2 to 4 pounds dewinged seed per acre (2.2 to 4.5 kg/ha) is usually sufficient; however, up to 8 pounds per acre (9 kg/ha) may be necessary to establish a satisfactory stand upon disturbed roadside areas. The seed is generally available from some commercial seed dealers and costs between \$2 to \$5 per pound (\$4.40 to \$11.00 per kg) for dewinged seed. Seed should be from a nearby source or be grown in a climate similar to that of the site being seeded unless other tested strains are known to have similar or better adaptation.

Major deterrents to achieving good seeded stands are the susceptibility of small seedlings to frost and damping-off, removal of planted seed by rodents, and clipping and destruction of young plants by small animals—mostly rabbits. Deferring plantings until as late in the season as possible will generally minimize losses from frost or damping-off. Coating seed with a repellent may help to cut down losses by rodents;

Figure 14—Seasonal fuel moisture content of foliage—leaves and current year's stem leaders—of seven native and introduced shrub species was recorded at Nixon test plot, North Mountain Experimental Area, Riverside County, California, from August 1971 to late September 1972. Plants were generally 3 to 6 years old and growing along rows at widely spaced intervals with light competition from annual plants. Range in percent of nonsilica ash content is shown for each species.



however, no practical means have been found that will effectively fend off rabbits from small plantings other than to fence the planted areas with small-mesh netting, such as 1-inch (2.5-cm) poultry wire, so that these animals cannot get through. Putting out grain treated with 1080 and strychnine poison or spraying plants with a repellent coating is only temporarily helpful (Plummer and others 1970). The saltbush plants after the first year are not nearly as susceptible to rabbits as the young seedlings.

Fourwing saltbush plants are 3 to 4 years old before they produce significant amounts of seed, but thereafter abundant crops are borne during most years. The fruit can be collected as it ripens from October to December by flailing it into large boxes or onto drop cloths spread beneath the plants, or by vacuum seed harvesters developed for this purpose (Plummer and others 1968). Dewinging the seed by running it through a hammermill equipped with sieve openings of 1/4 inch (0.6 cm) diameter improves germination and permits planting by conventional drills. The number per pound varies from 18,000 to 34,000 (40 to 75/g) for winged seed and after dewinging from 28,000 to 60,000 (62 to 132 g), of which about one-half have embryos (Springfield 1970). No

special treatment, other than dewinging, is necessary for this seed. Seed viability is maintained for several years when seed is kept in cloth containers at room temperature (Franclet and Le Houérou and others 1971; Plummer and others 1970; Springfield 1970).

Plantings of fourwing saltbush intended to help stop fire spread should be of sufficient size and density so they can slow down or dampen fire burning from adjoining chaparral. Solid bands, at least 25 feet (7.6 m) wide, could best serve this purpose if placed adjoining the native brush and buffered along the other edge with low-growing plants such as creeping sage. Annual grazing either by sheep or cattle, or mowing the plants at 3- to 4-year intervals would prevent accumulations of dead material and allow the saltbush to be most effective in reducing fire hazards.

Allscale saltbush (*Atriplex polycarpa* [Torr.] Wats.)—Allscale saltbush, also known as desert saltbush, cow-spinach and cow-lettuce, is native to desert and semidesert areas from California to Utah and south into Mexico. It is locally abundant throughout its range on slightly acid (pH 6.5) to strongly saline soils (pH about 8.0). Best development is on deep, well drained soil, and because of this, much of the

area it formerly occupied has been reclaimed for irrigated agriculture. It grows to a crown height and width of about 5 feet (1.5 m), although 3 feet (0.9 m) tall is more common. Its branching is intricate, frequently spiny, and small.

It is somewhat less cold tolerant than fourwing saltbush—its upper elevation is about 5000 feet (1524 m)—but is more drought hardy, often surviving with only 4 to 5 inches (10 to 13 cm) of fall and winter precipitation. The foliage is rated fair to good for domestic livestock (*fig. 15*), good for deer, and the plants provide excellent cover for quail. The plants sprout profusely from lower stems following mowing or clipping. Thus, this species has potential to produce fodder as an agronomic crop on marginal irrigated lands subject to prolonged drought and excessive salinity (Goodin and McKell 1970). The harvested fodder is a good source of protein but is low in fat and carbohydrates. The foliage has a high non-silica ash content ranging from 11 to 20 percent according to the season (*table 4*), and it effectively retains high levels of fuel moisture, usually over 100 percent throughout the year.

Allscale, in many respects, is similar to fourwing saltbush in ease of establishment and seed production but is more restricted in its adaptability. It could best be used at elevations below 3500 feet (1067 m) in southern California plantings. The seed does not require scarification; it germinates rapidly and usually within a few days under warm moist conditions.

Plants may grow to be 1 foot (30 cm) or taller, with a root system up to 4½ feet (1.4 m) deep and twice as wide during the first year. Most plants are dioecious and will bear fruit beginning the second year.

The seed maintains high viability for at least 5 years and probably longer if it is stored in porous containers such as cloth bags that will permit air exchange when stored at room temperatures. The seed has lost practically all viability within a few months when held at room temperature in tightly sealed containers, including plastic bags. However, if seed is stored in a refrigerator or deep freeze, it can and should be kept in a tightly sealed container.

Allscale saltbush seed is commercially available from some seed dealers and costs up to about \$5 per pound (\$11.00 per kg). To purchase it, however, prior arrangements should be made with a dealer in native plant seeds who may have to locate and collect it in the field.

Purple rockrose (*Cistus villosus* L.)—Purple rockrose is an upstanding, moderately dense evergreen shrub generally 2 to 4 feet (0.6 to 1.2 m) tall with rounded crowns 2 to 4 feet (0.6 to 1.2 m) in diameter. The foliage is dark green and slightly aromatic. During late spring and summer, plants bear showy lavender flowers. This plant is hardy and well adapted to many soils and other conditions from near the coast to 5000 feet (1524 m) or higher elevations in southern California. It is admirably suited and has

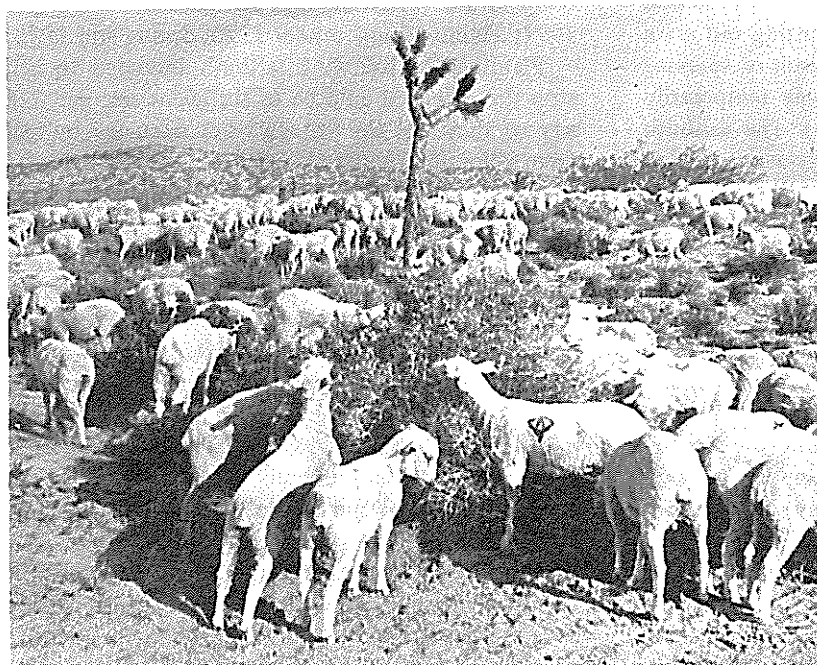


Figure 15—Several saltbush species provide palatable and nutritious browse for livestock and big game, and outstanding cover and nesting for upland game birds. This native stand of allscale or desert saltbush in San Bernardino County, California, provides a substantial portion of the forage used by sheep bands, especially during the late spring and early summer.

been planted extensively for erosion control and to some extent for landscaping (Juhren 1972). Plantings established 15 to 20 years ago in southern California have persisted, but plants stagnate beginning in 8 to 12 years and thereafter, dead fuel begins to accumulate (pers. commun., Kenneth R. Montgomery).

The foliage of purple rockrose contains from 5 to 9 percent ash (table 4), and it is relatively low in fat and volatile oils as compared to most other *Cistus* species (pers. commun., Kenneth R. Montgomery). Moisture content of the foliage generally drops below 70 percent during the late summer and fall.

When grown under favorable conditions on brush-cleared wildland sites, purple rockrose produces seed within 2 years. The seed ripens in late summer to early fall, and generally is held on the plants for several weeks after it matures. Thereafter, seedheads or capsules can be stripped or plucked off the plants into containers and seed can be separated and cleaned from this material by threshers, scarifiers, hammer-mills, and fanning mills. It is possible for a good worker to collect a pound (0.45 kg) or more of this seed per hour from plants bearing good seed crops. This seed is commercially available and currently costs about \$35 per pound (\$77 per kg).

There are about 525,000 seed per pound or 1150 per gram. Seed is partially dormant but several treatments will improve and hasten germination. The test results which follow were not directly comparable because the seed was from different sources and probably differed in viability:

	Germination (percent)	Peak of average germination (days)
Treated seed:		
Boiling water (1 min) ¹	92	6 to 10
Dry heat (80° C, 2 min) ¹	93	7 to 12
Gibberellic acid (200 p/m, 2 hr) ²	69	8
Controlled seed:		
Boiling water (1 min)	19	17 to 21
Dry heat (80° C, 2 min)	23	³
Gibberellic acid (200 p/m, 2 hr)	37	12

¹ Los Angeles County and State Arboretum, Arcadia (Pers. commun., Kenneth R. Montgomery).

² Forest Fire Laboratory, Riverside. Tests using other concentrations and soaking periods with gibberellic acid are still in progress.

³ Data not available.

We are not aware of any direct seedings of purple rockrose on wildland sites that have resulted in more than a sparse stand. Volunteer seedlings often survive in substantial numbers, however, in association with existing parent stands. This can occur after fire and on disturbed ground without the effect of fire. The potential to direct seed this species, therefore, would appear to be fairly good (pers. commun., Kenneth R. Montgomery).

Potted transplants such as are carried by some commercial nurseries have shown good survival and grown satisfactorily at several places in southern California. Plantings in 2 by 2 by 8 inch (5 by 5 by 20 cm) bands at Wolfskill, Nixon, and Vista Grande (table 2) had in most instances 70 percent or higher survival, and plants were growing satisfactorily 8 years after they were planted on two out of three sites. Survival and growth recorded during the first 4 years at these sites are as follows:

	Wolfskill	Nixon	Vista Grande
Elevation (feet)	2500	3500	5000
Survival (percent):			
First year	90	86	98
Second year	90	84	94
Fourth year	20	72	80
Plant growth, height by crown diameter (inches):			
First year	8 by 11	12 by 15	11 by 8
Second year	12 by 14	21 by 18	17 by 20
Fourth year	14 by 16	32 by 35	16 by 38

High mortality that occurred between the second and fourth year at Wolfskill and dieback of the plant tops in some years at Vista Grande indicate that this *Cistus* is not well adapted to either the drier conditions or colder temperatures that are found on some sites within the chaparral zone in southern California. Most of the plants injured by frost recovered to a large extent, however. Except for moderate clipping of young plants by deer, mostly during the first year, the species is not greatly affected by grazing or other destructive agents.

The primary use of purple rockrose should be for plantings on disturbed sites such as road cut and fill slopes to protect the soil and to reduce encroachment of flash fuels, and for landscaping.

APPENDIX

A. The Vegetation Around Structures

There is less open, unpopulated wildland, and more urban and urban-rural land with each passing year. Fire management around homes becomes less a matter of wildland strategy and more one of protecting homes built in the brushland or forest.

Much of the protection for a home should be "built in" by planners and builders. The County Supervisors Association of California (1965), in cooperation with forest fire protection agencies, suggest such things as (1) street names and numbers, (2) safe ingress and egress for personnel and equipment, (3) fire protection water facilities, (4) spacing of buildings, (5) clearance between brush or other vegetative growth and structures, and (6) community firebreaks.

For the owner of a home in brushland, management of the vegetation on and around his property is one of the best means to reduce loss during wildfire. This requires attention to landscape design, to type and species of plants to allow or encourage, to "fuel sanitation," and to irrigation of plants near the home.

The first step in vegetation management for fire safety has been outlined by State and county ordinances. These require removal of all flammable vegetation within 30 feet (9.1 m) of a structure. Single trees, shrub specimens, and ground covers are allowed if they will not transmit fire to the building. State or local authorities may require this zone be widened if the 30-foot (9.1-m) clearing is not sufficient. Clearing brush to 100 feet (30 m) or more from the downhill side of a building might be required to prevent radiation from igniting the building during wildfire, for example.

Fuel sanitation requires that dead and low-growing branches be pruned from trees and shrubs. Ground covers may also require pruning, particularly on dry sites; otherwise, fire will burn through them, although not with the same intensity as through native brushfields. Dry needles, leaves, and other debris must not be allowed to accumulate in quantity. Such materials will ignite from firebrands, burn intensely, and carry fire into brush or tree crowns. Fire spreads more rapidly in dry grass than in brush, and tall dense grass can support intense fire. Grass stands should be grazed or mowed.

Moisture content is generally considered the most important factor affecting flammability. Unirrigated woody plant growth contains its highest moisture content during the early spring, then gradually de-

clines to a low, frequently flammable level. Moisture content or irrigated brush in the San Bernardino Mountains also declined but not to the hazardous low levels in unirrigated chaparral (Youngner and others 1972). Unwatered landscaping is nearly always a fire hazard during the summer and fall. Watered and pruned landscape plants can provide some protection against fire.

Some plants burn more readily than others, so a knowledgeable homeowner will minimize planting of the obviously flammable species, and seek out plants that are less flammable.

Trees

The conifers as a group are more flammable than "broadleaved" deciduous trees. Coniferous trees include the pine (*Pinus*), deodar (*Cedrus*), cypress (*Cypressus*), cedar or juniper (*Juniperus*), incense-cedar (*Libocedrus*), and other cone-bearing trees. Broadleaved trees and shrubs are represented by oaks (*Quercus*), willows (*Salix*), maples (*Acer*), and many others. The conifers are more flammable because they contain materials such as resins and terpenes which burn readily, whereas most broadleaved species do not, or not as much. Also, moisture content of the coniferous foliage tends to be lower than that of deciduous trees. The difference in flammability is great enough that firebreaks of deciduous trees and shrubs have been recommended for coniferous forests (Fedrunnov 1952). However, Maire and Stoutemyer (1962) reported, following the Bel Air fire of November 1961, that many conifers around homes had not burned, even though they were killed.

Conifers will continue to be used as ornamentals because of their beauty, stateliness, and adaptation to our climate. They can be used with relative safety if they are irrigated, if dry needles are not allowed to accumulate on or beneath them, and they are used as specimen trees and not in plantations around the home. Species adapted to brushland zone conditions include:

Deodar (*Cedrus deodara* Loud.).

Cypress (*Cypressus* L.). Arizona cypress (*C. glabra* Sudw.), Forbes cypress (*C. forbesi* Jepson), Italian cypress (*C. sempervirens* L.), and Monterey cypress (*C. macrocarpa* Hartw.) are all used in landscaping.

Pines (*Pinus* L.). Monterey pine (*P. radiata* D.

Don.), Aleppo pine (*P. halepensis* Mill.), Canary Island pine (*P. canariensis* C. Smith.), Italian stone pine (*P. pinea* L.), Japanese black pine (*P. thunbergi* Parl.), Coulter pine (*P. coulteri* D. Don.), and Knobcone pine (*P. attenuata* Lemm.) include most choices for lower elevation planting.

Canary Island pine possesses the ability to generate new shoots (branches) along the main trunk, if fire kills existing branches. It shares this ability with very few other conifers, but some broadleaved tree species, coast live oak (*Quercus agrifolia* Nee.) for example.

Juniper or cedar (*Juniperus* L.), California juniper (*J. californica* Carr.) and Utah juniper (*J. utahensis* Engelm.) are well suited to hot areas.

Like the conifers, eucalypts are apt to be flammable, and for similar reasons—the high content of volatile oils in their leaves, and absence of high moisture content or minerals that might counteract the effect of the oils (King and Vines 1969). Some species slough bark, and build up considerable volumes of ground litter. Blue gum (*Eucalyptus globulus* Labill.) is notorious for all these faults and should be avoided in landscape plantings. Fire has spread in the litter beneath rows of blue gum, as well as through the crowns.

Some attractive medium-sized eucalypts (30 to 70 feet, 9 to 21 m) that endure a variety of low elevation climatic conditions and are less “messy” than others are red box gum or red box eucalyptus (*E. polyanthemos* Schau.), red ironbark or ironbark eucalyptus (*E. sideroxylon* Cunn.), and desert gum (*E. rudis* Endl.). Other eucalypts are planted as park, roadside, or specimen trees. Creek or red gum (*E. rostrata* Schlecht.) is often favored where a tree 100 feet (30 m) tall is acceptable.

Most broadleaved trees are acceptable for landscaping provided they are adapted to the area, are irrigated, and pruned. Brazilian pepper tree (*Schinus terebinthifolius* Raddi.), Peruvian or California pepper tree (*Schinus molle* L.) were reported to withstand fire well during the Bel Air and other southern California fires. Numerous other broadleaved trees are acceptable for California landscaping, and can be suggested by nurserymen.

Shrubs

All native shrubs will burn under extremely low soil moisture and relative humidity, and high wind-spread and air temperature, particularly if the stand is mature with 20 percent or more of the fuel dead. However, a few native shrubs are observed to be more flammable than the majority, and some less so. Laboratory

testing has also shown differences in flammability among shrub species (King and Vines 1969; Ching and Stewart 1962) but reasons are not always obvious.

Chamise (*Adenostoma fasciculatum* H. & A.) usually tops lists of native plants objectionable because of flammability. It is our most abundant shrub, making up perhaps 70 percent of the chaparral in southern California, and 60 percent statewide (Leonard and Carlson 1957). It has physical characteristics that contribute to a rapid rate of energy release (Countryman and Philpot 1970) and 8.5 to 12 percent of the leaves and small stems were “ether extractives”—waxes, oils, terpenes, and fats—that contain about twice the heat content of the extracted fuel, and which play an important role in fire spread (Philpot 1969). Chamise burns with a black oily smoke that has earned it a second common name, “greasewood.” Obviously, chamise should not be allowed in quantity close to structures.

California buckwheat inhabits lower mountain slopes and flats. Because it grows well on dry disturbed sites, it is planted along highways, and sometimes as a landscaping plant around homes. But because of a profusion of dry flower stalks, fine stems, shreddy bark, and low summer fuel moisture, mature stands of California buckwheat are quite flammable. This plant and the associated species have supported intense fires.

Other members of the coastal sage plant community are frequently very flammable. Plants such as California sagebrush (*Artemisia californica* Less.), white sage (*Salvia apiana* Jeps.), black sage (*S. mellifera* Greene.), and goldenbush (*Haplopappus* Cass.) drop leaves or die back during drought periods. The volume of dead twigs and ground litter frequently exceeds the live green. Such should be cleared from around structures.

Not native but potentially hazardous in a fire situation are bamboos and rosemary. Bamboo in dry situations drops lots of leaves, and these burn readily. Rosemary is an attractive, drought-enduring ground cover shrub which burns very readily. We have seen rows of it in wildland nursery plantings burn completely when less flammable species—purple rockrose and fourwing saltbush—of the same age on either side did not burn.

There are numerous native shrubs that may be left as specimen plants during brush clearing operations, or planted for the same purpose. They are generally less useful close to the home, however, than many nursery-produced varieties because they are hard to grow under irrigation. They need well drained soil

and are killed with frequent yard watering.

Three sumacs (*Rhus*) are acceptable. Sugarbush sumac (*R. ovata* Wats.), lemonadeberry (*R. integrifolia* [Nutt.] Benth. & Hook.), and laurel sumac (*R. laurina* Nutt. in T. & G.) are all attractive shrubs with stiff leathery leaves. Two wild cherries—Catalina cherry (*Prunus lyonii* [Eastw.] Sarg.) and Hollyleaf cherry (*P. ilicifolia* [Nutt.] Walp.) may be used. Toyon or Christmas-berry (*Heteromeles arbutifolia* M. Roem.) is another good choice. California coffeeberry (*Rhamnus californica* Ech.) is tolerant of moisture and attractive as well. Bush poppy (*Dendromecon rigida* Benth.) produces an abundance of bright yellow flowers which add to its attractiveness. Manzanitas (*Arctostaphylos* Adans.) and scrub oak (*Quercus dumosa* Nutt.) produce considerable litter and probably burn a little more readily than the other choices mentioned.

Several reports have come to the authors' attention of shrubs and ground cover from the plant genus *Myoporum* not being consumed during wildfire. These are not native to California, but are among the many useful plants nurserymen have available for home landscaping.

Several shrubs tested for low flammability on wild-

land sites are also useful for landscaping near the home. Several of the saltbushes can be used on dry or moist well-drained sites. Purple and Descanso rockrose will survive on dry rocky sites where it is difficult to establish other shrubs. Gum rockrose is more flammable and should not be used for this purpose.

Ground Covers

Many ground covers are satisfactory for home landscaping if they are irrigated and maintained relatively free of dead material. Montgomery and Stallings (1970) from Los Angeles County list 30 that will provide excellent fire protection if planted in a wide circle around structures. This listing was updated and enlarged in 1973 (Montgomery 1973). The Los Angeles Times (1969) published "A guide to ground covers" which lists or describes more than 40. Another source of information is Williamson (1973).

If ground is level or only gently sloping, any of the ground covers can be used. However if terrain is steeply sloping, deep-rooted low-growing woody species such as dwarf coyote brush, prostrate ceanothus, or low-growing saltbushes do the best job of holding the soil in place.

B. Index of Common and Scientific Names of Species

Grasses

Annual ryegrass *Lolium multiflorum* Lam.
Blando brome (softchess) *Bromus mollis* L.
Buffelgrass *Pennisetum ciliare* (L.) Link
Fountaingrass *Pennisetum setaceum* (Forsk.) Chiov.
Hardinggrass ... *Phalaris tuberosa* L. var. *stenoptera*
(Hack.) Hitchc.
Intermediate wheatgrass .. *Agropyron intermedium*
(Host) Beauv.
Perennial veldtgrass *Ehrharta calycina* Sm.
Pubescent wheatgrass ... *Agropyron trichophorum*
(Link) Richt.
Sandhill grass . *Brachiaria ciliatissima* (Buckl.) Chase
Sherman big bluegrass *Poa ampla* Merr.
Smilgrass *Oryzopsis miliacea* (L.) Benth.
Tall wheatgrass *Agropyron elongatum* (Host) Beauv.

Shrubs

Allscale saltbush .. *Atriplex polycarpa* (Torr.) Wats.
Australian saltbush *Atriplex semibaccata* R. Br.
Black sage *Salvia mellifera* Greene.

Bush poppy *Dendromecon rigida* Benth.
California buckwheat *Eriogonum fasciculatum* Benth.
California coffeeberry .. *Rhamnus californica* Esch.
California sagebrush *Artemisia californica* Less.
Castlevalley saltbush *Atriplex cuneata* A. Nels.
Catalina cherry *Prunus lyonii* (Eastw.) Sarg.
Caucasian artemisia *Artemisia caucasica* Willd.
Chamise *Adenostoma fasciculatum* H. & A.
Creeping or Sonoma sage . *Salvia sonomensis* Greene.
Deerweed *Lotus scoparius* (Nutt. in T. & G.)
Ottley
Descanso rockrose *Cistus crispus* L.
Dwarf baccharis or dwarf
coyote brush *Baccharis pilularis* DC.
Fourwing saltbush.. *Atriplex canescens* (Pursh) Nutt.
Gardner's saltbush *Atriplex gardneri* (Moq.) D. Dietr.
Goldenbush *Haplopappus* Cass.
Gray lavendercotton .. *Santolina chamaecyparissus* L.
Green galenia ... *Galenia pubescens* (Eckl. & Zeyh.)
Druce (1917)
Green lavendercotton *Santolina virens*
Gum rockrose *Cistus ladaniferus* L.
Hollyleaf cherry *Prunus ilicifolia* (Nutt.) Walp.

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1977. **Low-volume and slow-burning vegetation for planting on clearings in California chaparral.** USDA Forest Serv. Res. Paper PSW-124, 41 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Vegetation that is low-growing and either low in volume, slow burning, or both, is needed for reduction of fire hazard on fuelbreaks and other brush-cleared areas in California. Of over 50 shrub species and many grass species that were test planted, about 20 shrubs and an equal number of grasses were chosen for plot and field trials. Creeping sage, a few saltbushes, and a few grasses—mostly perennials—are adapted within the wide range of chaparral site conditions, and were successfully established by direct seedings as well as by other cultural methods on these sites. Shrub test results are tabulated and characteristics of each of the more promising species are described, with attention to usefulness for planting; techniques for collecting or treating seed to improve germination and for propagating plants; and methods for establishing these plants on wildland sites.

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