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Fagaceae—Beech family
Fagus L.
beech

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Growth habit, occurrence, and use. The beeches—the genus *Fagus*—includes 10 species of medium-sized, deciduous trees native to the temperate regions of the Northern Hemisphere (Rehder 1940). Only 1 species, American beech, is native to North America, although another, the European beech, has been widely planted as an ornamental in the Northeast (table 1). Some authorities have argued that there are separate northern and southern species of American beech, but this view is not widely supported (Tubbs and Houston 1990). Beeches that grow in northeastern Mexico are now classified as a variety of American beech—*F. grandifolia* var. *mexicana* (Martinez) (Little 1965). There is some evidence of geographic races of European beech in that species' native range (Rudolf and Leak 1974). Beech wood is used for flooring, furniture, veneer, plywood, ties, charcoal, and many specialty products. The trees are highly valued for ornamental plantings, and the mast is widely utilized by numerous birds and animals (Tubbs and Houston 1990).

Flowering and fruiting. Beech flowers are monoecious. The minute male and female flowers appear in the spring when the leaves are about one-third grown (table 2). The staminate flowers occur in densely clustered, drooping heads 8 mm wide, whereas the pistillate flowers are generally paired on stout stalks about 2.5 cm long (Brown and Kirkman 1990). Flowers of European beech are quite vulnerable to late spring frosts (Matthews 1955). The fruit is a prickly bur approximately 2 cm long, which opens soon after maturity in the fall (figure 1).

Each fruit contains 2 or 3 yellowish-brown or chestnut-brown, unevenly triangular nuts, 1 to 1.5 cm long (figures 2 and 3). Times of flowering, fruiting, and seed dispersal for the 2 species are listed in table 2. Natural seed dispersal is chiefly by gravity and by animals such as rodents and blue jays (*Cyanocitta cristata*) (Johnson and Adkisson 1985; Tubbs and Houston 1990). Information on height at maturity, minimum seed-bearing age, and interval between good seedcrops is shown in table 3.

Table 1—*Fagus,* beech: nomenclature and occurrence

Scientific name	Common name	Occurrence
F. grandifolia **Ehrh.**	**American beech,** beech	Nova Scotia to S Ontario & N Michigan, S to N Florida & E Texas
F. sylvatica **L.**	**European beech**	Europe; planted in NE US

Source: Little (1979).

Table 2—*Fagus,* beech: phenology of flowering and fruiting

Species	Flowering	Fruit ripening	Seed dispersal
F. grandifolia	March–May	Sept–Nov	Sept–Nov (after frost)
*F. sylvatica**	Apr–May	Sept–Oct	Oct–Nov (after frost)

Sources: Brown and Kirkman (1990), Rudolf and Leak (1974), Tubbs and Houston (1990).
* Dates are similar for western Europe and the northeastern United States.

Figure 1—*Fagus grandifolia*, American beech: nuts enclosed in a partially opened husk.

Figure 2—*Fagus sylvatica*, European beech: nut.

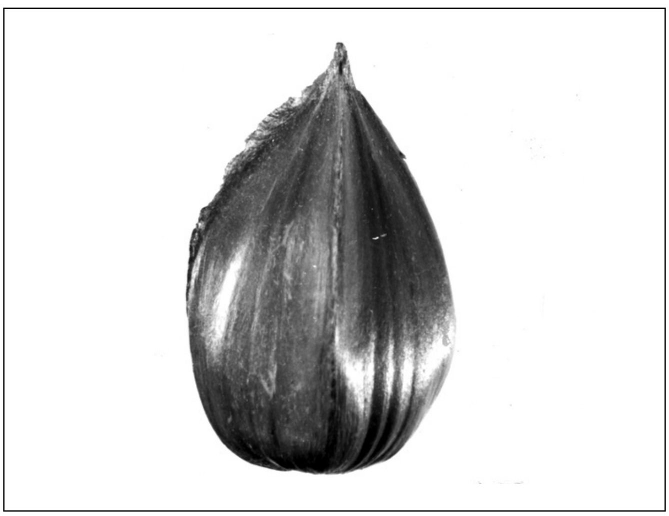
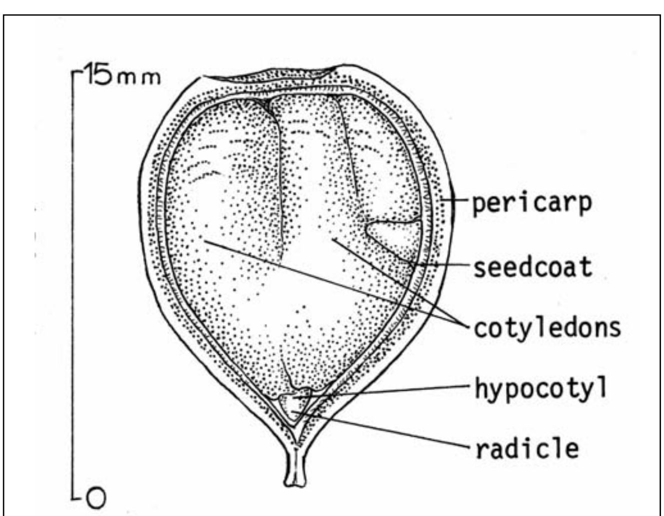


Figure 3—*Fagus grandifolia*, American beech: longitudinal section through a seed.



Long-term studies of seed production of European beech in England show widespread variation among trees and crop years (Harmer 1994). A positive correlation between size of the seedcrop and air temperature and amount of sunshine in July has also been recorded (Matthews 1955). A study in Hungary found that production of viable seeds was increased 3.5 times by fertilization of the stand with 200 kg/ha of N and 240 kg/ha of P_2O_5 (Fuhrer and Pall 1984). Predispersal destruction of seeds in Sweden by a moth—*Cydia fagiglandana* Z.—was found to range from 3 to 38% of the total crop, depending on crop size (Nilsson and Wastljung 1987). Studies in New England documented higher losses in American beech from insects, rodents, and birds combined (Gruber and Leak 1992; Leak and Gruber 1993). Records of seed production by American beech have shown that there is a great amount of natural variation, but no geographic or elevational patterns (Gysel 1971; Sain and Blum 1981; Stalter 1982). Like many other species, the better producers in any particular year will usually produce good seedcrops in other years (table 3) (Grisez 1975).

Collection and extraction. Beech nuts may be raked from the ground after they have fallen or shaken from the trees onto canvas or plastic sheets after the fruits open naturally (table 2). There is some evidence that seeds of European beech caught by nets suspended above the ground have less fungal infection than seeds raked from the ground (Dubbel 1989). Closed fruits also can be picked in the fall from trees recently felled in logging operations. Seed maturity is indicated by a completely brown fruit, and care should be taken to ensure that the seeds are fully mature when collecting unopened fruits. After the fruits are stripped from the branches, they should be spread to dry in a thin layer until they open and the seeds (also called nuts) can be shaken out. The seeds can be separated from empty fruits, leaves, and other large trash by screening. European beech seeds collected in Germany are sometimes separated from leaves, twigs, and fruit capsules with a tractor-mounted cleaning machine at the collection sites (Gottfriedsen 1991). Data on seed yields and weights are given in table 4.

In a good seed year, in France, a 150-year-old European beech high forest yielded 50 hl/ha (57 bu/ac) of seeds, whereas in Germany, a beech forest yielded 900 to 1,680 kg/ha (800 to 1,500 lb/ac) of seeds (Rudolf and Leak 1974).

Storage and pregermination treatments. Seeds of European beech can be stored for at least 6 years without loss of viability by drying the seeds to a moisture content of 8 to 10% at room temperature and holding them in sealed containers at temperatures from –5 to –15 °C (Muller and

Table 3—*Fagus,* beech: height, seed-bearing age, and seedcrop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Years between large seedcrops: Time	Location
F. grandifolia	21–37	1800	40	2–3	—
	—	—	—	4–5	Wisconsin
F. sylvatica	20–30	Long ago	40–80*	5–8	Mtn areas
	—	—	—	9–12	Great Britain
	—	—	—	3–10	—
	—	—	—	15–20	—

Source: Rudolf and Leak (1974).
* 40 to 50 years for open-grown trees and 60 to 80 years for trees in stands.

Table 4—*Fagus,* beech: seed yield data

	Fruit wt/vol		Seed wt/fruit vol		Cleaned seeds/weight: Range		Average		
Species	kg/hl	lb/bu	kg/hl	lb/bu	/kg	/lb	/kg	/lb	Samples
F. grandifolia	—	—	12	9	2,850–5,110	1,290–2,320	3,500	1,600	10
F. sylvatica									
Fresh fruits	50–53	39–41	—	—	4,000–6,200	1,800–2,800	4,630	2,100	24+
Air-dried fruits	39–45	30–35	—	—	—	—	—	—	—

Source: Rudolf and Leak (1974).

Bonnet-Masimbert 1982; Suszka 1974). Poulsen (1993) recommends that drying should be done at temperatures below 20 °C. This behavior would seem to put beeches into the orthodox class of storage behavior, although there is evidence that beeches fit somewhere between the orthodox and recalcitrant classes (Gosling 1991) or in the sub-orthodox class (Bonner 1990). The high lipid content of 40.7% reported for kernels of European beech (Prasad and Gulz 1989) would seem to support the sub-orthodox classification. The seeds are basically orthodox, however, and 5 years of storage is long enough for operational storage. There are no comparable data for American beech, but there are no reasons to suspect that this species cannot be treated in the same way. Beech seeds require cold stratification (prechilling) for prompt germination, and current practices with European beech have combined stratification and storage into a coordinated procedure. The first step is to determine how much stratification is needed to overcome dormancy (Suszka and Zieta 1977). Samples of fresh seeds are brought to maximum moisture content or mixed with moist sand and stored at 3 °C until about 10% of the seeds have started germination (radicles are visible). This period is assumed to be the amount of time required to overcome dormancy in that particular lot. The remainder of the seeds are adjusted to a moisture content of 28 to 30% and prechilled in plastic containers (without media) at 4 °C for this amount of time, plus 2 more weeks. At this level of moisture, dormancy is overcome, but germination does not begin (Muller and Bonnet-Masimbert 1983). The seeds are then brought to room temperature, or no higher than 20 °C (Poulsen 1993), without heating, dried to a moisture content of 8%, and stored in sealed containers at –5 °C (Muller and Bonnet-Masimbert 1989). The effect of stratification is retained, and germination is prompt when the seeds are sown. Moisture level is the key to successful stratification. Treatment without media can lead to excessive seed moisture; it should not exceed 30% (Muller and Bonnet-Masimbert 1983).

Long-term storage of beech seeds for germplasm conservation may be possible with cryopreservation techniques. Intact seeds may not survive the temperatures of liquid nitrogen (–196 °C) (Ahuja 1986), but excised embryos have survived the same conditions for at least 24 hours (Jorgensen 1990).

Germination testing. The prescribed testing method for European beech is to germinate stratified seeds on the top of moist blotters at 3 to 5 °C. Test duration varies according to degree of dormancy (see above) but may run up to 24 weeks, which includes 140 days of stratification at the same 3 to 5 °C (Suszka 1975). Some laboratories also test stratified beech seeds with the common alternating regime of 30 °C (day) and 20 °C (night) with acceptable results (table 5). Because of the lengthy tests, viability estimation by tetrazolium staining is recommended as an alternate method (ISTA 1993). Both tetrazolium and indigo carmine staining (Suszka 1991) are commonly used in Europe. North American testing rules (AOSA 1993) do not include either of these beech species, but the same methods should work for both. Germination is epigeal (figure 4).

Nursery practice. Beech seeds can be sown in the fall as soon after collection as possible, or stratified seeds can be sown in the spring. In the stratification/storage procedure described earlier for European beech, seeds can be removed from storage and planted at any time in the spring without additional treatment. This procedure eliminates the uncertainty over when to start stratification in time for spring-sowing and is favored by nurserymen in Europe (Gosling 1991). Sowing density should be 700 viable seeds/m^2 (65/ft^2) for European beech, which, on the average, should produce about 325 seedlings/m^2 (30/ft^2) (Aldhous 1972). Seeds should be covered with 12 mm ($^1/_2$ in) of soil. Fall-sown beds should be mulched until midsummer and given special protection against rodents (Rudolf and Leak 1974). Some seedbeds may require half-shade until past mid-summer. Vegetative propagation by cuttings is very difficult, but some successes have been reported for stem cuttings taken in late summer. Grafting is more common for ornamental selections (Dirr and Heuser 1987).

Figure 4—*Fagus grandifolia*, American beech: seedling development at 2, 5, and 7 days after germination.

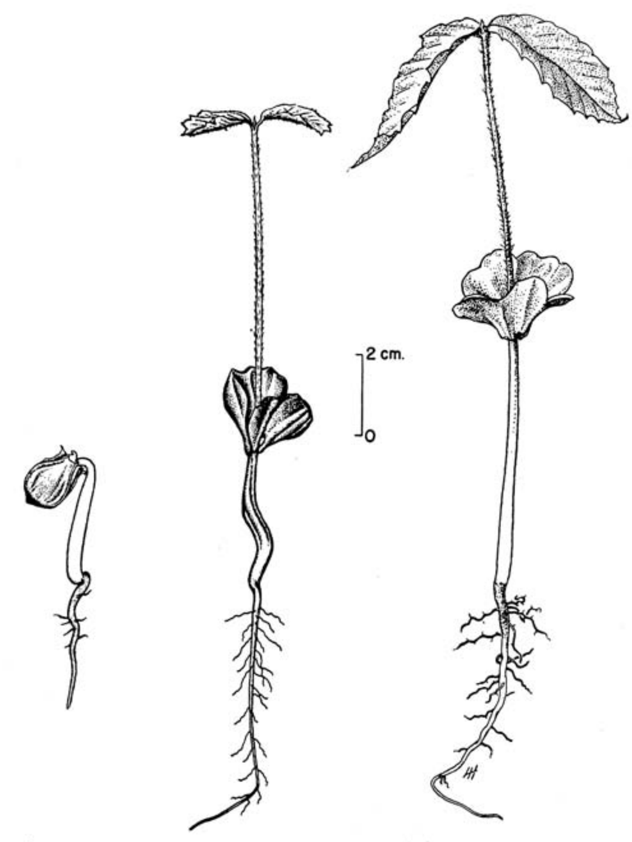


Table 5—*Fagus,* beech: germination test conditions and results

Species	Cold stratification (days)	Test conditions: Medium	Temp (°C) Day	Temp (°C) Night	Germination rate: Amount (%)	Germination rate: Period (days)	Germination (%)
F. grandifolia	90	Sand	30	20	84–47	85	—
F. sylvatica	42	Sand, paper	30	20	—	—	81
F. sylvatica							
Fresh seeds	140	Sand + peat	1	1	56–120	100	—
Stored seeds	150	Sand + peat	5	5	60–110	100	—

Source: Rudolf and Leak (1974).

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Rosaceae—Rose family

Fallugia paradoxa (D. Don) Endl. ex Torr.

Apache-plume

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Growth habit, occurrence, and use. The genus *Fallugia* contains a single species—Apache-plume, *F. paradoxa* (D. Don) Endl. ex Torr.—found throughout the southwestern United States and northern Mexico. It occurs mostly on coarse soils on benches and especially along washes and canyons in both warm and cool desert shrub communities and up into the pinyon–juniper vegetation type. It is a sprawling, much-branched shrub from 1 to 2.5 m in height that can root-sprout to produce extensive patches (Shaw and Monsen 1983). It has white to straw-colored, flaking or scaly bark and fascicles of small wedge-shaped leaves that are deeply divided into 3 to 7 lobes and are rusty-tomentose on the undersides. Apache-plume is reported to be evergreen in the warmer portions of its range (Shaw and Monsen 1983). It can be an important browse plant for both domestic and wild ungulates on some ranges and is also valuable for erosion control (Deitschman and others 1974). It is somewhat fire-tolerant, with the ability to resprout after burning (Shaw and Monsen 1983). Because of its handsome habit and showy flowers and fruits, it is used extensively for landscape plantings in the Southwest. It is hardy in areas far north of its natural range (Deitschman and others 1974; Shaw and Monsen 1983) and has potential for use in revegetation or as an ornamental over a wide geographic area.

Flowering and fruiting. Apache-plume has large, white, 5-petaled, roselike flowers borne singly or in small groups on elongate peduncles. In spite of the typical rose appearance, most plants of Apache-plume have been found to be functionally dioecious or sometimes monoecious (Blauer and others 1975). Each flower has a set of both stamens and pistils, but one or the other fails to develop completely, resulting in functionally unisexual flowers. The male flowers have numerous stamens, whereas the female flowers have 20 to 30 separate pistils borne on a hypanthium. These develop into hairy achenes with long, plumose styles. The clusters of styles are shining-pink and very showy in fruit, giving the plant its name.

Apache-plume flowers mostly in late spring to early summer, and flowers are usually not damaged by late frosts (Shaw and Monsen 1983). Summer rains may extend the season of flowering. The flowers are insect-pollinated and attract a wide variety of colorful insects (Blauer and others 1975). The single-seeded achenes (figures 1–3) ripen in midsummer and are detached and dispersed by wind. Good seedcrops are generally produced every 2 to 3 years (Deitschman and others 1974).

Seed collection, cleaning, and storage. The window of opportunity for harvest of Apache-plume is generally quite short because ripe fruits do not persist on the plants. When the achenes turn from greenish to reddish and the pink color of the styles starts to fade, the fruits may be collected by stripping or beating them into a hopper or other container or with a vacuum-harvester. Achenes comprise only 15 to 20% of collected material by weight. Unless the plumes are removed by chopping or rubbing or with a barley de-bearder or similar device, the collected material remains in a thick, entangled mass that cannot be handled or seeded. Once the styles are broken up, the material can be cleaned in a conventional fanning mill.

The seeds are held tightly within the achene and cannot be threshed out, so the achene is considered to be the seed

Figure 1—*Fallugia paradoxa*, Apache-plume: achene with style (tip broken).

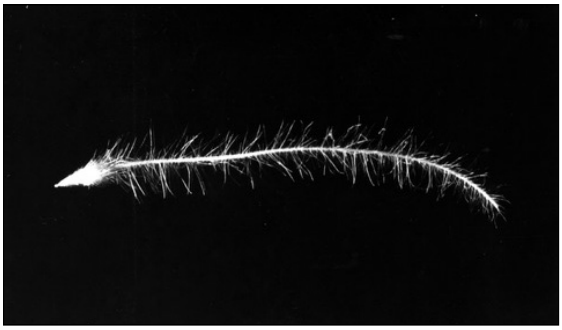


Figure 2—*Fallugia paradoxa*, Apache-plume: achene with style removed.

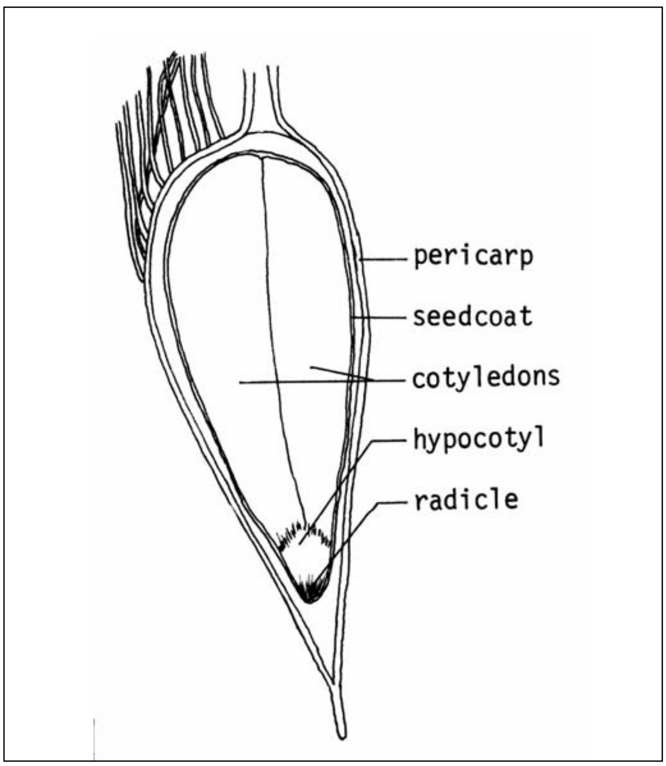


Figure 3—*Fallugia paradoxa*, Apache-plume: longitudinal section through an achene.

unit. Reported weights are 925 to 1,280 achenes/g (420,000 to 580,000/lb) (Deitschman and others 1974; Belcher 1985; Link 1993). Fill is sometimes quite low—for example, Link (1993) reported 30 to 40%—and unfilled fruits cannot be detected or removed in cleaning; it is therefore a good practice to check fill in the field before harvest. Seeds of Apache-plume apparently are orthodox in storage behavior, but they have a more limited shelf life in warehouse storage than those of related genera. Serious loss of viability commences after as little as 3 years, even if seeds are held at optimum moisture content (7 to 12%) (Belcher 1985; Deitschman and others 1974; Link 1993).

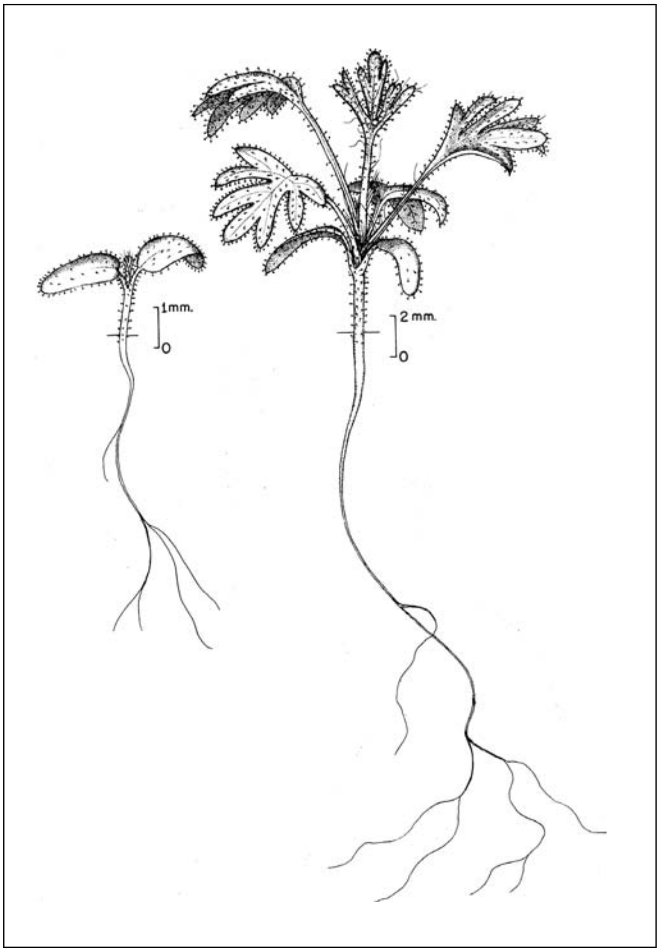
Germination and seed testing. Most workers report that seeds of Apache-plume germinate readily without pretreatment, at least when freshly harvested (Belcher 1985; Deitschman and others 1974; Link 1993; Veit and Van Auken 1993). Veit and Van Auken (1993) reported better germination for a seedlot from west Texas at lower light levels and with the styles removed, the latter possibly because of better seed–substrate contact. They also found that germination was better at higher incubation temperatures (85% at 20 to 25 °C vs. 51% at 5 to 10 °C after 60 days), in contrast to the results of Deitschman and others (1974), who reported that seeds of 2 lots from central Utah germinated to 60 and 73% (that is, to maximum viability) during 60 days at 0 to 3 °C. These differences may represent ecotypic differentiation between northern populations that emerge in response to winter precipitation and southern populations that emerge in response to summer rains. Chilling-responsive secondary dormancy that is induced during dry storage (Link 1993) may also represent an adaptive response, in that seeds that do not germinate in response to summer rains may develop a short chilling requirement that prevents them from germinating too late in the fall.

Belcher (1985) recommends 14 days of testing at 20 or 22 °C for evaluating the viability of Apache-plume seeds and states that 30 days of chilling at 3 to 5 °C may be helpful for some lots. Viability may also be evaluated using tetrazolium (TZ) staining. Achenes are soaked overnight in water, clipped at the cotyledon end, immersed for several hours in 1% TZ solution, and bisected longitudinally for evaluation (Belcher 1985).

Field seeding and nursery practice. Although Apache-plume has been successfully established via direct-seeding in the fall or spring in the northern part of its range and during summer rains in the southern part (Deitschman and others 1974), it is somewhat difficult to establish this way. Despite of their small size, the seeds must be covered in order for seedlings to establish, but planting them too deep can also prevent establishment. Veit and van Auken (1993) reported maximum emergence from seeds planted 1 to 2 mm ($^{3}/_{64}$ to $^{5}/_{64}$ in) deep in greenhouse trials, whereas planting depths of 3 to 6 mm ($^{1}/_{8}$ to $^{1}/_{4}$ in) have been recommended for seeding into nursery beds (Deitshman and others 1974). The seedlings are quite drought hardy but do not survive in competition with an understory of annual grass weeds or perennial grasses. Young seedlings are depicted in figure 4.

Apache-plume plants can be readily produced from seeds in either bareroot or container systems. They grow rapidly with irrigation, often flowering their first growing

Figure 4—*Fallugia paradoxa*, Apache-plume: seedling with primary leaves only (**left**); seedling with primary and secondary leaves (**right**).



season. For bareroot production, seeding into a firm seedbed prior to the season of most dependable moisture is recommended. When grown in the North, the seedlings are deciduous and can be safely lifted and transplanted once they lose their leaves. The stems are brittle and the roots often poorly developed, necessitating careful handling. For container production, direct-sowing without pretreatment is the usual practice, though some workers prefer to chill or cold-stratify the seeds for 30 days, either before or after planting, to ensure rapid and complete germination (Link 1993). A well-drained growing medium is required. Container-grown plants tend to be evergreen and must be hardened off carefully to minimize transplant losses.

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Rutaceae—Rue family
Flindersia brayleyana F. Muell.
Queensland-maple

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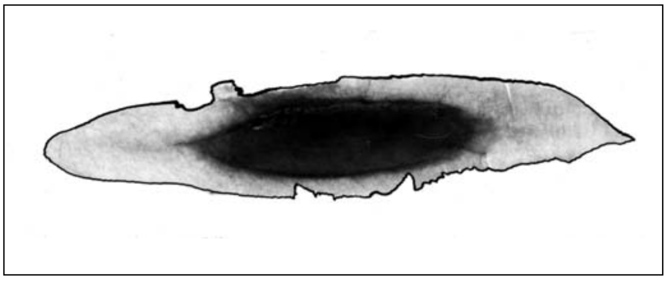
Synonym. *Flindersia chatawaiana* F.M. Bailey.

Growth habit, occurrence, and use. Queensland-maple (*Flindersia brayleyana* F. Muell.)—also known as Brayley flindersia, maple-silkwood, red-beech, and silkwood—is a native of Queensland, Australia, that was introduced to Hawaii in 1935 (Francis 1951; Wick 1974). It is a broadleaf, tropical hardwood tree that attains a height of 20 to 30 m at maturity. Queensland-maple ranks with mahogany, walnut, cedar, and blackwood as one of the best cabinet timbers of the world and is one of the most valuable species on the Australian market. The sapwood is pink and the heartwood a lustrous pale brown, often with interlocked and wavy grain (Little and Skolmen 1989). The heartwood is also used for veneer, plywood, and laminated panels and doors (Boas 1947). It is a medium-dense wood with an average specific gravity of 450 to 540 kg/m^3. Plantings in Hawaii have not, as yet, been commercially harvested.

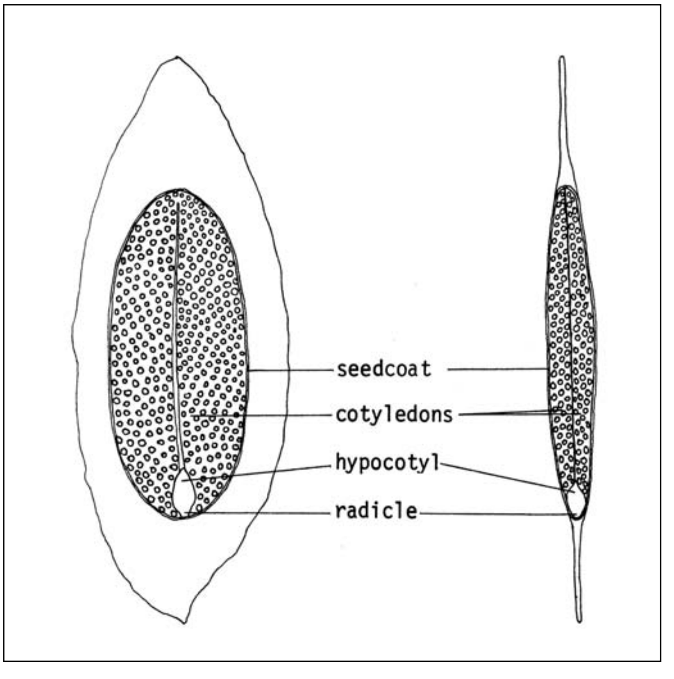
Flowering and fruiting. Queensland-maple has small (3 mm long), white, fragrant, 5-petaled bisexual flowers that generally form large panicles from August to September. The fruit is a cylindrical, hard-shelled, warty, 5-valved dehiscent capsule, about 6 cm long and 2.5 cm in diameter (Little and Skolmen 1989). In Hawaii, it generally ripens from June to July and releases its several flat, winged seeds (measuring 5 by 1 cm) from July through September (figures 1 and 2) (Little and Skolmen 1989; Neal 1965; Wick 1974). A tree usually starts bearing seeds at 8 years of age and produces an abundant crop annually (Wick 1974).

Figure 1—*Flindersia brayleyana*, Queensland-maple: seed.



Collection, extraction, and storage. When the capsules turn from green to brown, they are ripe and should be picked. In Hawaii, the capsules are picked from felled or standing trees. The fruits are spread on trays for air-drying or are oven-dried. As the capsules dry, they open, releasing the seeds. In Hawaii, there are between 9,800 and 11,700 seeds/kg (4,400 to 5,300 seeds/lb), or an average of about 10,500 seeds/kg (4,800 seeds/lb) (Wick 1974). In Queensland, Swain (1928) reported a range of 6,600 to 11,000 seeds/kg (3,000 to 5,000 seeds/lb). In Hawaii, the seeds are stored in airtight containers at 2 °C. The seeds do not store well and lose their viability within a year. Because seeds are easily damaged, they must be handled gently. The seeds are also very sensitive to chemicals used in storage or fumigation (Wick 1974).

Figure 2—*Flindersia brayleyana*, Queensland-maple: longitudinal section through two planes of a seed.



Germination. In Hawaii, good germination was obtained without any pregermination treatment (Wick 1974). In a test in Queensland, germination rates were 70% in 7 days and 90% in 20 days (Swain 1928).

Nursery and field practice. In Hawaii, Queensland-maple seeds are sown as soon as they are collected, at a rate of 150 to 200/m^2 (14 to 18/ft^2) and at a sowing depth of 0.6 to 1.2 cm ($^1/_4$ to $^1/_2$ in). Young seedlings should be provided overhead shade for about the first 2 months. Seedlings may be outplanted as 1+0 seedlings (Wick 1974).

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Rhamnaceae—Buckthorn family

Frangula P. Mill.

buckthorn

Andrew Youngblood

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Growth habit, occurrence, and use. The buckthorn genus—*Frangula*—and the closely related genus *Rhamnus* have until recently been treated as a single genus (*Rhamnus*) consisting of more than 125 species of evergreen or deciduous shrubs and trees with alternate branches and simple leaves with prominent pinnate veins (Hickman 1993). Kartesz and Gandhi (1994), however, used floral morphology and leaf venation, as well as anatomical features of xylem vessels, to support segregation of *Frangula*. Under their treatment, *Frangula* species lack winter bud scales, the pinnate leaf nerves are almost straight rather than arcuate, and thorns are absent. Both *Rhamnus* and *Frangula* are native to the temperate region of North America, Europe, and Asia and also occur in the Neotropics and southern Africa as shrubs and trees up to 1.5 m dbh and over 60 m tall (Johnston and Johnston 1978; Krüssmann 1985). The common name, buckthorn, is probably misapplied and is based on European species of *Rhamnus* that are thorny (Mozingo 1987; USDA 1937). At least 16 species and subspecies are distributed within the United States (table 1) (USDA NRCS 2001).

Glossy buckthorn, which is native to Europe, North Africa, and western Europe, also is naturalized in northeastern and central United States and southern Canada, where it grows to a height of 6 m and is often used for hedges. The fruits are eaten by American robins (*Turdus migratorius*), Bohemian waxwings (*Bombycilla garrulus*), cedar waxwings (*B. cedrorum*), rose-breasted grosbeaks (*Phencticus ludovicianus*), and starlings (*Sturnus vulgaris*). Dispersal of seeds by birds and subsequent germination and establishment represents a rapidly increasing problem; for example, this non-native invasive shrub has replaced natural open and semi-open wetland communities in southern Ontario (Catling and Porebski 1994).

Beechleaf buckthorn is a low-growing shrub with dark green leaves found in rock crevices, hanging gardens, and desert shrub communities in the Southwest (Welsh and others 1990).

Within North America, the largest assemblage of *Frangula* species in the genus is in the West, especially California and northern Mexico. Six subspecies of California buckthorn are recognized (Kartesz and Gandhi 1994), yet the extent to which published seed handling characteristics apply equally within this complex is unknown. California buckthorn is an evergreen shrub that reaches maximum heights of 2 to 6 m. The fruits were gathered historically by Native Americans for culinary as well as medicinal purposes and are a preferred food of birds and bears (Conrad 1987). California buckthorn var. *californica,* which was introduced on Mauna Kea on the island of Hawaii in 1940 to provide food for introduced game birds, is now well established and shows signs of becoming an invasive pest (Conrad 1996). Regeneration of California buckthorn is primarily by stump-sprouting after fire (Keeley 1981; Martin 1982; Conrad 1987).

Carolina buckthorn, native to eastern North American, is a deciduous shrub or small tree with maximum height of about 10 m. It often occurs over basic rock in moist deciduous woods (Radford and others 1968).

Cascara, or Pursh buckthorn, native to the coniferous forest zone in northwestern United States and British Columbia, is a deciduous tall shrub or tree that grows to a height of 12 m. The bark of cascara is harvested for its cathartic properties. According to Heiser (1993), cascara is northern North America's principal wild plant in terms of the number of drug products and the cascara derivative is considered the world's most widely used cathartic. The Spanish common name *cascara sagrada* means "holy bark" and may be derived from its use by Franciscan missionaries in California (Arno and Hammerly 1977). The low-growing and spreading variety *arbuscula* occurs on serpentine slopes in the Wenatchee Mountains of Washington and may tolerate open and dry sites (Kruckeberg 1982). Cascara regenerates primarily by stump-sprouting after fire (Leege 1979). It is an alternate host for crown rust—*Puccinia coronata* Corda—which causes yellow leaf spot in the aecial stage; economic

Scientific name & synonym(s)	Common name(s)	Occurrence
***F. alnus* P. Mill.** *Rhamnus frangula* L. *R. frangula* L. var. *angustifolia* Loud.	**glossy buckthorn**	Europe, W Asia, & N Africa: naturalized in Nova Scotia, S Quebec & S Ontario to Minnesota, S to Illinois, Ohio, Tennessee, West Virginia, W to Colorado, & Wyoming
F. betulifolia* (Greene) V. Grub. ssp. *betulifolia *R. betulifolia* Greene	**beechleaf buckthorn,** birchleaf buckthorn	Nevada, Utah, Arizona, New Mexico, Texas, & Mexico
***F. betulifolia* (Greene) V. Grub. ssp. *obovata* (Kearney & Peebles) Kartesz & Gandhi**	**obovate buckthorn**	Nevada, Arizona, & New Mexico
F. californica* (Eschsch.) Gray ssp. *californica *R. californica* Eschsch.	**California buckthorn**	California; naturalized on the Island of Hawaii
***F. californica* (Eschsch.) Gray ssp. *crassifolia* (Jepson) Kartesz & Gandhi**	**California buckthorn**	California
***F. californica* (Eschsch.) Gray ssp. *cuspidata* (Greene) Kartesz & Gandhi** *R. californica* Eschsch. ssp. *cuspidata* (Greene) C.B. Wolf *R. tomentella* Benth. ssp. *cuspidata* (Greene) J.O. Sawyer	**California buckthorn**	California
***F. californica* (Eschsch.) Gray ssp. *occidentalis* (T.J. Howell) Kartesz & Gandhi** *R. californica* (Eschsch.) ssp. *occidentalis* (T.J. Howell) C.B. Wolf *R. californica* (Eschsch.) ssp. *occidentalis* (T.J. Howell) Jepson	**California buckthorn**	Serpentine soils of SW Oregon & N California
***F. californica* (Eschsch.) Gray ssp. *tomentella* (Benth.) Kartesz & Gandhi** *R. californica* Eschsch. ssp. *tomentella* (Benth.) C.B. Wolf *R. tomentella* Benth.	**California buckthorn**	California
***F. californica* (Eschsch.) Gray ssp. *ursina* (Benth.) Kartesz & Gandhi** *R. californica* Eschsch. ssp. *ursina* (Greene) C.B. Wolf *R. tomentella* Benth. ssp. *ursina* (Greene) J.O. Sawyer	**California buckthorn**	California, Nevada, Arizona, & New Mexico

Table 1—*Frangula*, buckthorn: nomenclature and occurrence

damage by crown rust is confined to heavy damage in fields of oats grown in close proximity to plant communities containing cascara (Ziller 1974).

Red buckthorn is a low-growing deciduous shrub with reddish branchlets found on dry open slopes in chaparral and montane zones of California and Nevada.

The earliest know cultivation of species native to North America includes 1727 for Carolina buckthorn and the mid-1800s for California buckthorn and cascara (Krüssmann 1985).

Flowering and fruiting. The inconspicuous perfect flowers are either borne in small umbels or fascicles or are solitary. The flowers are bisexual and mostly 5-merous. White to greenish white petals (brown in beechleaf buckthorn) are equal to the sepals in number and alternating, or lacking. There are 5 stamens. The ovary has 2 or 3 cells. When Orme and Leege (1980) followed phenological changes in cascara in northern Idaho for 3 years, they found that flowering occurred in late May to mid-June and that fruits began developing 1 week later.

Fruits are drupaceous, the berrylike pulpy mesocarp embedding 2 or 3 smooth-sided stones (Johnston and Johnston 1978; Kartesz and Gandhi 1994) (figure 1). Fruits, which are generally black or reddish black, average 5 mm in diameter for Carolina buckthorn, 10 mm for cascara, 12 mm for red buckthorn, and up to 15 mm for California buckthorn. Dispersal is mostly by birds. Cascara begins to produce fruit when it is 5 to 7 years old (Hubbard 1974); comparable information for other species is lacking. Good seedcrops for all species are likely to occur in most years.

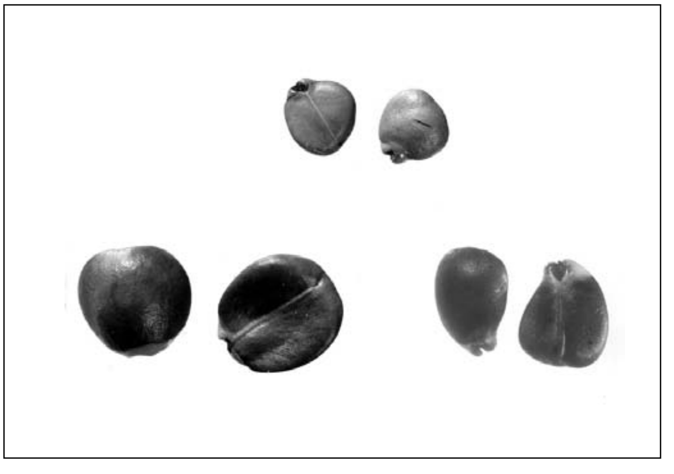
Table 1—*Frangula,* buckthorn: nomenclature and occurrence (continued)

Scientific name(s)	Common name(s)	Occurrence
***F. caroliniana* (Walt.) Gray** *R. caroliniana* Walt. *R. caroliniana* Walt. var. *mollis* Fern.	**Carolina buckthorn,** yellow buckthorn, yellowwood	New Jersey S to Florida, W to Missouri, Kentucky, Arkansas, & Texas
F. purshiana (DC.) Cooper *R. purshiana* DC.	**cascara,** *cascara sagrada,* Pursh buckthorn, chittam, coffeetree	British Columbia, Washington, Oregon, N California, also N Idaho & W Montana
***F. rubra* (Greene) V. Grub. ssp. *modocensis* (C.B. Wolf) Kartesz & Gandhi** *R. rubra* Greene ssp. *modocensis* C.B. Wolf	**Modoc buckthorn**	California
***F. rubra* (Greene) V. Grub. ssp. *nevadensis* (A. Nels.) Kartesz & Gandhi** *R. rubra* Greene ssp. *nevadensis* (A. Nels) C.B. Wolf	**Nevada buckthorn**	Nevada
***F. rubra* (Greene) V. Grub. ssp. *obtusissima* (Greene) Kartesz & Gandhi** *R. rubra* Greene ssp. *obtusissima* (Greene) C.B. Wolf	**obtuse buckthorn**	California & Nevada
F. rubra* (Greene) V. Grub. ssp. *rubra *R. rubra* Greene	**red buckthorn,** Sierra buckthorn, coffeeberry	California & Nevada
***F. rubra* (Greene) V. Grub. ssp. *yosemitana* (C.B. Wolf) Kartesz & Gandhi** *R. rubra* Greene ssp. *yosemitana* *C.B. Wolf*	**Yosemite buckthorn**	California

Figure 1—*Frangula purshiana*, cascara: fruit.

Collection, extraction, and storage. Fruits can be collected from the shrubs and trees when ripe; collecting fruits about 2 weeks before they are fully ripe may limit losses to birds (Hubbard 1974). Fruits can be run through a macerator with water soon after collecting and full seeds can be cleaned of other material by repeated decantation (Radwan 1976). Seeds typically are small, rounded, with one slightly flattened side, and a terminal knob (figure 2). Seeds may contain relatively little endosperm (figure 3). Data on yield of seeds are scant and based on limited samples: yields are about 11 seeds/g (312/oz) for California buckthorn and 6 seeds/g (170/oz) for cascara (Piper 1986).

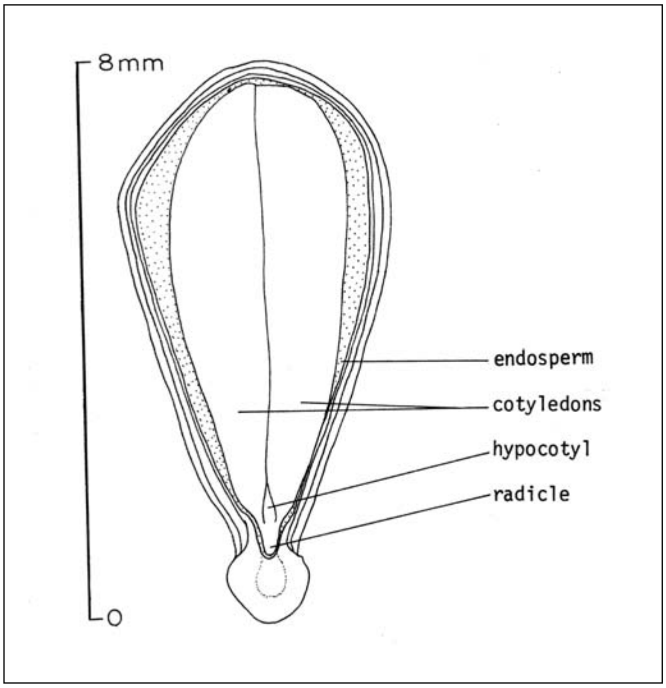
Figure 2—*Frangula*, buckthorn: seeds of *F. alnus*, glossy buckthorn (**top**); *F. californica*, California buckthorn (**left**); and *F. purshiana*, cascara (**right**).



Seed storage guidelines have not been developed for *Frangula* species, but it appears that seeds can be stored adequately for several years if they are kept in sealed containers at low temperatures (Hubbard 1974). Seeds of California buckthorn are relatively short lived (< 9 months) if allowed to dry to room conditions (Keeley 1987).

Pregermination treatment. Fresh seeds of California buckthorn apparently have no innate germination require-

Figure 3—*Frangula californica*, California buckthorn: longitudinal section through a seed.



ments (Hubbard 1974; Keeley 1981, 1987). During laboratory tests involving 1 month of stratification at 5 °C, however, more than 75% of the total germination occurred after 7 days of incubation at 23 °C in the dark. Germination increased to 90% when seeds were incubated with an initial heat treatment of 100 °C for 5 minutes and then placed on soil containing 0.5 g powdered charred wood (charate) of the chaparral shrub chamise—*Adenostoma fasciculatum* Hook. & Arn. This treatment is designed to simulate conditions after a chaparral fire (Keeley 1987). Seeds of cascara germinated best when stratified in the dark for 112 days at 5 °C, then incubated for 28 days at 30 °C for 10 hours under cool-white fluorescent light followed by 14 hours of darkness at 20 °C (Radwan 1976). Dormant seeds responded favorable to applications of 500 ppm of potassium gibberellate (K-GA_3) when light was available during germination and may represent a practical alternative to artificial cold stratification for breaking dormancy (Radwan 1976). Clean seeds of glossy buckthorn have been treated with sulfuric acid (H_2SO_4) for 20 minutes to break dormancy; the acid treatment should be done carefully because soaking the seeds of other buckthorns was harmful (Hubbard 1974).

There are no officially prescribed germination tests procedures for buckthorns. Viability tests by tetrazolium staining have been suggested for European species (Enescu 1991). Seeds should be soaked in water for 24 hours, cracked open in a vise, then re-soaked overnight. Staining should take place in a 1% tetrazolium solution for 24 hours at 30 °C (Dirr 1990). To be considered viable, the embryos must be completely stained, with the exception of the extreme third of the distal ends of the radicle and cotyledons.

Nursery and field practice. Detailed nursery techniques have not been developed for most *Frangula* species. The available information suggests that for most of the species, the seeds should be sown in the spring at a depth of 10 to 40 mm (0.4 to 1.6 in) after they have been treated to break dormancy (Hubbard 1974). In contrast, cascara seeds may germinate faster and produce more vigorous plants when seeds are sown at a depth of 3 mm (0.1 in) (Radwan 1976). Germination is epigeal, with thick, straight cotyledons (Kartesz and Gandhi 1994). Cascara has also been propagated by cuttings, and glossy buckthorn by grafting (Hubbard 1974).

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Theaceae—Tea family
Franklinia alatamaha Bartr. ex Marsh.
Franklin tree

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Synonyms. *Gordonia alatamaha* (Bartr. ex Marsh.) Sarg.; *Gordonia pubescens* L'Hér.

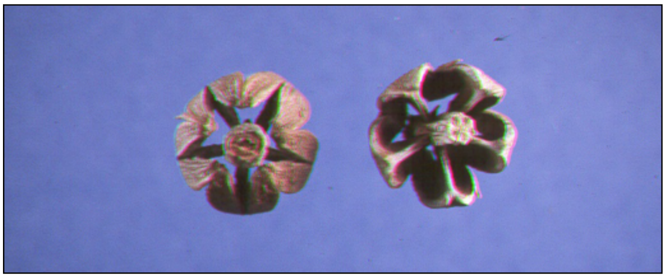
Other common names. franklinia, lost camellia, lost gordonia.

Growth habit, occurrence, and uses. Franklin tree—*Franklinia alatamaha* Bartr. ex Marsh.—was discovered by Bartram in 1765 on 0.8 to 1.2 ha of sandhill bogs near the mouth of the Altamaha River in Georgia, but the species has not been found in a native setting since 1803. Currently, it exists only in cultivation in USDA Hardiness Zones 5–9 (Everett 1981; Jacobson 1996; Wildman 1996). Franklin tree is a deciduous small tree or large multi-stemmed shrub reaching a height of 9 m (LHBH 1976). Upright spreading branches with leaves clustered at the tips give the plant a tightly rounded exterior appearance and its open interior reveals striated bark that adds year-round interest (Elias 1989; Wildman 1996).

Valued for ornamental characteristics, Franklin tree produces large, showy white flowers appearing from July to the first frost of autumn (Elias 1989; Schneider 1988; Wildman 1996). Lustrous dark green leaves turn "a blazing red in fall" before abscising to reveal an attractive smooth gray bark that is broken by lighter colored fissures (Wildman 1996). These attributes clearly make the species a superb specimen tree or small flowering tree in a mixed planting.

Flowering and fruiting. Perfect flowers, 7 to 9 cm in diameter, appear in July and are borne solitary in the axils of the leaves. Each flower consists of a 1.3-cm-diameter center, filled with golden yellow stamens, surrounded by 5 white petals (1 remains cupped). Flowering persists until the first frost (Elias 1989). Seeds are produced in 1.3- to 2.0-cm-diameter, 5-valved, subglobose, dehiscing, woody capsules that split alternately from above and below (figure 1) (LHBH 1976). Capsules persist through the winter, providing an excellent feature for identification (Wildman 1996). Each cell of a capsule contains 6 to 8 wingless seeds, 12- to 14-mm-long, that are angled due to mutual pressure during development (figures 2 and 3) (Sargent 1949; Small 1933).

Figure 1—*Franklinia alatamaha*, Franklin tree: capsules after seed release.



Collection of fruits, seed extraction, cleaning, and storage. Capsules should be collected in October to November, before they split, and then allowed to dry and open indoors. Seeds can then be shaken from the capsules and sown immediately (Dirr and Heuser 1987). Currently, no information regarding long-term storage of seeds of Franklin tree has been published.

Pregermination treatments. Seeds that are collected when the capsules split and sown immediately will germinate without any pretreatment (Dirr and Heuser 1987). Best germination, however, occurs after stratification (moist-prechilling) for 1 to 2 months (Dirr and Heuser 1987; Farmer and Chase 1977). If seeds are stored and allowed to dry, stratification becomes necessary (Hartmann and others 1997).

Germination tests. Farmer and Chase (1977) studied the influence of stratification, temperature, and light on seed germination of Franklin tree. Seeds were stratified at 3 °C for 0, 4, 8, or 12 weeks followed by germination at 14-hour day/10-hour night thermoperiods of 16/7 °C, 24/16 °C, or 29/24 °C. At each thermoperiod, seeds were maintained in darkness or subjected daily, during the high temperature portion of the cycle, to a 14-hour photoperiod of 2.2 klux provided by incandescent and fluorescent light sources. Results indicated the seeds have an obligate light requirement.

Figure 2—*Franklinia alatamaha*, Franklin tree: seeds.

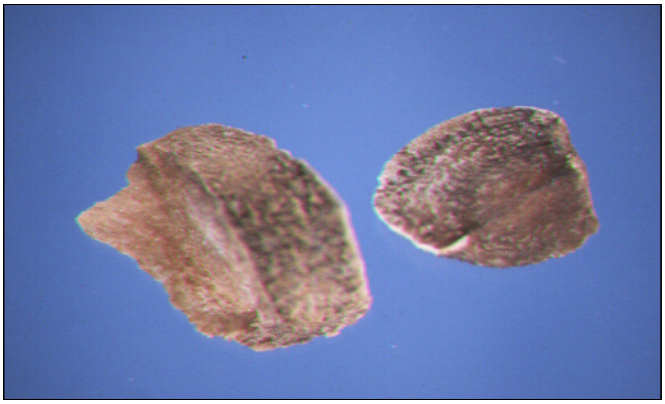
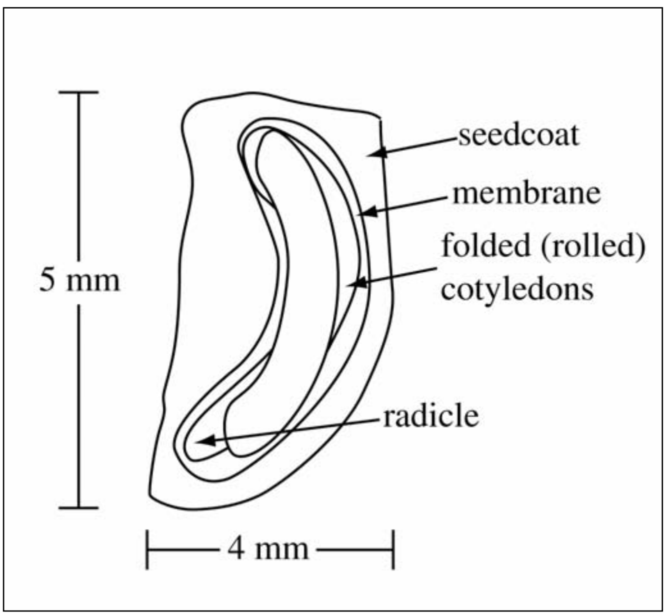


Figure 3—*Franklinia alatamaha*, Franklin tree: longitudinal section of a seed.



Regardless of temperature, germination in the dark was negligible for nonstratified seeds. However, in the presence of light, cumulative germination at 16/7 °C, 24/16 °C, or 29/24 °C was 2, 75, and 61%, respectively. Stratification enhanced germination by accelerating the rate of germination and reducing sensitivity of the seeds to light. After 4 weeks of stratification, total germination in the presence of light at 16/7 °C, 24/16 °C, and 29/24 °C was 5, 87, and 91%, respectively, in comparison to 2, 31, and 85%, respectively, for seeds in darkness. Germination following stratification for 8 weeks was similar to that of 4 weeks of stratification. Additional stratification for 12 weeks resulted in an increase in dark germination at 24/16 °C to 53% and a large increase in germination at 16/7 °C with dark and light germination of 32 and 52%, respectively.

Nursery practice. For field production, seeds sown in late winter to early spring will result in seedlings that grow quite vigorously, attaining heights of about 30 cm (12 in) by fall (Judd 1930). If container production is desired, Farmer and Chase (1977) recommend 8 to 16 weeks of stratification, after which seeds are sown to a 5-mm (0.2-in) depth in flats containing a medium of peat and perlite. Shoot emergence occurs in about 2 weeks at day/night germination temperatures of 27/21 °C. Seedlings should remain in flats until they reach a height of 3 to 5 cm (1 to 2 in), when they should be transplanted to 10-cm (4-in) pots containing a medium of finely ground peat moss. Plants are maintained in these pots under natural photoperiods for a period of 4 to 8 weeks and fertilized monthly with a complete soluble fertilizer. At this point, seedlings will have attained a height of 15 to 20 cm (6 to 8 in) and are ready for sale. Like many native ornamentals, Franklin tree prefers a moist, acidic soil (pH 5.5 to 6.5) that must be well drained (Schneider 1988). Although Franklin tree is relatively pest free, seedlings will often suffer from a root rot caused by *Phytophthora cinnamomi* Rands if soil conditions are too wet (Wildman 1996).

The species can also be propagated easily by stem cuttings taken from June to August. Treatment of cuttings with a solution of 1,000 ppm (0.1%) indolebutyric acid (IBA) will result in 90% rooting (Dirr and Heuser 1987). Although sexual propagation is possible as mentioned previously, seeds are usually quite expensive, making propagation by cuttings more economical (Schneider 1988).

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Oleaceae—Olive family

Fraxinus L.

ash

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Growth habit, occurrence, and uses. The genus *Fraxinus*—the ashes—is a large genus of deciduous trees whose members are valued for many reasons. In addition to the 9 native ash species, 2 European species that have been widely planted as ornamentals in North America (European and flowering ashes) are included in this manual (table 1). Practically all ashes have been planted to some extent for landscaping and in parks. Ashes make excellent shade trees in residential areas, and numerous selections of European and flowering ashes are in cultivation today (Dirr and Heuser 1987). Native favorites for landscaping are white and green ashes for the eastern and central United States and velvet ash for arid situations in the Southwest.

Geographic races and hybrids. Both green and white ashes exhibit ecotypic variation, but no patterns have been consistent enough to firmly establish geographic races (Kennedy 1990; Schlesinger 1990). White ash and Texas ash—*F. texensis* (Gray) Sarg.—intergrade in Texas (Schlesinger 1990). Oregon ash becomes very similar to velvet ash south of the Kern River in California (Owston 1990), which suggests intergrading of these 2 species. There is also some evidence that pumpkin ash is a true-breeding natural hybrid of white ash and green ash (Kennedy 1990). Several large provenance tests are underway with white ash (Clausen 1984; Clausen and others 1981) and green ash (Hendrix and Lowe 1990; Steiner and others 1988; Van

Table 1—*Fraxinus*, ash: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***F. americana* L.**	**white ash,** Biltmore white ash, Biltmore ash	Cape Breton Island, Nova Scotia, W to SE Minnesota, & S to Texas & Florida
***F. caroliniana* P. Mill.**	**Carolina ash,** swamp ash, water ash, pop ash	NE Virginia S to S Florida, W to Texas & Arkansas
***F. dipetala* Hook. & Arn.** *F. trifoliolata* (Torr.) Lewis & Epling	**two-petal ash,** flowering ash, foothill ash	SW Utah, W to Nevada, California, & Mexico
***F. excelsior* L.**	**European ash**	Europe & Asia Minor; widely planted in US
***F. latifolia* Benth.**	**Oregon ash**	Puget Sound in Washington to S California
***F. nigra* Marsh.**	**black ash,** basket ash, brown ash, hoop ash, swamp ash, water ash	Newfoundland to SE Manitoba S to Iowa & Delaware
***F. ornus* L.**	**flowering ash**	S Europe & W Asia; widely planted in US
***F. pennsylvanica* Marsh.** *F. pennsylvanica* var. *lanceolata* (Borkh.) Sarg.	**green ash,** red ash, Darlington ash, white ash, swamp ash, water ash	Cape Breton Island to Alberta, S to Texas & NW Florida
***F. profunda* (Bush) Bush**	**pumpkin ash,** red ash	S Maryland & Illinois, S to Louisiana & N Florida
***F. quadrangulata* Michx.**	**blue ash**	S Ontario and Wisconsin, S to NE Oklahoma & NW Georgia
***F. uhdei* (Wenzig) Lingelsh.**	**Shamel ash,** tropical ash, *fresno*	W-central Mexico through Guatemala; planted in Hawaii & Puerto Rico
***F. velutina* Torr.**	**velvet ash,** desert ash, leatherleaf ash, smooth ash, Modesto ash, Arizona ash, Toumey ash	Utah & Nevada, S to S California & SW Texas

Source: Little (1979).

Deusen and Cunningham 1982), and their results should provide more information about the variation in these species.

Flowering and fruiting. The small, usually inconspicuous flowers of most ash species appear in the spring (table 2) with or just before the leaves in terminal or axillary panicles (compound racemes). The flowers may be greenish yellow, greenish purple, or even greenish red (white ash) (Brown and Kirkman 1990; Vines 1960). Flowering ash is an exception, with showy, white flowers appearing after the leaves (Dirr and Heuser 1987). Flowering habit varies by species and may be dioecious, perfect, or polygamous (table 2). Ash fruits are elongated, winged, single-seeded samaras that are borne in clusters (figures 1–3). Samara length ranges from 2.5 to 7.5 cm, depending on species. In white ash, fruit size increases as latitude increases (Winstead and others 1977). Fruits mature by late summer or fall and are dispersed by wind shortly afterward (table 2). Samaras of pumpkin ash, which is found in swamps and river bottoms, are reported to remain viable in water for several months (Harms 1990). Samaras of black and blue ashes have a characteristic spicy odor. Fruiting data are summarized in table 3.

Collection of fruits. Ash fruits are usually collected in the fall when their color has faded from green to yellow or brown (Bonner 1974; Vines 1960). Soljanik (1961) recommended collecting the fruits of European and flowering ashes in Europe when the samaras are still slightly green and sowing can be done immediately. The aim of this strategy is to avoid the deep dormancy that is common in these species when they are fully mature. Other good indices of maturity are a firm, crisp, white, fully elongated seed within the samara (Bonner 1974; Soljanik 1961); minimum samara moisture content (Cram and Lindquist 1982); and maximum samara dry weight (Bonner 1973). There are several good chemical indices of maturity in green ash as well (Bonner 1973), but these are not practical for collection operations.

Clusters of samaras can be picked by hand or with pruners and seed hooks. Fully dried samaras may be shaken or whipped from limbs of standing trees onto sheets spread on the ground. Samaras can also be swept up from paved streets or other hard surfaces after they fall (Bonner 1974).

Local seedcrops of white and green ashes are often seriously damaged by ash seed weevils—*Thysanocnemis bischoffi* Blatchley, *T. helvola* Leconte, and *T. horridulus* (Casey) (Barger and Davidson 1967; Solomon and others 1993). The greatest reported losses have been in the Northeast and the Great Plains, with smaller amounts of damage in the South. The female deposits 1 egg per seed, and mature larvae exit the seeds from fall until the following spring. Direct control measures are rarely justified (Solomon and others 1993).

Figure 1—*Fraxinus americana*, white ash: cluster of samaras.

Table 2—*Fraxinus,* ash: flowering habit and phenology of flowering and fruiting

Species	Location	Flowering	Flowering habit	Fruit ripening	Seed dispersal
F. americana	—	Apr–May	Dioecious	Oct–Nov	Sept–Dec
F. caroliniana	—	Feb–Mar	Dioecious	Aug–Oct	—
F. dipetala	California	Apr–May	Perfect	July–Sept	—
F. excelsior	—	Apr–May	Polygamous	Aug–Sept	Winter–early spring
F. latifolia	—	Apr–May	Dioecious	Aug–Sept	Sept–Oct
F. nigra	—	May–June	Polygamous	June–Sept	July–Oct
F. ornus	NE US	May–June	Polygamous	—	—
F. pennsylvanica	—	Mar–May	Dioecious	Sept–Oct	Oct–spring
F. profunda	—	Apr–May	Dioecious	Sept–Oct	Oct–Dec
F. quadrangulata	—	Mar–Apr	Perfect	June–Oct	—
F. uhdei	Hawaii	Mar–May	Dioecious	July–Sept	July–Sept
	Puerto Rico	Nov–Jan	—	Aug	—
F. velutina	—	Mar–Apr	Dioecious	Sept	—

Sources: Bonner (1974), Francis (1990), Harms (1990), Kennedy (1990), Owston (1990), Rehder (1940), Schlesinger (1990), Vines (1960), Wright and Rauscher (1990).

Figure 2—*Fraxinus*, ash: single samaras of *F. americana,* white ash (**top left**); *F. caroliniana*, Carolina ash (**top center**); *F. dipetala*, two-petal ash (**top right**). *F. latifolia*, Oregon ash (**middle left**); *F. nigra*, black ash (**middle center**), *F. pennsylvanica*, green ash (**middle right**). *F. profunda*, pumpkin ash (**bottom left**), *F. uhdei*, tropical ash (**bottom right**), *F. velutina*, velvet ash (**lower right**).

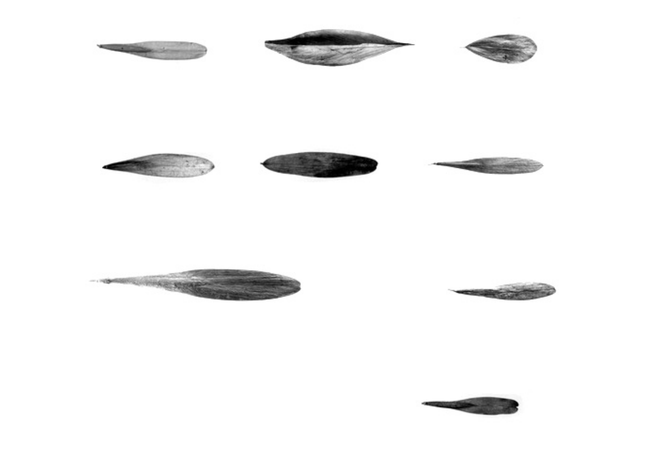


Figure 3—*Fraxinus pennsylvanica*, green ash: longitudinal section through the embryo of a samara.

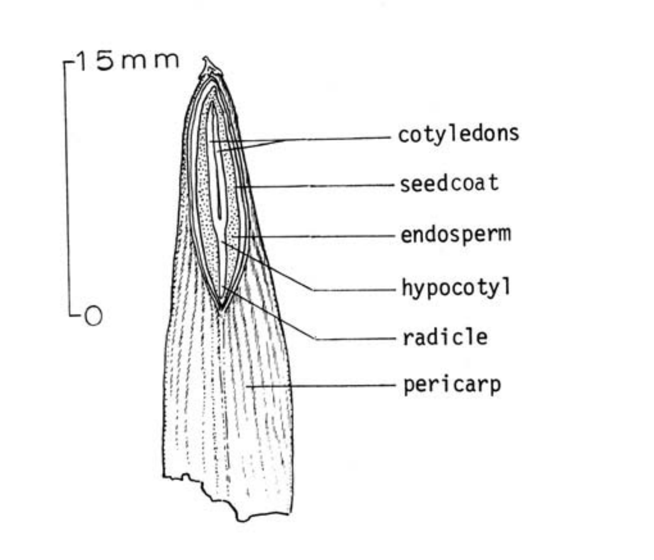


Table 3—*Fraxinus,* ash: height, seed-bearing age, and seedcrop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yr)	Years between large seedcrops
F. americana	21–24	1724	20	3–5
F. caroliniana	6–12	—	—	—
F. dipetala	2–6	—	—	—
F. excelsior	29–38	Long ago*	15	1–2
F. latifolia	18–24	—	30	3–5
F. nigra	12–24	1800	—	—
F. ornus	6–20	pre-1700	20	—
F. pennsylvanica	21+	1824	—	1
F. profunda	37	—	9	—
F. quadrangulata	4–9	1823	25	3–4
F. uhdei	37	1900	15	1
F. velutina	15	1900	—	—

Sources: Bonner (1974), Krinard (1989).
* Cultivated for many centuries (Rehder 1940).

Extraction and storage of seeds. Samaras should be spread in shallow layers for complete drying, especially when collected early. Dried clusters may be broken apart by hand, by flailing sacks of clusters, or by running the clusters through macerators or brush machines dry (Bonner 1974). Stems and trash can then be removed by fanning or with air-screen cleaners. Screen openings of 1 by 1 cm are good for white and green ash. De-winging of samaras is not necessary for storage or sowing, but many nurseries prefer to do so. Large amounts of samaras can be de-winged by dry maceration in a macerator or in brush machines (Karrfalt 1992), but they must be completely dry for the process to be successful. Smaller seedlots, such as those used for research or testing, can be de-winged in laboratory blenders operated at low speeds about half-full of water. Seed yield data for ashes are summarized in table 4.

Long-term storage studies with seeds of the ashes are few, but these seeds are definitely orthodox in their storage characteristics. Studies by Barton (1945) showed no loss in viability for 7 years for green and European ash seeds stored in sealed containers at 5 °C with seed moisture contents of 7 to 10%. Similar conditions have proved successful for flowering ash (Heit 1967) and Shamel ash (Bonner 1974).

Table 4—*Fraxinus*, ash: seed yield data

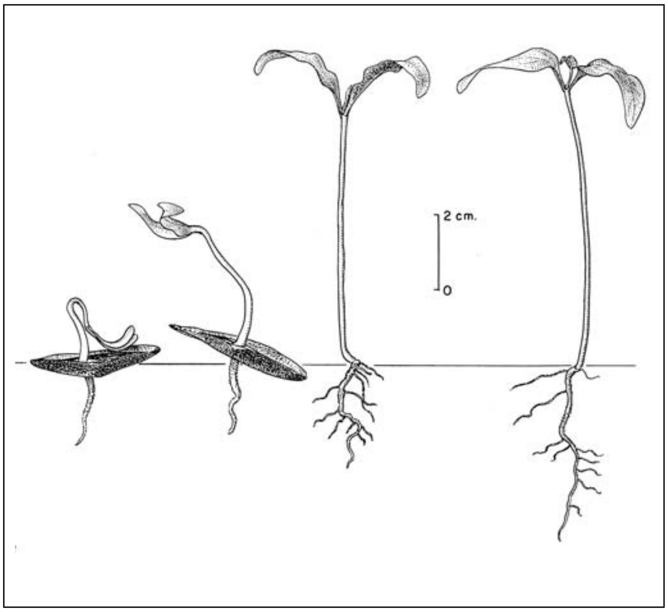
Species	Place fruit collected	Seeds/vol kg/hl	Seeds/vol lb/bu	Cleaned seeds/weight Range /kg	Range /lb	Average /kg	Average /lb	Samples	Seed moisture (%)
F. americana	Midwest	16*	12.4	12,220–40,100	5,540–18,185	28,930	13,120	7	—
	Mississippi	16*	12.5	12,600–24,900	5,712–11,288	18,680	8,470	2	11
F. caroliniana	Arkansas	—	—	—	—	13,660	5,744	1	13
F. dipetala	California	—	—	11,025–19,400	5,000–8,800	—	—	3+	—
F. excelsior	Europe	18	14	10,470–15,430	4,750–7,000	—	—	—	7–8
	USA	—	—	8,800–15,430	4,000–7,000	13,000	5,900	10+	—
F. latifolia	—	—	—	22,000–31,000	10,000–14,060	—	—	—	—
F. nigra	Great Lakes region	—	—	13,450–20,950	6,100–9,500	17,860	8,100	4	—
F. pennsylvanica	Midwest & Great Lakes region	—	—	24,250–54,250	11,000–24,000	38,850	17,260	51	—
	Arkansas & Mississippi	9†	7.2	35,060–74,150	15,900–35,630	46,200	20,950	9	10
F. profunda	Mississippi	—	—	6,830–7,270	3,000–3,300	7,050	3,200	5	—
F. quadrangulata	—	—	—	13,000–15,430	5,900–7,000	—	—	2+	—
F. uhdei	Hawaii	—	—	34,200–38,600	15,500–17,500	36,380	16,500	10	—
F. velutina	—	—	—	28,850–61,740	13,000–28,000	45,420	20,600	6	—

Sources: Bonner (1974), Owston (1990).
* Number of seeds per volume Midwest = 394,500/hl (139,000/bu); Mississippi = 326,540 (115,000/bu).
† Number of seeds per volume Arkansas–Mississippi = 416,620/hl (146,800/bu).

Pregermination treatments. Most species of ash exhibit a complex dormancy that is due to both seedcoat and internal factors. The seedcoat effect apparently is based on restriction of moisture and oxygen uptake, and scarification or removal of pericarp, seedcoats, or both will lead to quick germination of several species of ash (Arrillaga and others 1992; Bonner 1974; Gendel and others 1977; Marshall 1981). Karrfalt (1992) reported that de-winging white ash seeds with a brush machine led to quicker germination, apparently because the brushes scarified the seedcoats. Internal dormancy appears to be related to germination inhibitors or their balance with germination promoters (Kentzer 1966; McBride and Dickson 1972; Sondheimer and others 1974; Stinemetz and Roberts 1984; Tinus 1982; Tzou and others 1973). European and black ashes also have immature embryos that must complete development during after-ripening for good germination (Nikolaeva 1967; Suszka and others 1996; Vanstone and LaCroix 1975; Walle 1987). This condition has led to the use of warm incubation of imbibed seeds prior to cold stratification for overcoming dormancy in these species. For European ash, Tylkowski (1990, 1993) has recommended 16 weeks at 15 or 20 °C, followed by 16 weeks at 3 °C. Seed moisture content should be from 55 to 60% during this period, and a 1-hour re-soak in water should be carried out weekly in the warm phase and every 2 weeks in the cold phase. The warm phase can be less than 16 weeks if periodic examinations of longitudinal cuts of seeds show the embryo to have reached 80 to 90% of the seed length (Suszka and others 1996). In many cases, the same warm/cold treatment approach has been beneficial to green and white ashes from the northern portions of their ranges (Bonner 1974; Cram 1984; Tinus 1982). Cold stratification alone is usually sufficient for sources of these 2 species from the southern portion of their ranges (Bonner 1973, 1975). The degree of dormancy also seems related to seed age: older stored seeds appear more dormant than freshly collected ones (Bonner 1974; Tinus 1982). Shamel ash does not require pretreatment for prompt germination (Francis 1990). Pretreatment recommendations for dormant ashes are summarized in table 5. Germination is epigeal (figure 4) and may occur the spring following seedfall, or seeds may lie dormant in the litter for several years before germinating.

Germination tests. Official germination recommendations for ashes call for either 56 days (ISTA 1993) or 28 days (AOSA 1993) with stratified seeds on blotter paper with diurnally alternating temperatures of 30 °C in light and 20 °C in the dark. Prescriptions for individual species and some representative results of tests with stratified seeds

Figure 4—*Fraxinus nigra*, black ash: seedling development at 1, 2, 8, and 14 days after germination.



under or near these conditions are given in table 6. Recent research in Italy with European and flowering ashes suggests that alternating temperatures of 25 °C for 8 hours and 5 °C for 16 hours (both in the dark) are better than 30/20 °C because of the greater amplitude of temperature change (Piotto 1994).

Because of the dormancy encountered with seeds of this genus, rapid viability tests by embryo excision or tetrazolium staining are preferred over actual germination tests for all except green ash (AOSA 1993; ISTA 1993). Staining with indigo-carmine has been popular and successful with European ash (Suszka and others 1996). Rapid testing with x-rays is also possible, but relating the images to seed quality is reported to be difficult with white ash (Houston 1976).

Nursery practice. Ash seeds may be sown in the fall without stratification, especially in the northern United States. Seeds should be planted as soon as collected, preferably by mid-October (Eliason 1965). European ash is usually sown unstratified in August or September or stratified for 16 to 18 months and sown in March or April in England. Fall-sown seeds of this species will germinate the following spring, but yield is erratic (Aldhous 1972). Seeds treated with warm incubation, followed by cold stratification, as described earlier, can be stored non-dormant at –3 °C for up to 8 weeks before sowing, or dried up to 8 to 10% moisture at 20 °C and stored for up to 2 years before sowing (Suszka and others 1996). Fall-sown beds should be mulched with burlap or straw, and the mulch removed as soon as germination starts in the spring. For spring-sowing, stratified seeds should always be used. Seeds of most species should be drilled in rows 15 to 30 cm (6 to 12 in) apart at rates of 80 to 100 seeds/m (25 to 30/ft), or broadcast to achieve a bed density of 105 to 160 seedlings/m^2 (10 to 15/ft^2) (Bonner 1974; Williams and Hanks 1976).

Table 5—*Fraxinus,* ash: stratification treatments to promote germination

		Warm period		Cold period	
Species	**Medium**	**Temp (°C)**	**Days**	**Temp (°C)**	**Days**
F. americana	Sand	20–30	30	5	60
	Plastic bag*	—	—	3	56–84
F. caroliniana	Plastic bag*	—	—	3	60
F. dipetala	Sand, peat	—	—	2–5	90
F. excelsior	Sand†	—	—	Cool‡	480–540
	Sand, peat, or plastic bag*	20	60–90	4–5	60–90
F. nigra	Sand	20–30	60	5	90
	Peat	21	126	4	90
F. ornus	Soil	Warm‡	30	Cold‡	90
F. pennsylvanica	Moist substrate	20	60	0–5	210
	Plastic bag*	—	—	2–5	60–150§
F. profunda	Moist paper	—	—	5	60
F. quadrangulata	Sand	20–30	60	5	90
F. uhdei	—	—	0	—	0
F. velutina	Sand, soil	—	—	2–5	90

Sources: Bonner (1974), Bonner (1975), Francis (1990), Mirov and Kraebel (1939), Soljanik (1961), Steinbauer (1937), Vanstone and LaCroix (1975), Walle (1987).
* Naked stratification in plastic bags.
† In outdoor pits.
‡ Exact temperatures not given.
§ For seeds from southern sources, 2 or 3 months is enough, but for seeds from northern sources, 5 months is needed. The warm period is helpful but not essential for southern sources (Bonner 1974; Eliason 1965).

Table 6—*Fraxinus,* ash: germination test conditions and results for stratified seed

	Germination test conditions					Germination rate		Germination percentage	
Species	Daily light period (hrs)	Medium	Temp (°C) Day	Night	Days	Amt (%)	Days	Avg (%)	Samples
F. americana	—	Sand	30	20	24–40	49	24	54	3
	8	Paper	25	15	56	—	—	68	1
F. caroliniana	8	Kimpak	30	20	60	54	14	61	3
F. dipetala	—	—	—	—	—	—	—	71	2
F. excelsior	—	—	—	—	—	—	—	61	4
F. nigra	—	Sand	30	20	40	7	18	20	6
F. ornus	—	Soil	—	—	—	—	—	49	3
F. pennsylvanica	8	Paper	30	20	30–34	70	20	76	6
	16	Paper	30	20	42	71	21	80	3
	NDL	Sand	—	—	30	—	—	89	3
F. profunda	NDL	Soil	30	16	45	32	20	48	1
F. quadrangulata	—	Sand	30	20	56	43	40	44	1
F. uhdei	8	Kimpak	30	20	40	66	21	69	4
F. velutina	—	Sand	30	20	—	—	—	33	5

Sources: Bonner (1974), Bonner (1975), Cram (1984), Mirov and Kraebel (1939), Soljanik (1961), Tinus (1982).
NDL = Natural daylength in a greenhouse.

Recommendations for Shamel ash are 215 to 320 seedlings/m² (20 to 30/ft²) (Bonner 1974). Seeds should be covered with 6 to 19 mm (1/4 to 3/4 in) of soil, and shading of the beds for a short time after germination may be desirable. Some ash species are subject to severe defoliation by a fungus—*Marssonina gloeodes* (H.C. Greene) H.C. Greene—especially in northern nurseries, and control measures may be necessary. The normal outplanting age for North American ashes is 1+0, or in some cases 2+0. European ash stock is ordinarily outplanted as 1+1 or 2+0.

Shamel ash coppices readily, and shoot tip cuttings from these sprouts can be rooted (Francis 1990). Cuttings of green ash from 1+0 seedlings or 1-year-old coppice shoots root easily, but older material is extremely difficult to propagate (Kennedy 1990). Air-layering of green ash limbs on 5-year-old trees in Mississippi was 22% successful (Bonner 1963). Other ash species are not easily rooted, but ornamental selections are commonly propagated by budding and grafting (Dirr and Heuser 1987).

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Sterculiaceae—Sterculia family

Fremontodendron Coville

fremontia, flannelbush

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Growth habit, occurrence, and use. The genus *Fremontodendron* is endemic to California and adjacent areas of Arizona and Baja California. It includes 2 common and 1 rare species (table 1) (Kelman 1991). Fremontias are shrubs or small trees with evergreen leaves that are alternate, entire to lobed, and covered with characteristic stellate hairs. They are components of chaparral vegetation and are able to resprout abundantly after fire. The resprouts are valuable forage for deer and domestic livestock (Nord 1974). Fremontias are handsome plants that are used extensively in California for roadside and residential landscaping and are becoming known as native garden plants (Holmes 1993). Interspecific hybrids such as *F. mexicanum* × *F. californicum* 'California Glory' have been developed for horticultural use. Fremontias are drought-tolerant and have been successfully planted for watershed protection in wildland settings (Nord 1974).

Flowering and fruiting. The large, perfect, yellow to copper-colored flowers appear on the plants from April through June. They have a single perianth series that is fused into a saucer shape, 5 stamens fused into a staminal column, and a superior ovary. The flowers produce abundant nectar and are pollinated mostly by large native bees (Boyd 1994). Much of the seedcrop may be destroyed by insect larvae prior to dispersal, at either the flower bud or the immature fruit stage (Boyd and Serafini 1992). The large, bristly, 4- to 5-chambered capsules ripen from July to September and split open at the tip. The numerous reddish brown to black seeds are cast from the capsules by wind, hail, or animal disturbances (Nord 1974). The seeds have a more or less well-developed caruncle or elaiosome at the micropylar end (figure 1), and there is good evidence of dispersal by harvester ants, at least for eldorado fremontia (Boyd 1996). In that species, the testa is much thicker under the elaiosome than at other positions on the seed (figure 2), apparently as a protection from the ant dispersers that eat the elaiosomes. These ants act as predators on seeds that do not possess an elaiosome "bribe."

Seed collection, cleaning, and storage. Fremontias grow rapidly and reach reproductive age the second season

Figure 1—*Fremontodendron californicum*, California fremontia: seeds.

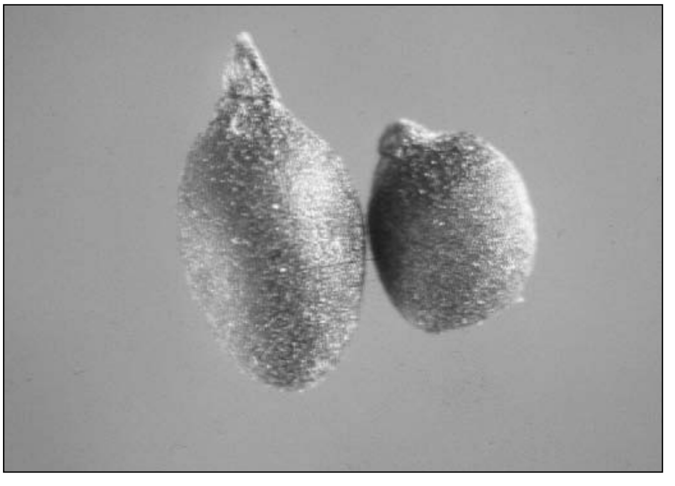
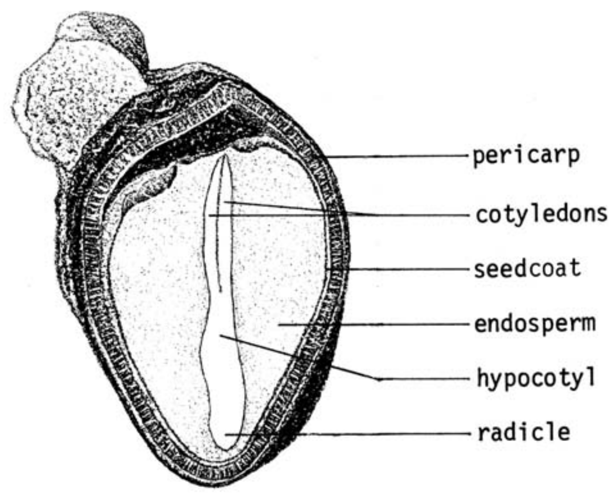


Table 1—*Fremontodendron,* fremontia: common names and occurred

Scientific name	Common name(s)	Distribution
F. californicum **(Torr.) Coville**	**California fremontia,** flannelbush	N to S California & central Arizona
F. decumbens **R. Lloyd**	**eldorado fremontia,** California flannelbush	One location in Eldorado Co., California
F. mexicanum **A. Davids.**	**Mexican fremontia,** Mexican flannelbush	San Diego Co., California & N Baja California

Source: Kelman (1991).

Figure 2—*Fremontodendron californicum*, California fremontia: longitudinal section through a seed



after emergence. Seed production is reportedly better in cultivated than in naturally occurring individuals (Nord 1974). The ripened seed may be retained in the capsule for up to a month, but it is best to collect seeds when the first capsules begin to split open (Nord 1974). Capsules are collected by hand stripping or beating into containers. Gloves are recommended to protect hands against the irritating capsule bristles. Capsules that do not open soon after collection should be soaked in water for a few minutes, then dried before extraction. Capsules may be broken up in a hammermill or other threshing device, and the seeds cleaned out by screening and fanning (Nord 1974). Seed weight varies among and within species (table 2). Fremontia species form persistent seed banks in the field and are probably long-lived in storage (orthodox). In field seed bank experiments with eldorado fremontia, there was little loss of viability over a 7-year period (Boyd and Serafini 1992).

Germination and seed testing. Fremontia seeds are not permeable to water and must be scarified, either mechanically or by heat, in order for them to imbibe the water (Boyd and Serafini 1992; Emery 1988; Nord 1974). For nursery propagation, the seeds are given a hot water treatment, that is, immersion in hot water (85 to 95 °C) that is then allowed to cool for 12 to 24 hours. In nature, wildfire provides the heat stimulus. Most, if not all, recruitment of new plants takes place after fire. Seedlings from plantings into mature chaparral using artificially scarified seed were destroyed by herbivores or succumbed to drought (Boyd and Serafini 1992). Although scarification is a requirement for imbibition, it may not be sufficient to induce germination. Seed collections of California fremontia and some collections of Mexican fremontia may also require a 2- to 3-month chilling treatment at 5 °C (Emery 1988; Nord 1974). In a study by Keeley (1987), a collection of California fremontia responded only minimally to heat shock treatments, perhaps because the chilling requirement was not fully met. For eldorado fremontia, scarification with chilling produced no significant increase in seedling emergence over scarification alone, whether the scarification was mechanical or heat-induced (Boyd and Serafini 1992). A heat treatment of 5 minutes at 100 °C plus incubation with charate from chamise (*Adenostoma fasciculatum* Hook. & Arn.) charcoal produced significantly higher emergence than heat shock scarification alone (72 vs. 58%). Charate-stimulated germination has been reported for other chaparral species and represents an adaptation for detecting the occurrence of fire (Keeley 1987, 1991).

Seed quality evaluation for fremontia may be carried out using tetrazolium staining (Boyd and Serafini 1992). The testa is first nicked and the seeds allowed to imbibe water overnight. They are then immersed in 1% tetrzolium chloride for 6 hours and bisected longitudinally for evaluation. The embryo is linear and is embedded in abundant endosperm (Nord 1974). Germination testing is difficult

Table 2—*Fremontodendron,* fremontia: seed yield data

	Seeds/weight		Maximum	
Species	**/kg**	**/lb**	**Fill %**	**germination %**
F. californicum	30,870–55,125	14,000–25,000	53	50
F. decumbens	26,460	12,000	100	72
F. mexicanum	44,100–66,150	20,000–30,000	100	55

Sources: Boyd (1966), Keeley (1991), Nord (1974).

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because the period of germination is apparently relatively long even for scarified and chilled seeds (Boyd and Serafini 1992; Nord 1974).

Field seeding and nursery practice. Direct-seeding in the fall using hot-water scarified seed has been successful for California fremontia (Nord 1974). Because of the relatively large seed size, spot-seeding or drilling with a rangeland drill at a depth of 10 to 25 mm (0.4 to 1 in) gave much better results than hydroseeding or broadcasting. Successful spring seedings required the use of chilled seed.

Fremontia species have been produced as container stock using the hot water soak plus chilling protocol for seed germination described above (Emery 1988; Nord 1974). They are also readily produced from stem cuttings (Nord 1974).

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