E

Fabaceae—Pea family

Ebenopsis ebano (Berl.) Barneby & Grimes

Texas-ebony

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Synonyns. *Pithecellobium flexicaule* (Benth.) Coult., *P. ebano* (Berl.) C.H. Muller, *Mimosa ebano* Berl., *Acacia flexicaulis* Benth.

Other common names. ebony blackbead, ape's earring.

Growth habit, occurrence, and use. *Ebenopsis* is a small genus, with only 2 species found in the United States. Texas-ebony occurs in Mexico and southern Texas and is the most valuable tree in the Rio Grande Valley. The species was formerly placed in the genus *Pithecellobium*; nomenclature of these species is discussed briefly in the *Pithecellobium* chapter of this book. The wood of Texas-ebony is used for furniture and fence posts, and the seeds can be used as a coffee substitute (they are boiled when green or roasted when ripe) (Vines 1960).

Flowering and fruiting. Texas-ebony flowers are yellow or cream-colored umbels about 4 cm in length borne in paniculate clusters on the end of twigs. They appear from June to August (Vines 1960). The legumes (pods) turn from green to dark brown or black as they mature in the fall. They are flat, about 13 cm long, and 2.5 cm wide (figure 1). The legumes are also indehiscent and may remain on the trees for a year or more. The seeds are reddish brown, bean-shaped, and about 1.5 cm long (figures 2 and 3). Weights range from 1,550 to 1,990 seeds/kg (700 to 900/lb) (Walters and others 1974).

Collection, extraction, and storage. Legumes are usually picked by hand from the trees and air-dried in the sun. Seeds can be extracted by hand-flailing or by using mechanical macerators. Legume fragments can by removed with screens. There are no long-term storage data for Texas-ebony, but it is a typical hardseeded legume with orthodox storage behavior. Storing seeds for several years should be easy at low moisture contents (<10%) and temperatures of 2 to 5 °C (Walters and others 1974).

Figure 1— *Ebenopsis ebano*, Texas-ebony: legume.

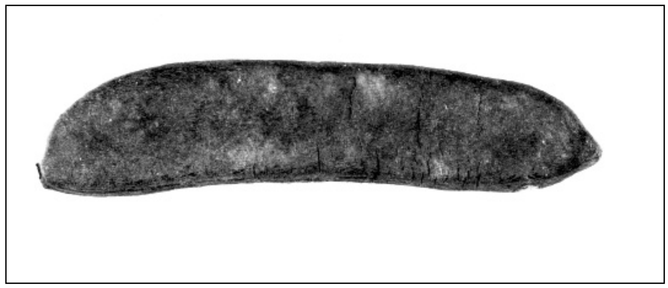
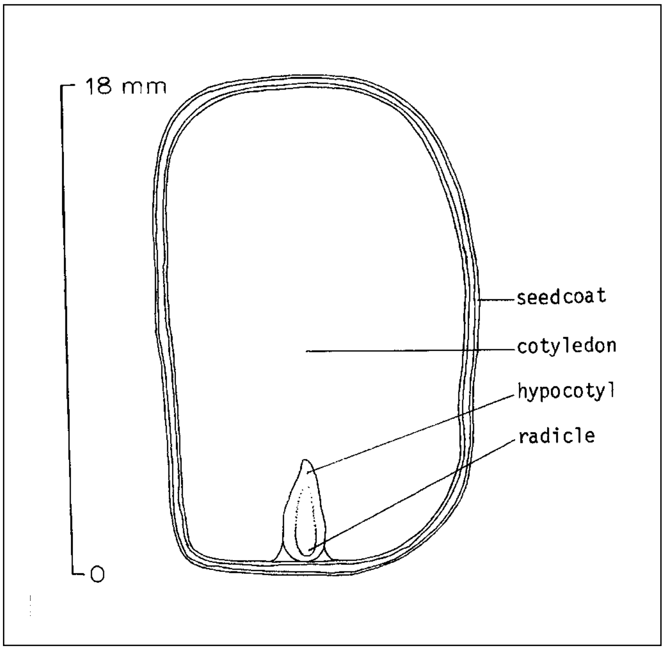


Figure 2— *Ebenopsis ebano,* Texas-ebony: seeds.

Germination. The seedcoats of Texas-ebony are very hard, and few seeds will germinate without scarification. Soaking in sulfuric acid for 30 to 150 minutes has yielded germination of 78 to 88% (Alaniz and Everitt 1978; Vora 1989). This wide variation in soaking times suggests considerable variation in hardness of the seedcoats. In such cases, time trials should be carried out with small samples to choose the optimum soaking period for a given seedlot. Official seed testing organizations do not include Texas-ebony in their prescriptions for testing, but alternating temperatures of 15 and 30 °C have been quite successful following acid scarification (Alaniz and Everitt 1978).

Figure 3— *Ebenopsis ebano*, Texas-ebony: longitudinal section through a seed.



Nursery practice. There is little information on nursery practices for Texas-ebony. Nurserybed densities of 160 to 215/m² (15 to 20/ft²) appear to be suitable for raintree (*Albizia saman* (Jacq.) F. Muell.), a similar species (Walters and others 1974), and the same is suggested for Texas-ebony. Optimum planting depth in a greenhouse was reported to be 1 cm (0.4 in) (Alaniz and Everitt 1978). Direct seeding in old fields in Texas was improved by mulching the seeds with a commercial straw blanket (Vora and others 1988), and either mulching or shading would seem to be beneficial in nursery beds in that region.

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Elaeagnaceae—Oleaster family

Elaeagnus L.

elaeagnus

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Growth habit, occurrence, and use. The genus *Elaeagnus* includes about 40 species of shrubs and trees, but there are only 3 species that are valuable for planting and for which reliable information is available (table 1). Although these deciduous trees and shrubs are grown often as ornamentals, they also produce edible fruits and serve as a source of wildlife food and as honey plants. Russian-olive is grown widely and has escaped from cultivation in many river lowland areas, particularly in the Great Plains, where it was extensively planted for shelterbelts (Olson 1974). In many areas, it has become invasive.

Flowering and fruiting. The fragrant, small, perfect flowers are borne in late spring (table 2) and are pollinated by insects (Mowry 1971). The fruit is a dry and indehiscent achene that is enveloped by a persistent fleshy perianth and hence is drupaceous (Jack 1969) (figures 1–3). The color of ripe fruit varies with the species (table 3). Seeds are often distributed by birds following consumption of the ripe fruits (Turcek 1961).

Collection of fruits; extraction and storage of seeds. Ripe fruits are collected by picking them from the plants by hand or by beating or stripping them from the branches onto canvas or plastic sheets, usually from September to December (Olson 1974). Fruits may be spread out to dry or run through a macerator with water and the pulp floated off or screened out (Heit 1968; Olson 1974). Accordingly, commercial seedlots may consist of either dried fruits or cleaned stones. Dried fruits or cleaned stones at a moisture content from 6 to 14% can be stored successfully in sealed containers at 1 to 10 °C (Heit 1967; Mickelson 1968; Olson 1974; Peaslee 1969). Under ordinary storage conditions, seeds of silverberry remain viable for 1 to 2 years and those of Russian-olive up to 3 years (Olson 1974). The number of cleaned seeds (stones) per weight and other important yield

Table 1—*Elaeagnus,* elaeagnus: nomenclature and occurence

Scientific name & synonym(s)	Common name(s)	Occurrence
***E. angustifolia* L.** *E. hortensis* Bieb.	**Russian-olive,** oleaster, narrow-leafed oleaster	S Europe, W & Central Asia; Pacific Northwest to Minnesota, S through Great Plains to Mexico
***E. commutata* Bernh. ex Rydb.** *E. argentea* Pursch, non Moench	**silverberry,** wolfberry	Quebec to Yukon, S to New Mexico, E to Nebraska
***E. umbellata* Thunb.** *E. crispa* Thunb.	**autumn-olive,** autumn elaeagnus	China, Korea, & Japan; Maine to New Jersey & Pennsylvania, W to SW Minnesota, occasionally S to South Carolina

Sources: Fernald (1950), Harrington (1954), Olson (1974), Rehder (1940), Small (1933).

Table 2—*Elaeagnus,* elaeagnus: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening	Seed dispersal	Seed size (mm)
E. angustifolia	—	June	Aug–Oct	All winter	12–13
E. commutata	Black Hills, South Dakota	June–July	Aug–Sep	Sep–Nov	8–9
E. umbellata	—	May–June	Aug–Oct	Sep–Nov	6–8

Source: Borell (1962), Dietz (1969), Hora (1981), McDermand (1969), Radford and others (1964), Rehder (1940).

Figure 1—*Elaeagnus angustifolia*, Russian-olive: fruit.

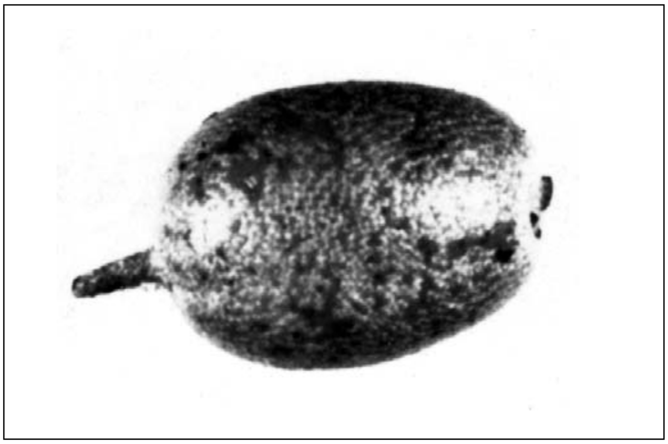
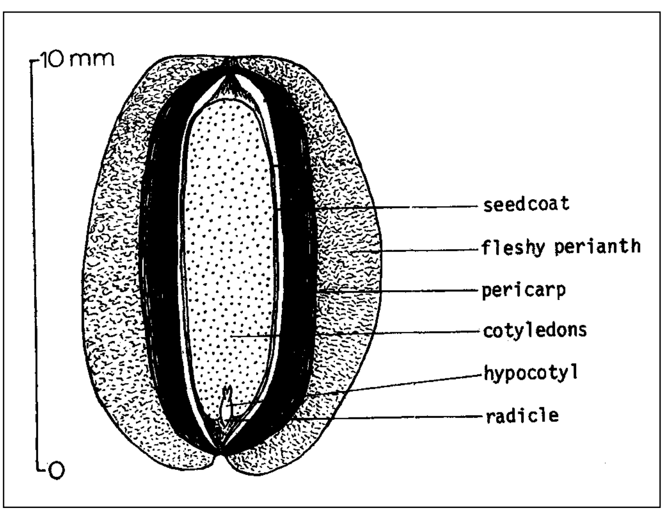


Figure 2—*Elaeagnus,* elaeagnus: achenes with fleshy perianth removed of *E. angustifolia*, Russian-olive (**left**) and *E. commutata*, silverberry (**right**).

Figure 3—*Elaeagnus angustifolia,* Russian-olive: longitudinal section through an achene enclosed in the fleshy perianth.



data are presented in table 4. From 4.5 kg (10 lb) of fruit, about 0.45 kg (1 lb) of cleaned seeds can be extracted. Fresh fruits of Russian-olive lost about 16 to 20% of their initial weight when air dried. The number of dried fruits per weight ranged from 3,970 to 9,900/kg (1,800 to 4,500/lb), with an average of 6,400/kg (2,900/lb). Purity of commercial seedlots for all 3 species has been high, ranging from 95 to 100% (Mickelson 1968; Olson 1974; Zarger 1968).

Pregermination treatments. Several pregermination treatments have been tested to overcome embryo dormancy in elaeagnus seeds. The most effective treatment is cold stratification at 1 to 10 °C for 10 to 90 days (Carroll 1971; Heit 1967, 1968; Lingquist and Cram 1967; Molberg 1969; Olson 1974). Stratification for less than 60 days is less effective than for longer periods (Carroll 1971). Intact autumn-olive seeds stratified at 5 °C from 2 to 6 weeks germinated less than 50% after 12 weeks at 25 °C, whereas seeds stratified for 10 to 14 weeks germinated completely in 12 weeks (Hamilton and Carpenter 1976). Allan and Steiner (1965) found that a 24-hour water soak followed by 45 days at 2 to 3 °C was sufficient to break dormancy in seeds of autumn-olive.

Russian-olive stones sometimes exhibit hard-seededness, and then should be soaked for $^1/_2$ to 1 hour in sulfuric acid before germinating (Heit 1967). The optimum length of after-ripening for Russian-olive was reached at 12 weeks (Hogue and LaCroix 1970). Belcher and Karrfalt (1979) found that snipping off 2 mm at the radicle end, after 7 days of water soaking, resulted in 96% germination. Snipping 2 mm at the cotyledon end only resulted in 50% germination. When 2 mm was snipped off both ends of the seeds, however, germination was 100%.

Seeds of Russian-olive that were not given a cold treatment but were soaked in Ethrel (2-chloroethyl phosphonic acid) germinated significantly better than seeds soaked in distilled water (Hamilton 1972). Concentrations of 300 and 600 ppm of Ethrel gave the maximum germination of 100 and 90%, respectively (Hamilton 1972). Germination was not further stimulated by giving the seeds 45 days of cold treatment before soaking in Ethrel (Hamilton 1972).

Gibberillic acid (GA_3) applied to autumn-olive seeds at concentrations of 500 and 900 ppm decreased the time of cold stratification and increased the total germination percentage (Hamilton and Carpenter 1976). A coumarin-like inhibiting substance was found in all parts of the dormant and fully chilled seeds of Russian-olive (Hamilton and Carpenter 1976). Gibberillic acid at concentrations of 100 and 500 ppm and kinetin at 100 ppm appear to reverse the action of the inhibitor (Hamilton and Carpenter 1976).

Silverberry seeds, with endocarps removed, reached 85 to 100% germination within 10 days (Corns and Schraa

Table 3—*Elaeagnus,* elaeagnus: height; seed-bearing age, seedcrop frequency, and fruit ripeness criteria

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yr)	Years between large seedcrops	Fruit ripeness criteria	
					Preripe color	Ripe color
E. angustifolia	46–9	Long cultivated	≥3	3	Whitish to silvery l	Silver-gray outer; emon-yellow inside
E. commutata	1.8–4.6	1813	—	1–2	Silvery green	Silver
E. umbellata	0.9–3.7	1830	6	—	Silvery, with	Red-pink brown scales

Sources: Borell (1962), Dietz (1969), Fernald (1950), Rehder (1940).

Table 4—*Elaeagnus,* elaeagnus: seed yield data

Species	Seed wt/fruit wt ratio	Cleaned seeds/weight				Samples
		Range		Average		
		/kg	/lb	/kg	/lb	
E. angustifolia	15–60	7,650–15,400	3,470–6,990	11,380	5,160	15
E. commutata	—	5,950–10,140	2,700–4,600	8,380	3,800	5
E. umbellata	5–10	46,525–84,670	21,100–38,400	62,180	28,200	30

Sources: Belcher and Washburn (1965), Carroll (1971), Harrington (1954), Heit (1970), Hinds (1967), McDermand (1969), Mickelson (1968), Molberg (1969), Mowry (1971), Olson (1974), Schumacher (1968), Zarger (1968).

1962). After intact seeds were stratified at 5 °C for periods of 40 to 110 days, the germination ranged from 23 to 75%, respectively (Corns and Schraa 1962). Supplemental treatments such as hot water soaks, gibberillic acid, and potassium nitrate (KNO_3) soaks did not affect the germination of silverberry (Corns and Schraa 1962).

Germination tests. Some germination test results on stratified seeds are listed in table 5. Germination is epigeal. Silverberry had the best total germination (95 to 96%) and speed of germination after 60 to 90 days of stratification at 4 °C (Morgenson 1990). Seeds of silverberry used for strip mine reclamation yielded the highest germination (80%) after a 2-day warm (50 °C) water soak (Fung 1984). Results for autumn-olive seeds indicated that the optimum germination was achieved with cold stratification at 5 °C for 16 weeks and a night/day temperature of 10/20 °C (Fowler and Fowler 1987). Tests on excised embryos of Russian-olive have been completed in a very short time (Heit 1955). Belcher and Karrfalt (1979) found that it took 1 hour to completely excise the embryo from the seed and it resulted in 100% germination after 3 days incubation at 20 to 30 °C. Viability testing with 2,3,5-triphenyl tetrazolium chloride stain yielded 86% viable seeds for Russian-olive and 68 % viable seeds for autumn-olive (Olson 1974). Rules of the International Seed Testing Association (ISTA 1993) call for the use of tetrazolium staining for elaeagnus. Seeds should be soaked in water for 18 hours, then cut transversely at both ends to open the embryo cavity. After 48 hours of soaking in 1% tetrazolium chloride, the seeds should be cut longitudinally to expose the embryos. The radicle tips and as much as one-third of the distal cotyledons can be unstained, and the seeds still considered viable. A secondary procedure calls for longitudinal cuts at the beginning.

Nursery practice. Seeds may be sown 13 to 25 mm ($^1/_2$ to 1 in) deep in the late summer or fall without stratification, or in the spring after 10 to 90 days of cold stratification (Baker 1969; Growl 1968; Hinds 1967; Jack 1969; McDermand 1969; Mickelson 1968; Molberg 1969; Olson 1974; Zarger 1968). July seeding after 90 days of stratification gave excellent germination of Russian-olive in southeast Saskatchewan (Cram and Elliott 1966). In Michigan, autumn-olive is seeded by broadcasting 1.7 kg of fresh fruit/ 10 m^2 of bed area (1 lb/25 ft^2) (Carroll 1971). At the Los Lunas Plant Material Center, Russian-olive is sown at a rate of 200 seeds, or 40 g (1.4 oz) of clean seeds/m, which yields 150 usable plants. In areas with a large population of mice, the pulp should be removed and cleaned seeds used for sowing (Carroll 1971). Russian-olive seedlings are susceptible to damage from rabbits and must be protected if these rodents are a problem.

Soil splash, which coats the pubescent leaves of newly emerged seedlings, is an important cause of mortality, and consequently, nursery beds should be mulched to cover the soil and prevent rain spattering (Carroll 1971; Growl 1968;

Table 5—*Elaeagnus*, elaeagnus: germination test conditions and results for stratified seedlots*

Species	Germination test conditions				Germinative energy		Germinative capacity	
	Medium	Temp (°C) Day	Temp (°C) Night	Days	Amt (%)	Days	Average	Samples
E. angustifolia	Sand	30	20	60	7–76	10–32	7–79	32
	Sand	—	—	21–40	—	—	54–90	11
	Moss	—	—	28	27	10	30	1
	Kimpak	30	20	28			68	19
E. commutata	Sand	30	20	50	52	13	60	1
E. umbellata	Kimpak	30	20	28			41	57
E. umbellata	—	30	10	—	—	—	93	—

Sources: Belcher and Washburn (1965), Heit (1968), Molberg (1969), Olson (1974).
* Seeds were stratified for 10 to 90 days at 1.1 to 10 °C.

Hinds 1967; Mickelson 1968; Molberg 1969; Olson 1974; Zarger 1968). A seedling density of 130 to 320/m² (12 to 30/ft²) is desirable (Baker 1969; Molberg 1969; Zarger 1968). Stock usually is field planted as 1+0 or 2+0 seedlings, and grows well in most soils, including limestone or alkaline soils (Stoeckeler 1946).

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Asteraceae—Aster family

Encelia Adans.

encelia

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Other common names. brittlebush, bush-sunflower.

Growth habit, occurrence and uses. The brittlebush genus—*Encelia*—includes 14 species of low branching shrubs native to western America. The plants are suffrutescent, often with a pungent odor (Benson and Darrow 1954). Ray flowers (sometimes absent) are yellow, usually conspicuous when present, and produce neither pollen or fertile seeds. Disk flowers are yellow or purple (Benson and Darrow 1954). Species frequently hybridize, especially in disturbed areas. Species commonly found in the southwestern United States are listed in table 1.

The brittle wood secretes a clear resin used by Native Americans as a glue. In some parts of Mexico, the resin has been burned as incense for religious ceremonies (Benson and Darrow 1954). The Cahuilla of the southwestern United States have used gum from this plant as a medicine; the gum was heated and applied to the chest to relieve pain (Bean and Saubel 1972).

Flowering and fruiting. Flowering can begin in February and continue through July, weather conditions permitting. Most encelia flowerheads are yellow or a brown- or yellow-purple. The achenes are densely compressed, obovate or wedge-shaped, with edges that are long-ciliate and faces that are glabrous or short-hairy (figures 1 and 2) (Jepson 1993).

Collection, extraction, and storage. Timing of seed collection is critical, as the achenes are easily blown from the plant after maturity (Kay and others 1977). Seeds may be hand-harvested and stored successfully for several years. Cleaning is difficult, for seeds are often mixed with dry flower and plant parts of similar size and weight. Studies on long-term storage of seeds of rayless encelia and Acton brittlebush showed good germination after 4 and 14 years, respectively (Kay and others 1988). Seeds of both species that were stored under 4 conditions (–15 °C, 4 °C, room temperature, and warehouse temperatures) also showed significantly poorer germination rates in the warehouse after 3 years. Storage conditions studied by Padgett and others (1999) showed that seedlots stored for 6 months in a stan-

Figure 1—*Encelia farinosa*, brittlebush: achenes.

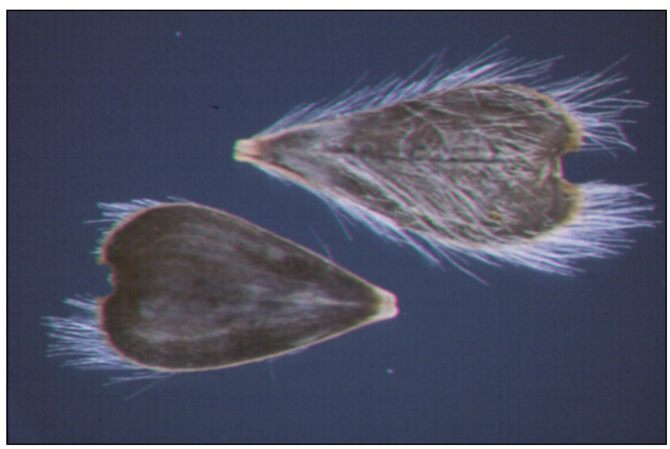

Table 1— *Encelia,* encelia: nomenclature and occurrence

Scientific name	Common names	Occurrence
***E. californica* Nutt.**	**California brittlebush**	Coastal California scrub to Baja California
***E. farinosa* Gray ex Torr.**	**brittlebush,** *incienso*, goldenhills	Deserts of SW Utah, Arizona, & NW Mexico
***E. frutescens* (Gray) Gray**	**rayless encelia**, green brittlebush	Deserts of S Nevada, W Arizona, & Baja California
***E. virginensis* A. Nels.**	**Virgin River encelia,** brittlebush	E Mojave to SW Virgin River, Utah, & NW Arizona
***E. virginensis* var. *actonii* (Elmer) B.L. Turner**	**Acton brittlebush**	SW California, SW Nevada to N Baja California

Source: Jepson (1993).

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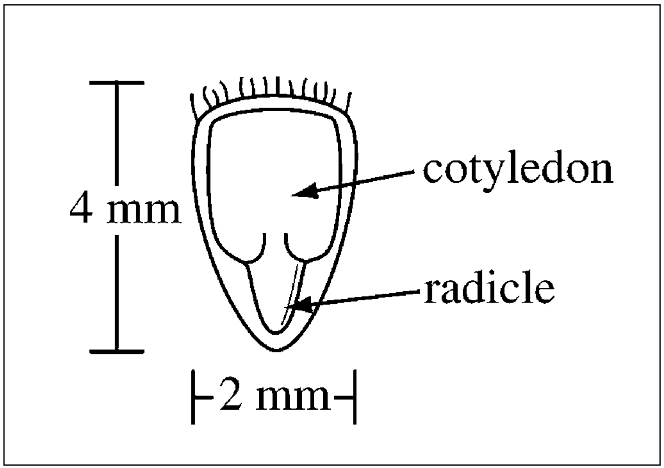
Figure 2— *Encelia farinosa,* brittlebush: longitudinal section through a seed.



dard refrigerator held at about 5 to 10 °C exhibited 2 to 3 times greater germination percentages than those stored at room temperature.

Pregermination treatment and germination tests. No seed treatment is necessary (Emery 1988). Some research has been done to test dormancy in encelias, especially in brittlebush. At Joshua Tree National Park (JTNP), germination of brittlebush was tested with direct sowing and with the following seed treatments: 24 hours of cold water soaking, 6 hours of cold water soaking, and 24 hours of leaching, with all seeds sown on moist blotter paper (CALR 1993). Results showed very low germination rates (<1%). Research at the University of California at Riverside (UCR) has shown that the most significant cause of poor germination is lack of viable embryos in nearly half of the seeds tested for viability and germination behavior (Padgett and others 1999). Pre-soaking appears critical, and gibberellic acid (GA) has enhanced germination rates 2 to 3-fold (Padgett and others 1999). Treatment tests subjected seeds to warm water soaking for 30 minutes, followed by soaking in 100 ppm GA in water for 30 minutes. These treated seeds were then sown on or in 3 different media: UCR soil mix, vermiculite, and germination paper. All seeds were incubated in low light at 25 to 30 °C. Two general trends were observed: seed treatment with gibberellic acid for 30 minutes significantly increases germination rates, and sowing into vermiculite followed by transplantation into sterile potting medium appears to be the best method for seedling germination and survival. The vermiculite is pre-soaked, and misted every 2 days to avoid drying out. Seeds sown into the UCR soil mix had severe damping-off problems, and results from the germination paper are thus far inconclusive. From the vermiculite, seedlings were successfully transplanted to larger containers and maintained in greenhouse conditions.

Work with Acton brittlebrush has correlated temperature and germination rates (Kay and others 1997):

Temperature (°C)	2	5	10	15	20	25	30	40
Germination (%)	0	1	47	65	55	5	7	0

Seeds were collected in late June 1973, yielding 1.96 kg of material of 24% purity. Cleaned seeds were 86% pure and had a pure fruit weight of 477,000 achenes/kg (216,721/lb). Emergence testing of encelia seedlots planted at 1-cm depth over a 10-day period showed a total emergence of 57%. Emergence at a 2-cm ($^3/_4$ in.) depth was somewhat reduced and delayed, whereas no plants emerged from a 4-cm ($^1/_2$ in). depth (Kay 1975).

Nursery practice. Both cuttings and seedlings of brittlebush and Virgin River encelia have been successfully planted into 76-cm (30-in) tall and 15.2-cm (6-in) diameter tubes at JTNP using a mixture of sand, perlite, and mulch with a slow-release fertilizer. Both species were also grown in 3.8-liter (1-gal) pots, 15.1-liter (4-gal) pots, and plant bands, with the greatest outplanting success being the 76-cm (30-in) tubes or "tall pots" (CALR 1993). Plants in the nursery require a hardening-off period of 1 to 2 weeks and may be subject to aphid predation. Seedlings must be transplanted with care, for branches break off easily (CALR 1993).

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E

Fabaceae—Pea family

Enterolobium cyclocarpum (Jacq.) Griseb.

guanacaste or earpod-tree

John K. Francis

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Growth habit, occurrence, and use. At maturity, the fast-growing *guanacaste* is a huge, spreading tree with feathery, bipinnately compound leaves. The trunks of open-grown trees are short and thick, tipped with an inverse cone-shaped crown; trunks of trees growing in closed stands have much longer boles. Guanacaste grows in both acid and alkaline soils (Bauer 1982) in forests and savannas from central Mexico (23°N) through Central America to about the Equator in northern Brazil (Little and others 1974; Pennington and Sarukhan 1968). However, the species has been widely planted in tropical and subtropical areas, including Puerto Rico, the U.S. Virgin Islands, Florida, and Hawaii (Francis 1988). Guanacaste is recommended for planting in areas that receive from 750 to 2,000 mm of mean annual precipitation (Bauer 1982; Fournier and Herrera 1977). Dry seasons of 1 to 6 months are normal in the native range (Bauer 1982; Janzen 1983). Guanacaste is principally used as an ornamental and shade tree in parks, estates, and broad avenues. It is also valued as a pasture shade tree, especially in Central America. Cattle, horses, and goats feed heavily on its sweet legumes (pods). The heartwood has a rich brown color and is in demand for cabinetry, furniture, crafts, and construction (Chudnoff 1984; Guridi 1980).

Flowering and fruiting. Small white flowers are borne in clusters or heads at the base of leaves (Little and others 1974; Pennington and Sarukhan 1968). Flowering takes place in March and April during the regrowth of new leaves after the leafless dry season (Hughes and Styles 1984; Janzen 1983). There is no indication in the literature as to the age at which flowers first appear; however, trees in a 26-year-old plantation in Puerto Rico had not yet flowered. The fruits are shiny, dark brown legumes that curve around one edge, giving them a shape that resembles a human ear (figure 1). Legumes are 7 to 12 cm in diameter and contain 8 to 18 seeds (Holdridge and Poveda 1975; Janzen 1983; Pennington and Sarukhan 1968); they mature the year they are formed and fall in March and April.

Collection, cleaning, and storage. Seeds can be collected in quantity by picking up the legumes after they have fallen to the ground. They can be separated by macerating the legumes and then washing them to remove the sticky syrup or by picking the seeds from the tough legumes with the point of a knife (Francis 1988). One thousand to a few thousand seeds are produced per tree. The 1.3- to 1.9-cm ($^1/_2$- to $^3/_4$-in) seeds (figure 2) number 1,100/kg (500/lb) (Janzen 1983; Neal 1965). The seeds store well according to Bauer (1982).

Germination. Without scarification, a moderate percentage of the seeds germinate over a span of several

Figure 1—*Enterolobium cyclocarpum*, guanacaste: seeds and legume.

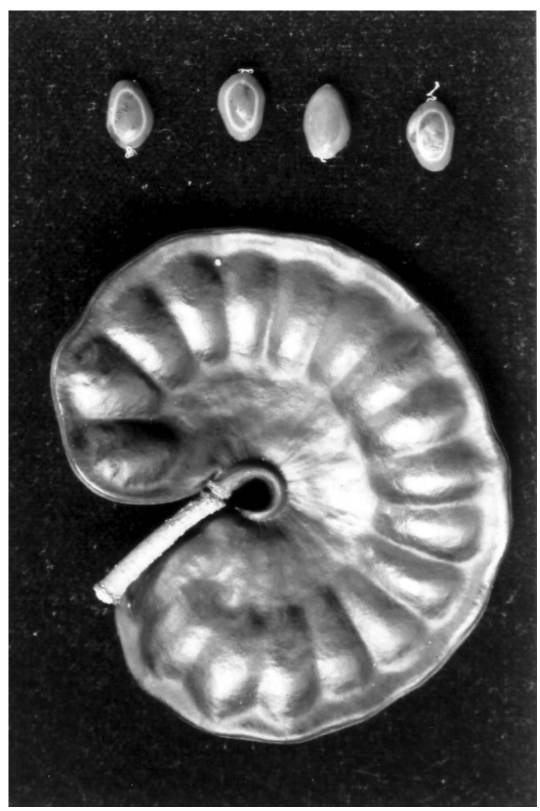
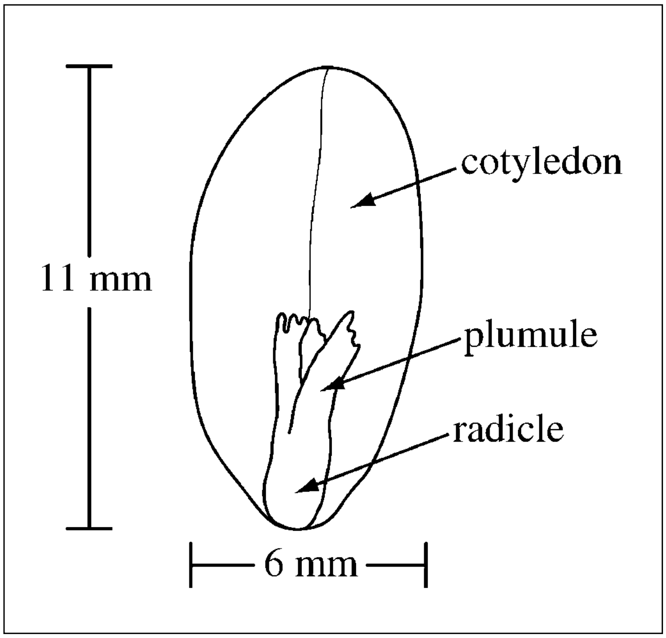


Figure 2—*Enterolobium cyclocarpum*, guanacaste: longitudinal section through a seed.



months. Scarified seeds in most kinds of soil germinate in 3 to 7 days. Germination values of 79 and 84% were observed in tests in Puerto Rico (Francis and Rodríguez 1993) and Costa Rica (Salazar 1985). A seed can be scarified by nicking it on a grindstone, by cracking it with a pair of pliers, or by immersing it briefly in boiling water. In nature, seeds are scarified and disseminated primarily when the legumes are eaten by domestic and wild ungulates or when they are nicked by rodents (Janzen 1983). Germination is epigeal (Francis 1988).

Nursery practice. Seeds may be sown in nursery beds, germination trays, or directly in pots. They should be covered with about 1 cm (.4 in) of soil or potting mix. Seedlings develop rapidly in full sunlight, reaching plantable size of about 0.5 m (20 in) in about 6 months (Francis 1988). The seedlings are very drought hardy and generally, good survival at outplanting can be obtained with potted seedlings and stump plants (Bauer 1982). A test of container seedlings in southeastern Mexico yielded an average of 77% survival (Beroni and Juarez 1980).

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Ephedraceae—Ephedra family

Ephedra L.

ephedra or Mormon-tea

Susan E. Meyer

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Growth habit, occurrence, and uses. The genus *Ephedra*—known in much of North America as Mormon-tea—comprises about 40 shrubby species that are found throughout the arid and semiarid regions of the Northern Hemisphere. Ephedras are gymnosperms that are characterized by their greatly reduced, bractlike leaves and their evergreen, broomlike photosynthetic stems. They are common plants in the semiarid region of western North America (table 1) and are often locally codominant with creosotebush (*Larrea tridentata* (Sessé & Moc. ex DC.) Coville), blackbrush (*Coleogyne ramosissima* Torr.), shadscale saltbush (*Atriplex confertifolia* (Torr. & Frem.) S. Wats.), and various species of sagebrush (*Artemisia* spp.). Species of ephedra are often the dominant vegetation on sand hills at middle elevations, where they perform an important role as sandbinders. They provide a significant source of browse for domestic livestock, especially sheep, and for wild ungulates such as mule deer (*Odocoileus hemionus*) and pronghorn antelope (*Antilocapra americana*). The seeds provide food for rodents and birds. The twigs, especially those of green Mormon-tea, are used to make a reputedly refreshing tea, although ephedrine, the pharmaceutically active compound found in the Old World species *E. sinica* Stapf., has not been detected in any North American species. Ephedras are attractive and interesting plants, with considerable potential for landscape use, and green Mormon-tea can now be readily obtained from commercial nurseries.

Flowering and fruiting. Ephedras are dioecious, with male and female cones occurring on separate plants. The cones are borne singly or in pairs or whorls at the branch nodes. The seeds are borne singly or in pairs in the axils of the female cone scales. The inner cone scales are modified to enclose the seed and form integuments that mimic the angiosperm pericarp. Flowering usually takes place in March through May, and seeds ripen from June through September, depending on elevation and species. The plants are wind-pollinated. Ephedra plants do not flower every year; their reproductive pattern could be described as mast fruiting, where most individuals in the population flower synchronously in a year with ample rainfall, and large quantities of seeds are produced. The population does not flower again for several years, whether or not a high-rainfall year occurs. The seedcrop may be damaged by late frosts, late spring drought, or infestations of pentatomid bugs.

The distribution of male and female ephedra plants is not random; individuals on dry slopes are overrepresented by males, whereas those growing on run-on surfaces are 4 times as likely to be females as males (Freeman and others

Table 1—*Ephedra,* ephedra: habit, habitat, and geographic distribution of some species used in revegetation

Scientific name	Common name(s)	Habit	Habitat	Distribution
***E. nevadensis* S.Wats.**	**Nevada Mormon-tea,** gray Mormon-tea, gray ephedra, gray Nevada joint-fir	Sprawling, gray-green, leaves in pairs, bases	Creosote bush shrub-land to pinyon–juniper woodlands	W US
***E. torreyana* S.Wats.**	**Torrey Mormon-tea,** Torrey ephedra, Torrey's joint-fir	Sprawling, gray-green, leaves in whorls of 3, bases gray	Creosote bush shrub to pinyon-juniper woodlands	Colorado Plateau, Chihuahuan Desert
***E. viridis* Coville**	**green Mormon-tea,** Brigham tea, green ephedra, Mormon-tea	Erect, broomlike, bright green, leaves in pairs, bases black	Blackbrush shrub land to mountain brush	W US

Sources: Welsh and others (1987).

1976). The genetic basis for sex differentiation in *Ephedra* is not known, but the spatial arrangement of males and females functions to maximize reproductive output, as it places males where their pollen can be easily wind-dispersed early in the season and females where they are more likely to have resources later in the season to ripen a seedcrop.

North American ephedra species fall into 2 groups characterized by differences in seed size and dispersal ecology (table 2). The large-seeded species (for example, green and Nevada Mormon-teas) are dispersed by scatter-hoarding rodents such as kangaroo rats (*Dipodomys* spp.), which deposit them in shallowly buried caches and later return to eat most of the seeds or sprouts. The cone scales in these species are small. In small-seeded species (for example, Torrey Mormon-tea) the outer cone scales are large and membranous, and the intact cones are often seen windrowed at some distance from adult plants. The seeds are apparently wind-dispersed, as they have long, awnlike points that probably make them unattractive to rodents. Cones with seeds intact may remain on the surface for many months.

Fruit collection, cleaning, and storage. Ephedra seeds (figures 1–3) are easily collected when fully ripe by beating the branches over a hopper or pan; in mast years, large quantities can be collected in a short time. The collection window is narrow and crops must be watched carefully, as ripe seeds can be dislodged by wind or rain in a single day. Seed fill is usually high (table 2), but it is a good idea to check fill in the field before harvesting, as late drought can prevent filling of seeds that otherwise look normal. After the seeds are thoroughly dried, they may be broken free of the cone scales in a barley de-bearder if necessary and then cleaned in an air-screen cleaner (fanning mill). The seeds are usually long-lived in warehouse storage if initially of high quality, and storage times of 15 years may result in little viability loss (Stevens and others 1981). In a warehouse storage experiment, seedlots stored from 10 to 20 years had an average viability of 80% (n = 3), whereas seedlots stored from 20 to 30 years had an average viability of 31% (n = 12). The vigor of the older lots was low, however, as evidenced by their low germination in response to chilling (<5% for lots >20 years old). It is doubtful whether seedlots >20 years old could be field-seeded successfully. The ability to remain highly viable for many years (orthodox storage behavior) facilitates stockpiling of ephedra seeds collected in mast years for use over the period when few seeds are produced.

Figure 1—*Ephedra nevadensis*, Nevada Mormon-tea: seed.

Seed germination and testing. Ephedra seeds are sometimes dormant at harvest, but this dormancy usually disappears through after-ripening after a few months in storage (Kay and other 1977). The dormancy also disappears after short periods (2 to 4 weeks) of chilling; this chilling also hastens the subsequent germination of nondormant seeds (Kay and others 1977; Meyer and others 1988). In experiments with 6-month-old seedlots, 7-day germination for unchilled seeds at 10 to 20 °C was 10% for 1 lot of green Mormon-tea, 49 to 54% for 2 lots of Nevada Mormon-tea, and 95 to 100% for 3 lots of Torrey Mormon-tea. The 7-day germination after 2 weeks of chilling at 1 °C was over 90% for all seedlots. Germination is generally highest at temperatures of 15 to 20 °C, except in more dormant lots, which show higher percentages of germinatation in temperature regimes that include a temperature in the chilling range (Young and others 1977). Germination is suppressed by higher temperatures, which probably prevent the

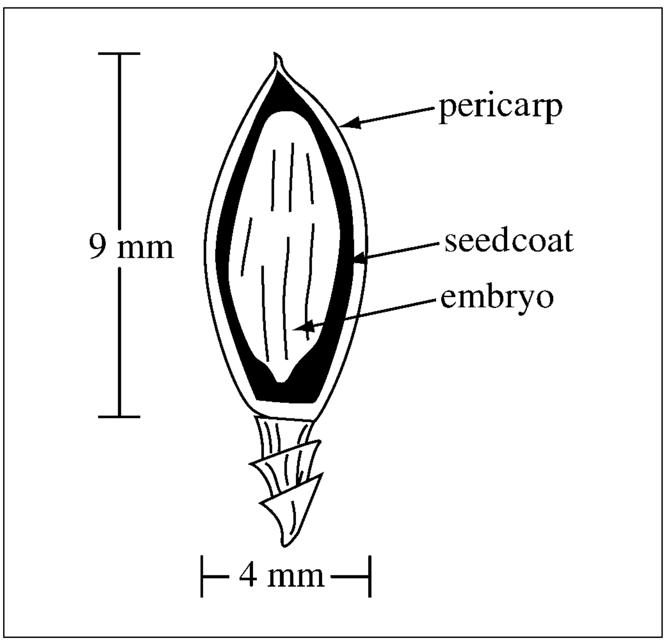
Table 2—*Ephedra,* ephedra: seed weight and viability data

	Seed weight				% viability	
	Range		Mean			
Species	/g	/oz	/g	/oz	Range	Mean
E. nevadensis	33–57	935–1,615	43	1,220	84–94	89
E. torreyana	108–128	3,060–3,630	118	3,345	76–91	83
E. viridis	28–62	790–1,760	47	1,330	46–100	89

Sources: Belcher (1985), Kay and others (1977), Meyer (1995), Meyer and others (1995), Monsen (1995).

Figure 2—Ephedra viridis, Torrey Mormon-tea: seeds (**outer**) and cone (**center**) with single seed.

Figure 3—*Ephedra nevadensis*, Nevada Mormon-tea: longitudinal section through a seed.



otherwise nondormant seeds from precocious summer germination. Ephedra seeds germinate readily during prolonged chilling. Kay and others (1977) reported 76% germination during a 30-day stratification at 2 °C for a Mojave desert collection of Nevada Mormon-tea. In chilling experiments with the 6 seedlots mentioned above, weeks to 50% germination at 1 °C varied from 6 to 7 weeks for the Torrey Mormon-tea collections and from 8 to 9 weeks for collections of the other 2 species. All viable seeds germinated during chilling within 12 weeks.

Official rules for testing green Mormon-tea call for a 4-week test at 15 °C, with the option of a 4-week prechill for more dormant lots (AOSA 1993; Meyer and others 1988). Ungerminated seeds should be scored for viability using tetrazolium staining, which is also an acceptable substitute for a germination test. Seeds should be allowed to imbibe water, then clipped or slit on the cotyledon end and immersed in 1% tetrazolium solution for 8 hours. Seeds are then bisected longitudinally for evaluation.

Nursery and field practice. Large-seeded species of ephedra have been successfully established from direct seeding using drilling or with a seed dribbler or thimble seeder. If seeds are distributed aerially, a method for covering them with soil must be provided, as the seeds must be planted for successful establishment. Seedlings emerge and establish quickly and can withstand considerable drought once established. Emergence is best from depths of 1 to 2 cm (4/10 to 8/10 in) (Kay and others 1977). Emergence in green Mormon-tea is epigeal and the seedlings resemble those of conifers, whereas emergence in Nevada Mormon-tea is reported to be hypogeal (Kay and others 1977). Late-fall-seedings have been successful in the northern part of the range, where most effective precipitation comes in winter; whereas early-summer-seedings are recommended in the southern part of the range, where rainfall comes in the summer.

Ephedra planting stock may be produced either in bareroot or container culture. Plants do best in a coarse well-drained medium. Roots are fragile, so stock must be handled very carefully to avoid damage. The root systems of container stock are often too small to bind the root plug together, and those of bareroot stock are also usually poorly developed, resulting in low root–shoot ratios. Outplanting success rates are generally quite low (<50%).

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Ericaceae—Heath family

Epigaea repens L.

trailing-arbutus

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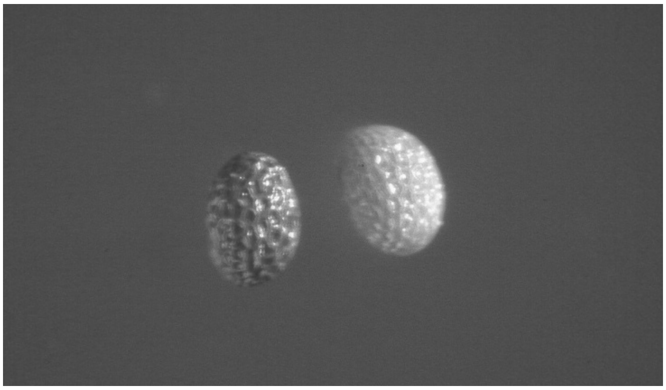
Other common names. mayflower, ground-laurel, gravel weed, mountain-pink, winter-pink, crocus, gravel plant.

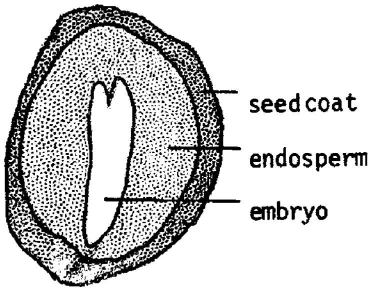
Growth habit, distribution, and use. Trailing-arbutus is an evergreen, prostrate, creeping shrub that grows in patches up to 60 cm in diameter (Bailey 1949). It is found growing in woodlands on acid, sandy soils from Florida to Mississippi, north to New England, southeast to New York, Pennsylvania, West Virginia, and Ohio. The variety *glabrifolia* Fern. ranges north from the higher parts of the Appalachian Mountains to Newfoundland, Nova Scotia, and Labrador and west to Saskatchewan (Fernald 1950). Although it is difficult to grow, trailing-arbutus has been planted as an ornamental since 1736 (Barrows 1936; Lemmon 1935). In some parts of its range it has become locally rare (Clay 1983). The blossoms are quite fragrant, and the fruits are sometimes eaten by small game. An infusion of the above-ground parts was used by the Cherokees to treat diarrhea in children (Jacobs and Burlage 1958).

Flowering and fruiting. The flowers are spicy smelling, pink to white in color, and bloom from March to May, although specimens have been known to bloom as early as January at low elevations in the southern part of its range (Stupka 1964). Flowering usually begins when plants are 3 years old (Steffek 1963). Flowering is normally dioecious, but perfect flowers may occasionally be found (Bailey 1949; Barrows 1936; Fernald 1950). Double-flowered forms and fall-blooming forms have been reported (Fernald 1950). The fruit is a 5-lobed, hairy, dehiscent capsule about 6 mm in diameter (Bailey 1949; Fernald 1950; Steffek 1963). The seeds are embedded in a sticky, white, fleshy pulp within the capsule (Barrows 1936; Clay 1983; Steffek 1963). A sample of 155 wild fruits contained an average of 241 (range: 29 to 415) tiny, shiny, brown, hard seeds per capsule (figures 1 and 2). In June and July, as the capsules ripen, the sutures split open and many of the seeds are ejected with some force (Blum and Krochmal 1974). As the sutures begin splitting, ants will commonly enter the fruits and rapidly remove all seeds (Clay 1983).

Collection of fruits; extraction and storage of seeds. Capsules should be collected after they are mature and before they eject their seeds. Small collections of capsules can be air-dried in open containers until seeds are ejected. The empty capsules can be separated by screening. One sample of cleaned seeds contained 22,700 seeds/g (643,750/oz) (Blum and Krochmal 1974). Storing seeds for more than 1 year is not recommended, but short-term storage at room temperature or in a refrigerator is satisfactory (Barrows 1936).

Figure 1— *Epigea repens*, trailing-arbutus: seeds (**top**) and longitudinal section through a seed (**bottom**).





E

Germination tests. Germination is epigeal and has been reported to require no pretreatment (Blum and Krochmal 1974). To secure complete germination on moist filter paper in petri dishes; however, Lincoln (1980) found it necessary to stratify seeds for 30 days at 5 to 8 °C and then germinate them at alternating temperatures of 15 to 25 °C or 20 to 30 °C with light at the higher temperature. This procedure yielded germination values of 92 and 90%, respectively.

Nursery and field practice. The seeds of trailing-arbutus are so small that sowing in small pots or trays filled with acid soil, sand, and peat moss or leaf mold mixtures is recommended (Blum and Krochmal 1974). The seeds should be scattered on top of the mixture, and the container should be covered with a glass plate or plastic bag to maintain a high humidity. With this method, germination takes place over a period of 22 to 66 days, with most germination occurring in 30 days (Barrows 1936). There are other reports of good germination within 3 to 5 weeks of time (Dirr and Heuser 1987).

When the seedlings have 3 to 5 leaves above the cotyledons, they may be transplanted to individual pots. High humidity should be maintained until the plants are well established (Barrows 1936). In 1 year, the plants develop into rosettes about 10 cm (4 in) in diameter (Blum and Krochmal 1974). Plants will tolerate a fairly wide range of acidity. Wild plants in Connecticut grew on soils ranging in pH from 7.67 to 4.65, but the larger plants occurred on the more acid soils (Barrows 1936; Coville 1911; Lemmon 1935; Steffek 1963).

Trailing-arbutus thrives best in association with mycorrhizal fungi. Including soil that was collected near healthy wild plants in soil mixtures will introduce the necessary fungus (Barrows 1936; Coville 1911, 1915). The mycorrhizal fungus also appears to be essential for propagation from cuttings (Barrows 1936). Stem cuttings taken in August have given 94% rooting in a sand–peat mixture without any treatment (Dirr and Heuser 1987).

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Asteraceae—Aster family

Ericameria parishii (Greene) Hall

Parish goldenweed

Raymond D. Ratliff and Franklin T. Bonner

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Synonyms. *Haplopappus parishii* (Greene) Blake, *Aplopappus parishii* (Greene) Blake, *Bigelovia parishii* Greene, *Chrysoma parishii* Greene.

Other common names. Parish goldenrod, Parish goldenbush, Parish heathgoldenrod.

Growth habit, occurrence, and uses. An erect shrub, Parish goldenweed has a mature height of 1 to 2.5 m (Jepson 1951). Plants 15 years old have attained heights of 2 m and crown spreads of 1.2 m (Everett 1957). Parish goldenweed occurs in the lower parts of the chaparral belt between 460 and 2,130 m of elevation in the mountains of southern California and Baja California (Munz and Keck 1959). Frequently, it is found on outwash fans and exposed hillsides. The primarily value of this species is for erosion control on dry slopes (Ratliff 1974). Since the final writing of this manual, several sections of the genus *Chrysothamnus* (see table 1) have been transferred to the genus *Ericameria*.

Flowering and fruiting. Parish goldenweed will flower and bear seeds at 2 years of age and produce seeds each year thereafter (Everett 1957). Flowering takes place from July to October (Munz and Keck 1959), and ripe seeds may be collected in October and November (Mirov and Kraebel 1937). The fruit of Parish goldenweed is a single-seeded achene (figure 1) that is handled as a seed. The achenes are about 2 mm long (figure 2), and there are about 3,600 cleaned achenes/g (101,900/oz) (Mirov and Kraebel 1937).

Collection, cleaning, and storage. Achenes are usually collected by hand and separated from their bristles by rubbing and blowing (Ratliff 1974). There are no known studies of storage, but the seeds are probably orthodox and can be easily stored at low temperatures and moisture contents.

Figure 1—*Ericameria parishii*, Parish goldenweed: achene with pappus removed.

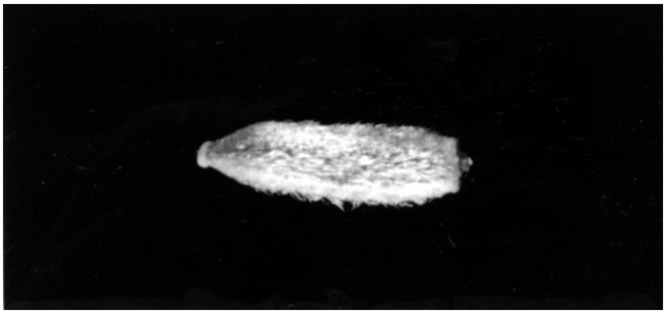
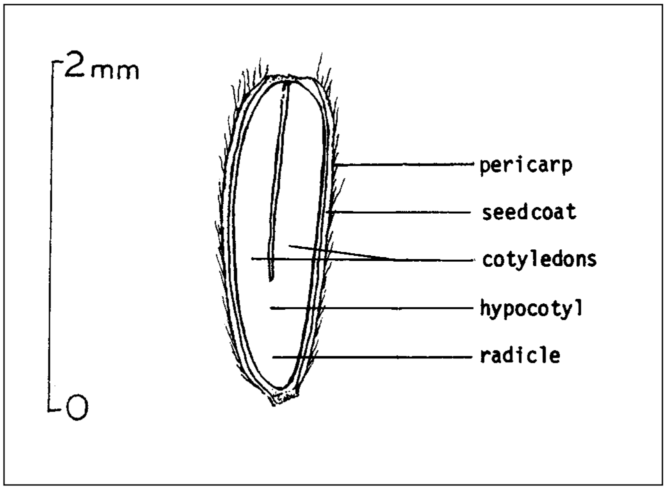


Figure 2—*Ericameria parishii*, Parish goldenweed: longitudinal section through an achene.



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Germination. Parish goldenweed seeds are not dormant, and no pretreatments are required to stimulate germination (Emery 1964). Seeds sown on sand began germinating in 4 days, and a maximum of 95% was obtained (Mirov and Kraebel 1937). Germination is, however, usually much lower (about 20%) because of a high percentage of defective seeds (Ratliff 1974). Parish goldenweed may also be propagated by cuttings (Jepson 1951).

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Polygonaceae—Buckwheat family

Eriogonum Michx.

wild-buckwheat, buckwheatbrush

Susan E. Meyer

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Growth habit, occurrence, and uses. The North American genus *Eriogonum*—wild-buckwheat, also buckwheatbrush—is made up of about 200 species of annual and perennial herbs and shrubs, most of which are found in the West. About half are woody, at least at the base. The habit of the woody species may be either (a) truly shrubby, (b) subshrubby, with annual renewal of upper shoots, or (c) pulvinate (mat-forming), with the woody shoots condensed into an above-ground caudex. The usually evergreen leaves are borne alternately and may be predominantly basal or borne along the stems. There may be whorls of leaves on the flowering stalks. The leaves are usually tomentose, at least below, and the stem nodes are often tomentose as well. The often-flat-topped inflorescences are usually borne above the leafy part of the plant and are conspicuous and characteristic even after seed dispersal.

Most plant communities in the West contain at least 1 species of woody wild-buckwheat (table 1). Some species are widely distributed and of wide ecological amplitude (for example, sulfurflower buckwheat brush), whereas others are narrowly restricted geographically and often edaphically as well (for example, pretty buckwheat brush). Wild-buckwheat species are often important pioneer plants after natural disturbance, and their presence may facilitate the establishment of later-successional species. This makes them useful for erosion control and for revegetation of anthropogenically disturbed sites such as mined land and highway rights-of-way (Ratliff 1974; Zamora 1994). Some species are important as browse plants for wild ungulates, particularly in the early spring when their evergreen habit makes them more highly nutritive than many other spring browse species (Tiedemann and Driver 1983; Tiedemann and others 1997). Some wild-buckwheat species are important bee plants. In California, Mojave buckwheatbrush has been rated third in importance for honey production, exceeded only by 2 native *Salvia* species (Kay and others 1977). Many wild-buckwheat species also have tremendous potential as easily grown, drought-tolerant ornamentals. Their interesting forms and leaf textures combined with masses of showy, long-lasting flowers make them excellent candidates for home xeriscapes. Named varieties that have been released are 'Sierra' sulfurflower wild-buckwheat (Stevens and others 1996) and 'Umatilla' snow wild-buckwheat (Tiedemann and others 1997).

Flowering and fruiting. The small, usually perfect flowers of wild-buckwheat are borne in clusters within cup-like or cylindrical involucres that are variously solitary or arrayed in capitate, cymose, or paniculate inflorescences. Each flower consists of a perianth with 9 stamens inserted at its base and a superior 1-celled and 1-seeded ovary. The perianth is made up of 6 fused segments in 2 whorls of 3. The ovary ripens in fruit into a usually 3-angled achene (figures 1 and 2). This achene is held more or less tightly within the perianth, depending on the species. For example, in snow wild-buckwheat the achenes fall free of the perianth at dispersal, whereas in Shockley wild-buckwheat the woolly perianth with the achene enclosed is the dispersal unit. The ovule within the seed is anatropous, so that the radicle end is pointing outward and upward. This makes it possible for germination and emergence to take place with the perianth still attached.

Wild-buckwheat species may flower at any time from early spring to fall, depending on species and habitat. Within a given habitat, species may bloom in succession. For example, at mid-elevation in central Utah, cushion wild-buckwheat blooms in spring, followed by James wild-buckwheat in early to midsummer, and finally by lace buckwheatbrush in late summer and fall. The bloom time for any species usually lasts well over a month, and the plants are almost as showy in fruit as in flower. The flowers are insect-pollinated.

Seed collection, cleaning, and storage. The window of opportunity for seed collection of wild-buckwheats is often rather wide, as the fruits usually persist on the plant for 2 to 3 weeks after maturity (Stevens and others 1996). When achenes are mature, the perianths dry and often change color, turning brown or rusty. At this point, the achenes can be harvested by hand-stripping or by beating them into hop-

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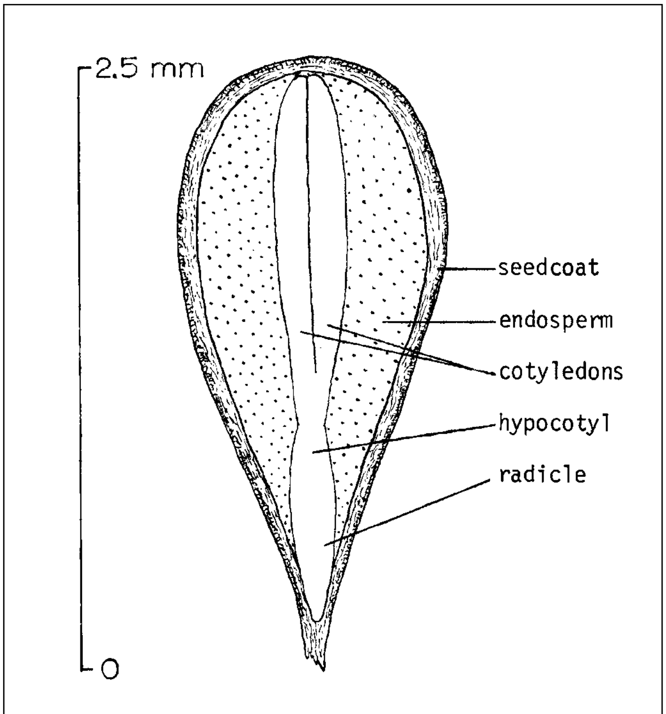
Table 1— *Eriogonum*, wild-buckwheat: habit, habitat, and geographic range

Species	Common name(s)*	Habitat	Range
Shrubs			
***E. corymbosum* Benth.**	**lace buckwheatbrush,** buckwheatbrush, crisp-leaf buckwheat	Desert shrub, pinyon juniper, mostly on shales	Colorado Plateau, Uinta Basin, & adjacent areas
***E. fasciculatum* Benth.**	**Mojave buckwheatbrush,** California buckwheatbrush, flat-top buckwheatbrush	Warm desert shrub, coastal sage scrub, chaparral, pinyon-juniper	Mojave & Colorado Deserts & coastal & cismontane S California
***E. heermannii* Dur. & Hilg.**	**Heermann buckwheatbrush,** molecule model plant	Warm desert shrub, mostly on rock outcrops	Mojave Desert
Subshrubs			
***E. brevicaule* Nutt.**	**shortstem wild-buckwheat**	Open, barren hills, mountain brush to alpine	Central Rocky Mtns of Wyoming, Utah & Idaho
***E. heracleoides* Nutt.**	**Wyeth wild-buckwheat,** parsnipflower buckwheat	Sagebrush–grassland to aspen & Douglas-fir	N Rocky Mtns from BC to central Utah
***E. jamesii* Benth.**	**James wild-buckwheat**	Desert shrub to mountain brush & ponderosa pine	S Rocky Mtns S into N Mexico
***E. niveum* Dougl. ex Benth.**	**snow wild-buckwheat**, snow eriogonum	Sagebrush–grassland	Columbia River Plateau
***E. umbellatum* Torr.**	**sulfurflower wild-buckwheat,** sulfur wildbuckwheat	Sagebrush–grassland to spruce–fir	Widespread in W North America
Pulvinate/ Mat-forming			
***E. bicolor* M.E. Jones**	**pretty buckwheatbrush**	Cold desert shrub, on Mancos Shale	Central Utah
***E. ovalifolium* Nutt.**	**cushion wild-buckwheat,** roundleaf buckwheat	Wide range, from cold desert to alpine	Widespread, W North America
***E. shockleyi* S. Wats.**	**Shockley wild-buckwheat,** mat buckwheat	Desert shrub to pinyon–juniper	Idaho & Colorado to SE California, Arizona, & New Mexico

Source: Meyer and Paulsen (2000).
Note: The genus *Eriogonum* is not that of the true, domesticated buckwheat, hence the common names of wild-buckwheat and buckwheatbrush.

Figure 1—*Eriogonum fasciculatum*, Mojave buckwheatbrush: achene in calyx (**left**) and achene without calyx (**right**).

Figure 2—*Eriogonum fasciculatum*, Mojave buckwheatbrush: longitudinal section through a seed excised from an achene.



pers or other containers. Combine harvesting has proven successful for sulfurflower wild-buckwheat in seed production fields (Stevens and others 1996). The harvested material will include achenes, perianths, involucres, and inflorescence branches. After the material is dried thoroughly, it may be threshed in a barley de-bearder and cleaned with a fanning mill. Species with tightly held achenes may require hand-rubbing through screens or on a rubbing board, which is also an alternative cleaning method for small seedlots of any species. The material should not be handled too roughly, as the radicle end of the achene is often slender and easily damaged. Achene weights vary both among and within species but are usually in the range of 350 to 1,360/g (10,000 to 39,000/oz) (table 2). Seed quality is also variable (table 2).

There are few published reports of viability evaluation beyond germination percentages obtained without pretreatment, which may underestimate viability if there is a dormant fraction. Stevens and others (1996) report that viabilities of >90% may be expected from sulfurflower and Wyeth wild-buckwheats in an agronomic setting if seeds are harvested when fully mature; these values are comparable to those for wild-collected lots of many species (table 2). Insects may damage 10 to 35% of the fruits prior to harvest, but damaged seeds are normally eliminated in cleaning. Post-harvest damage from insect infestations is also possible (Stevens and others 1996). There is little information on maintenance of viability during storage for species of wild-buckwheat. Stevens and others (1996) report high viability for sulfurflower and Wyeth wild-buckwheats during 10 to 15 years in warehouse storage, which would indicate orthodox storage behavior. Other species are perhaps comparable.

Seed germination and testing. Germination is epigeal (figure 3). Seedlots of many species of wild-buckwheats contain at least a fraction that will germinate without any pretreatment (tables 2 and 3) (Young 1989). The size of this fraction depends on species and on the particular lot involved. Stevens and others (1996) report that seeds of sulfurflower and Wyeth wild-buckwheats lose dormancy during short periods of dry storage, and Mojave buckwheatbrush seeds are also reported to dry after-ripen (Kay and others 1977). Dormant seeds of most species we have examined lose dormancy during chilling at 1 °C for periods of 8 to 12 weeks (table 3).

To date there are no formal procedures for evaluating the seed quality of wild-buckwheat species, and tetrazolium (TZ) staining is probably the procedure most commonly employed. To evaluate using TZ, achenes are soaked overnight in water, clipped through both pericarp and seed coat at the cotyledon end (the wide end or hilum), and placed in 1% TZ solution for several hours at room temperature. Achenes are bisected longitudinally for evaluation (Belcher 1985).

Field seeding and nursery practice. Wild-buckwheats are generally readily established from direct seeding (Ratliff 1974; Stevens and others 1996; Tiedemann and Driver 1983; Zamora 1994). They establish best when seeded at a depth of 2 to 5 mm ($^{1}/_{16}$ to $^{3}/_{16}$ in), either by drilling or by broadcasting followed by covering (for example, raking). Seeding should take place before the season of maximum precipitation, which is generally fall or early winter in

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Table 2—*Eriogonum,* wild-buckwheat: achene weights and typical viability percentages

Species	Achenes/weight /g	Achenes/weight /lb	Viability %	Viability Test
SHRUBS				
E. corymbosum	900	410,000	93	Post-chilling cut test
	2,000	900,000	—	—
E. fasciculatum	1,330	600,000	4–34	Germination %, no pretreatment
	520–1,085	236,000–490,000	20–46	Germination %, no pretreatment
E. heermannii	660	300,000	95	Post-chilling cut test
SUBSHRUBS				
E. brevicaule	700	320,000	84	Post-chilling cut test
E. heracleoides	350	160,000	95	Post-chilling cut test
	310	141,000	87	Post-chilling cut test
E. jamesii	350	160,000	—	—
E. niveum	1,290–1,360	585,000–620,000	52–72	Germination %; no pretreatment
E. umbellatum	470	213,000	86	Post-chilling cut test
	265	120,000	—	—
PULVINATE/MAT-FORMING				
E. bicolor	960	436,000	47	Post-chilling cut test
E. ovalifolium	990	450,000	95	Post-chilling cut test
E. shockleyi	750	340,000	86	Post-chilling cut test

Sources: Belcher (1985), Kay and others (1977), Meyer and Paulsen (2000), Stevens and others (1996), Tiedemann and Driver (1983).
* Post-chilling cut tests (AOSA 1996) are considered accurate for recently harvested seedlots; however, tetrazolium staining (TZ) is required for seedlots stored for more than 2 years.

Table 3—*Eriogonum,* wild-buckwheat: germination percentages

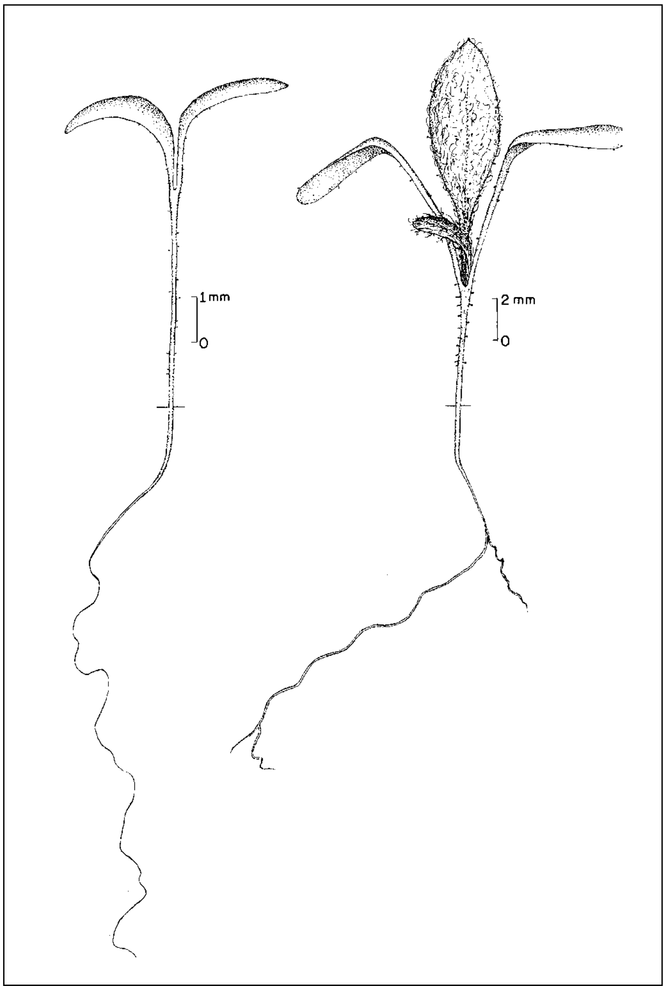
Species	Samples	Germination* (% of total viable seeds) No chill	4 weeks	8 weeks	12 weeks	16 weeks
E. brevicaule	2	3	28	65	86	96
E. corymbosum	3	28	79	100	100	100
E. heracleoides	3	4	11	30	55	77
E. jamesii	2	54	79	91	94	100
E. ovalifolium	2	22	74	98	98	100
E. umbellatum	4	7	30	74	99	100

Source: Meyer and Paulsen (2000).
* Germination percentage determined after 0 to 16 weeks of chilling at 1 °C followed by 4 weeks of incubation at 10/20 °C

northern rainfall regions and midsummer in southern rainfall regions. Most wild-buckwheats are early seral and do not compete well with heavy stands of perennial grasses. Wild-buckwheats planted for field seed production are reported to reach 30 to 50% of maximum production, 200 to 400 kg/ha (180 to 360 lb/ac), the second year after planting (Stevens and others 1996).

Most species of wild-buckwheat are also easily propagated in a nursery setting. Shaw (1984) reported that Wyeth wild-buckwheat may be successfully produced as 1+0 bareroot stock. Because of the taprooted habit, plants must be lifted carefully. Other woody wild-buckwheats could probably be produced as bareroot stock, but no published information is available. Wild-buckwheats may also be produced as container stock; book planters or tube containers such as those used for producing conifer seedlings are most appropriate. Nondormant lots may be direct-sown, whereas seedlots requiring chilling may be sown as chilled seed or as young germlings (Landis and Simonich 1984). Seedlings of many species grow rapidly and should not be held in small containers for more than a few months. Many species flower the first year and may even form flowering stalks while still in small tube containers.

Figure 3—*Eriogonum fasciculatum*, Mojave buckwheatbrush: very young seedling (**left**) and older seedling (**right**).



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Myrtaceae—Myrtle family

Eucalyptus L'Her.

eucalyptus

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Growth habit, occurrence, and use. The genus *Eucalyptus* comprises more than 523 species and 138 varieties, and new species and varieties are still being described (Blakely 1955; Johnston and Marryatt 1965; Penford and Willis 1961). Some are very tall trees, whereas others are woody shrubs (Jacobs 1979). Eucalypts are mainly native to Australia, but a few species are also native to the Philippines, New Guinea, and Timor (Hall and others 1963). Eucalypts are among the most widely cultivated forest trees in the world for ornamental use, shade, soil and site protection, wood production, and pulp making (Chippendale and others 1969). They are planted in southern Europe, the Middle East, Africa, India, Pakistan, China, North and South America—especially in Brazil, Uruguay, Chile, and Argentina (Jacobs 1979; Penford and Willis 1961).

This genus was first introduced into the United States with plantings in California and the Hawaiian Islands about 1853 (LeBarron 1962; Penford and Willis 1961). Eucalypts have also been planted, but to a limited extent, in Arizona, Florida, Georgia, Mississippi, and Texas (Geary and others 1983; Hunt and Zobel 1978; Metcalf 1961). About 250 species have been introduced into the United States and most of them are grown in California and Hawaii as ornamentals because of their decorative flowers and pleasing shapes (Jacobs 1979). Bluegum eucalyptus has been the most extensively planted eucalyptus in the United States, mainly in California, for the last 100 years (Metcalf 1961). It was initially grown for timber production but now is rarely used for this purpose. However, it is still widely used for fuel, shelterbelts, windbreaks, and has promise as a low-cost source of hardwood fiber (Krugman 1970). Among the other species that are promising for California conditions are river redgum, manna, mountain-gum, shining, and rosegum eucalyptuses (Ledig 1989). A number of other species are still being tested in California for their general landscape value (Hamilton 1979). In Florida, rosegum, robust, and river redgum eucalyptuses have been widely tested and are most promising as a source of wood fiber (Geary and others 1983; Uhr 1976). In Hawaii, several species, including rosegum, robust, red-ironbark, saligna, and bluegum eucalyptuses, have been planted as windbreaks and for watershed protection, as well as for timber and biofuel production (LeBarron 1962; Whitesell and others 1992). There are numerous other species that hold promise for future fiber production, windbreaks, and for environmental forestry purposes (Fujii 1976; King and Krugman 1980) (table 1).

Geographic races and hybrids. Many eucalypts have an extensive natural distribution, and members of the same species often grow under very different environmental conditions (Boden 1964; Eldridge 1978; Hall and others 1963; Jacobs 1979). Although detailed scientific information as to the development of geographic races is lacking for most species, there is considerable genetic variation in those species with wide natural distribution and it can be assumed that numerous races do exist (Jacobs 1979; Miles 1990). For planting eucalypts in the United States, geographic origin must be considered in selecting a suitable seed source from species wtih extensive natural ranges, such as the widely grown river redgum eucalyptus (Eldridge 1975; Karschon 1967; Pryor and Byrne 1969). As a general rule, seed source selection should at least be based on a knowledge of the absolute minimal and maximal temperatures under which the species grows in its native range (Zon and Briscoe 1911). Differential low temperature tolerance has been demonstrated for different sources of broadleaf sallee (*E. camphora* R.T. Baker) and brown-barrel, lemon-gum, and manna eucalyptuses (Boden 1964; Hunt and Zobel 1978). Precipitation appears to be of less importance, but must also be considered in selecting the proper seed source.

Under natural conditions, hybridization between species of the same subgeneric group will take place. It is relatively common in some cases, for example, brown-barrel × narrow peppermint eucalyptus (*E. fastigata* × *radiata* Seibert ex DC.) and robusta × rosegum eucalyptuses (Boden 1964;

Table 1—*Eucalyptus,* eucalyptus: nomenclature and natural and extended ranges

Scientific name & synonym(s)	Common name(s)	Natural range	Extension
E. camaldulensis **Dehnhardt** *E. rostrata* Schldl.	**river redgum eucalyptus,** red-gum, long-beak eucalyptus	Australia	California, Hawaii, & Arizona
E. citriodora **Hook.**	**lemon-gum eucalyptus,** lemon eucalyptus, lemon-gum	Central & N Queensland, Australia	California & Hawaii
E. dalrympleana **Maiden**	**mountain-gum eucalyptus,** white-gum, dalrymple eucalyptus	SE Australia	California & Hawaii
E. delegatensis **R.T. Baker** *E. gigantea* Hook. f.	**alpine-ash eucalyptus,** delegate eucalyptus	SE Australia	California
E. fastigata **H. Deane & Maiden**	**brown-barrel eucalyptus**, cuttail eucalyptus	SE Australia	California
E. glaucescens **Maiden & Blakey**	**tingiringy-gum**	SE Australia	California
E. globulus **Labill.**	**bluegum eucalyptus**, bluegum, Tasmania bluegum, Tasmanian blue eucalyptus	SE Australia	California, Hawaii, & Arizona
E. grandis **W. Hill ex Maiden**	**rosegum eucalyptus,** tooler eucalyptus.	E Australia	California, Florida, & Hawaii
E. microcorys **F. Muell.**	**tallowwood eucalyptus**	E Australia	California
E. nitens **(H. Deane & Maiden) Maiden**	**shining eucalyptus,** silver-top shining-gum	SE Australia	California & Hawaii
E. obliqua **L'Her.**	**messmate stringybark eucalyptus**	SE Australia	California
E. paniculata **Sm.**	**gray ironbark eucalyptus,** ironbark	E Australia	California & Hawaii
E. pilularis **Sm.**	**blackbutt eucalyptus**	E Australia	California & Hawaii
E. regnans **F. Muell.**	**mountain-ash eucalyptus,** swamp-gum giant eucalyptus	SE Australia	California
E. robusta **Sm.** *E. miltiflora* Poir.	**robusta eucalyptus,** swamp-mahogany, beakpod eucalyptus	E Australia	California, Florida, Hawaii, & West Indies
E. rudis **Sm.**	**desert eucalyptus,** moitch eucalyptus, desert-gum	W Australia	California & Florida
E. saligna **Sm.**	**saligna eucalyptus,** Sidney bluegum eucalyptus, flooded-gum	E Australia	California & Hawaii
E. sideoxylon **A. Cunningham**	**red ironbark eucalyptus,** mulga ironbark eucalyptus, red-ironbark	SE Australia	California & Hawaii
E. viminalis **Labill.**	**manna eucalyptus,** ribbon eucalyptus, white-gum, ribbongum	SE Australia	California & Hawaii

Sources: Chippendale and others (1969), Johnston and Marryat (1965), Krugman (1974).

Jacobs 1979; Penford and Willis 1961; Pryor 1979). A number of hybrids have been described, but their value for planting in the United States must still be demonstrated. When grown under plantation conditions outside their natural habitat, species hybridization will occur more often, and seed collections from small plantations of closely related species should be discouraged if hybrid seeds are not desired (Boden 1964).

Flowering and fruiting. The flower clusters develop enclosed within an envelope formed by 2 bracteoles—small leafy structures. These bracteoles split and are shed during development, revealing the flower buds (Boland and others 1980; Penford and Willis 1961). The perfect flowers are white, yellow, or red, often in axillary umbels, corymbose, or paniculate clusters (Blakely 1955). In a few cases, the flowers develop singly as with bluegum eucalyptus, but most often they are in 5- to 10-flowered axillary umbels as with river redgum and manna eucalyptuses (Blakely 1955). Sepals and petals are united to form a cap in the bud, which drops off at anthesis. The stigma is receptive within a few days after the cap drops (Barnard 1967) and pollination is mainly carried out by insects. The ovary has 3 to 6 locules with many ovules. There is a wide range in flowering times for the eucalypts (King and Krugman 1980). In California, some species such as manna eucalyptus may flower all year; other species, such as river redgum and gray ironbark eucalyptuses, flower in the spring; tingiringy-gum and mountain-gum eucalyptus in the summer; rosegum eucalyptus in the fall; and tallowwood eucalyptus in winter (table 2) (King and Krugman 1980; Krugman 1970, 1974).

The fruit is a hemispherical, conical, oblong, or ovoid hard woody capsule 6 to 25 mm in diameter, that is loculicidally dehiscent at the apex by 3 to 6 valves (Blakely 1955; Boland and others 1980). The seeds are numerous and extremely small in most species (table 3; figure 1). The size of fertile seeds within a given seed collection varies widely. Usually only a few seeds are fertile in a single capsule, and capsule size may influence seed size (Blakely 1955). When more than 1 seed ripens in a locule, the seeds are variously shaped and angular (figure 1). When solitary, the seed will be ovate or orbicular-compressed (Blakely 1955). The seedcoat is most often thin and smooth, but it can be ribbed, pitted, or sculptured in various ways (Blakely 1955; Penford and Willis 1961). Usually the seedcoat is black or dark brown in color as in manna eucalyptus or pale brown as with alpine-ash eucalyptus (table 3).

The embryo consists of bipartite or 2-lobed cotyledons that are folded or twisted over the straight radicle (Blakely

Table 2—*Eucalyptus,* eucalyptus: height at maturity and phenology of flowering and fruiting of trees grown in California

Species	Height at maturity (m)	Flowering	Fruit ripening	Seed dispersal
E. camaldulensis	18–36	Feb–Apr	July–Oct	Begins 8–9 months after flowering
E. citriodora	24–39	Nov–Jan	May–Aug	—
E. dalrympleana	18–36	June–Aug	Aug–Oct	Oct–Nov
E. delegatensis	30–83	Apr–June	Apr–July	May–July
E. fastigata	18–60	Apr–May	July–Aug	—
E. glaucescens	4–12	July–Aug	May–Sept	Nov–Feb
E. globulus	45–54	Nov–Apr	Oct–Mar	Oct–Mar
E. grandis	42–54	Sept–Nov	—	—
E. microcorys	30–45	Dec–Feb	—	—
E. nitens	30–90	Apr–July	May–June	May–June
E. obliqua	15–75	Apr–July	May–Aug	—
E. paniculata	24–42	Feb–May	—	—
E. pilularis	36–60	Dec–Mar	Jan–April	All year
E. regnans	52–105	Apr–July	June–Sept	—
E. robusta	24–27	Jan–Mar	—	—
E. rudis	9–15	Jan–Mar	—	—
E. saligna	15–45	Apr–June	Oct–Dec	—
E. sideroxylon	12–30	June–Sept	—	—
E. viminalis	15–45	All year	12 months after flowering	20–22 months after flowering

Source: Krugman (1970).

Table 3—*Eucalyptus,* eucalypus: description of viable seeds and chaff

Species	Seed size (mm) Length	Seed size (mm) Width	Seed color	Chaff color
E. camaldulensis	0.75–1.75	0.5–1.0	Yellow-brown	Yellow-brown to orange
E. citriodora	4.25	2.5	Black	Brownish red
E. delegatensis	1.25–3.75	1.0–1.75	Pale brown or brown	Pale brown or brown
E. fastigata	1.25–3.25	0.5–1.25	Pale brown or brown	Pale brown or brown
E. glaucescens	1.25–2.5	1.0–1.75	Black or dark brown	Pale red-brown
E. globulus	2.25	1.75	Dark brown	Brownish red
E. nitens	1.25–2.5	1.0–1.75	Black or dark brown	Pale red-brown
E. obliqua	1.0–2.0	0.75–1.25	Dark brown	Orange-brown or brown
E. regnans	1.25–2.5	0.5–1.25	Pale brown or brown	Pale brown or brown
E. robusta	1.5	0.75	Dark brown	Brownish red
E. saligna	1.25	1.0	Black	Brownish red
E. sideroxylon	1.0–2.0	0.75–1.5	Dark brown or black	Orange-brown
E. viminalis	1.25–2.5	1.5	Black or dark brown	Pale red-brown

1955; Krugman 1974). There is no endosperm (Blakely 1955; Krugman 1974) (figure 2). Fruits ripen at various times during the year, depending on the species (table 2). Dispersal is largely by wind within a month or two after ripening for most species, for example, bluegum and shining eucalyptuses. For other species, such as manna eucalyptus, dispersal may not take place until 10 months after ripening (table 2). Good seeds are produced by most species by 10 years of age (Grose 1969). For mature trees the interval between large seedcrops is from 2 to 5 years.

Collection of fruits. Collecting mature eucalyptus fruits should present no serious problems, other than reaching the fruit in very tall trees, because for most species there is a relatively long interval between seed ripening and opening of the capsule (table 2). However, it is important to take care to collect only well-developed, closed capsules, because capsules at different stages of maturity—as well as buds, flowers, and empty capsules—will be found on a single branch (Boland and others 1980; Krugman 1974). The capsules should be spread in a thin layer to permit rapid drying and to prevent mold formation (Boland and others 1980; Grose and Zimmer 1958b). The most common method is to air-dry the capsules for a few hours to a few days, depending on the maturity of the capsules (Boland and others 1980; Grose and Zimmer 1958b). Drying temperatures should not exceed 37.7 °C for prolonged periods, because high temperature may strengthen the dormancy of species such as alpine-ash, brown-barrel, shining, and mountain-ash eucalyptuses and tingiringy-gum (Grose 1969; Grose and Zimmer 1958b). Capsules can also be kiln-dried for relatively short periods (Boland and others 1980; Grose 1969). Fruit drying schedules for some of the common species are listed in table 4.

Figure 1—*Eucalyptus*, eucalyptus: seeds (**from left to right**) of *E. camaldulensis*, river redgum eucalyptus; *E. delegatensis*, alpine-ash eucalyptus; and *E. fastigata*, brown-barrel eucalyptus (**top**). *E. grandis*, rosegum eucalyptus; *E. microcorys*, tallowwood eucalyptus; *E. nitens*, shining eucalyptus (**second row**). *E. obliqua*, messmate stringybark eucalyptus; *E. paniculata*, gray ironbark eucalyptus; and *E. pilularis*, blackbutt eucalyptus (**third row**). *E. regnans*, mountain-ash eucalyptus, *E. robusta*, robusta eucalyptus; and *E. rudis*, desert eucalyptus (**fourth row**). *E. saligna*, saligna eucalyptus; *E. sideroxylon*, red ironbark eucalyptus; and *E. viminalis*, manna eucalyptus (**bottom row**).

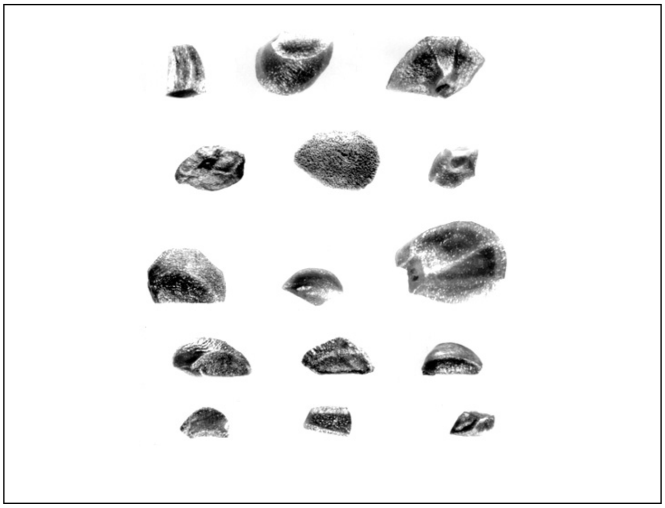
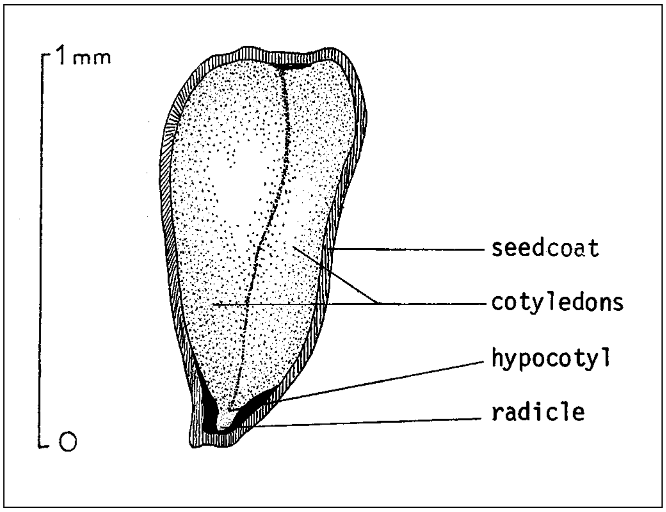


Figure 2—*Eucalyptus rudis*, desert eucalyptus: longitudinal section thorough a seed.



Extraction and cleaning. Once the capsules are open, they should be vigorously shaken to remove the seeds. Shaking is especially important if the capsules are somewhat immature, because viable seeds may not have separated completely from the capsule's placenta. Thus, unless the capsules are shaken, only infertile seeds will be extracted (Boland and others 1980; LeBarron 1962). When examined, immature capsules may appear empty after the aborted seeds are removed, because viable seeds are normally attached at the base of the capsule (LeBarron 1962). Viable seeds are extracted along with the unfertilized or aborted ovules, which are known collectively as "chaff" (Boland and others 1980; Grose and Zimmer 1958b). Large impurities such as the remains of twigs, capsules, and leaves can be removed by screening. Smaller impurities can be removed by specific-gravity separators such as the one used in the air-column method (Boland and others 1980; Grose 1969). For a few species, viable seeds can be separated from the remaining chaff by employing sieves of the appropriate mesh size (Boland and others 1980). Because viable seeds and chaff of

Table 4—*Eucalyptus,* eucalyptus: fruit drying schedules

	Air-drying		Kiln-drying	
Species	Temp (°C)	Time (days)	Temp (°C)	Time (hrs)
E. camaldulensis	32	1	59	3
E. delegatensis	32	3	59	6
E. globulus	21	5	—	—
E. obliqua	32	3	59	5
E. regnans	32	3	59	6
E. sideroxylon	21	4	—	—
E. viminalis	21	6	—	—

most species cannot be separated by the usual methods, commercial seed suppliers sell chaff along with the fertile seeds. The proportion by weight of chaff to viable seeds is in the range of 5:1 to 30:1 (Grose and Zimmer 1958b). For some species, such as mountain-ash eucalyptus, the seeds and chaff are identical in size and color; for others, such as river red-gum eucalyptus, the seeds and chaff are similar in color but different in size (table 3). For most species, there are some differences in color and size, so that viable seeds can be separated from chaff to some extent if necessary. Because of their very small size, seeds of eucalyptus species are normally sold by weight with the chaff. The average number of viable seeds plus chaff per weight ranges from 770/g (21,900/oz) for river redgum eucalyptus to 35/g for blackbutt eucalyptus (1,000/oz) (table 5). There may be as many as 2,100 seeds/g (59,500/oz) for river redgum eucalyptus or as few as 7 seeds/g (200/oz) for blackbutt eucalyptus.

Storage. Eucalyptus seeds are orthodox in storage behavior. They should be stored in air-tight containers that are as completely filled as possible to reduce the amount of air (Boland and others 1980). Prior to storage, the seeds should be treated to kill insect pests, by either fumigation or placing paradichlorbenzene crystals in the container (Boland and others 1980).

Eucalypts seeds have germinated after 30 years of storage at room temperature, but the germination was very low (Penford and Willis 1961). Most seeds can be successfully stored for periods up to 10 years in air-tight containers at moisture contents of 4 to 6% and temperatures of 0 to 5 °C (Boland and others 1980; Grose 1969; Grose and Zimmer 1958b). It should be possible to store these seeds successfully for even longer at temperatures below 0 °C (Krugman 1970).

Pregermination treatments. Most eucalyptus seeds need no pretreatment to ensure adequate germination if fresh seeds are used (Boland and others 1980; Grose and Zimmer 1958b). A few species—such as tingiringy-gum and alpine-ash, brown-barrel, shining, and mountain-ash eucalyptuses—are normally dormant at the time of collection and will require pretreatment. Stratification of moist seeds stored in a plastic bag at temperatures of 3 to 5 °C for a period of 3 weeks will break the dormancy of these 5 species, except for alpine-ash eucalyptus, which should be stratified for 4 weeks (Boland and others 1980; Grose 1969). Longer stratification periods of 6 to 8 weeks are often recommended.

Dormancy between different seedlots of the same species can vary considerably. In addition, different methods of extraction and storage can induce dormancy in nondormant seed or strengthen primary dormancy in normally dormant seeds (Krugman 1970). If the seeds fail to germinate after the recommended shorter stratification periods, then a longer period should be tried before the seeds are considered nonviable. Because most seeds are stored before they are used, stratification for 3 to 4 weeks at a temperature of 3 to 5 °C is recommended for all eucalyptus seeds to ensure faster and more uniform germination (Hinkle 1968; Krugman 1970).

In a few cases, chemicals have been employed to overcome seed dormancy. The germination of unstratified and dormant seeds of alpine-ash, brown-barrel, and mountain-ash eucalyptuses was improved by germinating the seeds in a solution of gibberellic acid (Bachelord 1967). However, not all seedlots of the same species responded to gibberellic acid (Krugman 1970).

Germination tests. Standard methods for testing germination in other seeds are not used for eucalyptus seeds because of their small size and the presence of so much chaff, which can exceed the weight of viable seeds. Instead, samples for germination are of equal weight, not number (Boland and others 1980; Grose and Zimmer 1958b; ISTA 1993; Turnbull and Doran 1987). Such methods as the excised-embryo and tetrazolium tests are impractical (Boland and others 1980; Grose and Zimmer 1958b). The

E

Table 5—*Eucalyptus,* eucalyptus: seed yield data

	Viable seeds/(weight of seeds + chaff)				
	Range		Average		
Species	/g	/oz	/g	/oz	Samples #
E. camaldulensis	65–2,100	1,800–59,500	770	21,900	41
E. citriodora	80–220	2,200–6,200	140	4,000	15
E. dalrympleana	65–285	1,800–8,100	195	5,500	7
E. delegatensis	40–125	1,100–3,500	75	2,100	13
E. fastigata	90–210	2,500–5,900	150	4,300	6
E. glaucescens	40–120	1,000–3,000	35	2,000	2
E. globulus	20–70	500–9,100	150	2,500	10
E. grandis	200–1,200	5,600–34,000	700	20,000	13
E. microcorys	530–900	1,500–25,600	85	6,800	22
E. nitens	230–550	6,600–15,700	385	10,900	7
E. obliqua	20–160	500–4,500	85	2,400	18
E. paniculata	65–340	1,800–9,600	75	5,000	8
E. pilularis	7–85	200–2,400	35	1,000	28
E. regnans	20–530	600–15,000	315	8,900	11
E. robusta	220–700	6,200–20,000	390	11,000	12
E. rudis	270–1,100	7,600–31,000	600	17,000	9
E. saligna	85–915	2,400–26,000	460	13,000	9
E. sideroxylon	65–440	1,800–12,500	240	6,800	16
E. viminalis	265–445	7,500–12,600	350	10,000	6

Sources: Grose and Zimmer (1958b), Larsen (1965).

International Seed Testing Association (1993) recommends a sample unit of 0.10 to 1.0 g of seeds, depending on the species. Seeds are placed on 1 or more layers of moist paper and germinated at a constant temperature of 15 to 35 °C, depending on the species (Grose 1969; Scott 1972). Some species may require alternating temperatures of 20 °C for 16 hours and 30 °C for 8 hours (ISTA 1993). The tests are normally conducted under lights, although lights are not necessary for all species. Recommendations for individual species are listed in table 6. Official rules (ISTA 1993) provide recommendations for many more species. Immature seeds of mountain-ash eucalyptus should be tested under lights (Penford and Willis 1961).

If an approximate estimate of viability is desired, a known weight of dry seeds can be soaked in water and then squashed systematically. All seeds that show a firm white embryo can be recorded as viable (Grose and Zimmer 1958b).

Soundness of eucalyptus seeds is highly variable. Seeds collected from individual trees of bluegum eucalyptus in California showed from 2 to 80% germination after 30 days (Krugman 1970). Germination of from 11 to 98% has been reported for other species (table 7).

Nursery practice. On the United States mainland, eucalyptus seeds are rarely sown directly in the nursery, a practice once common in Hawaii. The most common practice for growing eucalyptus seedlings is to germinate the

Table 6—*Eucalyptus,* eucalyptus: germination test conditions

Species	Daily light exposure (hrs)	Temp (°C)	Days
E. camaldulensis	24	35	14
E. citriodora	0	25	14
E. dalrympleana	24	25	14
E. delegatensis†	0	20	14
E. fastigata‡	0	25	14 or 21
E. glaucescens‡	24	20	14 or 21
E. globulus	24	25	14
E. grandis	0	25	14
E. microcorys	24	20§	28
E. nitens‡	24	20	14 or 21
E. obliqua	0	20	14
E. paniculata	24	20§	28
E. pilularis	0	20	14
E. regnans‡	24	25	21
E. robusta	24	20	28
E. rudis	24	35	14
E. saligna	24	25	28
E. sideroxylon	24	20	14
E. viminalis	24	25	14

Sources: Grose (1969), ISTA (1966, 1993).
* Seeds germinated on 2 layers of moist, filter paper in a petri dish (Grose 1969).
† Prechilled for 28 days at 3.3 to 5 °C (Grose 1969).
‡ Prechilled for 21 days at 3.3 to 5 °C (Grose 1969).
§ Treated at 20 °C for 16 hours, then 30 °C for 8 hours.

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Table 7—*Eucalyptus,* eucalyptus: germination test results		
Species	**% Germination**	**Duration (days)**
E. citriodora	51	15
E. grandis	98	29
E. microcorys	76	24
E. pilularis	11	29
E. robusta	84	18
	100	21
E. sideroxylon	69	49

Sources: Floyd (1964), Ganguli (1966), Krugman (1974), Scott (1972).

seeds in small pots, boxes, or wooden flats. Commonly used containers are wooden flats or plastic containers 45 to 50 cm (18 to 20 in) long and 40 to 50 cm (16 to 20 in) wide, and 10 to 12.5 cm (4 to 5 in) deep with good bottom drainage (Hinkle 1968; Jacobs 1955). The planting medium should be porous, friable, and light textured, such as a light, sandy loam (Hinkle 1968; Holmes and Floyd 1969; Willan 1985). The medium must permit good drainage and should not cake or become hard on the surface after watering. Because of possible weed and disease problems, the soil should be sterilized. Various mixtures are also used, with the most common consisting of equal parts (by volume) of sand, soil, and organic matter. The flats are filled to a depth of 7.5 to 10 cm (3 to 4 in) and the soil surface is leveled.

Because of their small size, the seeds are mixed with a little sand, and the mixture then is spread evenly over the soil surface (Hinkle 1968; Jacobs 1955; Penford and Willis 1961). The seeds are covered with 3 mm of fine sand, peat, or sphagnum moss to prevent surface drying.

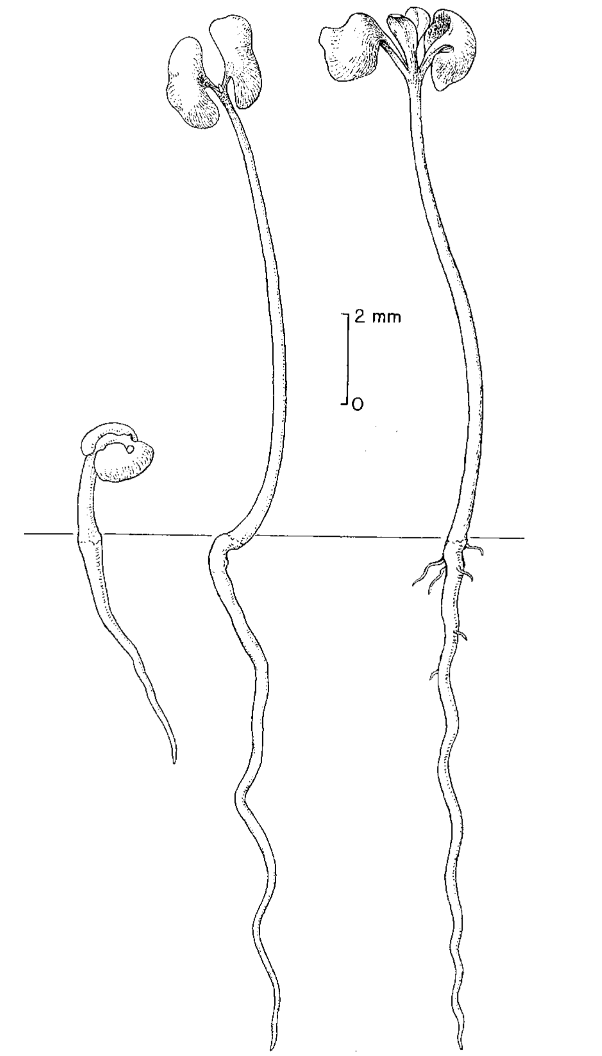
A newer method to ensure more precision in sowing eucalyptus seeds is to coat them and form a mini-pellet (Geary and Millier 1982; Willan 1985). The seed dressing is usually an inert material serving as a sticker on which other materials can be added. One successful method involves a coating of fine silica sand filler and a polyvinyl alcohol binder (Geary and Millier 1982). In addition, fungicides and insecticides can also be added.

Enough seeds should be sown to raise between 500 and 2,000 plants/flat (table 8). Depending on seed size, this should represent about 7 g ($^1/_4$ oz) of seed/flat (Krugman 1970). The flats should be well watered and drained just before planting and should be protected from wind, heavy rains, and excessive heat. The emerging seedlings may require protection from birds and rodents in some locations.

Table 8—*Eucalyptus,* eucalyptus: seedlings produced per weight of seeds		
	Seedlings produced/seed weight	
Species	**/g**	**/oz**
E. camaldulensis	175	5,000
E. citriodora	60	1,700
E. glaucescens	99	2,830
E. globulus	28	800
E. microcorys	7	180
E. paniculata	6	160
E. robusta	14	400
E. viminalis	111	3,160

Sources: Zon and Briscoe (1911).

Figure 3—*Eucalyptus*, eucalyptus: seedling development for manna eucalyptus at 1 day (**left**) and 8 days (**center**) and desert eucalyptus at 42 days (**right**).



Seedling care. Germination is epigeal (figure 3), begins in 7 to 10 days, and is completed in 3 to 4 weeks (Boland and others 1980; Jacobs 1955; Krugman 1974). Because the seeds are small and the seedlings very delicate, overhead watering should be with a fine spray and care must be taken to maintain adequate soil moisture.

When the seedlings are about 6 to 8 weeks old and have developed 2 pairs of leaves and a third pair is just visible above the cotyledons, they can be transplanted into suitable containers for further growth (Hinkle 1968; Jacobs 1955).

In transplanting, the seedlings should be lifted by the tip of a sturdy leaf, and not by the soft delicate stem. A dibble should be used to protect the fibrous root system. Prior to lifting, the seedlings should be hardened off by exposure to the open air away from full sunlight and strong winds for a few days to a week. A variety of different containers, from Jiffy™ pots to tin cans, have been used with success (Holmes and Floyd 1969; Jacobs 1955). The containers should be large enough to permit the development of strong plants, but small enough to permit ease of transportation. Tubes should be at least 4 cm (1.5 in) in diameter and 15 to 30 cm (6 to 12 in) long (Jacobs 1955). When metal tubes are employed, they are made so that they can be readily opened in the field and then later cleaned and reused. After transplants are placed in containers, care must be taken to prevent damage to them. Seedlings should be well watered and shaded from full sunlight. Fine gravel can be placed on the surface of the container to restrict slime molds. After several weeks the transplants can be placed in the open so that they can become hardy. They should be ready for outplanting in 4 to 5 months, depending on the species and growing conditions (Jacobs 1955).

Because of the rapid growth of eucalyptus seedlings, care must be taken lest they become pot-bound. Seedlings should not be permitted to grow in small containers for extended periods before outplanting.

Seeds can be sown directly in a standard 1.2-m-wide (4-ft-wide) nurserybed. The soil should be first fumigated to kill weed seeds and pathogens, then watered well and drained before sowing. Because seeds are small, even distribution is difficult when they are broadcast sown. Seeds should be sown in narrow strips or rows, covered with a thin layer of sand or peat, and watered thoroughly (Penford and Willis 1961). Under very hot conditions the nursery beds should be shaded. Young eucalyptus seedlings need a great amount of light, so only moderate shade is recommended. If bareroot stock is desired, the seedlings are left in the beds for about 6 to 12 months. More commonly, the seedlings are lifted after 5 to 10 weeks and planted in individual containers. Because of differences in seed size and purity among species seedlots, the variation in number of seedlings produced, by a given weight of seeds, will vary widely (Zon and Briscoe 1911).

Vegetative propagation. Vegetative propagation by rooting and grafting has been successful in some of the eucalypts. The following species have been rooted successfully: lemon-gum, red-ironbark, river redgum, mountain-ash, robust, desert, mountain-gum, blue-gum, rosegum, and manna eucalyptuses (Blomstedt and others 1991; Jacobs 1979; Linnard 1969; Penford and Willis 1961). But in the main, only shoots with juvenile leaves have been rooted, and these most often from trees younger than 5 years (Jacobs 1979; Penford and Willis 1961). Eucalyptus can also be propagated by grafting. At the present time, vegetative propagation appears to be a practical method for producing eucalypts in large numbers only in countries where labor is inexpensive, for example, Brazil (Jacobs 1979). The production of possibly useful cultivars is both difficult and expensive, for cuttings from mature eucalyptus trees do not readily root (Chippendale and others 1969).

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Celastraceae—Bittersweet family

Euonymus L.

euonymus, spindletree

John C. Zasada and Paul O. Rudolf

Dr. Zasada retired from the USDA Forest Service's North Central Forest Research Station;
Dr. Rudolf (deceased) retired from the USDA Forest Service's North Central Forest Experiment Station

Growth habit, occurrence, and use. The genus *Euonymus* includes about 170 species of deciduous or evergreen shrubs and small trees, sometimes creeping or climbing, native to North and Central America, Europe, Asia, Madagascar, and Australia (Krüssmann 1960; Rehder 1940). The majority of species are native to east Asia from 52°N latitude to the Tropics (Nikolaeva 1967). Because of their attractive fruits and foliage, the euonymus species are planted widely for ornamental purposes. Winged spindletree, described by Dirr (1990) as "one of the finest landscape plants for American gardens," has brilliant red foliage in the fall (it is commonly known as burning-bush) and prominent corky wings on the stem that add variety to the winter landscape. Euonymus species show a large amount of variability: for example, Dirr (1990) listed about 70 cultivars recognized by horticulturists. At least one of these introduced species—European spindletree—has become naturalized and is considered invasive in the Northeast; other species do not appear to be as aggressive (Dirr 1990; Fernald 1950; Gleason and Cronquist 1963; Voss 1985). The deciduous and evergreen euonymus used as ornamentals in Britain have been described by Lancaster (1981). They also have value for wildlife food, shelterbelts, and minor wood products; at least 1 species is a source of gutta (Nikolaeva 1967). Eight species that have been used for conservation plantings are described in tables 1 and 2.

The 3 native species (table 1) described by Fernald (1950) occur in sites generally described as "rich" and with a mesic to wet soil water regime. In Wisconsin, eastern wahoo is most common in southern wet forests that are

Table 1—*Euonymus,* eunoymus: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
E. alata **(Thunb.) Sieb.** *Celastris alatus* Thunb.	**winged spindletree,** winged euonymus, corkbush, burning-bush	Central China, Manchuria, E Siberia, Korea, Japan, & Sakhalin
E. americana **L.**	**American strawberry-bush,** bursting-heart, hearts-a-bustin, brook euonymus	New York to Illinois to Texas to Florida
E. atropurpurea **Jacq.**	**eastern wahoo,** burning-bush, wahoo	W New York to S Ontario, central Michigan & Minnesota, SE North Dakota, S to NW Nebraska, central Kansas, & E Texas, E to Arkansas, Tennessee, & N Alabama
E. bungeana **Maxim.**	**winterberry euonymus**	N China, Manchuria, & Korea
E. europaea **L.**	**European spindletree,** European euonymus	Europe to W Asia (to 900 m in mtns)
E. hamiltoniana **spp.** ***maackii*** **(Rupr.) Komarov**	**Maack euonymus**	N China & Korea
E. obovata **Nutt.**	**running strawberry-bush,** running euonymus	W New York & S Ontario to central Michigan, Illinois, S to West Virginia, Kentucky, & Missouri
E. verrucosa **Scop.**	**warty-bark euonymus,** warty spindletree	S Europe & W Asia

Sources: Dirr (1990), Rudolf (1974).

Table 2— *Euonymus,* euonymus: height and year first cultivated

Species	Height at maturity (m)	Year first cultivated
E. alata	0.9–3.1	1860
E. americana	0.9–1.8	1697
E. atropurpurea	1.8–6.2	1756
E. bungeana	4.0–6.2	1883
E. europaea	3.1–7.1	Long ago
E. hamiltoniana ssp. *maackii*	1.5–5.2	1880
E. obovata	0.3–0.6	1820
E. verrucosa	0.9–2.2	1763

Sources: Dirr (1990), Fernald (1950), Lancaster (1981), Rehder (1940).

dominated by silver maple (*Acer saccharinum* L.), black willow (*Salix nigra* Marsh.), and other trees characteristically found on wet sites (Curtis 1959); in Michigan, it is described as a floodplain species (Voss 1985). European spindletree, the naturalized exotic, is generally found on moist to wet sites, and floodplains in central Europe where it occurs naturally (Lee and others 1991). Historically, the roots, bark, and seeds were used for medicinal purposes with the warning that products of each may be poisonous to some individuals (Foster and Duke 1990; Snow and Snow 1988).

Flowering and fruiting. The usually perfect flowers, borne in clusters, bloom in the spring. The fruit, which ripens in late summer or fall, is a 4- to 5-celled (occasionally 2- to 3-celled) capsule that is usually lobed and sometimes winged (figure 1). Ostrobuka and Bencat (1987) found that winged spindletree pollen germinated in sucrose concentrations of 15, 20, and 25%, with 20% giving best results. Each fruit cell contains 1 or 2 seeds enclosed in a fleshy, usually orange aril (figure 2). Natural seed dispersal usually occurs soon after the fruits are fully ripe. Seed dispersal of European spindletree is primarily by birds, with robins (*Erithacus rubecula*) being a principal disperser in Britain. Some species ingest the entire aril, whereas others carry it to a perch and remove the pulp and drop the seeds (Snow and Snow 1988). Fruits of European spindletree have some of the highest lipid and protein contents reported for plants (Snow and Snow 1988). The flowering and fruiting habits of 8 species are summarized in tables 3 and 4.

Fruits are generally available annually. Flower bud differentiation occurs from early June to mid-August and weather conditions during this period will affect fruit production potential (Tomita and Uematsu 1978).

The fruit of European spindletree contains 1 to 5 seeds. Dry weight of the fruit is 0.17 g, with the seed accounting for about 45% of the dry weight. At maturity the water content is about 50% (fresh weight basis) (Lee and others 1991; Nielsen and Iroquoian 1988). Lee and others (1991) described the seeds of European spindletree as poisonous and little used by birds; however, Snow and Snow (1988) document a substantial use of fruits by birds, stating that the seeds are not consumed.

Figure 1—*Euonymus*, euonymus: top views of open capsules of *E. americana*, American strawberry-bush (**left**) and *E. atropurpurea*, eastern wahoo (**right**).

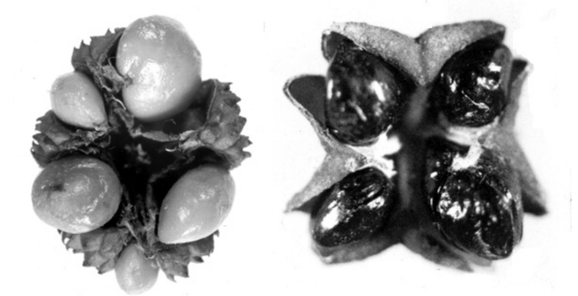
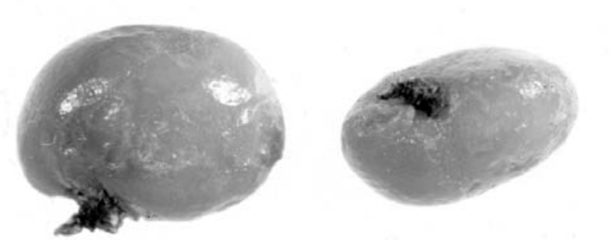


Figure 2—*Euonymus americana*, American strawberry-bush: seeds enclosed in their fleshy arils.



Collection of fruits. Seeds may be collected in late summer or fall by picking the ripe fruits from the bushes or trees by hand or by shaking them onto an outspread canvas. They should then be spread out to dry for several days in a warm room but need not be completely dry to be cleaned (Myatt and others 1991).

Extraction and storage of seeds. Seeds can be processed with a macerator (Stein and others 1974). The plate on the separator should be set slightly larger than the seeds and adjusted as necessary to prevent too many seeds from being lost with the pulp (Myatt and others 1991).

Smaller seedlots can be extracted by beating the fruits in a canvas bag and then rubbing them through a coarse, round-hole grain screen. The fruits may be macerated in water and the seeds extracted by flotation (Rudolf 1974). Following dry extraction, the chaff can be removed by

Table 3—*Euonymus,* euonymus: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening
E. alata	New England & Japan	May–June	Sept–Oct
E. americana	Carolinas	May–June	Sept–Oct
E. atropurpurea	—	May–June	Sept–Oct
E. bungeana	NE US	June	Sept–Oct
E. europaea	NE US & Europe	May–June	Aug–Nov
E. hamiltoniana ssp. *maackii*	NE US	June	Oct
E. obovata	—	April–June	Aug–Oct
E. verrucosa	NE US & Germany	May–June	Aug–Oct

Sources: Fernald (1950), Lancaster (1981), Radford and others (1964), Rehder (1940), Sus (1925), Snow and Snow (1988), Voss (1985), Wappes (1932), Wyman (1947).

Table 4—*Euonymus,* euonymus: fruit form and color of flowers, fruits, and seeds

		Color			
Species	**Fruit form**	**Flower**	**Ripe fruit**	**Seed**	**Aril**
E. alata	Divided nearly to base in 4 separate pods (sometimes 1–3)	Yellowish	Reddish-purplish	Brown*	Orange-red
E. americana	3- to 5-lobed	Reddish green–greenish purple	Pink-rose	Yellowish white	Scarlet
E. atropurea	Smooth, deeply 3- to 4-lobed, 4-celled	Purple	Pink–purple	Light brown	Scarlet
E. bungeana	Deeply 4-lobed & 4-angled	Yellowish	Yellowish–pinkish white	Whitish or pinkish	Orange
E. europaea	Smooth, 4-lobed, 3 to 5–celled	Yellowish green	Rose red-pink†	White	Orange
E. hamiltoniana ssp. *maackii*	4-lobed	Yellowish	Pink	Red	Orange
E. obovata	Usually 3-lobed	Greenish purple	Crimson	Tan	Orange-scarlet
E. verrucosa	Deeply 4-lobed	Brownish	Yellowish red	Black	Orange-red‡

Sources: Bailey (1939), Dirr (1990), Fernald (1950), Rehder (1940), Snow and Snow (1988).
* Black, in one variety.
† Whitish, in one variety.
‡ Seed not wholly covered by aril.

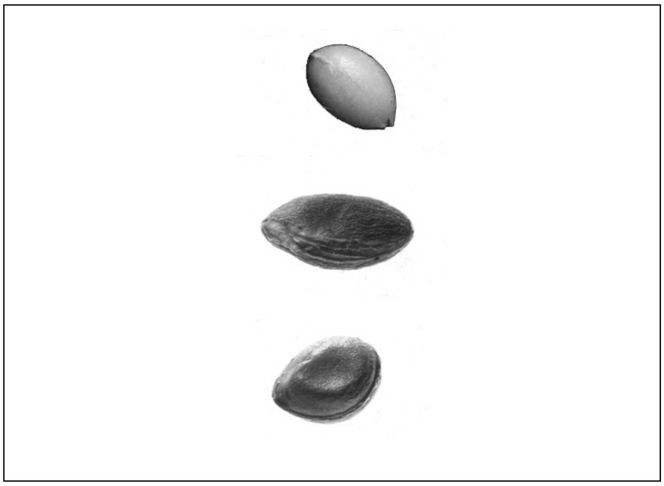
winnowing. The pulpy arils can be removed (figure 3) by rubbing the seeds through coarse-mesh wire cloth after they have dried several weeks, but this is difficult to do without breaking the relatively thin seedcoats (Lee and others 1991) and injuring the seeds. If the arils (which are sometimes oily) are not removed, the seeds may not store as well. As a result, commercial seeds are treated rather gently in extraction and seedlots usually contain seeds with parts of the arils still attached, along with completely clean seeds (figure 4).

The numbers of seeds per weight cleaned to this variable degree are shown in table 5. Forty-five kilograms (100 lb) of ripe fruits will yield about 4.5 to 9.1 kg (10 to 20 lb) and an average of 7.1 kg (16 lb) of cleaned seeds, based upon data for American strawberry-bush, eastern wahoo, European spindletree, and warty-bark euonymus (Gorshenin 1941; Rudolf 1974; Swingle 1939).

Seed weights can vary significantly within a population. Nielsen and Iroquoian (1988) reported that the variation in the dry weight of 1,000 seeds ranged from about 28 to 40 g among 8 individual European spindletree plants. Mature seeds from different positions in the plant varied significantly in seed weight; seeds from the top and shaded parts of the crown were 5% greater and 7% less than mean seed weight, respectively (Nielsen and Iroquoian 1988).

Seeds of European spindletree and warty-bark euonymus can be kept satisfactorily for 2 years in ordinary dry storage (Gorshenin 1941; Sus 1925), or in dry cold storage in sealed containers at 1 to 2 °C (Heit 1967). However, more recent Russian reports have shown high viability maintained for at least 7 years under moist conditions at constant temperatures, either warm (15 to 20 °C) or cold (Nikolaeva 1967). Any drying in storage reduced viability (Nikolaeva

Figure 3—*Euonymus*, euonymus: seeds with arils removed of *E. americana*, american strawberry-bush (**top**); *E. atropurpurea*, eastern wahoo **(middle**); and *E. obovata*, running euonymus (**bottom**).



1967). Moist cold storage may be the most practical and effective way of retaining high viability of euonymus seeds for extended periods (table 6).

Pregermination treatments. Seeds of most euonymus species have dormant embryos. Cold stratification is adequate to break dormancy for some species, but warm stratification followed by a cold period is needed for maximum germination for other species (table 7) (Dirr 1990; Dirr and Heuser 1987; Nikolaeva 1967; Singh 1985; Yu and others 1976). The length of the warm period should be adjusted, depending on the temperature used for cold stratification. For example, Nikolaeva (1967) suggests a 2- to 3-month period of warm stratification if cold stratification is at 0 to 3 °C. Table 7 provides the range of temperatures for warm and cold stratification that have been effective for breaking dormancy. Nikolaeva (1967) provides a thorough discussion of the effects of temperature, water availability, seed maturation, and storage alone and in combination on germination. There may also be some variation in germination among European spindletree seeds formed under different climatic conditions (Dawidowicz-Grezgorzewska and Beranger-Novat 1989).

Variation in dormancy can be significantly different among plants. Nielsen (1988), for example, reported that germination of European spindletree seeds collected from 10 different plants varied from 0 to 30% following stratification

Table 5—*Euonymus,* euonymus: seed yield data

		Cleaned seeds/weight				
		Range		Average		
Species	Place collected	/kg	/lb	/kg	/lb	Samples
E. alata	NE US	41,110–69,620	18,600–31,500	55,250	25,000	2+
E. americana	Durham Co., North Carolina	63,300–100,113	30,000–45,300	77,571	35,100	3+
E. atropurpurea	Carver Co., Minnesota; Cole Co., Missouri; & rangewide	19,227–88,400	8,700–40,000	37,349	16,900	8
E. bungeana	US	—	—	29,835	13,500	1+
E. europaea	Russia, Netherlands, & NE US	18,785–35,360	8,500–16,000	29,393	13,300	32+
E. obovata	Clinton Co., Michigan	—	—	49,725	25,500	1
E. verrucosa	Russia	35,950–58,870	16,300–26,700	45,084	20,400	10+

Sources: Barnes (1969), Gorshenin (1941), Heit (1968a), NBV (1946), Nielsen and Eriksen (1988), Rudolf (1974), Sus (1925), Swingle (1939).

Table 6—*Euonymus,* euonymus: seed storage conditions

	Seed storage conditions		
Species	Seed moisture	Temp (°C)	Viable period (yrs)
*E. atropurpurea**	Air-dry	–1.1–3.3	—
E. europaea	Dry	—	1–2
	Moist	15–20 or 2.8	7
*E. obovatas**	Air-dry	1.1–3.3	—
E. verrucosa	Air-dry	20	2
	Moist	15–20 or 2.8	7

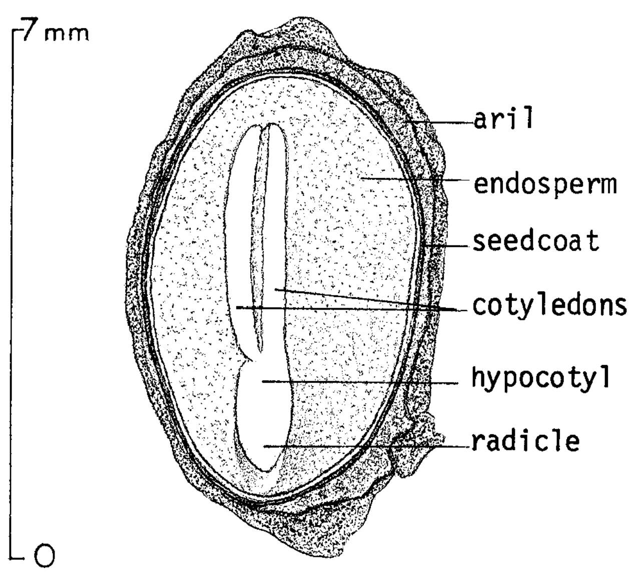
Sources: Gorshenin (1941), Heit (1967), NBV (1946), Nikolaeva (1967), Rudolf (1974), Sus (1925), Swingle (1939).
* Seed stored in closed containers.

Table 7—*Euonymus,* euonymus: stratification treatments

Species	Moisture-holding medium	Warm period Temp (°C)	Warm period Days	Cold period Temp (°C)	Cold period Days
E. alata	Sand or peat	—	0	0–10	90–100
E. americana	Perlite–peat mix	—	0	5	139
E. atropurpurea	Sand	20–30	60	5	60
	Sand	—	0	2.8–5	60–180
E. bungeana	Sand, peat, or filter paper	—	0	2.8–10	61–120
E. europaea	Sand, peat, or filter paper	20–25	60–90	32–50	60–120
		—	—	2.8–5	60–120
E. hamiltoniana ssp. *maackii*	Sand or filter paper	—	0	0–10	60–90
E. obovata	Sand	—	0	2.8–5	60–150
E. verrucosa	Sand or filter paper	15–20	60–90	0–10	120–150

Sources: Heit (1968a), Nikolaeva (1967), Rudolf (1974), Shumailina (1949), Swingle (1939).

Figure 4—*Euonymus europaea,* European spindletree: longitudinal section through a seed.



at 4 to 6 °C. This variation may have been significantly different if seeds had been subjected to warm stratification before cold stratification (table 7) (Nikolaeva 1967).

The morphological changes that occur during pretreatment are important indicators of the adequacy of the pregermination treatment. An increase in seed volume, cracking of the seedcoat, and protrusion of the tip of the hypocotyl occur during warm stratification or warm stratification hastens these changes when seeds are moved to cold stratification. Completeness of germination depends on these changes in seed morphology (Nikolaeva 1967).

There seems to be little information on the natural germination pattern of euonymus seeds. Untreated seeds of European spindletree germinated mainly in the second year after sowing (Lee and others 1991), suggesting that the alternation of warm and cold stratification also regulates germination under field conditions. Although birds are important in the dispersal of European spindletree seeds, the seeds may (which can cause some degree of scarification) or may not pass through the digestive tract of birds, depending on the species taking the seeds (Snow and Snow 1988).

Germination tests. Germination is epigeal (figure 5). Germination tests on stratified seeds can be run in sand flats, germinators, or petri dishes. ISTA (1993) recommends 45 days of stratification at 3 to 5°C, then a 28-day test at 20/30 °C for European spindletree. Viability can also be estimated by the embryo excision method (Heit 1966) or tetrazolium staining (ISTA 1993). Germination test conditions are summarized in table 8.

X-radiography has been used to assess viability in fresh European spindletree seeds. However, stored seeds should be stained with tetrazolium to determine viability (Smirnova and Tikhomirova (1980).

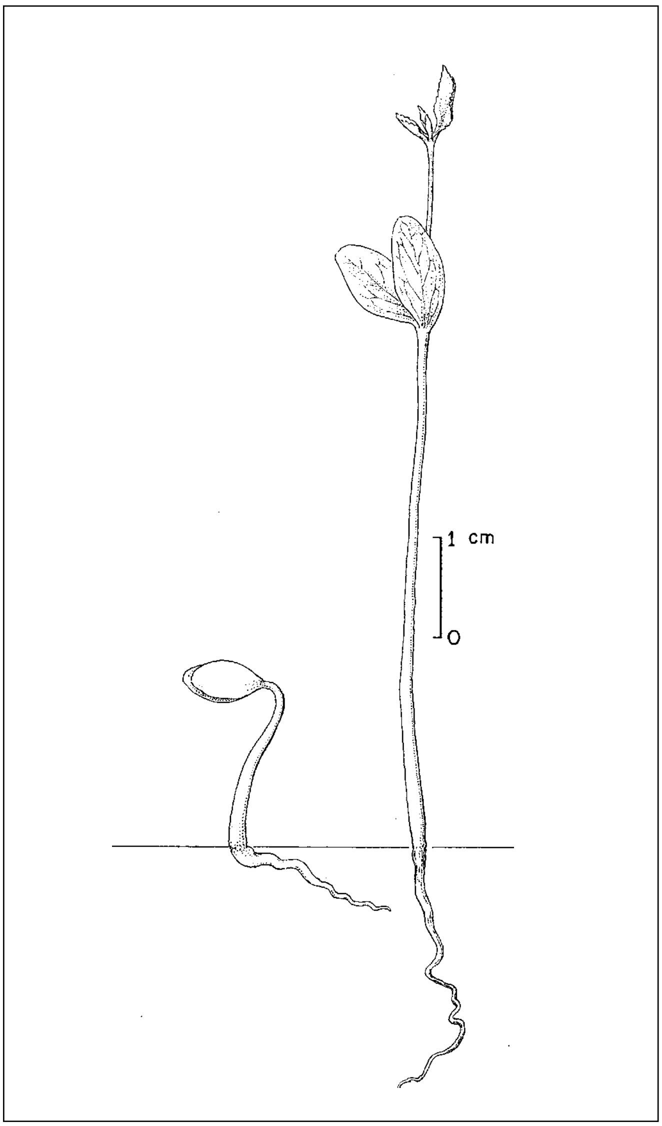
Nursery practice. Seedlings can be grown in containers or nurserybeds. For best results, cleaned euonymus seeds should be sown in the fall soon after collection, before the seeds have dried out (Heit 1968a&b; NBV 1946). If sowing after seeds have been collected is not feasible, stratified seeds can be planted (table 6) early the next spring or the next fall (NBV 1946). Details for most species are lacking, but for European spindletree, recommendations are to sow the seeds 6 mm ($^1/_4$ in) deep at a density to produce 422 seedlings/m^2 (40/ft^2) of nurserybed (NBV 1946). The beds should be mulched with pine straw (NBV 1946). Tree percentages range from about 10% for winterberry euonymus to 20% for eastern wahoo and 25% for European spindletree (Swingle 1939).

Table 8—*Euonymus,* euonymus: germination test conditions and results on stratified seeds

Species	Medium	Germination test conditions: Temp (°C) Day	Night	Days	Avg germ capacity (%)	Purity (%)	Soundness (%)	Samples
E. americana	Filter paper	21.1	21.1	14	15	—	—	1
E. atropurpurea	Sand flats	30	20	61	40	75	88	2
E. bungeana	Germinator	10	0	60	20	—	—	1
E. europaea	Sand flats, germinators	25	20	60	71	75	96	22+
E. hamiltoniana ssp. *maackii*	Germinators	20	15	60	75	—	—	3+
E. verrucosa	Sand flats, filter paper	20	12	60	70	75	96	7+

Sources: NBV (1946), Nikolaeva (1967), Rudolf (1974), Swingle (1939).

Figure 5—*Euonymus europaea*, European spindletree: seedlings 1 and 12 days after germination.



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K

Chenopodiaceae—Goosefoot family

Krascheninnikovia lanata (Pursh) A.D.J. Meeuse & Smit

winterfat

D. Terrance Booth

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Synonyms. *Eurotia lanata* (Pursh) Moq., *Ceratoides lanata* J.T. Howell, *Diotis lanata Pursh*; see appended notes on nomenclature.

Other common names. white-sage.

Growth habit, occurrence, and use. Winterfat is a sub-shrub that in early spring appears as small bunches of new leaves closely joined to dead-looking low stems that have new shoots arising from woody bases. By late summer, the shrub's attractive foliage is 20 to 80 cm high and often crowned with dense clusters of handsome, white, fruiting bracts. The leaves can grow to 5 cm and are narrow and entire, with strongly revolute margins. Leaves and herbaceous stems have short white hairs that give the plant its characteristic gray-green color and its *Eurotia* synonym (from the Greek *euros,* meaning mold).

Winterfat habitats are characterized by drought and temperature extremes. It grows in scattered clusters or uniform stands on dry plains, foothills, and mountains from western Nebraska and Texas to California and from northern Mexico to the prairie provinces and the Yukon Territory of Canada, north to the vicinity of Lake Kluane, Alaska (Coupland 1950; Hulten 1968; Stevens and others 1977; Welsh 1974). In the Great Basin, winterfat occupies thousands of hectares in pure stands and may be found at elevations from the lower Sonoran zone to ridges over 3,048 m in elevation (Stevens and others 1977). Soils supporting winterfat are low in sodium and other soluble salts but often high in carbonates of calcium and magnesium; soil textures vary from clays to sandy and rocky loams (Nelson 1962; Stevens and others 1977).

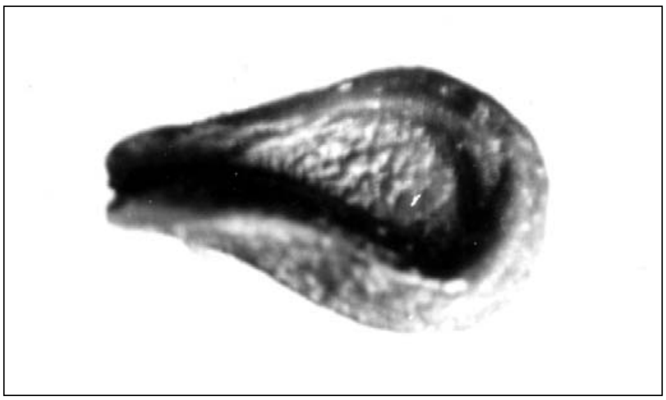
Native stands are highly valued as forage for livestock and wildlife (Asay 1959; Jones and Barclay 1972; Nelson 1905; Plummer and others 1968), but many have been depleted or destroyed by abusive grazing or by wildfire in combination with the invasion of exotic annual grasses. Winterfat is regularly used in re-vegetating disturbed lands, has value as an ornamental, and is recommended for reseeding to restore depleted western rangelands and for providing waterfowl nesting cover on the Canadian prairies. It was first cultivated in 1895 (Springfield 1974b). Notable progress has been made in seed handling and seeding methods so that disturbed lands sown with winterfat regularly develop healthy stands.

Ecotypic variation. Winterfat displays strong ecotypic variation that appears to account for the range of habitats occupied by the species. This variation must be considered when collecting seeds for a particular environment or use (Bai and others 1997b; Plummer and others 1968; Workman and West 1969). Seed quality and seedling vigor differ by collection (Booth 1992; Moyer and Lang 1976; Springfield 1968a), with some differences appearing as adaptive compromise between seed quality and the demands of stressful environments (Booth 1990a; Booth and Haferkcamp 1995). The selection of high-vigor lines may be possible (Riedl and others 1964), but studies are needed to understand genetic and environmental interactions with seed quality and cultivar adaptability.

Flowering and fruiting. Flowers are small, gray-green, and inconspicuous and are likely cross-pollinated by wind (Riedl and others 1964). The plants are dioecious or monoecious. Flowers bloom from June to August, depending on elevation and weather. Staminate flowers have a 4-parted calyx with 4 exerted stamens. Pistillate flowers have 2 styles emerging from between 2 united bracts. At maturity the bracts have formed fluffy white diaspores (seed-containing dispersal units) that decorate the fruiting spikes and function in seed dispersal, embryo protection, and in promoting the establishment and survival of the seedling (Booth 1988, 1990b). Bract hairs are 2 to 8 mm long in spreading tufts (figure 1). Each pair of bracts enclose an indehiscent, pubescent, 1-seeded fruit (utricle) (figure 2). The seedcoat is thin and transparent and is most easily discerned on naked imbibed or germinating seeds. Diaspores disperse in the fall or winter and collect in aggregations on the soil surface (figure 3). Plants may produce seeds the first

Figure 1—*Krascheninnikovia lanata*, winterfat: fruiting spike.

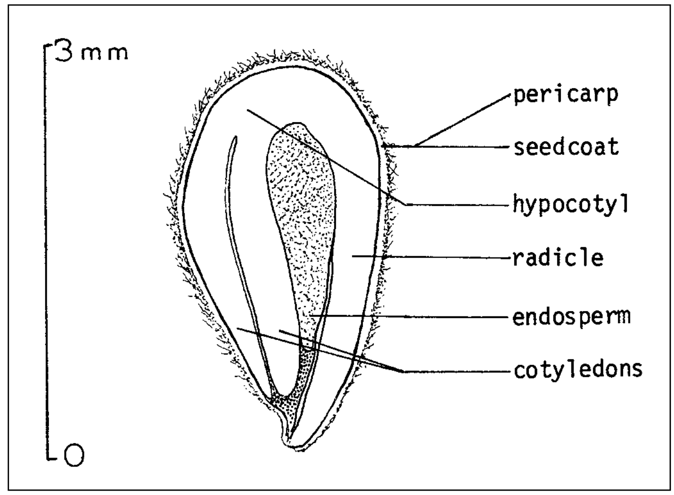
Figure 2—*Krascheninnikovia lanata*, winterfat: cleaned seed.



year and produce abundant crops annually (table 1). A 10-year-old stand has produced 78 to 90 kg/ha (70 to 80 lb/ac) of "fruit"
(diaspores) (Springfield 1974b). Good seed quality depends on the mother plant's maintaining transpiration rates during seed and diaspore development (Booth 1990a).

Seed collection and storage. Seeds are harvested by stripping the diaspores from the bushes or by cutting and drying the fruiting spikes. Harvest time is mid-September in Saskatchewan (Romo 1995) to mid-October or early November at lower latitudes (Strickler 1956; Wasser 1945; Wilson 1931). Mechanized harvest methods have been tried (Springfield 1974b), but most collectors have found it more efficient to hand-harvest. However, Majerus (2003) described harvesting winterfat seeds with a combine. Dry diaspores should be stored without threshing or other processing to prevent accelerated aging. Harvested material will contain unfilled diaspores, but there are no practical methods for separating these from the germinable diaspores (Allen and others 1987). Percentage diaspore fill may be determined by threshing small samples. This is quickly done using equipment described by Booth and Griffith (1984).

Figure 3—*Krascheninnikovia lanata*, winterfat: sectional schematic of diaspore (seed).



Winterfat seeds are orthodox in storage behavior but their viability decreases after 6 to 12 months at ambient conditions (Hilton 1941; Springfield 1968a,b; Wilson 1931). Viability is maintained longer when seeds are stored in sealed containers at 4 to 5 °C (Springfield 1968c, 1973, 1974a), but seedling vigor will continue to decrease (Booth and others 1999). To maintain seedling vigor during long-term storage (more than 6 months), winterfat diaspores should be held at –20 °C.

Germination. Diaspores germinate naturally during cold or cool weather. Seeds imbibe readily, and the rate and total weight gain vary by temperature (Bai and others 1999; Booth and McDonald 1994) and by oxygen concentration (Booth 1992). Holding imbibed diaspores at 0 to 5 °C will improve germination, germination rate, and seedling vigor of most seed lots (Booth 1992; Booth and Schuman 1983; Strickler 1956) though the vigor of fresh seeds (4 months after harvest) is unlikely to be affected by imbibition temperature (Bai and others 1998a; Booth and others 1999). Winterfat's capability to germinate at freezing temperatures is well documented (Booth 1987b; Hilton 1941; Wilson 1931; Woodmansee and Potter 1971) and is reported to allow winterfat to establish in stressful environments (Springfield 1968a; Workman and West 1967). Dettori and others (1984) measured germination of threshed seeds of 3 collections, including an Asian species, at 55 temperature combinations ranging from 0/0 to 40/40 °C. Germination occurred over a wide range of temperatures. but the optimum germination occurred most frequently at 0 to 5 °C alternating with 15 to 20°C. Allen and others (1987) noted evidence of increased mold growth with alternating temperatures and temperatures above 15 °C.

Table 1— *Krascheninnikovia lanata,* winterfat: diaspore weights by source and harvest year

			Diaspores/weight			
		Years	Mean*		Range	
Source	Collections	harvested	/g	/oz	/g	/oz
Colorado	3	1982, 84, 94	147	5.2	137–203	4.8–7.1
New Mexico	3	1984	231	8.1	208–270	7.3–9.5
Nevada	1	1983	175	6.2	175	6.2
Saskatchewan	1	1994	147	5.2	147	5.2
Utah	2	1982, 84	212	7.5	167–257	5.9–9.0
Wyoming	2	1994	177	6.2	173–181	6.1–6.4
Total	12	—	—	—	—	—

Sources: Allen and others (1987), Booth (1994).
* Mean + SD = 198 + 15.ß
† 'Immigrant'.

Germination is most suitably tested by imbibing diaspores at 0 to 5 °C for 4 or 5 days followed by incubation at 15 °C. A longer cold treatment, 6 to 15 days, may increase the germination rate and seedling vigor for some seedlots, especially those that are less than 3 months or more than 12 months after harvest. Seeds less than 3 months from harvest may require after-ripening (Springfield 1972). Germination is not affected by light (Hilton 1941) and is rapid at warm temperatures.

Nursery and field practice. In the past, it was considered important to thresh the seed from the diaspore to simplify seeding with mechanized equipment (Springfield 1974b). However, that practice is no longer recommended because the bracts aid in seedling establishment, and threshing damages the seeds (Booth 1984, 1989a&b, 1990b; Booth and Schuman 1983). Broadcasting diaspores results in good establishment in depressions, in litter, and in protected sites (Stevens and others 1977). Diaspores can also be sown with a cultipacker (Luke and Monsen 1984), with a hydroseeder (Pellant and Reichert 1984), as pelleted diaspores, and in seed tapes (Booth 1987a&b). Use of the cased-hole punch seeder (Booth 1995) is effective and allows diaspores to be sown through fabric mulch. Natural establishment occurs with cool temperatures and high surface moisture and with a mat of diaspores on the soil surface (figure 3) (Booth 1987b, 1989a, 1990b; Gasto 1969; Wilson 1931; Woodmansee and Potter 1971). Fall-seeding is recommended (Zabek and Romo 1998). Under-snow germination produces vigorous seedlings and contributes to seeding success. Winterfat seeds and seedlings can show freeze-tolerance (Bai and others 1997a; Booth 1987b, 1989a; Hilton 1941; Stricker 1956; Woodmansee and Potter 1971), but reduced germination or loss of seedlings can also occur (Bai and others 1997b; Booth 1989a; Hodgkinson 1975; Stevens and others 1977). Ecotype, imbibition temperature, conditioning, and stage of growth are factors influencing seed and seedling freeze-tolerance (Bai and others 1997b; Booth 1989a; Hodgkinson 1975).

Winterfat can be transplanted as container-grown or bareroot plants. Shaw and Monsen (1984) recommended beds producing bareroot seedlings contain 167 to 222 seedlings/m^2 (15 to 20/ft^2). These should be lifted as 1+0 stock in the spring before they break dormancy. Shaw and Monsen (1984) found that 93% of mechanically transplanted seedlings were alive after 5 growing seasons when these recommendations were followed.

Notes on nomenclature. The type specimen for winterfat was collected by the Lewis and Clark expedition "On the banks of the Missouri River, in open prairies" and was described as *Diotis lanata* by Pursh in 1814 (Pursh 1814). Moquin-Tendon (1840) placed the species in the genus *Eurotia* (Adanson 1763) and listed as synonyms *Diotis, Axyris* (Linnaeus 1753), *Ceratoides* (Gagnebin 1755), and *Krascheninnikovia* (Gueldenstaedt 1772). For more than 2 centuries, botanical authors followed Adanson or Meyer's emended interpretation of Adanson's description in major botanical works and in numerous papers dealing with winterfat description, value, management, ecology, and culture (Meyer 1933, as cited by Howell 1971). In 1964, Ball reapplied the name *Krascheninnikovia* (Tutin and others 1964). Subsequently, Howell (1971) applied *Ceratoides* to *E. lanata*, and Meeuse and Smit (1971) joined Tutin and others in using *Krascheninnikovia*. Chu, in his Flora of China, has also choosen to use *Krascheninnikovia* (Stutz 1995). A 1976 attempt by the Russian Grubov to conserve (retain the use of) the name *Eurotia* was rejected (Brummitt 1978).

Although the International Code of Botanical Nomenclature was changed to allow such action, *Eurotia* was unfortunately not re-submitted for conservation (Wiersema 2000). North American authors have shown a disinclination to accept the procedural name change and some have continued to publish using the name *Eurotia*.

K. lanata has 1 subspecies, *subspinosa,* in southern Arizona (Kearny and Peebles 1960; Munz and Keck 1968) and 1 released cultivar, 'Hatch' (Stevens and Monsen 1988). Losina-Losinskaja (1930) defines 5 Eurasian species and Chu defines 7 (Stutz 1995).

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