Ericaceae—Heath family

Kalmia latifolia L.

mountain-laurel

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Synonyms. *Kalmia latifolia* var. *laevipes* Fern.

Other common names. Broad-leaved laurel, calico-bush, spoonwood, ivy, mountain ivy, big-leaved ivy, ivy-bush, laurel-leaves, and calmoun.

Growth habit and occurrence. The genus *Kalmia* L. consists of about 6 species of evergreen or deciduous shrubs native to North America and Cuba (LHBH 1976). Of these species, mountain-laurel—*Kalmia latifolia* L.—has for a number of reasons attracted the most attention. Mountain-laurel is a broad-leaved, evergreen shrub that is dense and symmetrical when young but develops an open, loose habit with age (Dirr 1990). Typically, the shrub reaches a height and spread of 1.5 to 2 m. However, heights of 4.6 to 9 m have been reported (Bridwell 1994; Dirr 1990). The species has a wide range, from coastal Maine to northwestern Florida, primarily along the Appalachian Mountain range, westward to Louisiana and northward into southern Ohio and Indiana (Fernald 1950; Jaynes 1997). This range includes USDA Hardiness Zones 4 to 9 (Dirr 1990). Mountain-laurel is often found in rocky or gravelly woods and clearings, typically on acid or sterile soils (Fernald 1950). A common associate of mountain-laurel in the mountainous regions of the southern United States is rosebay rhododendron—*Rhododendron maximum* L. Together, these 2 species form almost impenetrable thickets, sometimes known locally as "laurel slicks" or "rhododendron hells" (Olson and Barnes 1974).

Use. Mountain-laurel is an excellent ornamental shrub for shady borders and for naturalizing (Dirr 1990). As an understory shrub, it effectively prevents water runoff and soil erosion (Jaynes 1997). Clumps and thickets of mountain-laurel are a haven for wildlife, providing year-round cover and protection (Jaynes 1997). Practical considerations aside, Rehder (1986) has described mountain-laurel as one of the most beautiful American flowering shrubs. In addition to the value of the species as a landscape plant, the foliage is also used in Christmas decorations and the fine-grained and durable wood is used for making pipes and other items (Jaynes 1997). Unfortunately, the foliage of mountain-laurel is poisonous and caution should be exercised when planting in a landscape utilized by young children or grazing animals (Jaynes 1997; Mabberley 1993).

Geographic races and hybrids. Five races of mountain-laurel have been identified:

- *Kalmia latifolia* f. *angustata* Rehd.
- *Kalmia latifolia* f. *fuscata* (Rehd.) Rehd.
- *Kalmia latifolia* f. *myrtifolia* (Bosse) K. Koch.
- *Kalmia latifolia* f. *obtusata* (Rehd.) Rehd.
- *Kalmia latifolia* f. *polypetala* (Nickolsen) Beissner, Schelle, & Zabel.

There are 4 interspecific crosses that produce progeny:

- *K. polifolia* Wangenh. × *K. latifolia*—reciprocal cross did not result in seed set (Jaynes 1997)
- *K. latifolia* × *K. hirsuta* Walt.—reciprocal cross also set seed (Jaynes 1997)
- *K. angustifolia* L. × *K. latlifolia*—reciprocal cross did not result in seed set (Jaynes 1997)
- *K. polifolia* × *K. microphylla* (Hook.) A. Heller—reciprocal cross also set seed (Jaynes 1997)

There is also 1 intergeneric cross known to produce progeny:

- *K. latifolia* × *Rhododendron williamsianum* Rehd. & Wils.—putative hybrid (Jaynes 1997)

Flowering and fruiting. Mountain-laurel typically flowers between April and June, depending on local climate (Radford and others 1968). Floral color ranges from white to a deep rose with purple markings (Dirr 1990). There have been many cultivar selections across this color spectrum

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(Jaynes 1997). An individual shrub commonly has hundreds of terminal inflorescences (corymbs), each with 50 to 300 flowers (Rathcke and Real 1993). Flower size also varies with different forms and cultivars of the species, but the normal diameter ranges from 2 to 2.5 cm (Dirr 1990). Flowers have an unusual pollination mechanism, with 10 anthers held in pouches along the inside of the corolla (Mabberley 1993). When pollen is ripe, a visiting insect—typically a bumble bee (*Bombus ternarius* Say)— triggers the release of the anthers (Rathcke and Real 1993). The pollen is then cast over the insect so that cross pollination can occur with the next flower of mountain-laurel visited by the insect. Typically, mountain-laurel is considered to be a non-selfing species (Fryxell 1957; Jaynes 1997). A recent study by Rathcke and Real (1993) suggested that certain populations of mountain-laurel may be able to self-fertilize in the absence of pollinators. Autogamy seems most likely to have evolved for reproductive assurance under competition for pollinator service (Rathcke and Real 1993). The fruit is a brown, 5-valved, globular dehiscent capsule about 6 mm in diameter, borne in clusters, that matures in September and October (Radford and others 1968) (figure 1).

Collection of fruits and seed extraction. Once seed capsules have turned brown and dried, seeds are mature and ready for harvest. Harvested capsules should be placed in a coin envelope, paper bag, or small vented container and allowed to dry for an additional 2 to 4 weeks at about 21 °C. Capsules will then open, and their seeds can be shaken loose (Blazich 1996; Jaynes 1997). The seeds are cleaned by gently shaking them down a creased sheet of paper (Jaynes 1997). Seeds will move down the paper faster than the chaff. This process should be repeated several times until clean seeds are separated. If the capsules are collected prematurely, they will not dehisce and must be crushed. This treatment results in large amounts of debris that can be removed effectively by sieving. Viable seeds can also be separated from chaff and empty seeds by using an air-column blower or by placing crushed capsules in water and allowing viable seeds to sink (Jaynes 1997). Seeds of mountain-laurel are extremely small, with cleaned pure seeds averaging 50,000/g (1.4 million/oz) (Jaynes 1997). Each seed is about 1 mm long and 0.3 mm wide, with a ribbed or striated surface (figures 2 and 3).

Storage. Seeds of mountain-laurel can remain viable for several years when stored at room temperature (Glenn and others 1998; Wyman 1953). However, longevity of seeds can be extended greatly (up to 15 years) if seeds are stored at 4.4 °C (Jaynes 1997). When dried to a moisture content of 5%, seeds have been stored successfully for 4 years at –18 or 4 °C with no loss in viability (Glenn and others 1998). Storage under these conditions suggests that the species is orthodox in storage behavior, and that viability can be maintained for extremely long periods of time.

Pretreatments and germination tests. After harvest, there is no inhibiting dormancy, and seeds germinate readily with no pretreatment necessary (Fordham 1960; Jaynes 1997). However, stratification (moist-prechilling) for 8 weeks or soaking seeds overnight in 200 ppm gibberellic acid may increase germination (Jaynes 1997). Seeds of mountain-laurel require light for germination (Jaynes 1971; Malek and others 1989). Malek and others (1989) conducted a 30-day germination study of seeds from a native popula-

Figure 1—*Kalmia latifolia*, mountain-laurel: cluster of capsules (**top**) and a single capsule (**bottom**).

Figure 2—*Kalmia latifolia*, mountain-laurel: seeds.

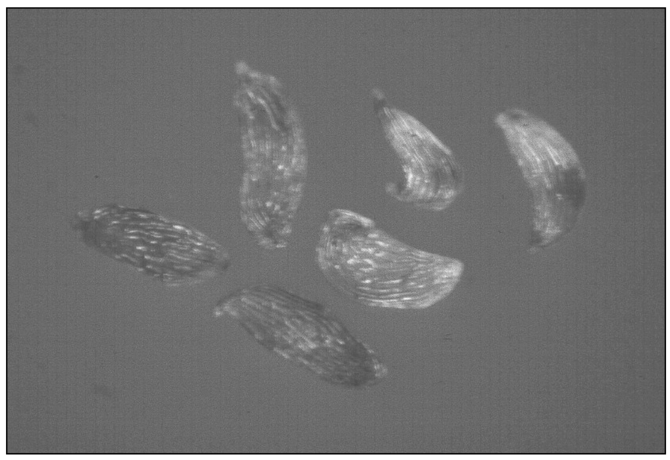
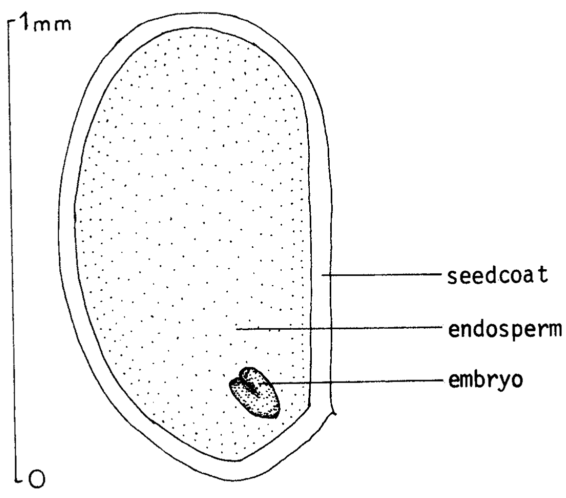


Figure 3—*Kalmia latifolia*, mountain-laurel: longitudinal section of a seed.



tion growing in Avery County, North Carolina. Seeds were germinated at 25 °C or an 8/16-hour thermoperiod of 25/15 °C with daily photoperiods of 0, $^1/_2$ hour, $^1/_2$ hour twice daily, 1 hour, or 2, 4, 8, 12, or 24 hours. The cool-white fluorescent lamps used as the light source provided a photosynthetic photon flux (400 to 700 nm) of 42 μmol/m^2/sec (3.2 klux). For both temperatures, no germination occurred during the 30-day test period for seeds not subjected to light. At 25 °C, increasing the length of the photoperiod increased germination, with germination of 82 and 90% occurring by day 27 for the 12- and 24-hour photoperiods, respectively. The alternating temperature of 25/15 °C enhanced germination when light was limiting. At this temperature, germination ≥ 87% occurred by day 24 for photoperiods ≥ 8 hours. There are no test methods prescribed for official testing of this species.

Nursery practice. Seeds should be sown directly on peat, placed under lights, and maintained at 24 °C (Dirr 1990). Other media can also be used (Jaynes 1997). Initial seedling growth is very slow (Dirr and Heuser 1987; Weinberg 1984), although Malek and others (1992) reported that seedling growth can be optimized under long-day conditions with 9/15-hour day/night temperatures of 22 to 26/22 °C. To stimulate seedling growth further, the ambient atmosphere can be supplemented with 2,000 ppm carbon dioxide (Jaynes 1997). Seedlings should be transplanted 2 to 6 months after germination into pots with a medium consisting of 70 liters (2 bu) peat, 35 liters (1 bu) perlite, 17 liters ($^1/_2$ bu) coarse sand, and 15 to 30 g (0.5 to 1 oz) hydrated lime and fertilized every 3 weeks with a 20-20-20 ($N:P_2O_5:K_2O$) water-soluble fertilizer at a rate of 1.2 g/liter (0.04 oz/1.06 qt) (Jaynes 1997).

Traditionally, mountain-laurel has been propagated vegetatively by layering, grafting, and stem cuttings. However, there has been limited success with vegetative propagation by stem cuttings and results appear to be genotype specific (Dirr and Heuser 1987). On the other hand, micropropagation (tissue culture) has proven very successful and has led to wide availability of outstanding selections and hybrids of the species (Lloyd and McCown 1980).

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K

Araliaceae—Ginseng family

Kalopanax septemlobus (Thunb. ex A. Murr.) Koidz.

castor-aralia

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Synonym. *K. pictus* (Nakai).

Growth habit, occurrence, and use. The genus *Kalopanax* comprises 1 species of deciduous, small to medium-sized tree that is native to China, Japan, eastern Russia, and Korea (LHBH 1976; Ohashi 1994). Castor-aralia—*K. septemlobus* (Thunb. ex A. Murr.) Koidz.—was introduced in 1865 and has been used primarily for ornamental purposes, as a shade tree yielding a tropical effect in USDA Hardiness Zones 4 to 7 (Dirr 1990; Hillier 1991; Krüssmann 1984; van Gelderen and others 1994; Wijnands 1990). It is a valuable tree in China (Zhao and others 1987) and the wood may be suitable for bentwood, carving, and some interior use (KRRT 1987). The dried bark has been used as a medicine in China for various ailments (Sano and others 1991). Analysis of the nutrient content of leaves of castor-aralia showed plentiful levels of calcium, magnesium, zinc, iron, and beta-carotene, making it a potential food source of high nutritive value (Liu and others 1998). Phytochemical investigations have allowed the isolation and characterization of saponin and phenolic compounds (Porzel and others 1992; Sano and others 1991; Shao and others 1989, 1990; Sun and others 1990) that are reported to show preventive activity against stress-induced changes in mice.

Castor-aralia is an upright, oval-rounded tree that can obtain heights of 24.4 to 27.4 m in the wild, but under cultivation practices usually 12.2 to 18.3 m (Dirr 1990). The branches are coarse, stout, and bear numerous broad-based prickles (Dirr 1990; Hillier 1991). The leaves are quite variable—but somewhat similar in shape to sweetgum, *Liquidambar styraciflua* L.—changing to yellow or red in the fall (Dirr 1990). Another variety—*K. septemlobus* var. *maximowiczii* (Van Houtte) Hand.-Mazz.—has leaves that are deeply lobed (5–7) and incised to beneath the middle of the blade (Krüssmann 1984).

Flowering and fruiting. The perfect, white flowers, which bloom in July to early August (sometimes as early as May in parts of Japan), are produced in numerous umbels, forming large terminal panicles that measure 30.5 to 61 cm across (Dirr 1990; Hillier 1991; Rudolf 1974). The fruits are globose drupes about 0.4 cm wide with a persistent style (bluish black in color) that contains 2 flat seeds (Dirr 1990; Krüssmann 1984). The fruits, which ripen in September–October, have a fleshy coat and are relished by birds (Dirr 1990; Dirr and Heuser 1987).

Collection of fruits; extraction, cleaning, and storage of seeds. The fruits are harvested by hand or shaken onto canvas as they ripen in September–October (Rudolf 1974). Fruits should be run through a macerator with water to extract the seeds (figure 1). Although more recent information was not attainable, Sins (1925, cited by Rudolf 1974) reported that about 3.6 to 4.5 kg (8 to 10 lb) of clean seeds can be obtained from 45.4 kg (100 lb) of fresh fruits. The number of cleaned seeds per weight was 220,000/kg (99,790/lb) (Satoo 1992). The seeds (figure 2) have small embryos and contain endosperm tissue (Rudolf 1974). Reports indicate that seeds can be kept satisfactorily for 1 year under ordinary storage conditions (Sins 1925, cited by Rudolf 1974). However, the use of sealed containers kept at 0 to 5 °C is suggested for longer storage periods.

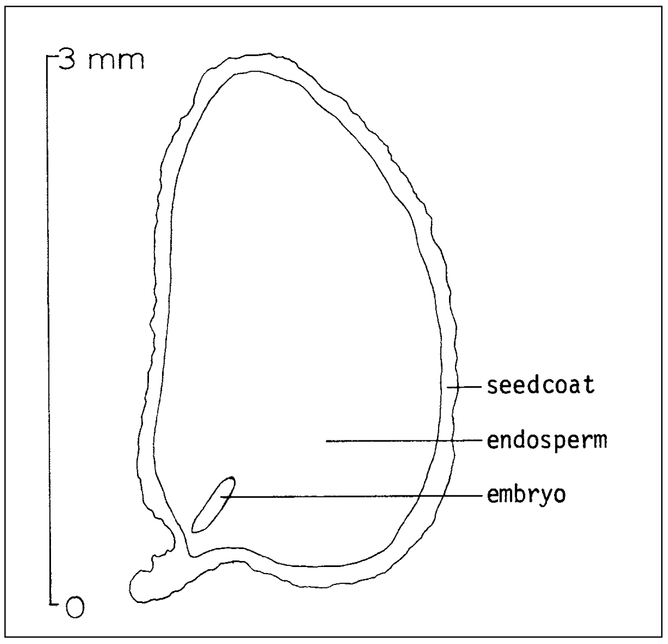
Figure 1—*Kalopanax septemlobus*, castor-aralia: cleaned seed extracted from the fleshy fruit.

Pregermination treatments. Under natural conditions, castor-aralia seeds require a 2-year germination period (Sato 1998). Dormancy of the seed is caused by neutral (coumarin) and acid (abscisic) inhibitors present in the seedcoat and endosperm, and by an impermeable seedcoat (Dirr 1990; Huang 1987a&b). Warm temperatures of 15 to 25 °C for 3 to 5 months followed by cold stratification at 0 to 5 °C for 2 to 3 months will overcome seed dormancy and give reasonable germination (Dirr and Heuser 1987; Huang 1986, 1987b; Sato 1998; Xu and Han 1988). Soaking the seeds in sulfuric acid for 30 minutes will substitute for the warm stratification period (Dirr and Heuser 1987; Rudolf 1974).

Germination tests. Tests in germinators or sand flats for 60 days is suggested (Rudolf 1974).

Nursery practice and seedling care. Fresh seeds that have been cleaned and dried can be sown in the fall but will not germinate for 2 years (Dirr and Heuser 1987; Satoo 1992). Stratified seeds should be sown in the spring (Rudolf 1974). The seeds should be sown in well-prepared beds at a rate of 1,760 to 3,300/m^2 (164 to 307/ft^2) to give 200 to 300 seedlings/m^2 (19 to 28/ft^2) (Satoo 1992). Castor-aralia can be propagated by root cuttings (Dirr and Heuser 1987; Macdonald 1986). Root cuttings, 7.6 to 10.2 cm (3 to 4 inches) in length, should be dug soon after frost and then placed upright (proximal end) in a medium kept in a cool greenhouse with bottom heat (Dirr and Heuser 1987). Stem cuttings are difficult, if not impossible, to root from mature trees (Dirr and Heuser 1987).

Figure 2—*Kalopanax septemlobus*, castor-aralia: longitudinal section through a seed.



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K

Chenopodiaceae—Goosefoot family

Kochia Roth

kochia

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Growth habit, occurrence, and use. Two woody-based non-rhizomatous sub-shrub species of kochias are found in the western United States. The widely distributed native, gray molly, and its introduced and closely related counterpart (Blackwell and others 1978), forage kochia, are found in salt-desert, sagebrush, pinyon–juniper, and dry mountain brush communities (table 1). Erect to steeply ascending annual stems growing from a woody base and long-lived prostrate branches attain heights of 5 to 50 cm for gray molly (Welch and others 1987) and 10 to 100 cm for forage kochia (Baylan 1972).

Each species provides nutritious winter forage for livestock (Baylan 1972; Blauer and others 1976). Variability in preference by livestock (Shishkin 1936) and mule deer (*Odocoileus hemionis*) (Davis and Welch 1985) has been observed among ecotypes of forage kochia.

Both species have potential for use in revegetation of saline and alkaline soils on arid and semi-arid sites (Blauer and others 1976; Clarke and West 1969; Francois 1976; Romo and Haferkamp 1987) and forage kochia has been used successfully in stabilizing mine spoils (Frischknecht and Ferguson 1984). Perhaps the greatest potential use of forage kochia is in providing cover and forage on degraded western cold-deserts (McArthur and others 1974; Monsen and Turnipseed 1990; Pendleton and others 1992). Where established, it effectively competes with weeds such as halogeton (*Halogeton glomeratus* (Bieb.) C.A. Mey.) and cheatgrass (*Bromus tectorum* L.) (Blauer and others 1993; McArthur and others 1990). Natural spread of forage kochia from seeds can be rapid where perennial cover is lacking. The high water content of stems and leaves during summer months and crown sprouting capacity make this species especially desirable for desert landscapes prone to high fire frequencies (Kitchen and Monsen 1999).

Geographic races and hybrids. Blackwell and others (1978) concluded that the random variation in pubescence in gray molly did not justify dissection of this species to subspecies level. Conversely, forage kochia is a complex species represented by 3 known ploidy levels (2X, 4X, and 6X) (Pope and McArthur 1977) and extensive phenotypic variation in plant stature, stem color and diameter, leaf size and pubescence, growing season, and adaptability to soils (Baylan 1972). Numerous regional ecotypes have been grouped into as many as 4 species; however, a single species with 2 subspecies—*virescens* (Frenzl) Prat. (green-stem) and *grisea* Prat. (gray-stem and highly variable)—is the most commonly accepted (Baylan 1972).

About 40 accessions of forage kochia have been introduced to the United States, primarily for evaluation as candidates for revegetation of disturbed arid and semi-arid regions in the western United States (Kitchen and Monsen 1999). To date, a single cultivar, 'Immigrant' (2X, ssp.

Table 1—*Kochia,* kochia: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***K. americana* S.Wats.** *K. vestita* (S.Wats.) Rydb. *K. americana* var. *vestita* S.Wats.	**gray molly,** green molly	Oregon to Montana S to California, Arizona, & New Mexico
***K. prostrata* (L.) Schrad.** *K. suffruticulosa* Lessing *Salsola prostrata* L.	**forage kochia,** prostrate kochia, summer-cypress, prostrate summer-cypress	Deserts, steppes, & mtns of Central Asia, W to the Mediterranean Basin, & E to Manchuria; naturalized in W North America

Sources: Shishkin (1936), Welsh and others (1987).

virescens), has resulted from this research (Stevens and others 1995). 'Immigrant' has been planted on several thousand acres in Utah, Idaho, and surrounding states. Small plantings of other accessions (ssp. *grisea*) also exist (Blauer and others 1993; McArthur and others 1990; Monsen and Kitchen 1995; Monsen and Turnipseed 1990).

Flowering and fruiting. Kochia flowering structures are described as one to several, mostly perfect, inconspicuous, sessile flowers occurring in axils of foliose bracts (Welsh and others 1987). Stems are potentially floriferous throughout (Blackwell and others 1978). Flowering is indeterminate from May to August for gray molly and from July to September for forage kochia (Shishkin 1936). The fruit is a 1-seeded utricle that is enclosed in a thin, fragile perianth (figure 1). The perianth is horizontally winged at maturity. Perianth pubescence for forage kochia is highly variable (Baylan 1972). Seeds are oval to orbicular in shape and 1 to 2 mm in diameter. The embryo is bent into roughly the shape of a horseshoe, a common configuration for this family (figure 2).

Fruit collection and cleaning. Fruits of forage kochia ripen from September to November (Baylan 1972) whereas those of gray molly are generally ripe by mid-October. Fruits are easily dislodged when fully ripened and dry. They are hand-harvested by stripping individual stems or by beating seeds into a hand-held hopper with a badminton racket or similar device. Mechanical harvest techniques for forage kochia seeds include mowing stems just before fruits are ready to shatter, drying, and combining. Vehicle-mounted mechanical sweepers are also used to harvest fully ripened fruits from solid stands (Stevenson 1995). Although harvesting the fruits before the seeds are fully ripened can reduce losses to shattering, it also results in lower seed viability

Figure 1—*Kochia prostrata*, forage kochia: fruits in perianth.

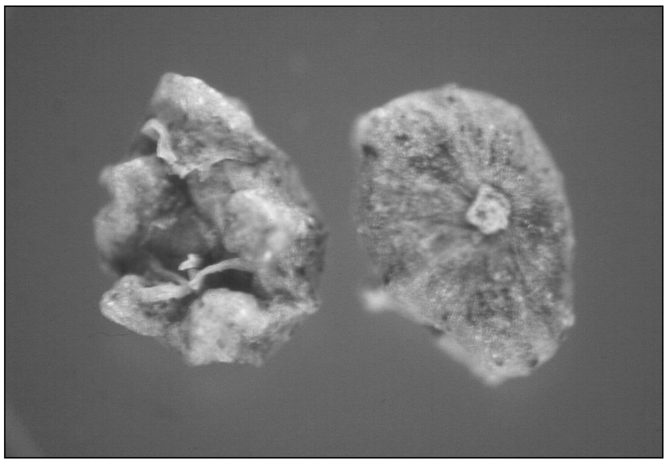
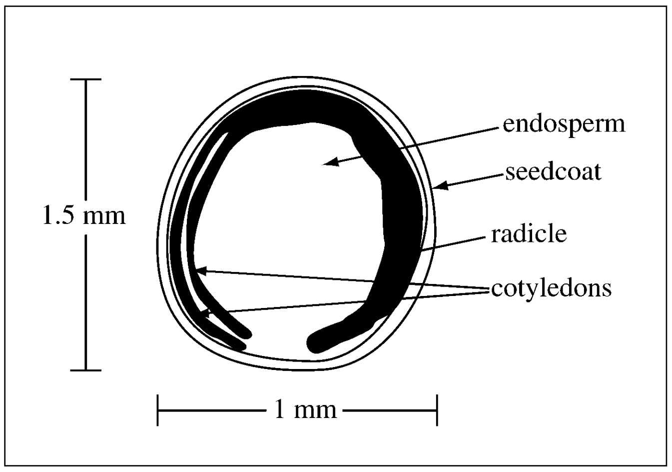


Figure 2—*Kochia prostrata*, forage kochia: longitudinal section through a seed.



percentages (Waller and others 1983).

The cleaning process removes empty fruits and fragments of fruits, leaves, and small stems using a barley debearder and multi-screened fanning mill (air-screen cleaner). Attainable purities for 'Immigrant' forage kochia depend upon harvest method and experience (Stevenson 1995). Hand-picked lots can usually be cleaned to at least 90% purity. Purities for lots harvested with mechanical harvesters are slightly lower (80 to 85%), whereas the combine method seldom produces purities greater than 70%. High-purity lots contain from 500,000 to 1,000,000 seeds/kg (225,000 to 450,000/lb) (Kitchen and Monsen 1999).

Storage. Kochia seeds are orthodox in storage behavior, but they are short-lived when storage temperatures are above 5 °C and seed moisture content is not controlled (Jorgensen and Davis 1984). Significant losses in forage kochia seed viability have been reported as early as 2 months after harvest (Baylan 1972); however, losses usually do not occur during the first 6 months of storage. Young and others (1981) reported viabilities of 18 to 34% for lots representing 13 accessions after 4 years of warehouse storage. Seed moisture contents above 7 to 8% and warm storage temperatures accelerate seed mortality. Baylan (1972) attributed this to loss of limited seed reserves through accelerated respiration rates. Storage life can be extended by drying seeds to between 4 and 8% water content and storing them in sealed containers at cool (< 5 °C) temperatures (Kitchen and Monsen 1999).

Seed germination and testing. Initial dormancy (0 to 75%) and rate of after-ripening of forage kochia seeds varies among ecotypes and years of harvest (Kitchen and Monsen 1999). After-ripening requires from 0 to 12 months at room temperature and longer in cold storage (Baylan 1972; Kitchen and Monsen 1999). Germination of recently harvested seeds is enhanced by fluorescent light and moist chilling. Germination of after-ripened or chilled seeds occurs across a wide range of temperatures and osmotic potentials (Young and others 1981; Romo and Haferkamp 1987). Germination rate at near freezing temperatures (2 °C) for recently harvested seeds is asynchronous within accessions and highly variable among ecotypes. Mean germination time shortens as seeds after-ripen (table 2). Field studies have demonstrated that when after-ripened seeds (with a rapid, synchronized germination rate) are sown in late fall/early winter, premature germination results in poor stand establishment (Kitchen and Monsen 1999). Haferkamp and others (1990) attributed poor establishment from 1-year-old forage kochia seeds to loss of seed viability and/or vigor. Their data show that in germination tests of laboratory-stored seeds, germination rate had greatly increased for 1-year-old seed when compared to the same lots tested fresh. This suggests that the poor establishment that they observed for 1-year-old seeds may have been related, at least in part, to change in germination rate, as has been observed by Kitchen and Monsen (1999) and Stewart and others (1999). Kitchen and Monsen (1995) also observed that seeds stored for more than 2 years at refrigerated and frozen temperatures retain full viability and are able to delay germination sufficiently for successful stand establishment.

Germinating gray molly seeds tolerate higher salinity levels than do seeds of many halophytic forage plants (Clarke and West 1969). In limited germination trials conducted on a single lot of fresh gray molly seeds, the level of initial dormancy was 26% and the cold temperature germination rate was comparable to that of fresh lots of forage kochia seeds (Monsen and Kitchen 1999).

Seed viability can be difficult to determine from tetrazolium chloride staining due to interference of embryonic chlorophyll. Independent laboratory tests for the same seed lot often produce variable results. Laboratory germination tests are also sometimes inconsistent due to difficulty with seedling normality classification. Dormant healthy seeds germinate normally and rapidly after the seedcoat is pierced.

Nursery and field practice. Forage kochia transplants are easily grown as bareroot and container stock from non-dormant seeds. For best results, seeds should be sown in growth medium 4 to 6 mm ($^1/_8$ to $^1/_4$ in) deep. Germinants are susceptible to fungal root pathogens, dictating clean greenhouse culture techniques. Transplant survival from early spring planting is commonly 90% or higher using standard practices (Monsen and Kitchen 1995).

Seeding should be conducted in the fall or early winter for best establishment from direct seeding on non-irrigated untreated sites (Haferkamp and others 1990). Proper seeding rate varies from 0.5 to 4.5 kg/ha (0.5 to 4.0 lb/acre) (pure live seeds) depending on species mix, site conditions, and seeding method. Successful spring plantings have been reported using after-ripened seeds (Monsen and Turnipseed 1990). Irrigated fields can be sown during summer months. Seed placement at or near the soil surface is critical for successful establishment (Baylan 1972; Stevens and Van Epps 1984). Satisfactory stands have been achieved from broadcasting seeds on the soil surface or on snow with little or no seed-bed preparation (Kitchen and Monsen 1999).

Table 2—*Kochia prostrata,* forage kochia: mean germination times as affected by temperature of dry storage

	Mean germination times (days to 50% germination)			
Accession*	**Fresh**	**20 °C**	**2 °C**	**–5°C**
314929†	72 a	11 b	60 a	67 a
343101	51 a	12 b	46 a	55 a
356818	53 a	14 b	51 a	58 a
356826	108 a	11 c	86 b	90 b
358941	81 a	12 c	63 b	76 a
Mean	71 a	12 b	61 a	69 a

Source: Kitchen and Monsen (1999).
Note: Within an accession, means followed by the same letter are not significantly different at the $P < 0.05$ level. Five accessions of forage kochia were germinated at 2 °C after 24 months of dry storage at 20, 2, or –5 °C; controls were freshly collected seeds.
* Accession numbers are plant introduction (PI) numbers assigned by the USDA Natural Resource Conservation Service's Plant Materials Center in Pullman, Washington.
† 'Immigrant'.

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K

Sapindaceae—Soapberry family

Koelreuteria paniculata Laxm.

panicled golden raintree

Charles H. Michler and Paul O. Rudolf

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Growth habit, occurrence, and use. Native to China, Korea, and Japan, the panicled golden raintree—also called pride-of-India, China tree, and varnish tree—is a small deciduous tree ranging from 5 to 11 m tall that has been cultivated since 1763, chiefly for ornamental purposes (Rehder 1940).

Flowering and fruiting. The irregular (or apparently polygamous) yellow flowers occur in broad, loose, terminal panicles and bloom from July to September (Krüssmann 1960; Ohwi 1965; Plouvier 1946). The fruits are bladdery, triangular, 3-celled capsules about 3 to 5 cm long (figure 1); when they ripen in September and October they change from a reddish color to brown. Within the papery walls of ripe fruit are 3 round, black seeds (figure 2) (Rehder 1940; Rudolf 1974). The seeds are naturally dispersed from fall to the next spring (Pammel and King 1930). Good seedcrops are borne almost annually (Rudolf 1974).

Collection of fruits; extraction and storage of seeds. Capsules should be collected from trees in September and October for extraction and cleaning the seeds. The yield from 46 kg (100 lb) of fruits is about 32 kg (72 lb) of cleaned seeds (Plouvier 1946). Cleaned seeds per weight ranged from 5,700 to 7,700/kg (2,600 to 3,500/lb), and averaged 6,394/kg (2,900/lb) for 3 samples. Four samples of commercial seedlots averaged 99% in purity and 95% in soundness (Rudolf 1974; Swingle 1939; Zentsch and Kaul 1968). One sample that was stored in fruit jars with loosely fastened lids and exposed to temperatures ranging from about 4 to 32 °C showed 50% germination at the end of 10 years (Toumey 1921).

Pregermination treatments. Dormancy in seeds appears to be caused by an impermeable seedcoat and possibly by an internal condition of the embryo. In a series of tests, soaking seeds in sulfuric acid for 1 hour plus 90 days of stratification in moist sand at 4.5 °C gave the best results (Rudolf 1974). In another series of tests, mechanically scarified seeds germinated promptly and well (Zentsch and Kaul 1968). Mechanical scarification followed by stratification for 90 days produced complete germination in 9.7 days (Garner 1979; Garner and Lewis 1980). Seed exposure to an electro-

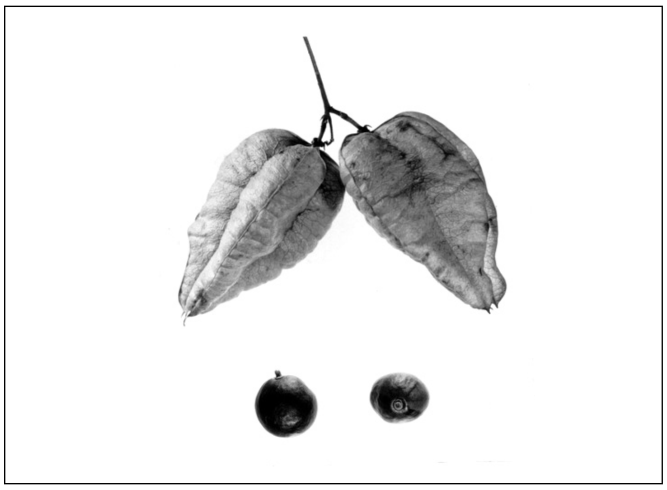


Figure 1—*Koelreuteria paniculata*, panicled golden raintree: capsules (**top**) and seeds (**bottom**).

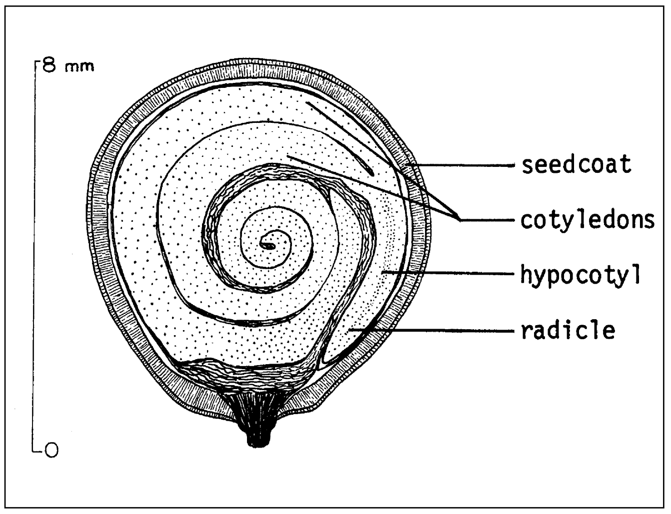


Figure 2—*Koelreuteria paniculata*, panicled golden raintree: longitudinal section through a seed.

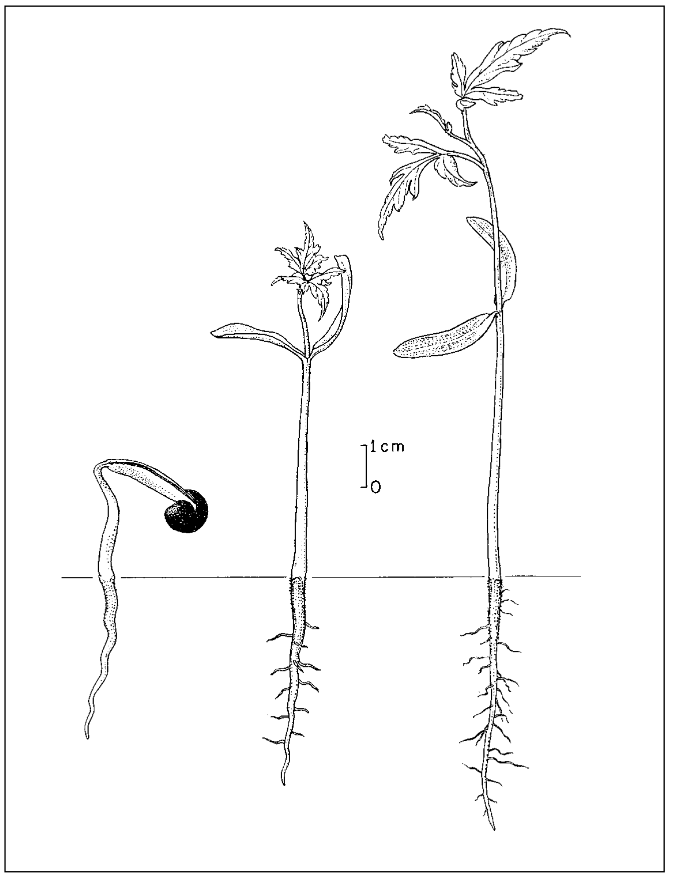
magnetic field of 100 gauss for 4.3 seconds increased germination after scarification from 56 to 97% (Maronek 1975).

Germination tests. Germination is epigeal (figure 3). Germination should be tested in sand flats or germinators for 5 to 10 days at 20 (night) to 30 °C (day), using 200 to 400 seeds that were acid treated and then stratified for each test. One test of untreated seeds gave a germination rate of only 2% in 29 days, whereas seeds of the same sample gave 52% after the acid plus stratification treatment recommended above (Rudolf 1974). In another test, 74% of untreated seeds germinated in 54 days, compared with 91% of mechanically scarified seeds in 23 days (Zentsch and Kaul 1968). Official seed testing agencies recommend tetrazolium staining for germination tests of panicled golden raintree. The suggested procedure is to soak the seeds in water for 18 hours, then remove the seedcoat before staining for 24 hours at 30 °C in a 1% solution (ISTA 1993).

Nursery practice. Untreated seeds may be sown in the fall and scarified seeds can be sown in the spring (some seedlots may require stratification after scarification) and covered with 6 to 13 mm ($^1/_4$ to $^1/_2$ in) of soil. Seedlots sown immediately after collection in fall usually give reasonably good results (Swingle 1939). A target bed density is about 300 to 315 seedlings/m^2 (30/ft^2). Tree survival is about 70% (Jack 1969). Seedlings should be lifted as 2+0 stock (Jack 1969).

This species should be planted only in sunny locations, but it is not particular as to soil type (Bailey 1939). It may also be propagated by layers, cuttings, or root cuttings (Bailey 1939).

Figure 3—*Koelreuteria paniculata*, panicled golden raintree: seedling development at 1, 3, and 5 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.

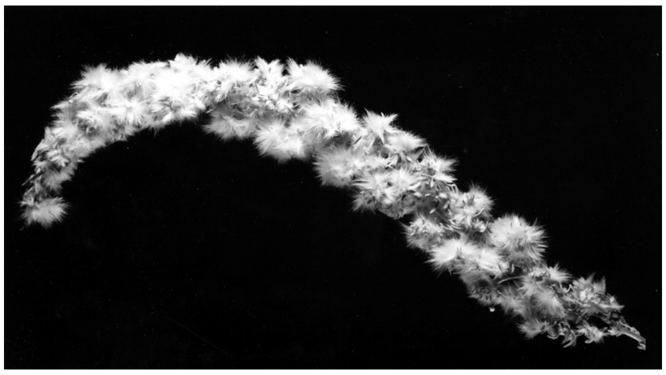


Figure 2—*Krascheninnikovia lanata*, winterfat: cleaned seed.

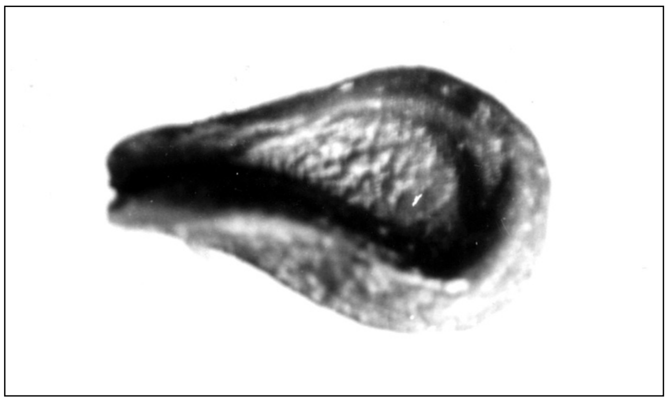
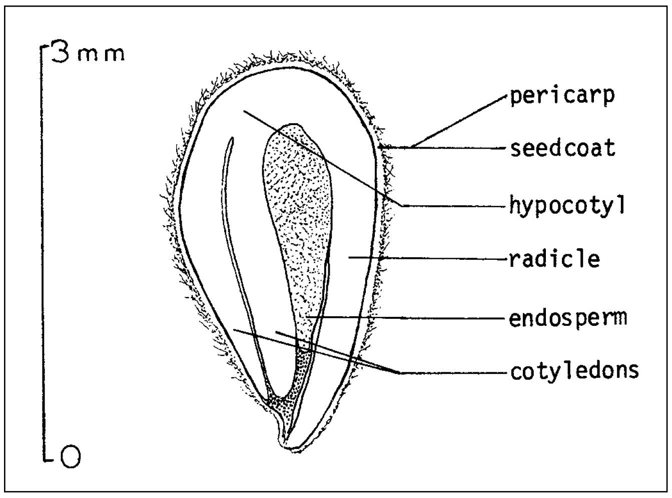


Figure 3—*Krascheninnikovia lanata*, winterfat: sectional schematic of diaspore (seed).



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).

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.

K

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

Source	Collections	Years harvested	Diaspores/weight Mean* /g	Mean* /oz	Range /g	Range /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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Fabaceae—Pea family

Laburnum Medik.

laburnum

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Growth habit, occurrence, and use. The genus *Laburnum* includes 4 species of deciduous trees and shrubs native to central and southern Europe (Krüssmann 1984; LHBH 1976; Scheller 1974). Laburnum species have been cultivated for centuries, primarily for ornamental purposes. Laburnum arches and walks are a popular feature in many large gardens (Wasson 2001). The species is adaptable to many soil types, including limestone, but prefers well-drained soil and light shade (Dirr 1990; Krüssmann 1984; Rudolf 1974). All parts of the plant, particularly the seeds, are poisonous (Krüssmann 1984; LHBH 1976). Seeds and other parts of the plant contain the alkaloid cytisine, which can be fatal to humans and animals (Dirr 1990; Greinwald and others 1990; Leyland 1981). The 2 species and a hybrid of interest are described in table 1.

Scotch laburnum is a small tree with a short, sturdy trunk and flat to round-topped crown; it is considered to be the superior garden species (Dirr 1990). Common laburnum tends to be a low branched, bushy, wide-spreading tree (Dirr 1990; LHBH 1976). Waterer laburnum, a natural hybrid between Scotch and common laburnums, is a distinctly upright, oval to round-headed small tree or shrub (Dirr 1990). The foremost laburnum in cultivation today is Waterer laburnum 'Vossii', a superior tree with dense habit, racemes up to 60 cm in length, and a tolerance of alkaline soils (Dirr 1990; Krüssmann 1984).

Flowering and fruiting. The perfect, ornate, golden yellow flowers are 1.9 cm long and are borne on 15- to 25-cm pendulous racemes; Scotch laburnum has racemes that are 25 to 38 cm (Dirr 1990). Flowers bloom from May to June, and the flowers of Scotch laburnum and Waterer laburnum 'Vossii' are fragrant (Hillier 1991; Krüssmann 1984). The fruit is a brown legume (pod), 5.1 to 7.6 cm long, with black seeds (figures 1 and 2) (Rudolf 1974). The legume of Scotch laburnum is winged, forming a knifelike edge (Dirr 1990). The seeds are tardily dehiscent, ripening from late August to October (Rudolf 1974). Each legume contains several black seeds (only 1 or 2 for Waterer laburnum 'Vossii'), and good seedcrops are borne annually (Krüssmann 1984; Rudolf 1974).

Collection of fruits; extraction, cleaning, and storage of seeds. Legumes should be harvested from the trees beginning in September through November and spread out on flats in a shed or loft with good air circulation to dry (Macdonald 1986; Rudolf 1974). Newspaper should be placed over the legumes to prevent the seeds from being ejected away from the flats. Seeds are extracted by breaking the legumes by hand or by machine threshing (Macdonald

Table 1—*Laburnum,* laburnum: nomenclature, occurrence, growth habit, height at maturity, and date of first cultivation

Scientific name & synonym(s)	Common name(s)	Occurrence	Growth habit	Height at maturity (m)	Year first cultivated
Laburnum alpinum **(Mill.) J. Presl.**	**Scotch laburnum,** alpine goldenchain	S Alps, N Apennines, NW Yugoslovia, S	Tree	6.1	1596
L. anagyroides **Medik.** *L. vulgare* Bercht. & Presl.	**common laburnum,** goldenchain tree	Slovakia & Czech Republic, & Central & S Europe	Tree	6.1–9.1	1560
L.* x *watereri **(Kirchn.) Dipp.** *L. alpinum* x *L. anagyroides*	**Waterer laburnum,** goldenchain tree	Observed (1856) wild in Tyrol & Switzerland, now in cultivation	Tree/shrub	3.7–4.6	1875

Sources: Dirr (1990), Hillier (1991), Krüssmann (1984), LHBH (1976).

L

Figure 1—*Laburnum anagyroides*, common laburnum: legume (**top**) and exterior view of a seed (**bottom**).

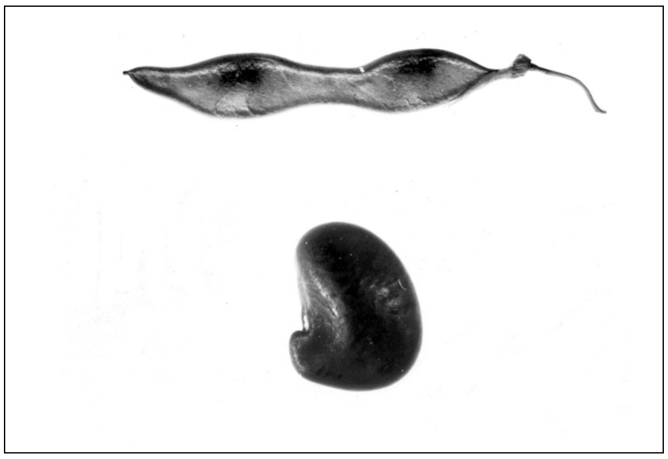
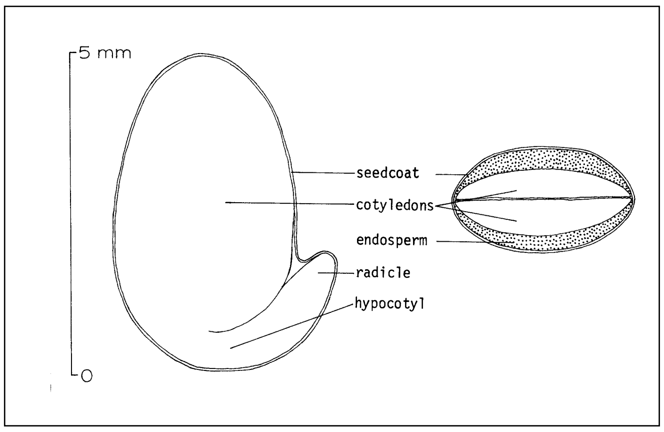


Figure 2—*Laburnum anagyroides,* common laburnum: longitudinal section through a seed.



1986). The seeds and debris are separated by sieving or by using a directed flow of air. About 45 kg (100 lb) of legumes will yield about 11 kg (25 lb) of cleaned seeds (Rudolf 1974). The following values for number of cleaned seeds per weight for laburnum species have been found: Scotch laburnum, 31,966 to 35,004/kg (14,500 to 15,878/lb); common laburnum, 35,273 to 37,478/kg (16,000 to 17,000/lb); and Waterer laburnum, 40,917/kg (18,560/lb); with 85% germination and 90 to 99% purity, depending upon cleaning techniques (Allen 1994). The dried legumes may be stored overwinter in sacks placed in a dry shed or loft. Seeds stored dry in sacks will retain good viability for 2 years (Dirr and Heuser 1987; NBV 1946, cited by Rudolf 1974).

Pregermination treatments. Laburnum seeds do not germinate readily unless the impermeable, hard seedcoat is ruptured by mechanical or sulfuric acid scarification. Mechanical scarification of common laburnum seeds resulted in 99% germination (Stilinovic and Grbic 1988). Dirr and Heuser (1987) reported that 30 to 60 minutes of sulfuric acid treatment resulted in good germination. A sulfuric acid treatment for 80 minutes and storage for at least 8 months improved germination rates for common laburnum (Laroppe and others 1996). A 2-hour sulfuric acid treatment resulted in 68% (Scotch laburnum) and 100% (Waterer laburnum) germination (Dirr and Heuser 1987). Seeds of Waterer laburnum that were collected when the seedcoat was soft (late July in Boston, Massachusetts) and left "as is"or punctured with a needle produced uniform germination in 5 days (Dirr and Heuser 1987).

Germination tests. Testing prescriptions of the International Seed Testing Association (ISTA 1993) call for mechanical scarification by piercing or by removing a piece of the testa at the cotyledon end and soaking seeds in water for 3 hours before testing them at alternating 20/30 °C for 21 days on germination paper. An alternative method is to scarify seeds by soaking them in concentrated sulfuric acid for 1 hour, washing, and germinating as above (ISTA 1993). Tests of treated seeds can also be done at a constant 20 °C for 14 days, and light is not required (Rudolf 1974). Germination rates averaged about 80% in 7 days, and percentage germination about 86% in more than 12 tests (NBV 1946; Schubert 1955, cited by Rudolf 1974).

Nursery practice and seedling care. Scarified seeds may be sown broadcast or in drills in late spring at a rate of 150 to 200/m^2 (14 to 19/ft^2) for lining-out stock and 100 to 150/m^2 (9 to 14/ft^2) for rootstocks (Macdonald 1986). The seeds are covered with 6 mm ($^1/_4$ inch) of soil. Field-planting has been done with 2+0 stock (Rudolf 1974). This species can also be propagated by layering and rooting hardwood cuttings taken during the fall and late winter; cultivars are propagated by grafting or budding onto laburnum seedling rootstocks (Dirr and Heuser 1987; Hartmann and others 1990; LHBH 1976; Macdonald 1986; Whalley and Loach 1981, 1983). Micropropagation of Waterer laburnum 'Vossii' has been reported, but plants cultured *in vitro* have slowed growth as compared to plants multiplied by grafting (Gillis and Debergh 1992).

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L

Lythraceae—Loosestrife family

Lagerstroemia L.

crape-myrtle

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Occurrence, growth habit, and uses. There are about 55 species in the crape-myrtle genus—*Lagerstroemia*. They are indigenous primarily to the Asian and Pacific island tropics but also occur in China, India, Korea, Japan, and Australia (Bärner 1962; LHBH 1976). Many are important timber species, producing wood of quality suitable for cabinetry and construction that is also highly resistant to decay and destructive insects (Bärner 1962; Howard 1948). Three species are cultivated in North America, all for their horticultural interest (table 1).

One species of crape-myrtle, *Lagerstroemia indica* L., and its hybrids with *L. fauriei* Koehne—both of which are called crape-myrtle—are used widely in landscape plantings in warmer parts of the continental United States, particularly the South. *Lagerstroemia indica* is indigenous to China, whereas *L. fauriei* was introduced in 1956 by Creech (1958, 1985) from seeds collected on Yakushima Island, Japan. Many cultivars have been named, including a few of strict *L. fauriei* parentage (Dirr 1998; Egolf and Andrick 1978; Raulston and Tripp 1995). Cultivars of crape-myrtles are typically cold hardy to USDA Zone 7, but some cultivars have withstood temperatures of –23 °C without injury (Egolf 1990b). There have been reports of tropical species, particularly Queen's crape-myrtle, growing in frost-free portions of the United States corresponding to USDA Zones 10 and 11 (Egolf and Andrick 1978; Everett 1981; Menninger 1962).

Crape-myrtles are deciduous trees or shrubs exhibiting considerable variability in height; they range from 0.9 to 10 m tall, with occasional specimens reaching 14 m (Dirr 1998; Egolf and Andrick 1978). They are observed commonly as upright, multi-stemmed plants, the bottom third to half devoid of leaves, generally exposing very handsome, sinuate trunks (Dirr 1998; Egolf and Andrick 1978). The crown is variably rounded to vase-shaped. Queen's crape-myrtle may reach 24 m in height in the United States and 30 m in the Asian tropics (Chudnoff 1980).

As a result of their ornamental attributes, crape-myrtles are used extensively as landscape plants. Due to their broad range of heights, they can be observed growing as specimen plants, hedges, mass plantings, or lining streets and alleys (Dirr 1998; Egolf 1981a&b, 1986a&b, 1987a&b, 1990a&b). Crape-myrtles have also been maintained successfully as herbaceous perennials by annual hard pruning to the ground, and they are treated as herbaceous plants where winter temperatures are low enough to kill aerial portions without injuring the roots (Everett 1981; Huxley 1992). Although widely adaptable, crape-myrtles grow best in full sun and in heavy loam to clay soils with a pH of 5.0 to 6.5 (Egolf 1981a&b, 1986a&b, 1987a&b, 1990a&b; Egolf and Andrick 1978). Crape-myrtles are not grown in the United States for timber use.

Table 1—*Lagerstroemia,* crape-myrtle: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***L. fauriei* Koehne**	**crape-myrtle,** crapemyrtle	Yakushima Island, Japan
***L. indica* L.** *L. elegans* Wallich ex Paxt.	**crape-myrtle,** crapemyrtle	China, Vietnam, Himalayan region, & Japan
***L. speciosa* (L.) Pers.** *L. flos-reginae* Retz.	**Queen's crape-myrtle**, pride-of-India	India, Burma, Sri Lanka, Malayan Peninsula, & Australia

Sources: Bärner (1962), Creech (1958), Huxley (1992), LHBH (1976).

Geographic races and hybrids. Various crape-myrtle species hybridize readily. Beginning in 1962, the United States National Arboretum pursued an extensive program of crape-myrtle breeding and selection, under the direction of Egolf (Egolf and Andrick 1978). Between 1981 and 1990, the National Arboretum released 20 cultivars of crape-myrtle, most of them selections of complex crosses between *L. indica* and *L. fauriei* (Egolf 1981a&b, 1986a&b, 1987a&b, 1990a&b). These cultivars combine successfully the superior flowering attributes of *L. indica* with resistance to mildew—*Erysiphe lagerstroemiae* E. West—of *L. fauriei* (Egolf 1981a&b, 1986a&b, 1987a&b, 1990a&b; Mizel and Knox 1993). Several also display the exceptional and colorful, exfoliating bark of *L. fauriei,* as well as outstanding fall foliage color (Dirr 1998; Egolf 1981a&b, 1986a&b, 1987a&b, 1990a&b).

Flowering and fruiting. Spectacular flowering is the trait that most often justifies use of crape-myrtles as landscape plants. The red, white, pink, or purple flowers, each 1.5 to 5.0 cm in diameter, are produced in 12- to 44-cm-long tapered panicles, each comprising 25 to 500 flowers. The flowers are perfect, 6-petaled, and distinctively crinkled. Stamens are numerous, as are ovules (Egolf 1990b; Egolf and Andrick 1978; LHBH 1976). The inflorescences are terminal and prominently displayed at the end of the current year's growth. Flowering occurs from June to September in the mid-Atlantic states and the Southeast, with some variability between cultivars. Many cultivars have extended flowering periods, lasting up to 3 $^1/_2$ months (Dirr 1998; Egolf and Andrick 1978). Fruits are globose, dehiscent, 6-valved capsules, 5 to 15 mm in diameter, that reach maturity in the fall and persist through the winter (figure 1). Each capsule contains 20 or more winged seeds. Seeds are 7 to 11 mm long (figures 2 and 3) (Egolf and Andrick 1978; LHBH 1976).

Collection of fruits, seed extraction, cleaning, and storage. Published information on fruit collection and seed extraction of crape-myrtles is generally lacking, but the capsules should be dried for seed extraction. Dirr and Heuser (1987) placed mature fruits in paper bags for drying, followed by shaking to remove seeds. No information is available currently regarding proper storage conditions to maintain viability, but the seeds appear to be orthodox in storage behavior, indicating that low seed moisture and temperatures would be sufficient for storage. In India, Queen's crape-myrtle seeds average 150,000 to 175,000/kg (68,000 to 79,400/lb) (Khullar and others 1991).

Figure 1—*Lagerstoemia* indica, crape-myrtle: open fruit (capsule).

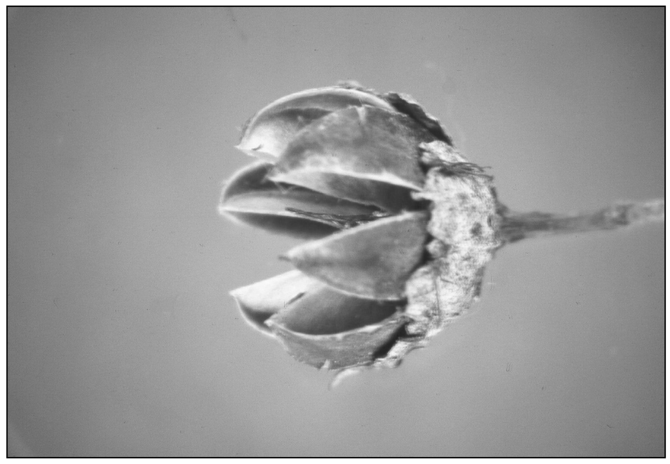


Figure 2—*Lagerstoemia* indica, crape-myrtle: seeds.

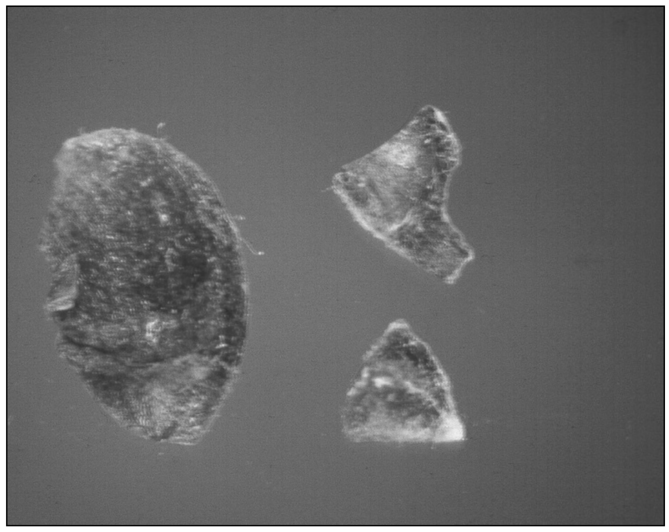
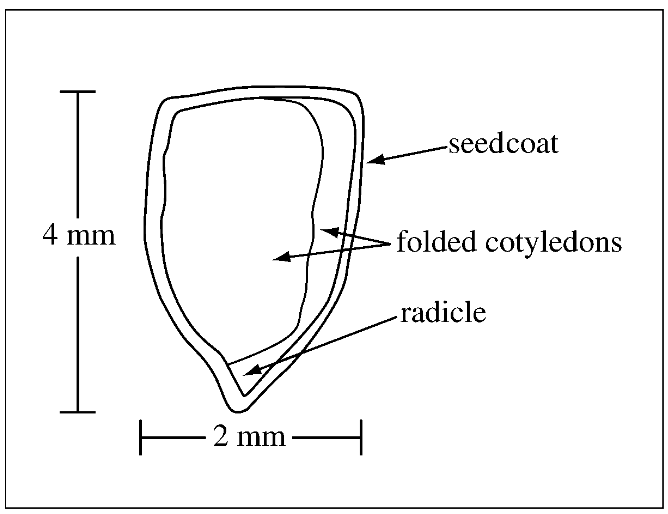


Figure 3—*Lagerstoemia indica*, crape-myrtle: longitudinal section of a seed.



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Pregermination treatments and germination tests. Seeds germinate readily without pretreatment, although stratification (moist prechilling) for 1 month at 4 °C is sometimes advised to synchronize germination (Dirr and Heuser 1987; Raulston and Tripp 1995). There are no officially prescribed test procedures for this genus. However, Babele and Kandya (1986) demonstrated that tetrazolium staining is a reliable and rapid technique for determining seed viability of *L. parviflora* Roxb.

Nursery practice, and seedling care. Egolf and Andrick (1978) reported that without stratification, seeds sown at 15 °C germinated within 10 days. They recommended that seedlings be transplanted into individual pots shortly after emergence and then fertilized lightly. In a warm greenhouse, such seedlings will make rapid growth, and often bloom the first summer from a December or January sowing. Dirr (1998) reported that germination occurs in 2 to 3 weeks for seeds sown immediately following collection in January. Seedling populations of crape-myrtles, whether of hybrid origin or not, are noted for heterogeneity in height, flower color, floriferousness, and cold hardiness.

At present, commercial propagation of crape-myrtles is primarily by stem cuttings. Softwood, hardwood, or root cuttings have been used successfully (Dirr and Heuser 1987; Egolf 1990b; Egolf and Andrick 1978; Hartmann and others 2002). Micropropagation techniques have also been reported (Yamamoto and others 1994; Zhang and Davies 1986).

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Pinaceae—Pine family

Larix P. Mill.

larch

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Occurrence. The larches—*Larix* P. Mill.—of the world are usually grouped into 10 species that are widely distributed over much of the mountainous, cooler regions of the Northern Hemisphere (Hora 1981; Krüssmann 1985; Ostenfeld and Larsen 1930; Rehder 1940; Schmidt 1995). Some species dominate at the northern limits of boreal forests and others occur above subalpine forests (Gower and Richards 1990). Seven species are included (table 1)—the others, Master larch (*L. mastersiana* Rehd. & Wils.), Chinese larch (*L. potaninii* Batal.), and Himalayan larch (*L. griffithiana* (Carr.))—are rarely planted in the United States. All species (except possibly Himalayan larch) are hardy in the United States (Bailey 1939). However, the seeds should come from a site with comparable conditions, as demonstrated at the Wind River Arboretum in southwestern Washington, where 7 larch species, some with several varieties, and 1 hybrid were planted from 1913 to 1939 (Silen and Olson 1992). European larches there are doing better than Asian species in this warm, moist Washington state climate. The native western larch specimens from more continental climates with lower humidity are doing poorly. In 1992, a larch arboretum containing all species, several varieties, and 3 hybrids of larch was established at Hungry Horse, Montana, within the natural range of western larch (Shearer and others 1995).

Growth habit. *Larix* is one of the few conifer genera with deciduous needles. The trees are valued for their light green hues in the spring and shades of yellow to gold in the

Table 1—*Larix,* larch: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***L. decidua* P. Mill.** *L. europaea* DC. *L. larix* Karst	**European larch**	Mtns of central Europe up to about 2,500 m; widely planted throughout Europe & NE US (43–54°N & 7–27°E)
***L. gmelinii* (Rupr.) Rupr.** *L. dahurica* Turcz. ex Trautv. *L. cajanderi* Mayr	**Dahurian larch**	E Siberia to NE China & Sakhalin; limited planting in N Europe, Canada, & NE US (35–72°N & 89–82°E)
***L. kaempferi* (Lamb.) Carr.** *L. leptolepis* (Sieb. & Zucc.) Gord. *L. japonica* Carr.	**Japanese larch**	Japan, usually from 1,220–2,440 m; planted in N Europe, Asia, & E US (35–37°N & 138–143°E)
***L. laricina* (Du Roi) K. Koch**	**tamarack**, eastern larch, American larch, hackmatack	Newfoundland & W along tree line to Alaska; SE through NE British Columbia to Great Lakes region, E to New England; local in NW Virginia & W Maryland (41–68°N & 51–158°W)
***L. lyallii* Parl.**	**subalpine larch,** alpine larch, tamarack	High mtns of SW Alberta, SE British Columbia, N central Washington, N Idaho, & W Montana (45–52°N & 116–124°W)
***L. occidentalis* Nutt.**	**western larch,** hackmatack, Montana larch, mountain larch, tamarack, western tamarack	W Montana to E Oregon & Washington & S British Columbia (43–52°N, 117–124°W
***L. sibirica* Ledeb.** *L. russica* (Endl.) Sabine ex Trautv. *L. europaea* var. *sibirica* (Ledeb.) Loud.	**Siberian larch,** Russian larch	NE Russia & W Siberia; limited planting in N US & Canada (45–72°N & 36–112°E)

Source: Rudolf (1974).

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fall. Branching is usually pyramidal with spreading branches (Hora 1981). Maximum height for the 10 species ranges widely, influenced by elevation and site conditions. Subalpine and Chinese larches often grow at or near timberline and mature trees may reach only 7 to 13 m in height (Krüssmann 1985). The tallest known subalpine larch, as reported by Arno and Habeck (1972), grows on a protected, favorable site and reached 46 m. Western larch, tallest of the world's larch species, can reach about 61 m (Schmidt and others 1976; Schmidt and Shearer 1990).

Use. Of the 3 American species, tamarack and western larch are used for reforestation. Because of its rot resistance, larch wood is especially valuable for posts, transmission poles, railroad ties, and mine props. Most larches are now recognized as important for timber production, habitat or food for wildlife, watershed protection, environmental forestry, and also for ornamental purposes (Rudolf 1974). Venetian turpentine can be obtained by tapping larches; a water-soluble trisaccharide sugar melecitose is extracted from wood chips (Dallimore and Jackson 1967; Hora 1981). Probably because of this high sugar content, black bears—*Ursus americanus cinnamomum*—often seek out vigorous young pole-size western larch in late spring and feed on the inner bark and cambium, usually on the lower 1 to 2 m of the trees (Schmidt and Gourley 1992). Often the trees are girdled and die; partially girdled trees frequently produce large cone crops following damage (Shearer and Schmidt 1987).

Genetics. Larch species vary widely in growth rates, cold hardiness, form, pest resistance, and other characteristics. This variability is often under strong genetic control and genetic gain is expected through tree improvement efforts (Eysteinsson and Greenwood 1995). Winter hardiness, change in foliage color, and cessation of height growth of Japanese larch were correlated with latitude of provenance origin, but date of bud flush was not (Toda and Mikami 1976). Further, branching habit, stem crookedness, spiral grain, and disease susceptibility varied between provenances. Genetic variation of tamarack throughout its range is comparable to other species of woody plants with extensive ranges (Cheliak and others 1988). Based on genetic differences in total height and survival of 210 clones of 5-year-old vegetatively propagated tamarack in central New Brunswick, Park and Fowler (1987) believed that clonal forestry was a good option for this species. Farmer and others (1993) also showed genetic variation in height of tamarack was related to rate and duration of shoot elongation and from differences in late-season elongation.

Conversely, low genetic variation occurs among populations of western larch for growth, phenology, and cold hardiness (Rehfeldt 1982) compared with other Rocky Mountain conifers. Rehfeldt (1983) identified an 11% variation associated with the elevation of the seed source and recommended that seedlots not be transferred more than ± 29 m or ± 2 contour bands. Based on genetic variation in allozymes of western larch seeds, Fins and Seeb (1986) cautioned transferring seeds from eastern Washington to north Idaho and recommended that seedlots for planting should include seeds from a diversity of locations within an area. Hall (1985) concluded that yields of cones and seeds from interspecific and intraspecific crosses and open-pollinated seeds of European larch were reduced in hybrid crosses compared to non-hybrid crosses. Wide variation in yield suggests that both genetic and environmental factors are important in controlling yield of seeds.

Hybrids. Larches hybridize readily (Rudolf 1974; Lewandowski and others 1994; Young and Young 1992), and geographic isolation is a major factor for lack of hybridization. Natural hybrids of western and subalpine larches occur where their ranges overlap (Carlson and Blake 1969; Carlson and others 1990). Seeds from natural hybrid trees closely resemble those of western larch (Carlson and Theroux 1993). Reciprocal cross pollinations between western and subalpine larches were successful, and germination of seeds from these crosses was higher than that of seeds from either parent (Carlson 1994).

L. kaempferi × *decidua*, known as *L.* × *eurolepis* A. Henry and commonly called Dunkeld larch, originated about 1900. It has been planted extensively in northwestern Europe and to a lesser extent in the eastern United States and Canada because it combines desirable characteristics of both parent species and grows faster than either (Eliason 1942; MacGillivray 1969). *L. kaempferi* × *sibirica,* known as *L.* × *marschlinsii* Coaz, was originated in 1901. *L. laricina* × *decidua*, known as *L. pendula* Salisb. or weeping larch, was originated before 1800 (Rehder 1940). Many other larch hybrids are known. Several larch species and hybrids were tested as potential short-rotation fiber crops for the Northeast and the Great Lakes region (Einspahr and others 1984) and in Wisconsin (Riemenschneider and Nienstaedt 1983); Dunkeld larch showed best growth in both studies. Seeds from a single provenance of Japanese larch and 6 provenances of European larch had, after 5 years, 3 times the growth potential of seeds from native red pine (*Pinus resinosa* Ait.) in another Wisconsin study (Lee and Schabel 1989).

Geographic races. Geographic races have developed in many widely distributed larch species, and these often exhibit marked differences in growth rates and other characteristics (Rudolf 1974). The European larch includes at least 5 geographic races (often considered to be subspecies or varieties) that roughly coincide with major distributional groups of the species (Debazac 1964; McComb 1955):

- Alpine, in south central Europe
- Sudeten, principally in Czechoslovakia
- Tatra, in Czechoslovakia and Poland
- Polish, principally in Silesia
- Romanian (several small outliers)

The races differ in seed size and viability, survival after planting, growth rate, phenology, form, and resistance to insects and disease (Dallimore and Jackson 1967; McComb 1955; Rudolf 1974). The races respond differently in different localities, but in the northeastern United States and Canada, the Polish and Sudeten races grow most rapidly and are recommended for planting there although they do not always have the best form (Hunt 1932; MacGillivray 1969). Sindelar reported (1987) that in Czechoslovakia, seedlings of Dunkeld larch and *L. decidua* × *gmelinii* grew better on sites with high levels of pollution than did European larch seedlings. Sindelar (1982) recommended that seed orchards of European larch contain many clones in order to prevent excessive propagation of a few fertile clones. A Scots race mentioned in older references probably developed in Scotland from plants of Sudeten origin (Rudolf 1974). European seed sources perform similarly in northeastern United States as in Great Britain, Germany, and Italy (Genys 1960).

Some varieties of Dahurian larch that are confined to definite areas appear to be geographic races (Debazac 1964). These include the following varieties:

- *japonica* (Maxim. ex Regel) Pilg.
- *principis-rupprechti* (Mayr) Pilg.
- *olgensis* (A. Henry) Ostenf. & Syrach., known as Olga Bay larch (Rehder 1940)

In China, *L. principis-rupprechti* and Olga Bay and Chinese larches are recognized as distinct species rather than geographic races of Dahurian larch (Chinese Academy of Sciences 1978). Tests in Finland showed marked differences in survival, growth rate, cold hardiness, and susceptibility to insect attack between trees from Korean and Sakhalin seed sources (Kalela 1937). A limited trial in North Dakota was unsuccessful (Cunningham 1972). Trees of Olga Bay larch seem suitable for planting in north central United States and adjacent Canada.

Because of the extensive natural range of tamarack, geographic races probably exist. Studies by Cheliak and others (1988); Farmer and others (1993), and Park and Fowler (1987) reported differences in growth, such as total height based on latitude and late-season elongation. Two-year-old seedlings of tamarack grown in Minnesota from seeds from several origins showed significant differences in total height and a tendency for bud set to occur earliest in seedlings from northern sources (Pauley 1965).

Japanese larch is native to a 363-km^2 area in the mountains of central Honshu, where it grows in scattered stands at elevations of 900 to 2,800 m (Asakawa and others 1981). Despite this small native range, test plantings of Japanese larch in several parts of the United States and eastern Canada, Japan, China, Great Britain, and Germany have shown significant differences among seed sources in tree height, survival, terminal bud set on leader, number of branchlets, insect resistance, winter and spring cold damage, and susceptibility to sulfur fumes (Hattemer 1968; Heimburger 1970; Lester 1965; MacGillivray 1969; Wright 1965). Progeny of seeds from diverse sources respond differently to particular environments, so that no general recommendations can be made as to the best races for specific localities. However, seeds from sources in the northern part and the higher elevations of Honshu have produced progeny with earlier hardening off and less early frost damage than have seeds collected from farther south and at lower elevations (Hattemer 1968; Heimburger 1970; Lester 1965; Wright 1965).

Siberian larch stock grown from seeds from the Altai region seem to be less cold hardy than stock grown from seeds from other parts of the range (Tkachenko and others 1939). Limited trials in North Dakota suggest that this species could be used as the tallest member of a multiple-row shelterbelt (Cunningham 1972).

Flowering. Male and female flowers of the larches are borne separately on the same tree. Cones are usually scattered throughout the non-shaded crown with seed cones more frequent higher in the crown and pollen cones more frequent lower in the crown (Eis and Craigdallie 1983), but there usually is considerable overlap. They occur randomly with the leaves on the sides of twigs or branches and usually open a few days before needle elongation. The male flowers are solitary, yellow, globose-to-oblong bodies that bear wingless pollen. The female flowers are small, usually short-stalked, erect, red or greenish cones that ripen the first year.

The seed cones and pollen cones usually are differentiated in terminal positions on short-shoot axes that completed at least 1 cycle of annual growth (Krüssman 1985; Owens and Molder 1979a). However, the seed and pollen cone buds of tamarack (Powell and others 1984) and Japanese larch (Powell and Hancox 1990) can differentiate laterally on long shoots the year they elongate. Furthermore, as tamarack plantations go from 5, 6, to 7 years of age, the number of trees bearing seed and pollen cones and the number of cones per tree increased each year (Tosh and Powell 1991). Top-grafting buds of 2-, 5-, 9-, 45-, and 59-year-old Japanese larch on 17-year-old trees shortened the time to produce female and male strobili by about 5 years over untreated controls (Hamaya and others 1989). Loffler (1976) found that yield of European larch seeds in seed orchards usually increased with graft age and in comparison to the natural forest, the cones provided more and larger seeds of better quality. Ten years after planting in a common garden, western larch cone production was twice as great for trees grafted with mature scions as for seedlings and five times greater than for rooted cuttings (Fins and Reedy 1992). The number of seed and pollen cones increased on 30- to 32-year-old western larch as average spacing expanded from 2 m to 3 m and wider (Shearer and Schmidt 1987). The average number of cones produced per tree during a good cone crop increased 27 times as the diameter classes increased from 10 to 15 cm to 30 to 36 cm, a reflection of the greater crown volume (Shearer 1986). Xu (1992) found similar relationships for Dahurian larch in China.

There was no relationship of the number of cone scales of Olga Bay larch or their color, shape, size, or structure to site characteristics, developmental stage of trees, or other biological factors (Suo 1982). Developing larch cones range in color from red to green with a range of intermediate shades. Raevskikh (1979) reported that red- and green-coned forms of Dahurian larch produced better quality seeds than did rosy-coned forms. Western larch cones are red, green, and brown in color, but no differences were detected in seed quality by color (Shearer 1977). Ripe cones become brownish and have woody scales, each of which bears 2 seeds at the base (Dallimore and Jackson 1967; Rehder 1940). The seed has a crustaceous, light-brown outer coat; a membranaceous, pale chestnut-brown, lustrous inner coat; a light-colored female gametophyte; and a well-developed embryo (figures 1 and 2) (Dallimore and Jackson 1967; Rehder 1940). Occasionally, atypical cones are found on larches. Tosh and Powell (1986) identified and studied proliferated and bisporangiate cones on tamarack planted 5 or 6 years earlier.

Figure 1—*Larix occidentalis*, western larch: seed with wing.

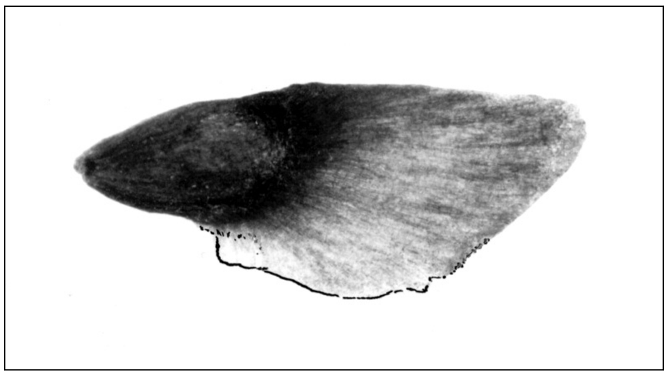
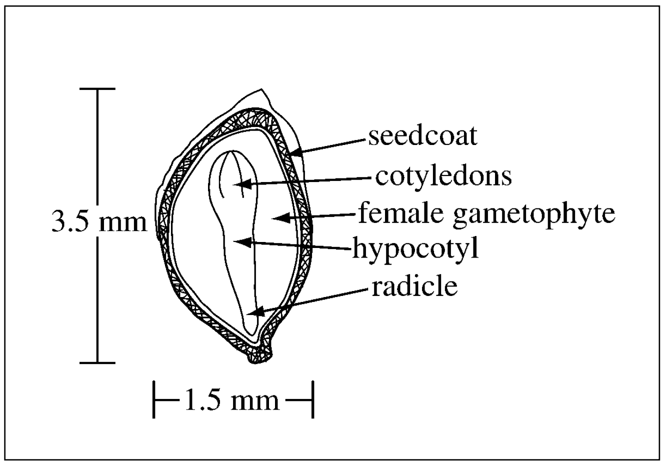
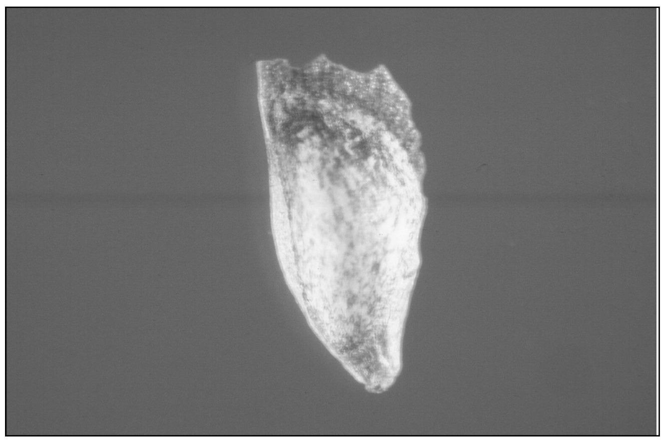


Figure 2—*Larix*, larch: longitudinal section through a seed of *L. laricina*, tamarack (**top**) and a de-winged seed of *L. occidentalis*, western larch (**bottom**).





A 10-year phenological record of western larch in the Northern Rocky Mountains showed a wide range in time of bud-burst, pollination, and cone opening (Schmidt and Lotan 1980). A 21-year phenological study of subalpine larch showed that spring temperature, not photoperiod, was a chief factor that determined bud-burst date (Worrall 1993). Morphological studies increased our understanding of characteristics of cones and seeds of tamarack (O'Reilly and

Farmer 1991) and for subalpine and western larches and their natural hybrids (Carlson and Theroux 1993). Seedcoats of subalpine larch are thicker than those of western larch and may be a partial barrier to germination (Carlson 1994).

Larch seeds are winged, nearly triangular in shape, and chiefly wind dispersed. Empty cones may remain on the trees for an indefinite period. Seeds of western larch carry long distances (Shearer 1959), but seeds of tamarack in Alaska fall close to the point of origin (Brown and others 1988).

An embryological study of European, Japanese, and Siberian larches showed that the embryos attained full size by early- or mid-August and that the seeds were fully developed by the end of August. The development was most rapid in Siberian larch (Hakansson 1960). Larches often have a high proportion of hollow seeds, as reported by Shearer (1990) and Trenin and Chernobrovkina (1984). The time of pollination is critical to development of viable and high-quality western larch seeds (Owens and others 1994). The high proportion of non-viable seeds was attributed to (1) underdeveloped ovules at pollination; (2) ovules that either were not pollinated or were not fertilized; (3) factors that prevented pollen germination, pollen tube growth, or fertilization; (4) problems associated with self-pollination; and (5) inhibited ovule development. Shin and Karnosky (1995) identified abortion of female strobili and embryo degeneration as major factors reducing seed yields of tamarack and European, Japanese, and Siberian larches in the upper peninsula of Michigan, although the previously mentioned 5 factors also caused seed loss. Factors contributing to empty seeds in European larch included lack of pollination, disturbances during megasporogenesis, failure of pollen to reach and germinate on the nucellus, and embryo degeneration (Kosinski 1986, 1989).

Throughout much of the range of western larch, frost often limits the number of developing cones that mature (Shearer 1990). Lewandowski and Kosinski (1989) described spring frost damage to 14 grafted Polish clones in a seed orchard of European larch. In late May 1968, frost completely killed the cone crop of Olga Bay larch growing above 1,000 m in northeastern China (Suo 1982). Frost may also limit cone production of subalpine larch most years (Arno 1990). Loffler (1976) found that late spring frost killed a high proportion of European larch cones. An inexpensive electrical resistance device that prevents frost damage has been used to protect pollinated female strobili of European and Dunkeld larches after controlled crossings (Ferrand 1988).

Indoor (potted) orchards are used to produce western larch seeds and to control the environmental conditions that often limit cone production in natural or planted stands (Remington 1995). Ross and others (1985) suggested many other advantages. Flowering of tamarack was promoted on potted, indoor, and field-grown grafts by foliar sprays of giberellin ($GA_{4/7}$) and root pruning (Eysteinsson and Greenwood 1990). Seed cone flowering decreased per centimeter of branch length as ortet age increased from 1 to 74 years (Eysteinsson and Greenwood 1993). Ross (1991) determined that response to combinations of stem girdles and $GA_{4/7}$ injections on 17-year-old western larch varied greatly in flowering response. Only the effects of girdling (not $GA_{4/7}$) were effective in promoting strobilus production in grafts on 10-year-old Japanese larch (Katsuta and others 1981).

Damage. During poor cone crop years with some larch species, many of the seeds are destroyed by weevils (Rudolf 1974). Several insects limit western larch cone and seed production. The major cone feeding insects are the larch cone maggot (*Strobilomyia laricis* Michelsen), western spruce budworm (*Choristoneura occidentalis* Freeman), a woolly adelgid (*Adelges viridis* Ratzeburg), and cone scale midges (*Resseliella* sp.) (Dewey and Jenkins 1982; Jenkins and Shearer 1989; Miller and Ruth 1989; Shearer 1984, 1990). Turgeon (1989) determined that larvae of the larch cone maggot infested more tamarack cones in the upper and mid-crowns than cones in the lower crowns. Larvae of the larch cone maggot also feed on cones of Siberian, European, Dahurian, and Japanese larches and tamarack in southern and central Finland (Pulkkinen 1989). During infestations of the western spruce budworm, the insect larvae decrease cone production of western larch by severing cone-bearing twigs and also by damaging developing cones and seeds on the trees (Fellin and Schmidt 1967; Fellin and Shearer 1968). Similarly, the eastern spruce budworm (*Choristoneura fumiferana* (Clem.)) greatly decreases cone and seed production of tamarack (Hall 1981). The eastern spruce budworm and cone fly (*Lasiomma viarium* Huckett) larvae caused most damage to seeds of tamarack in 1982 and 1983 in New Brunswick and Maine, whereas other insects caused lesser damage (Amirault 1989; Amirault and Brown 1986). A recent review of insects that may influence larch cones and seeds in Canadian seed orchards listed 19 species in 4 families: 1 insect species for subalpine larch, 17 species within 4 families for tamarck, and 4 species within 3 families for western larch (de Groot and others 1994). In British Columbia, neither tamarack nor western larch have major insect pests (Eremko and others 1989).

Atmospheric fluorides can reduce the size of seeds, percentage germination, numbers of seeds per cone, and numbers of cones per tree. Reproductive failure and mortality of tamarack in Newfoundland have resulted in their replacement by more tolerant species (Sidhu and Staniforth 1986).

Micropropagation and genetic engineering. Micropropagation techniques can supplement reliance on larch seeds for a broad range of tree improvement and regeneration needs. Karnosky (1992) suggests biotechnology can help produce genetically superior larch by (1) mass propagation, (2) disease screening, and (3) transfer of genetic information through genetic engineering techniques. Organogenesis from young and mature larch callus tissues is reported (Bonga 1984; Chapula 1989). Lelu and others (1993) developed somatic embryogenesis techniques for several species and hybrids of larch. Full-sib immature zygotic embryos were produced from induction of embryonal masses for European and Dunkeld larches and *Larix* × *leptoeuropaea* (Lelu and others 1994a). Thompson and von Aderkas (1992) successfully regenerated western larch from immature embryos. Protoplasts of Dunkeld larch can be effectively isolated from embryonal mass and cultured to produce somatic plantlets (Charest and Klimaszewska 1994). Further, Lelu and others (1994b) showed that the number of mature somatic embryos of *Larix* × *leptoeuropaea* produced per gram (fresh weight) of embryonal mass was influenced by embryogenic line, sucrose concentration, and abscisic acid concentration. No universal maturation medium was recommended because of the interactive effects of these 3 factors. High plantlet survival was achieved in the greenhouse through either of 2 acclimatization methods (Lelu and others (1994c). In gymnosperms, gene transfer was first accomplished in European larch; transfer was mediated by *Agrobacterium rhizogenes* and subsequent regeneration of the transgenic plants (Huang and others 1991). Shin and others (1994a&b) reported that transgenic European larch plants were produced that use *Agrobacterium*-mediated single gene transfer to promote insect (*Bt* toxin gene) and herbicide (*aroA* gene) resistance.

Collection of cones. Larch cones should be collected as soon as they ripen; different species ripen at various times from August to December (table 2). Larch cones are picked from trees in forests, seed production areas, seed orchards, and potted tree collections or they can be gathered from felled trees, slash, or squirrel caches. In Tyrol, European larch seeds were picked from the snow by hand; they can also be gathered in late winter from canvas spread on the ground before the trees were shaken to release the seeds (Rudolf 1974). In most species, ripe cones are brown. Tests show that seedcoats are hard and that female gametophytes are firm. Often seeds mature earlier than expected and the period for cone collection for tamarack (Smith 1981) and western larch (Shearer 1977) can be expanded. Cones of Siberian larch should be harvested when needles start to turn yellow to assure high-quality seeds (Lobanov 1985). Data on height, seed-bearing age, seed crop frequency, and ripeness criteria are listed in tables 3 and 4.

Exraction of seeds. Freshly collected cones should be spread out in thin layers to dry in the sun or in well-ventilated cone sheds. The cones can be opened by solar heat, by heating in a cone kiln or room, or by tearing them apart mechanically (Rudolf 1974; Tkachenko and others 1939). Recommended kiln schedules are 8 hours at 49 °C for tamarack and 7 to 9 hours at 43 °C for western larch (Rudolf 1974).

After opening, cones should be run through a shaker to remove the seeds. Sometimes equipment must be modified to extract larch seeds (Saralidze and Saralidze 1976). Seeds can then be de-winged by a de-winging machine, by treading in a grain sack, or by hand-rubbing. The integument, which attaches the wing to the seed, is difficult to remove in normal processing without damage (Edwards 1987). Finally,

Table 2—*Larix*, larch: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening	Seed dispersal
L. decidua	Europe, E US & Canada	Mar–May	Sept–Dec	Sept–spring
L. gmelinii	Russia	—	Sept–Nov	Feb–Mar
	NE China	May–June	Sept	—
	Japan	Late Apr–early June	Early–late Sept	—
L. kaempferi	Japan, Europe	Apr–May	Sept	Winter
	Japan	Late Apr–mid-May	Mid–late Oct	—
L. lyallii	Rangewide	May–June	Aug–Sept	Sept
L. occidentalis	W Montana & N Idaho	Apr–June	Aug–Sept	Sept–Oct
L. sibirica	Russia	Apr–May	Sept–Nov	Sept–Mar

Sources: Arno and Habeck (1972), Asakawa and others (1981), Chinese Academy of Sciences (1978), Kaigorodov (1907), Ohmasa (1956), Rudolf (1974), Shearer (1990), Tkachenko and others (1939).

Table 3—*Larix,* larch: height, seed-bearing age, and seedcrop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Years between large seedcrops
L. decidua	9–40	1629	10	3–10
L. gmelinii	20–30	1827	14–15	2–4
L. kaempferi	30–40	1861	15	3
	—	—	12–16	4–8
L. laricina	9–20	1737	40	3–6
L. lyallii	9–25	1904	30	2–10
L. occidentalis	30–55	1881	25	2–10
L. sibirica	??–40	1806	12	3–5

Sources: Arno and Habeck (1972), Asakawa and others (1981), ODLF (1962, 1966), Schmidt and Shearer (1990), Tulstrup (1952).

Table 4—*Larix,* larch: color and size of mature cones

Species	Preripe color	Ripe color	Length (mm)
L. decidua	Green, rosy, brown	Light brown	19–38
L. gmelinii	—	—	19–25
	—	Yellow brown–deep brown	17–27
	—	Light purple–deep purple	16–24
	—	Light red–red with shine	17–24
	—	Dark red with shine	26
L. kaempferi		Brown	19–32
L. laricina	—	Brown	13–19
L. lyallii	Green–purple	Green–dark purple	38–51
L. occidentalis	Green-brown-purple	Green-brown-purple	25–38
L. sibirica	—	Brownish	25–38

Sources: Raevskikh (1979), Rehder (1940), Rudolf (1974), Shearer (1977), Suo (1982)

seeds should be cleaned with a blower or fanning mill. A mechanical macerator is routinely used for processing tamarack cones and for de-winging larch seeds (Wang 1995). Seed yields for 5 species are listed in table 5 and the number of cleaned seeds for 7 species is shown in table 6. Simak (1973) reported that, although European larch seeds can be upgraded by flotation in 80% to absolute alcohol for 5 to 15 minutes with a loss of less than 5% germinability, he recommended using water as an optimal liquid for flotation. In addition, Simak (1966) also reported that a seed sample of Himalayan larch had 28% filled seeds and weighed 4.68g /1,000 seeds (214,000 seeds/kg). Cooling cones and seeds of western larch so that the resin forms globules and becomes less sticky facilitates extraction and cleaning (Zensen 1980).

Purity of larch seedlots has ranged from 84 to 94%, but filled seed values have consistently been low at 50 to 70% (Rudolf 1974). The low percentage of filled seed may be attributed to the development of many unfertilized seeds and to woody or resin deposits in them. The woody tissue or resin hinders their removal in the cleaning process (Edwards 1987; Rudolf 1974). In lots of tamarack seeds from Ontario, 50% were sound; most of the unsound seeds had incompletely developed embryos and endosperm (Farmer and Reinholt 1986). Hall and Brown (1977) found similar conditions among seeds of European and Japanese larches and their hybrids. Seeds of western larch also have a high proportion of embryo failures (Owens and Molder 1979b). Use of X-radiography was recommended to evaluate the quality of tamarack seeds because flotation in 95% ethanol killed 52% of germinable seeds (Eavy and Houseweart 1987). A purity of 80% and a viability (germinative capacity) of 20% were recommended in 1966 as minimum standards for western larch (WFTSC 1966). Current standards for tree seeds to be certified under OECD Certification in Ontario require a minimum of 95% purity for tree seeds, resulting in an average germinability of 75 to 80% at 15 years for tamarack (Wang 1995).

Storage of seeds. Because larch seeds can be stored for long periods at seed moisture contents of 5 to 10% in sub-freezing temperatures, Bonner (1990) classifies them as "true orthodox" seeds. Gordon (1992) found that larch seeds can be stored at 6 to 8% moisture content at 1 to 3 °C for 25 years with little or no loss of germination quality. European larch seeds keep well for a year or two if stored in the cones (Rudolf 1974). Tamarack seeds store very well at 2 °C for 10 years (Wang 1982). Details on seed storage for 6 species are shown in table 7. There was no significant difference in viability of European larch seeds stored at 0 °C or in liquid nitrogen (–196 °C) for 1 to 6 days (Ahuja 1986). European larch seeds (Sudeten source) collected in 1956 and stored at 9% moisture content showed little decrease in germination, if any at all, over a 12-year period (Hill 1976).

Pregermination treatments. Seeds of most larch species germinate without pretreatment, but stratification in moist medium usually hastens the germination process. Subalpine larch has a thick seedcoat and seeds rarely germinate after 30 days of stratification on moist blotting paper, but Carlson (1994) and Shearer and Carlson (1993) obtained good germination by stratifying seeds for 30 days in a slightly acid, sphagnum-based soil. Germination of subalpine larch also improved after seeds were soaked in 1% hydrogen peroxide for periods of 6 to 24 hours (Shearer 1961). Other pre-germination treatments used for western larch seeds include soaking them in water for 18 days at 1 °C or in USP 3% hydrogen peroxide (H_2O_2) for 12 to 24

Table 5—*Larix,* larch: seed yield data

		Cone wt/cone vol		Seed yield/cone vol	
Species	**Place collected**	**kg/hl**	**lb/bu**	**kg/hl**	**lb/bu**
L. decidua	NE US Ontario, &	31	24	1.16	0.90
	Europe	—	—	.96	0.75
		24–35	19–27	0.96–2.57	0.75–2.00
L. gmelinii	Japan	26.3	20	—	—
L. kaempferi	Japan & Europe	35.5–37	28–29	—	—
		24–35	19–27	0.96–1.28	0.75–1.00
L. laricina	Great Lake states	32	25	0.96	0.75
	Ontario	—	—	0.71	0.55
L. occidentalis	Idaho & Montana	32	25	64	0.50
L. sibirica	Russia	—	—	*	—

Sources: Asakawa and others (1981), Eliason (1942), Eremko and others (1989), NBV (1946), Ohmasa (1956), ODLF (1966), Rudolf (1974), Tulstrup (1952).
* Here, 1.81 kg of seeds were extracted from 45.36 kg of cones (Gorshenin 1941).

Table 6—*Larix,* larch: numbers of cleaned seeds

		Cleaned seeds (x1,000)/weight				
		Range		Avg		
Species	**Place collected**	**/kg**	**/lb**	**/kg**	**/lb**	**Samples**
L. decidua	Alps*	93–214	42– 97	154	70	141+
	Tatra Mtns (Slovakia)	161–269	73–122	198	90	20
	Sudeten Mtns†	205–265	93–120	229	104	4
	—	150–229	68–104	187	85	12
	Romania	152–225	69–102	179	81	4
	Europe & NW US	93–269	42–122	159	72	190+
L. gmelinii	—	176–465	80–211	265	120	21
	Sakhalin	359–425	163–193	390	177	5
	Korea	203–331	92–150	236	107	12
	Japan	241–551	109–191	—	—	—
L. kaempferi	NE US	170–302	77–137	249	113	14
	Japan	150–503	68–228	265	120	68+
	Europe	126–335	57–152	254	115	17+
	Japan	117–333	53–151	190	86	—
L. laricina	—	463–926	210–420	701	318	16
	Ontario	494–723	224–328	556	252	10+
L. lyallii	NW US	231–359	105–163	313	142	4
L. occidentalis	NW US	216–434	98–197	302	137	131+
L. sibirica	Europe	68–163	31– 89	97	44	71+

Sources: Asakawa and others (1981), Eliason (1942), Heit and Eliason (1940), NBV (1946), Ohmasa (1956), ODLF (1966), Rudolf (1974), Shearer (1961, 1977), Simak (1967).
* Alpine race.
† Sudeten race.

Table 7—*Larix,* larch: storage conditions for seeds in sealed containers

Species	Seed moisture content (%)	Temp (°C)	Viable period (yr)
L. decidua	9	9–10	12
	7.5	2–4	14
L. gmelinii	6.2	2–4	15
L. laricina	7	2	10
	5.5–9.8	2–4	17–18
L. kaempferi	12.1	2–4	23
L. lyallii	4–8	-18	—
L. occidentalis	6–9	-18	—
	6	4	16*
L. sibirica	6–8	1–3	25
	6	2–4	13

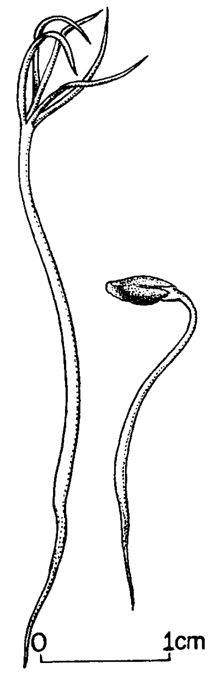
Sources: Heit (1967), Kiaer (1950), Rudolf (1974), Schubert (1954), Wang (1982), Wang and others (1993).
*Viability of 5% retained after 16 years of storage.

hours (Schmidt 1962; Shearer and Halvorson 1967). Unstratified seeds of tamatrack from Ontario provenances germinated completely in light at a range in incubation temperatures but only stratified seeds could be germinated in the dark at lower temperatures (Farmer and Reinholt 1986). Brown (1982) reported similar results for tamarack seeds from Alaska. Wang (1995) reported pregermination results for 4 species of larch:

- Daurian larch seeds did not require cold stratification or prechilling for maximum germination, but seeds stratified for 3 weeks germinated more uniformly with or without light. Non-stratified seeds germinate best with a 16-hour photoperiod than in darkness or with an 8-hour photoperiod.
- Japanese larch seeds that were stratified for 3 weeks showed significantly more germination than those that were not stratified.
- European larch seeds did not require stratification for maximum germination.
- Tamarack seeds did not require stratification for maximum germination but their germination rate was much improved.

One or two cycles of cold stratification followed by dehydration improved percentage and speed of germination of a variety of Dahurian larch (*L. gmelinii* var. *principis-rupprechtii* Mayr) (Chang and others 1991). Kuznetsova (1978) found that germination of Dahurian larch seeds was enhanced by storing moist seeds in cloth bags on frozen soil under snow.

Figure 3—*Larix laracina*, tamarack: seedling development at 1 **(right)** and 8 (**left**) days after germination.



Germination. Germination of larch seeds is epigeal (figure 3) and may be tested in germinators or sand flats. Both the Association of Official Seed Analysts (AOSA 1993) and the International Seed Testing Association (ISTA 1993) recommend the same germination test procedures: germination on top of moist blotters or other paper products for 21 days at temperatures alternating diurnally from 20 °C during a 16-hour dark period to 30 °C during an 8-hour light period. For western larch, duplicate tests of untreated seeds and seeds that are stratified for 21 days at 3 to 5 °C are recommended. An attainable standard for purity and viability for western larch seeds is 90 and 60%, respectively (Stein and others 1986). Further, they recommend that test seeds be germinated either on the top of blotters or in petri dishes at 20 to 30 °C for 3 weeks in light. Li and others (1994) showed that light may reduce germination of stratified seeds and had no effect on unstratified seeds of western larch. Sorensen (1990) recommended short stratification periods for germination in a warm greenhouse but longer ones will improve uniformity of emergence. Methods used and average results for 6 larch species are summarized in table 8. Less-used techniques to increase germination of Siberian larch include (a) presoaking seeds and subjecting them to laser radiation (Dobrin and others 1983) and (b) subjecting seeds to UHF electromagnetic field exposure (Golyadkin and others 1972).

Table 8—*Larix*, larch: germination test conditions and results

	Cold	Germination test conditions*				Germination rate		Germination	
	stratification		Temp (°C)			Amount		Avg	
Species	(days)	Medium	Day	Night	Days	(%)	Days	(%)	Samples
L. decidua	0	Moist paper	30	20†	30	—	—	36	368
	0	Moist paper or blotters	30	20	21	—	—	—	—
L. gmelinii	0	Moist paper, sand	30	20	30	47	18	52	23
L. kaempferi	0–30	Moist paper	30‡	26§	30	25	20	43	179
	21	Moist paper or blotters	30	20	16	—	—	—	—
L. laricina	60	Sand	30	20	50	33	29	47	16
	0	Moist paper	30	20	21	—	—	—	—
L. lyallii	0//	Moist paper	18	18	39	3	21	14	1
L. occidentalis	30	Soil	—	—	100	—	—	15	1
	0–42	Moist paper	30	20	30	—	—	57	104
	21	—	30	20	21	—	—	—	—
L. sibirica	0	Moist paper or blotters	30	20	21	—	—	—	—

Sources: AOSA (1993), Carlson and Blake (1969), Heit and Eliason (1940), ISTA (1993), Rudolf (1974), Shearer (1961), Simancik (1968).
* Daily light period was 8 to 16 hours.
† Constant temperatures at 26 °C and at 20 °C also were used.
‡ Cold stratification generally recommended for at least 21 days.
§ Constant temperatures at 24 °C and at 20 °C also were used.
// Seeds were soaked in USP 3% H_2O_2 for 24 hours in lieu of stratification.

Table 9—*Larix*, larch nursery practice

	Sowing	Seedlings		Sowing depth		Mulch			Tree	Outplanting
							Depth			
Species	season	/m²	/ft²	mm	in	Type	mm	in	percent	age (yrs)
L. decidua	Fall or spring	431–538	40–50	3–6	0.13–.25	Straw, litter, or burlap*	—	—	10	2+0, 1+1, 2+1, or 1+2
L. laricina	Fall	269	25	6	0.25	None	—	—	35	2+0
L. leptolepis	Spring†	753–861	70–80	3–6	0.13–.25	None	—	—	10–20	1+1 or 2+1
L. occidentalis	Spring†	323–592	30–35	3–6	0.13–.25	Sawdust	10	.38	40	1+0
L. sibirica	Spring†	323–431	30–40	3–6	0.13–.25	—	—	—	30	2+0 & 1+1

Source: Rudolf (1974).
* Only fall-sown beds should be mulched.
† Only seeds that have been stratified in moist sand or vermiculite at 0 to 9.5 °C for 14 to 42 days.

L

Nursery practice. Larch seeds should be sown unstratified in the fall or stratified in the spring and covered with 3 mm (0.13 in) of sand or nursery soil. Fall-sown beds should be covered with burlap or mulched with straw or litter over the first winter; the mulch can be removed before germination commences in the spring (Rudolf 1974). Hrabi (1989) determined that soaking European larch seeds in water for 24 hours followed by drying, also for 24 hours, permitted mechanized sowing and resulted in high germination. Some details as to nursery practice for 5 species are listed in table 9. Larches have few enemies in the nursery, although a species of the fungus *Verticillium* sometimes damages western larch plantations in the seedbed (Rudolf 1974).

The weight of Japanese larch seeds had some effect on initial size of seedlings, but most variation was attributed to differences in the rate of germination (Logan and Pollard 1981).

Larches grow in almost any kind of soil, including clay and limestone, but they develop best when grown in the open on somewhat moist, but well-drained soils. Proper selection of planting sites and seed sources reduce the risks associated with growing non-native larch (Robbins 1985). Tamarack and introduced larches growing on appropriate sites produce high fiber yields on rotations that are economically attractive (Carter and Selin 1987). The larch casebearer (*Coleophora laricella* (Hübner)) and the western spruce budworm (*Choristoneura occidentalis* Freeman) may cause serious damage to western larch plantations in the West (Fellin and Schmidt 1967) and the larch sawfly (*Pristiphora erichsonii* (Hartig)) may damage all species of larch in many areas.

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Zygophyllaceae—Caltrop family

Larrea tridentata (Sessé & Moc. ex DC.) Coville

creosotebush

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Synonyms. *Larrea tridentata* (DC.) Cov.

Other common names. greasewood, *gobernadora, hediondilla*.

Growth habit and occurrence. Creosotebush—*Larrea tridentata* (Sessé & Moc. ex DC.) Coville—is an evergreen shrub native to the arid subtropical regions of the southwestern United States, Mexico, Argentina, and Chile (Benson and Darrow 1945). Whether the North American species *L. tridentata* is distinct from the South American species *L. divaricata* Cav. has been unclear (Benson and Darrow 1945), but most recent authors recognize *L. tridentata* as a separate species. It is the dominant shrub in all 3 warm deserts of the United States: the Mojave, Sonoran, and Chihuahuan Deserts (Barbour and others 1980). Although creosotebush can grow on a variety of substrates, it is most abundant on calcareous soils (Musick 1978). Stands vary in density and stature, depending on the aridity of the site (Woodell and others 1969). Under very low rainfall, shrubs are smaller and more widely spaced than those in stands under more mesic conditions. Morphological and physiological adaptations of the genus *Larrea* to growth under xeric conditions are well studied (Barbour and others 1974, 1977). Despite dominance of the species in xeric sites, the emergence and growth of seedlings is favored by mesic conditions. Moisture, neutral pH, low salinity, and moderate temperatures are conducive to successful germination and seedling establishment (Barbour and others 1977).

Use. Creosotebush is not browsed by livestock. Although an edible livestock feed has been made from creosotebush and a valuable antitoxidant has been extracted from the shrub (Duisberg 1952), no economically feasible program for gathering and using large amounts of creosotebush has been developed. Creosotebush, like other common plants with peculiar odor or taste, has been used in traditional medicine to cure various ills (Benson and Darrow 1945). In arid and semiarid parts of the Southwest, creosotebush is used for landscaping and reclamation of disturbed lands (Day and Ludeke 1980; Graves and others 1978; Williams and others 1974).

Flowering and fruiting. Creosotebush has perfect flowers. It blooms most profusely in the spring but may flower from time to time throughout the year (Kearney and Peebles 1951; Valentine and Gerard 1968). The fruit is a densely white, villous, 5-celled capsule (Kearney and Peebles 1951). When fruits are cast, they separate into individual carpels, each normally containing 1 seed (figures 1 and 2) (Martin 1969). Carpel fill under natural conditions averages 35% (range 12 to 62%) (Valentine and Gerard 1968). Plants may fruit sparingly at 4 to 6 years of age and reach full fruiting maturity at 8 to 13 years (Martin 1974). Annual production ranges from 39 to 278 fruits/100 g (11 to 79/oz) of branch or from 119 to 1,714 fruits/plant (Valentine and Gerard 1968).

Collection, extraction, and storage. Ripe fruits may be collected from the shrub in the late spring or early summer. Fumigation or dusting fruits with insecticide is advisable to prevent insect damage. Clean seeds, extracted from the carpels, are small—there are about 374,800/kg (170,000/lb)—and are not usually available on the market (Knipe and Herbel 1966; Martin 1969). Viability of seeds in carpels declined little after 2 to 4 years in dry storage at room temperatures, and some 7- to 8-year-old lots germinated well (Barbour and others 1977; Valentine and Gerard 1968). This information strongly suggests that the seeds are orthodox in storage behavior and should store well for many years at low temperatures and moisture contents.

Figure 1—*Larrea tridentata*, creosotebush: single carpel.

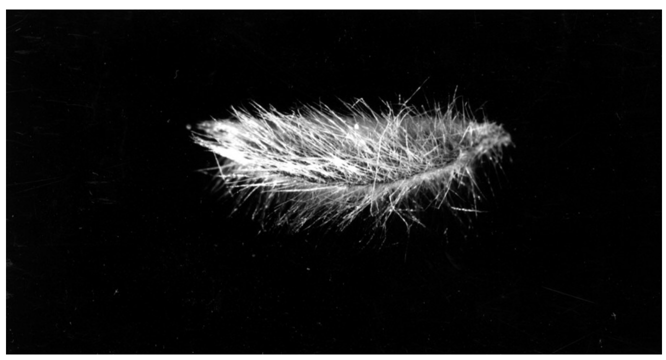

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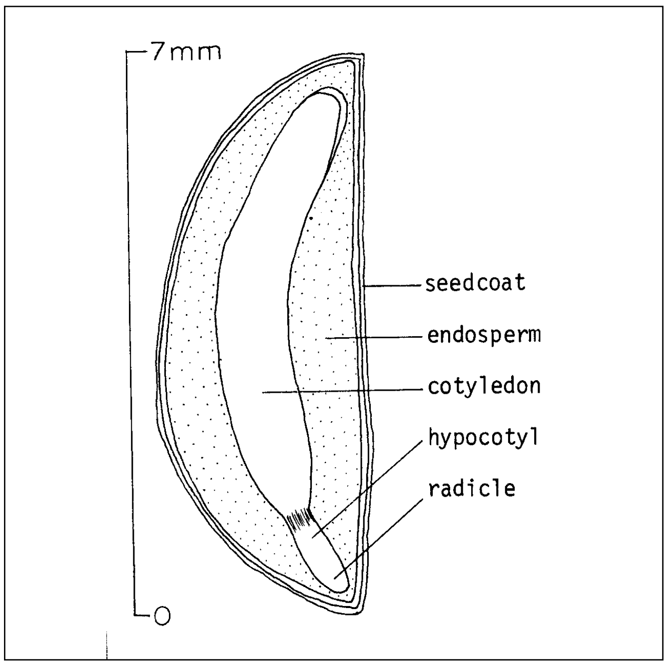
Figure 2—*Larrea tridentata*, creosotebush: longitudinal section through a carpel.



Pregermination treatments. Creosotebush seeds in carpels exhibit some seedcoat dormancy (McGee and Marshall 1993). Germination can be increased by removal of the carpel (Tipton 1984) and, to a lesser extent, by leaching of the intact carpel (Barbour 1968; Tipton 1984). Partial destruction of the carpel by mechanical abrasion is known to increase germination. Seeds in carpels so treated have a high average percentage germination (93%) over a range of 10 to 60 °C. Yet, exposing seeds to warm temperatures (over 37 °C) has been found to reduce germination, and continuous exposure to cold temperatures prior to sowing is desirable (Barbour 1968). Storage in partially sealed plastic bags with activated carbon for 30 days at 2 °C is recommended for high percentage germination (Graves and others 1975).

Germination. There are no official testing prescriptions for creosotebush. In one series of tests, germination of unscarified seeds (computed on filled carpel basis) in carpels at 17 °C ranged from 55 to 90% (average 74%) (Valentine and Gerard 1968). Carpels were dusted with fungicide and placed on moist blotter paper in petri dishes in humidified germinators (Valentine and Gerard 1968). Fungicide treatments may delay and reduce germination, however (Tipton 1985). Conditions conducive to germination include darkness (Barbour 1968; Tipton 1985), high moisture with wetting and drying cycles (Barbour 1968; McGee and Marshall 1993), temperatures near 23 °C, low salinity, and near-zero osmotic pressure (Barbour 1968).

Seedling care. Seedling survival is very low in natural populations (Ackerman 1979), and large-scale seedling establishment is thought to be rare (Barbour 1968). Heavy rains in late summer increase seedling germination and survival (Ackerman 1979; Boyd and Brum 1983). Under laboratory conditions, maximum root growth occurred at 29 °C in a medium that was slightly acidic, non-saline, and near-zero in osmotic pressure (Barbour 1968). Seedlings grown in acidic media are highly susceptible to phosphorus toxicity (Musick 1978).

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L

Ericaceae—Heath family

Ledum L.

Labrador-tea

Tricia L. Wurtz

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Other common names. trapper's-tea, trapper's tea.

Growth habit, occurrence and use. The genus *Ledum*—Labrador-tea—comprises 3 evergreen shrubs with a wide distribution (table 1). Plants range from 0.3 to 0.8 m tall and are much-branched. The leaves are leathery, lance-shaped, and hairy on the lower surface and have a characteristic spicy fragrance. Labrador-tea produces seeds vigorously; in its natural environment it can reproduce either from seeds (McGraw and Shaver 1982) or vegetatively (Sumner 1964). The below-ground system develops as result of layering by the above-ground shoots, and as much as 5 times more biomass has been documented below-ground than above, with clones covering 5 to 10 m^2 (Calmes and Zasada 1982). Marsh Labrador-tea is an alternate host for spruce needle rust—*Chrysomyxa ledicola* Legerh. (Ziller 1974). Sumner (1964) gives a detailed description of Labrador-tea morphology in interior Alaska. Leaves of marsh Labrador-tea can be boiled to make an aromatic tea; excessive doses can cause drowsiness or intestinal disturbance. Labrador-tea produces a sesquiterpene, germacrone, that makes it highly unpalatable to snowshoe hares (Reichardt and others 1990). Western Labrador-tea contains toxic alkaloids known to be poisonous to livestock (MacKinnon and others 1992).

Flowering and fruiting. Flower buds are initiated in the summer months at the tips of new shoots. They overwinter and flower the following spring, in late May and early June (Reader 1982). Flowers are white, with protruding stamens; they occur in numerous umbel-like clusters. Fruits occur as drooping clusters of dry capsules (figure 1). A large number of seeds are produced per flower. Sumner (1964) found a range of 34 to 181 seeds per fruit in her study of marsh Labrador-tea in interior Alaska. Extensive flowering is common. Seeds are small (bog Labrador-tea, 1.8 to 3.0 mm by 0.2 to 0.3 mm; marsh Labrador-tea, 1.4 to 2.0 mm by 0.2 to 0.3 mm) (Karlin and Bliss 1983). Seedcoats are golden and translucent, with a loose, elongated testa that aids wind dispersal (Densmore 1997). Calmes and Zasada (1982) found that only 45% of bog Labrador-tea seeds were filled.

Extraction, cleaning, and storage of seeds. Seed capsules open as they dry, readily releasing seeds. Empty capsules can be separated from seed with a fine-mesh sieve. Most seed viability is lost within 1 year of collection. When seeds were stored for 22 months at 4 °C, germination dropped from 58 to 16% (Karlin and Bliss 1983).

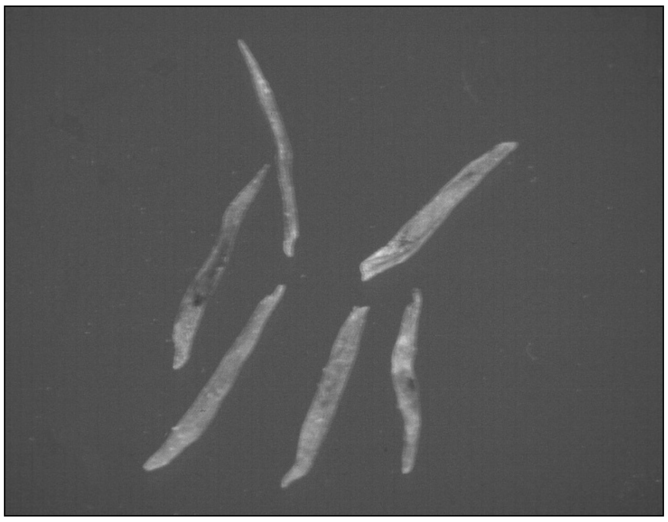
Pre-germination treatments. Labrador-tea does not require cold stratification for germination, but most data suggest that stratification improves germination. In a study of marsh Labrador-tea, seeds exhibited shallow dormancy (Calmes and Zasada 1982); 30 days of cold stratification

Table 1—*Ledum,* Labrador-tea: nomenclature and occurrence

Scientific name & synonym	Common name	Occurrence
***L. glandulosum* Nutt.**	**western Labrador-tea**	N Europe
***L. palustre* L. ssp. *decumbens* (Ait.) Hulten** *L. palustris* ssp. groenlandicum (Oeder) Hulten	**marsh Labrador-tea**	SE & interior Alaska; Canada E to Newfoundland, S to New Jersey, Ohio, Minnesota, & Washington
***L. groenlandicum* Oeder.** *L. decumbens* (Ait.) Lodd ex Steud.	**bog Labrador-tea**	Alaska & E through Canada to Greenland; S to Labrador & Hudson Bay; also N Europe & Asia

Sources: Juntila (1972), Viereck and Little (1972).

Figure 1—*Ledum groenlandiicum*, bog Labrador-tea: individual dry capsules.



increased the rate and percentage of germination. Densmore (1997) achieved 100% germination of marsh Labrador-tea at 20 °C and with 20 hour day-length following cold stratification. In another study, marsh Labrador-tea germinated best without any stratification (Karlin and Bliss 1983).

Germination tests. Seeds can be sprinkled on the surface of a moist substrate and covered with clear plastic film. Light is required for germination (Calmes and Zasada 1982; Karlin and Bliss 1983); germination is enhanced with longer day-lengths (Densmore 1997). In addition to light, optimal germination conditions include a continually moist, somewhat acidic substrate (pH 5.5) and mean daily temperatures ≥ 17 °C (Karlin and Bliss 1983). Treating seeds with gibberellic acid greatly increased germination under a variety of environmental conditions (Junttila 1972).

Nursery practice. Marsh Labrador-tea has been successfully propagated from seeds for horticultural purposes. The seeds should be sown thinly in boxes of pure, finely sifted peat moss, and then covered with a fine dusting of peat moss (Sheat 1948). Cuttings taken from mature plants in mid-December rooted well (Dirr and Heuser 1987), but below-ground stem cuttings produced few new shoots (Calmes and Zasada 1982). Half-mature side shoots can be pulled off and rooted in a mixture of peat moss, loam, and sand (Sheat 1948).

Seedling care. Labrador-tea seedlings are fragile and slow-growing. After 4 months of growth in a greenhouse, seedlings of bog Labrador-tea were only a few millimeters tall (Sumner 1964). Though seeds can germinate in water-saturated substrates, seedling survival and establishment are enhanced with better drainage.

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Fabaceae—Pea family

Lespedeza Michx.

lespedeza

Richard T. Busing and Willis G. Vogel

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Growth habit, occurrence, and use. The genus *Lespedeza* includes about 140 species of shrubs, sub-shrubs, and herbs (Hensen 1957). Most species are native to the temperate regions of eastern Asia and only about 11 species are considered native to North America (Clewell 1966). All native species are herbaceous; however, several species of shrub lespedeza have been introduced into the United States (table 1). The non-native shrub lespedezas tend to have herbaceous stems with woody bases. All species listed in table 1 are planted for conservation and management purposes (Kelsey and Dayton 1942; Strausbaugh and Core 1964). Both shrub and Thunberg lespedezas are commonly referenced in the floristic literature (Gleason and Cronquist 1991). Leafy lespedeza, a less frequently referenced species, is noted by some to occur in the central-eastern United States (Clewell 1966; Isely 1990; Kartesz 1994). Although the name *L. japonica* has been used since the 1930s, many of the *L. japonica* materials have been re-identified as *L. thunbergii* (Vogel 1974). Classification of these shrubs is difficult and confused because of variation resulting from interspecific hybridization (Clewell 1966). Shrub lespedeza is the most common and widely planted shrub in the genus in the United States (Davison 1954; Vogel 1974).

Lespedeza shrubs are adapted primarily to the southeastern two-thirds of the United States, except for southern Florida (Clewell 1966; Davison 1954). They are planted mainly for wildlife food and cover (Owsley and Surrency 1989) and for erosion control (Gabrielson and others 1982; USDA SCS 1980). Soil enrichment by nitrogen-fixing symbionts is also a potential benefit (Allen and Allen 1981). The seeds are preferred quail food (Crider 1952; Davison 1954; Vogel 1974). Some plantings have been made for ornamental purposes (Clewell 1966; Crider 1952). Grown to maturity, plants of shrub lespedeza may reach a height of 3 m but more commonly 1.2 to 2.4 m (Crider 1952; Davison 1954; Vogel 1974). In management for seed production, stems of some shrub lespedezas must be cut back to the ground (Davison 1954; Vogel 1974).

Superior strains. Superior strains of shrub lespedeza have been selected and developed mostly at the plant material centers of the USDA Natural Resources Conservation Service (formerly the Soil Conservation Service) in the East and Southeast (Vogel 1974). Strains 100 and 101 of shrub lespedeza were developed for their greater production of seed and persistence of fruits on the plants after ripening (Davison 1954). *L. bicolor* 'Natob' matures seeds much earlier and is more winter-hardy than any other strain of shrub lespedeza grown in the United States. Thus, it can be grown farther north than other shrub lespedezas (Clewell 1966). A selection of Thunberg lespedeza called VA-70 (USDA SCS

Table 1—*Lespedeza,* lespedeza: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
L. bicolor **Turcz.**	**shrub lespedeza,** bicolor lespedeza	Origin: E Asia; Arkansas to Virginia, S to N Florida & Texas
L. cyrtobotrya **Miq.**	**leafy lespedeza,** shrub lespedeza	Origin: temperate E Asia; central E US
L. thunbergii **(DC.) Nakai** *L. sieboldii* Miq. *L. racemosa* Dipp. *L. formosa* Koehne *L. japonica* Bailey *Desmodium penduliflorum* Oudem.	**Thunberg lespedeza**	Origin: E Asia; similar range as shrub lespedeza but not as far N; best adapted to N Florida, S Alabama, & S Mississippi

Sources: Clewell (1966), Isely (1990), Kartesz (1994), Vogel (1974).

1980) ripens seeds a month earlier than most strains of shrub lespedeza, thus adapting it to the mountains and more northerly areas of the South (Vogel 1974).

Seeds of these strains have been marketed, but production has been so erratic that seed supplies can be scarce or nonexistent. Some problem exists in maintaining seed supplies of pure strains, apparently because of cross-pollination.

Flowering and fruiting. The flowers are loosely arranged on elongate racemes and are mostly rose-purple, with gradation to white in some variants (Ohwi 1965; Rehder 1940; Strausbaugh and Core 1964). The chasmogamic flowers may be self- or cross-pollinated (Clewell 1966; Crider 1952; Ohwi 1965). Honey bees (*Apis mellifera* L.), bumble bees, and other insects are necessary for pollination (Crider 1952; Graetz 1951).

Time of flowering and fruiting varies among species and strains, but it is also controlled by the latitude where the plants are grown. Flowering occurs mostly in July and August but will begin in June in Mississippi and as late as September in Maryland. The brown fruits are 1-seeded indehiscent legumes (pods) that mature mostly in late September and October (Vogel 1974) (figure 1). The legumes fall to the ground when ripe, and most of them are down by early winter (Crider 1952).

A light seedcrop may occur the first year from 1-year-old transplants, and good seedcrops can be expected each succeeding year (Crider 1952). Seeds of shrub lespedeza are pale brown to olive and copiously flecked with purple. Seeds of Thunberg lespedeza are solid dark purple (Musil 1963) (figure 1). Seeds of lespedeza have little or no endosperm (figure 2).

Collection of fruits; extraction and storage of seeds. Shrub lespedeza seeds are most commonly harvested with a combine as soon as the fruits are ripe and moderately dry. The combined material, which includes stems, intact legumes, and hulled seed, is air-dried and then cleaned to separate seed and legumes from the stems and inert matter. Seeds that remain in their legumes can be hulled by running them again through a combine or through a huller-scarifier and then should be cleaned (Vogel 1974).

Seed yields may exceed 560 kg/ha (500 lb/ac) (Byrd and others 1963), but more commonly yields range from 336 to 447 kg/ha (300 to 400 lb/ac) (Crider 1952; Vogel 1974). Weight of cleaned seeds per volume was 67 kg/bu (60 lb/bu) (Vogel 1974). The number of cleaned seeds is about 187,000/kg (85,000/lb) for common shrub lespedeza (Crider 1952; Strausbaugh and Core 1964; Vogel 1974); 140,000/kg (64,000/lb) for 'Natob' bicolor (Crider 1952; Vogel 1974); and 154,000 to 159,000/kg (70,000 to 72,000/lb) for Thunberg lespedeza (Strausbaugh and Core 1964; Vogel 1974).

Seeds are stored at 10 °C and 40% relative humidity. They may be stored either hulled or unhulled, but seeds stored in the hull remain viable longer than hulled seeds. Length of viability varies with harvest years and storage treatment, but seeds have been viable after 20 years of storage (Vogel 1974).

Figure 1—*Lespedeza, lespedeza:* legumes (**above**) of *L. bicolor*, shrub lespedeza (**left**) and *L. thunbergii*, Thunberg lespedeza (**right**); and seeds (**below**) of *L. bicolor*, shrub lespedeza (**left**) and *L. thunbergii*, Thunberg lespedeza (**right**).

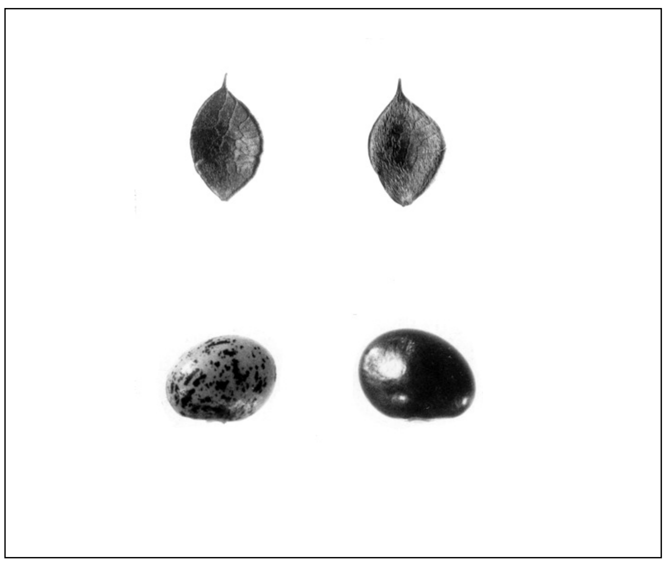
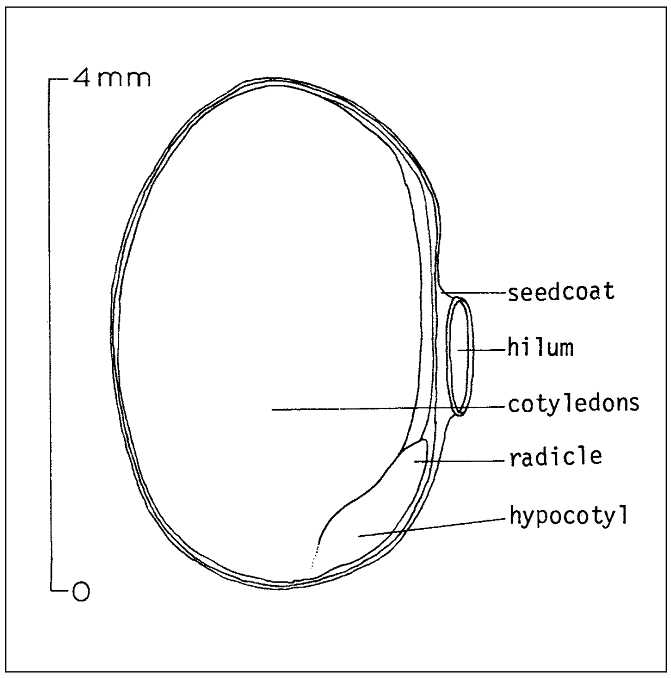


Figure 2—*Lespedeza thunbergii*, Thunberg lespedeza: longitudinal section through a seed.



Pregermination treatments. A high percentage of shrub lespedeza seeds have hard seedcoats and should be scarified before planting. Mechanical scarification is the preferred method. A huller-scarifier is one machine used for this purpose (Vogel 1974). About 50% of the seeds cleaned in a hammermill will be scarified. Fifty percent scarification allows a good stand to become established the first year but holds some seeds dormant for germination the second year. This could help assure stand establishment in case of failure or poor establishment the first year (Vogel 1974). Seeds can also be scarified by immersion in concentrated sulfuric acid for 30 minutes, followed by washing and drying (Crider 1952). The acid treatment causes less damage to older brittle seeds than does mechanical treatment (Vogel 1974).

Germination tests. Germination tests can be made by placing seeds between blotters in a petri dish, in a rolled towel (either horizontally or vertically), or in sand or soil and holding them at temperatures of 20 °C for 16 hours and 35 °C for 8 hours for each day. Light is not required, but it has been used with no effect on germination. First counts of germinated seeds are made at 7 days and last counts at 21 days. Percentage germination is similar for all 3 species; the average is about 76%. Seed purity is 95% or higher (Vogel 1974).

Nursery practices. Seeds should be broadcast in large quantities—11 to 16 kg/ha (10 to 14 lb/ac)—on a firm seedbed lacking weeds (USDA SCS 1980). Inoculation with a specific *Rhizobium* strain is recommended at the time of planting (USDA SCS 1980). When growing seedlings for transplanting, rows should be spaced 0.9 to 1.2 m (3 to 4 ft) apart and planted with 39 to 66 seeds/m (12 to 20 seeds/ft) of row. Seeds inoculated with group 4 (cowpea) inoculant are sown in shallow furrows and covered 6 to 13 mm ($^1/_4$ to $^1/_2$ in) deep. Mid-spring is the ideal time for seeding. The time interval for seeding starts in the spring at the last expected frost date and continues thereafter for about 6 weeks. Seeds are treated with tetramethethylthiuram disulfide (thiram) for fungus control. About 95% of the 1-year-old seedlings are usable. For producing wildlife food, direct seeding in the field is more popular than transplanting seedlings (Crider 1952; Vogel 1974). Optimal growth occurs in well-drained, non-acidic soils (USDA SCS 1980).

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L

Fabaceae—Pea family

Leucaena leucocephala (Lam.) de Wit.

leucaena

C. D. Whitesell and John A. Parrotta

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Other common names. leadtree, *zarcilla*, *popinac*, *koa haole, tantau*.

Synonyms. *Leucaena glauca* (L.) Benth., *L. blancii* Goyena, *L. glabrata* Rose, *L. greggii* Watson, *L. latisiliqua* (L.) W.T. Gillis, *L. salvadorensis* Standl.

Growth habit, occurrence, and use. The genus *Leucaena* includes about 50 species of trees and shrubs that are native to Central America and southeast Asia. Leaves, legumes (pods), and young seeds of at least 4 *Leucaena* species have been used by humans for food since the time of the Mayans (Brewbaker and others 1970). Leucaena—*Leucaena leucocephala* (Lam.) de Wit.—the most widespread member of the genus, originated in Mexico and Central America (Brewbaker and others 1972) but is now considered pantropical. It is found throughout the West Indies from the Bahamas and Cuba to Trinidad and Tobago and has become naturalized in southern Texas and southern Florida; it also has been planted in California (Little and Wadsworth 1964). The species was introduced to Puerto Rico and the Pacific Islands during the Spanish colonial era and to Hawaii about 1864. It invades cleared areas and forms dense thickets, either as a shrub or small tree up to 10 m in height (Takahashi and Ripperton 1949). This species is evergreen when moisture is not a limiting factor. Strains of leucaena can be categorized as one of two types: the "common" (or "Hawaiian") and the "giant" (or "Salvadorian") (Brewbaker and others 1972). The common type, representing the strains most commonly naturalized outside of the species' native range, is a drought-tolerant, branchy, abundantly flowering, and aggressive shrub or small tree. The Salvadorian type is an erect tree that attains heights up to 20 m (Brewbaker and others 1972; NAS 1984). In many parts of the world, the species is considered a weed.

Leucaena is used for a variety of purposes, including timber, fuelwood, forage, and organic fertilizer. It is planted as a shade tree for coffee, cacao, and other cash crops; for soil fertility improvement; erosion control; and site preparation in reforestation (Neal 1965; NAS 1984; Parrotta 1992; Whitesell 1974). The light reddish heartwood is easily worked but is of low to medium durability. It is used for light construction, boxes, and particleboard. The wood is considered a promising source of short-fiber pulp for paper production. The protein-rich leaves and legumes are widely used as fodder for cattle, water buffalo, and goats. The protein content of dry forage ranges from 14.0 to 16.2% (Oaks and Skov 1967). Depending on variety, the protein consists of 19 to 47% mimosine (Brewbaker and others 1972), an amino acid that can cause weight loss and ill health in monogastric animals such as pigs, horses, rabbits, and poultry when leucaena fodder comprises more than 5 to 10% (by weight) of the diet. Ruminants (cows, buffalo, and goats) in most parts of the world (except for Australia, Papua New Guinea, and parts of Africa and the Pacific) have stomach microorganisms that render mimosine harmless.

Flowering and fruiting. Flowering phenology varies widely among varieties and with location. The common type varieties flower year-round, often beginning as early as 4 to 6 months after seed germination. The giant varieties flower seasonally, usually twice a year. The spherical, whitish flower heads are 2.0 to 2.5 cm in diameter and are borne on stalks 2 to 3 cm long at the ends or sides of twigs (Parrotta 1992). The fruits, generally produced in abundance from the first year onward, are flat, thin legumes that are dark brown when ripe; they measure 10 to 15 cm long and 1.5 to 2.0 cm wide. A legume contains 15 to 20 seeds (Parrotta 1992). The seeds are small (8 mm long), flat, teardrop-shaped, shiny, and dark brown with a thin but fairly durable seedcoat (figures 1 and 2). The seeds are usually released from dehiscent legumes while still on the tree, although unopened or partially opened legumes may be carried some distance by wind. The legumes are commonly eaten by and pass through the digestive tracts of livestock, which appear to be important dispersal agents in pastures.

Figure 1—*Leucaena leucocephala*, leucaena: seed.

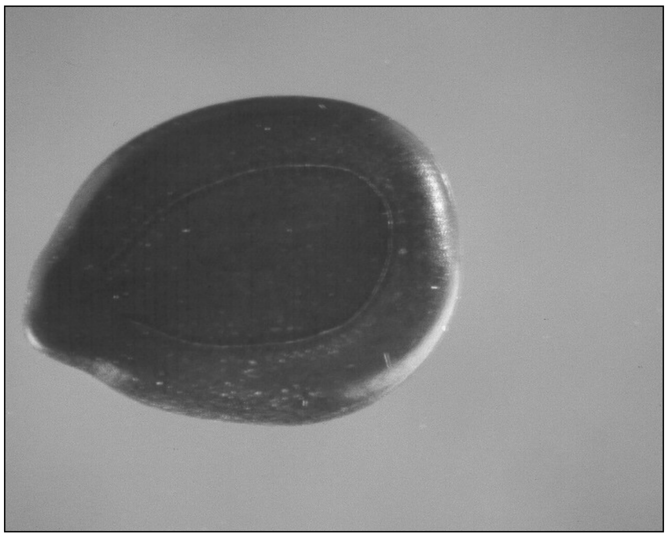
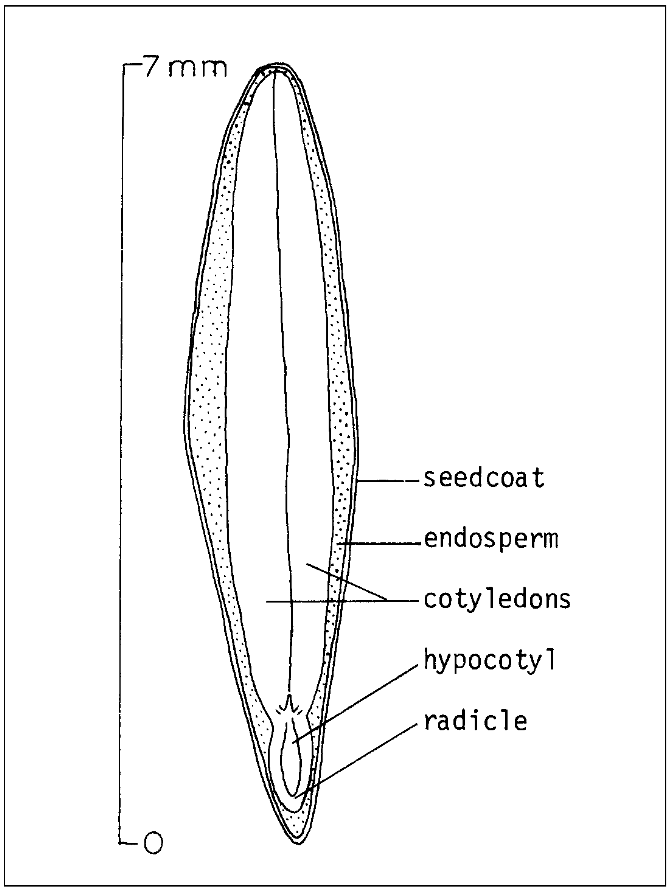


Figure 2—*Leucaena leucocephala*, leucaena: longitudinal section through a seed.



Collection, extraction, and storage. Legumes may be collected from branches when ripe, before dehiscence; they should be sun-dried and then threshed to release seeds. Threshing is commonly done by beating the dried legumes in cloth bags. There are about 17,000 to 24,000 clean seeds/kg (11,000/lb) (Parrotta 1992). Unscarified seeds will remain viable for more than 1 year when stored under dry conditions at ambient temperatures and up to 5 years stored at 2 to 6 °C. Dried, scarified seeds will remain viable for 6 to 12 months (van den Beldt and others 1985; Daguma and others 1988; Parrotta 1992).

In Hawaii the larvae of a recently introduced beetle—*Araecerus levipennis* Jordan—can destroy the seed. At times, virtually all of the legumes in certain stands are infested (Sherman and Tamashiro 1956). Seeds should be fumigated as soon as possible after collection to kill the larvae. Because of the uncertain status of methyl bromide at this time, local extension authorities should be consulted about an appropriate fumigant to use.

Pregermination treatments. Although seeds may be sown without scarification, mechanical scarification (abrasion with sandpaper or clipping the seedcoat) or either of the following 2 treatments are used to ensure more rapid and uniform germination (Parrotta 1992): (a) immersion in hot water (80 °C) for 3 to 4 minutes followed by soaking in water at room tmperature for up to 12 hours or (b) soaking in concentrated sulfuric acid for 15 to 30 minutes. Scarification may be followed by inoculation with nitrogen-fixing *Rhizobium* bacteria (mixed with finely ground peat) after coating the seeds with a gum arabic or concentrated sugar solution. Pre-sowing inoculation of seeds facilitates good field establishment in soil devoid of effective rhizobia strains.

Germination tests. Germination rates are commonly 50 to 98% for fresh seeds (Daguma and others 1988; NAS 1984). Scarified seeds germinate 6 to 10 days after sowing; unscarified seeds germinate 6 to 60 days after sowing (Parrotta 1992). Germination in leucaena is epigeal.

Nursery practice. Leucaena seeds germinate on or near the soil surface and should not be planted deeper than 2 cm ($^3/_4$ in). Nursery media should be well-drained, have good nutrient and water-holding capacity, and have a pH between 5.5 and 7.5 (van der Beldt and Brewbaker 1985). Light shade is recommended during the first few weeks of seeding development, and full sun thereafter (Parrotta 1992). Taproot development is rapid in young seedlings. Seedlings generally reach plantable size (height of 20 cm or 8 in) in 2 to 3 months. Plantations may be established by direct seeding (Francis 1993) or by planting container seedlings, bareroot seedlings, stem cuttings (2 to 5 cm in diameter).

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Ericaceae—Heath family

Leucothoe fontanesiana (Steud.) Sleum.

drooping leucothoe

Frank A. Blazich and Mark C. Starrett

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Synonyms. *Andromeda fontanesiana* Steud.; *Leucothoe catesbaei* (Walter) A. Gray, *Leucothoe editorum* Fern. & Schub.

Other common names. highland doghobble, doghobble, switch ivy, fetterbush.

Growth habit, occurrence, and uses. Drooping leucothoe—*Leucothoe fontanesiana* (Steud.) Sleum.)—as its common name implies, has a graceful, arched habit (Bridwell 1994). The plant is a broad-leaved, evergreen shrub, 1 m tall, with a spread of 1.2 to 1.8 m (Halfacre and Shawcroft 1975). Drooping leucothoe spreads by underground stems and can produce impenetrable thickets (Halfacre and Shawcroft 1975). These dense thickets have often hindered hunting from horseback, ensnaring both dogs and horses, hence the common names "doghobble" and "fetterbush." This species occurs naturally in moist wooded areas along the Appalachian Mountains of the United States, from Virginia to Georgia and Tennessee (Ingram 1961). In its native habitat, drooping leucothoe occurs as an undergrowth accompaniment to taller shrubs such as rhododendron (*Rhododendron* L. spp.) or mountain-laurel (*Kalmia latifolia* L.) (Melvin 1981). Drooping leucothoe is a robust, hardy shrub that can be cultivated in USDA Hardiness Zones 5 to 8. However, a cool, shady, well-drained site must be selected for the southern landscape (Dirr 1990).

The species is best suited for landscape use in lightly shaded sites with moist soil that is high in organic matter (Ingram 1961). Typically, the plant is utilized as an understory shrub to complement other understory plants that have a leggy habit (Dirr 1990). Drooping leucothoe can best be used as a cover on shady banks and is especially effective in mass plantings (Dirr 1990). An additional quality that increases the value of this plant in the landscape is its rich, lustrous, dark green foliage, which becomes reddish bronze in autumn and eventually turns bronze-purple in winter, thus providing seasonal interest (Halfacre and Shawcroft 1975; Odenwald and Turner 1987). No geographic races or hybrids have been described currently in the literature.

Flowering and fruiting. White, waxy, urn-shaped flowers are borne on small, pendant, axillary racemes in May and scent the air with a pungent fragrance (Dirr 1990; Odenwald and Turner 1987). Although individual flowers are small (0.6 cm long), they are clustered along 5.0- to 7.5-cm-long racemes and provide a striking contrast to the dark green foliage (Dirr 1990).

Collection of fruits, seed extraction, cleaning, and storage. Capsules and seeds ripen in mid- to late autumn and can be collected at that time (Wyman 1953). Capsules are removed from the plant and lightly beaten, then rubbed to open them completely (Dirr and Heuser 1987); then, seeds are shaken from the capsules. Viability can be poor if seeds are not graded rigorously. Seeds are quite small (figures 1 and 2). When dried to a moisture content of 3% and cleaned, pure seeds averaged 22,900/g (650,000/oz) (Blazich and others 1991). Seeds will remain viable if stored dry at room temperature and used within 2 years (Wyman 1953).

Figure 1—*Leucothoe fontanesiana*, drooping leucothoe: seeds.

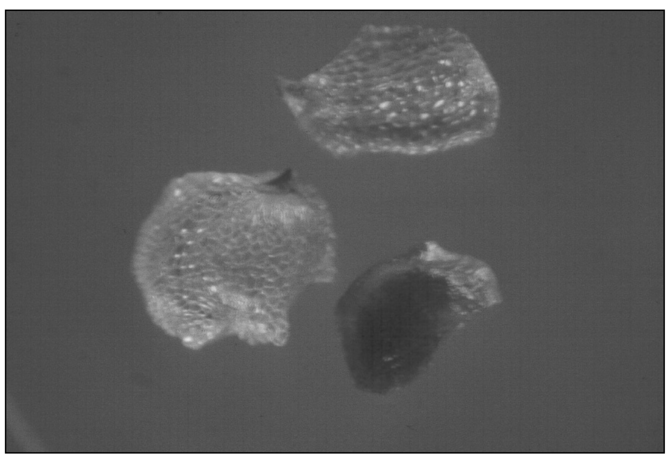
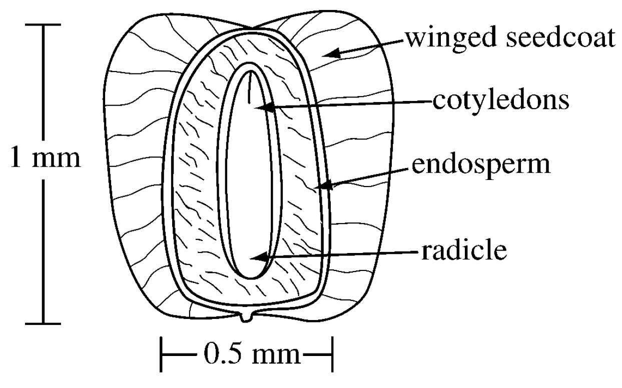


Figure 2—*Leucothoe fontanesiana*, drooping leucothoe: longitudinal section of a seed.



Glenn and others (1998) reported that seeds will remain viable for several years if stored in a sealed container at –18 or 4 °C. This suggests that the seeds are orthodox in storage behavior.

Germination tests. There are no prescribed methods for official tests of this species, but the seeds germinate readily without pretreatment (Dirr and Heuser 1987; Fordham 1960). Seeds of drooping leucothoe require light for germination (Blazich and others 1991). Blazich and others (1991) conducted a 30-day germination study utilizing seeds from a native population of plants growing in Henderson County, North Carolina. Seeds were germinated at 25 °C or an 8/16 hour thermoperiod of 25/15 °C with daily photoperiods of 0, $^1/_2$, $^1/_2$ twice daily, 1, 2, 4, 8, 12, or 24 hours. The cool-white fluorescent lamps utilized as the light source provided a photosynthetic photon flux (400 to 700 nm) of 35 μmol/m^2/sec (2.8 klux). For both temperatures, no germination occurred during the 30-day test period for seeds not subjected to light. At 25 °C, increasing photoperiod increased percentage germination values of 60 and 68% occurring by day 24 for the 12- and 24-hour photoperiods, respectively. The alternating temperature of 25/15°C enhanced germination when light was limiting. At this temperature, germination ≥ 85% was reached by day 27 for photoperiods ≥ 2 hours. Germination is epigeal.

Nursery practice. Typically, the germination medium is kept at 24 °C via bottom heat (Bir 1987). Seeds are sown on the surface of a steam-pasteurized medium, such as pinebark sifted through a 6-mm-mesh (0.25-inch-mesh) screen. They are irrigated slightly and the surface of the germinating medium is thereafter never allowed to dry completely (Bir 1987). One recommended practice is to fertilize seedlings at the first true leaf stage with a half-strength solution of a 15-45-5 ($N:P_2O_5:K_2O$) fertilizer (Bir 1987). After 2 weeks, the seedlings are then fertilized with a full-strength solution applied weekly until they are transplanted into liner flats or pots (Bir 1987). Drooping leucothoe can also be propagated vegetatively by rooting stem cuttings (Dirr and Heuser 1987). The species roots readily from cuttings taken during the months of June through December without a need for exogenous auxin application (Dirr and Heuser 1987).

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Oleaceae—Olive family

Ligustrum L.

privet

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Growth habit, occurrence, and uses. The genus *Ligustrum*—the privets—includes about 50 species native in eastern Asia and Malaysia to Australia, with 1 species occurring in Europe and North Africa (Bean 1978; Rehder 1940). Privets have been widely distributed and cultivated outside of their indigenous distributions, and many varieties and cultivars are recognized (Bailey 1947; Bean 1978; Ohwi 1965; Rehder 1940). At least 4 species have naturalized in the United States, several over broad geographic regions (table 1). European, or common, privet is widely naturalized in eastern North America. California privet has been planted from coast to coast in the southern United States and has naturalized extensively in the Southeast.

The privets are deciduous or evergreen shrubs or small trees ranging from 2 to 12 m in height (table 2). Maximum heights reported in the United States are 7.8, 24.9, and 12.8 m, respectively, for California, Chinese, and Japanese privets (AFA 1996). Growth form ranges from compact dense shrubs to small trees with slender spreading branches. Privets grow readily in many kinds of soil (Bailey 1947; Bean 1978; Meikle 1958) and in moisture regimes ranging from very dry to stream-side and floodplain (Lee and others 1991; Seymour 1982). They establish on roadsides, sand dunes, open and closed woodlands, tree borders, and other disturbed areas (Bailey 1947; Radford and others 1968; Seymour 1982; Wilson and Wood 1959).

Table 1—*Ligustrum,* privet: nomenclature and occurrence

Scientific name	Common name(s)	Occurrence
***L.ovalifolium* Hassk.**	**California privet**	Planted across S US from Virginia to California; extensively naturalized from Virginia to Florida
***L. japonicum* Thunb.**	**Japanese privet**	Planted in SE US from North Carolina to Alabama, to Louisiana & Texas; naturalized locally
***L. lucidum* Ait. f.**	**glossy privet**	Scattered from Pennsylvania S to Texas
***L. sinense* Lour.**	**Chinese privet,** *trueno de seto*	Planted in SE US from Virginia to Georgia, Oklahoma, & Texas; widely naturalized
***L. vulgare* L.**	**European privet,** common privet	Widely naturalized in E North America

Sources: Little (1979), Rehder (1940), Wilson and Wood (1959), Vines (1983).

Table 2—*Ligustrum,* privet: height, leaf habit, color, and size of mature fruit

Species	Height at maturity (m)	Leaf habit	Fruit color	Fruit size (mm)
L. ovalifolium	5	Deciduous or half-evergreen	Purple-black, black	5–8
L. japonicum	2–12	Evergreen	Purple-black, blue	6–10
L. lucidum	3–10	Evergreen	Purple-black, blue-black	8–10
L. sinense	4–10	Deciduous or half-evergreen	Purple-black, blue-black	4–7
L. vulgare	5	Deciduous or half-evergreen	Lustrous black	6–8

Sources: Bean (1978), McMinn and Maino (1937), Ohwi (1965), Radford and others (1968), Rehder (1940), Vines (1983).

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The privets are valued for landscape shrubbery because of their handsome white flowers and dark green foliage; ready establishment; and resistance to insects, dust, and air pollution (Bailey 1947; Howe and Woltz 1981). California privet grows well even in the spray of salt water (Bailey 1947). Japanese privet is an excellent evergreen shrub for shaping into hedges, screens, or topiary (distinctive shapes such as globes or animals) (Vines 1983). Glossy privet is an evergreen tree suited for growing in narrow areas, making it a fine choice for a street or lawn tree. Several privets have been used as garden hedges, but their innumerable, fibrous roots are invasive and may impoverish adjacent flower beds (Meikle 1958).

Privets are also useful as wildlife habitat, windbreaks, and erosion-control plantings. Although the lengthy availability of fruits and seeds indicates that they are not generally relished by wildlife, some consumption by birds has been observed (Martin and others 1951; Van Dersal 1938; Vines 1983).

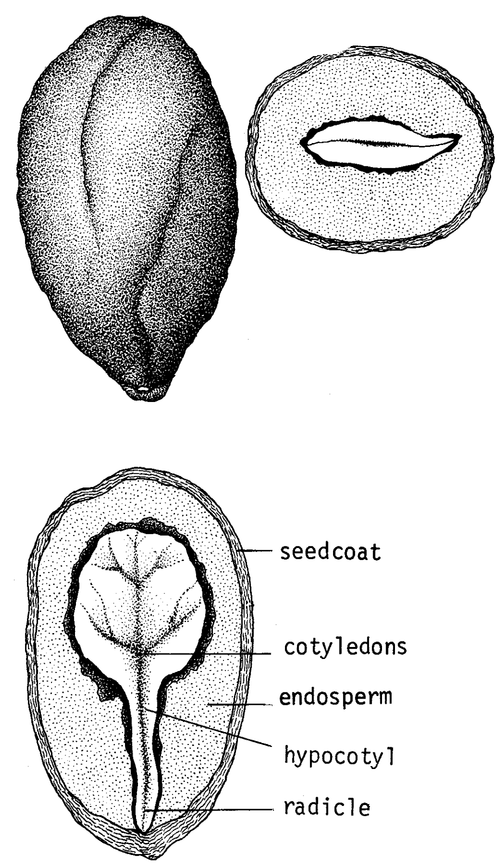
Flowering and fruiting. The terminal panicles bearing privet flowers range from 3 to 20 cm long and are usually somewhat narrower in width than length (Bean 1978). The flowers are small, perfect, always a shade of white, and usually fragrant. However, the fragrance of some privet flowers may be considered "objectionable at close quarters" (Bean 1978). Summer is the main flowering period, but timing and duration varies by species (table 3). There is evidence that Japanese privet seedlings require winter chilling to stimulate blooming (Morita and others 1979).

The fruits are 1- to 4-seeded berrylike drupes with membranaceous to stony endocarps about 4 to 10 mm long (figures 1 and 2; table 2). Fruits ripen from September to November (table 3) and those of some species often remain on the panicles into winter (Rehder 1940). Ripened fruits generally range in color from dark blue to black. The fruits in some varieties of European privet, however, are not black: f. *chlorocarpum* (Loud.) Schelle has green fruits; f. *leucocarpum* (Sweet) Schelle, white fruits; and f. *xanthocarpum* (G. Don) Schelle, yellow fruits (Bean 1978).

According to incidental observations, privet species produce seedcrops almost annually, but systematic records of crop size and occurrence are not available (Dirr and Heuser 1987).

Collection, extraction, and storage. Ripe privet fruits may be stripped from panicles by hand in the fall or early winter. If the fruits are already dry, they can be stored uncleaned, but prompt cleaning is generally better. Seeds can be separated from fresh or remoistened pulp by running the fruits with ample water through a macerator. For some privet species, particular care must be taken during cleaning to ensure that their soft-coated seeds are not damaged (figure 1).

Figure 1—*Ligustrum sinense*, Chinese privet: oblong seed (**upper left**); longitudinal section (**lower left**) and cross section (**right**).



Privet seeds are relatively small and vary in size and weight by species (table 4). In one sampling, seeds of European privet constituted 54% of fruit biomass on a dry-weight basis (Lee and others 1991).

Storage of cleaned European privet seeds in ordinary dry conditions was recommended long ago (Chadwick 1935), but little has been reported on the success of this practice. It seems likely that their longevity could be prolonged by closed storage at cool temperatures or even at –18 °C, which has proven satisfactory for many tree species that tolerate low moisture content.

Pregermination treatments and germination tests. Fresh privet seeds that have been cleaned will germinate in 60 days without stratification (Heit 1968; Dirr and Heuser 1987). Stored seeds, however, require 30 to 60 days of cold stratification at 0 to 5 °C to induce prompt germination (Chadwick 1935; Dirr and Heuser 1987; Heit 1968; Shumilina 1967). Fifteen days of warm stratification at 18 to 20 °C or alternating warm and cold stratification were suc-

Figure 2—*Ligustrum lucidum,* glossy privet: seeds.

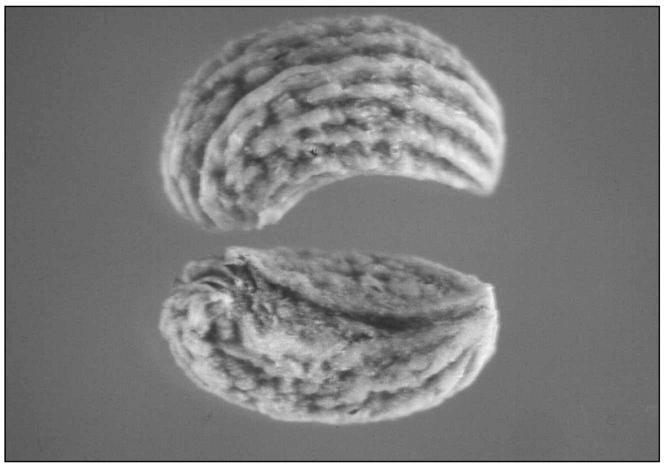


Table 3—*Ligustrum,* privet: phenology of flowering and fruiting

Species	Flowering	Fruit ripening
L. ovalifolium	June–July	Sept–Nov
L. japonicum	June–Sept	Sept–Nov
L. lucidum	July–Sept	Sept–Oct*
L. sinense	Mar–July	Sept–Nov*
L. vulgare	June–July	Sept–Oct*

Sources: Radford and others (1968), Rehder (1940), Vines (1983).
* Fruits persist into winter.

cessful treatments on some seedlots in Russia (Shumilina 1967). Some germination may occur in lengthy stratification.

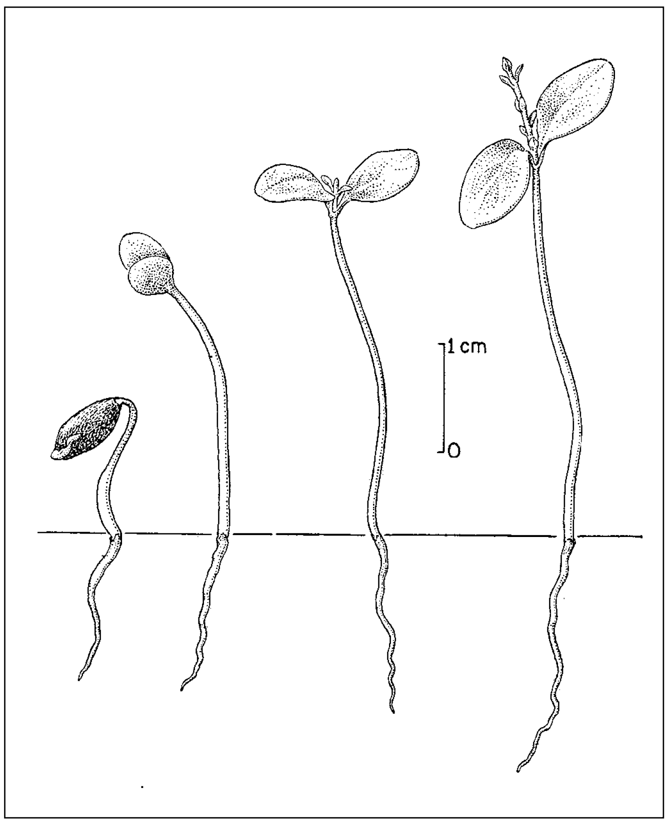
Best germination results have been obtained by running tests for 60 days at 10 °C for 16 hours/day and 30 °C for 8 hours (Heit 1968). In Australian tests, optimum constant germination temperature for fresh seeds of glossy privet was 15 °C and for Chinese privet, 20 to 25 °C (Burrows and Kohen 1983). Germination of European privet seeds ranged from 88 to 92% in tests conducted in New York (Heit 1968). Germination is epigeal (figure 3), and light is not needed for germination.

Viability of seeds can also be determined by a tetrazolium (TZ) staining test as recommended by the International Seed Testing Association (ISTA 1996). Privet seeds should be soaked in water for 18 hours at 20 °C, then cut transversely at the distal end and longitudinally with a scalpel or razor blade to expose the embryo, followed by immersion in a 1% TZ solution for 20 to 24 hours at 30 °C. Those seeds with the embryo and all nutritive tissue stained red are considered viable.

Nursery practice. Fall-sowing is advisable for best seedling production, maximum growth the first year, and less early seedling losses (Heit 1968). Fresh, cleaned privet seeds germinate readily when sown in the fall. In spring sowings, seeds from storage may require 1 or 2 months of stratification to ensure uniform germination with minimum hold-over (Bailey 1947; Dirr and Heuser 1987). One- or two-year seedlings are used for outplanting.

Vegetative propagation is the preferred method for producing privet species or varieties and ensuring continuation of the same characteristics in successive generations. All species are easy to root from vegetative stem cuttings and many growers root them in outside beds (Bailey 1947; Dirr and Heuser 1987; Keever and others 1989; Regulski 1984). Non-dormant cuttings should be rooted under a mist system to prevent them from drying out during summer months. Dormant cuttings can be set in rows outdoors during the fall, winter, or early spring. Shoot and root initiation and growth of dormant and non-dormant privet cuttings can be accelerated, even doubled, by appropriate applications of growth regulators, bleach, and wetting agents (Dirr and Heuser 1987; Yang and Read 1991, 1992; Rauscherova and Tesfa 1993). Pre-emergence herbicides did not affect stock plants of glossy privet or the rooting of cuttings taken from them (Cantanzaro and others 1993).

Figure 3—*Ligustrum vulgare*, European privet: seedling development 1, 5, 50, and 132 days after germination.



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Lauraceae—Laurel family

Lindera Thunb.

spicebush

Victor Vankus, Kenneth A. Brinkman, and H. M. Phipps

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Growth habit, occurrence, and uses. The genus *Lindera*—spicebush—comprises 80 species of deciduous or evergreen trees or shrubs (Huxley and others 1992). The 3 deciduous species (table 1) native to the United States are generally found in moist woodlands, usually as understory plants. Common spicebush is a deciduous shrub to 4.6 m tall; it has been cultivated since 1683 and is valuable for wildlife food and environmental plantings. The fruits are eaten by grouse (*Bonasa umbellus*), quail (*Colinus virginianus*), pheasants (*Phasianus colchicus*), and other birds (Grimm 1957). The dried fruit has been used as a substitute for allspice and the leaves, bark, and fruit for their medicinal properties as a treatment for coughs and colds (Bremness 1994; USDA Forest Service 1948). Both common and Japanese spicebushes (table 1) are grown and sold by the horticultural industry for their spring flowers and aromatic and colorful fall foliage (Huxley and others 1992). Common spicebush is commonly used as a root stock for cuttings of Japanese spicebush (Boyle 1997). Pondberry and bog spicebush are both much less abundant than common spicebush and have much smaller ranges (table 1). Pondberry was listed as an endangered species by the USDI Fish and Wildlife Service in 1986.

Flowering and fruiting. The yellow to yellow-green flowers of spicebush are dioecious or polygamous and appear from March to May before the leaves (Fernald 1950). The fruits, which begin developing in May, are red drupaceus berries ripening in August or September (Rehder 1940). Each fruit contains a single seed that is light violet-brown with flecks of darker brown (figures 1 and 2). The affects of sun and shade habitats on flower production, sex ratio, and resulting population dynamics of common spicebush have been studied by Niesenbaum (1992) and Cipollini and others (1994).

Collection of fruit; extraction and storage of seeds. Spicebush fruits should be collected at maturity from August to October (Van Dersal 1935). Seedcrops can vary from year to year. Seed collectors must pay careful attention to fruit maturity to ensure that seeds are collected at the optimal time and to limit loss of seeds to birds. Fruits collected before maturity had seeds with low or no viability (Boyle 1997). The fresh fruits should be de-pulped in water, the pulp floated off, and the seeds thoroughly air-dried (Brinkman and Phipps 1974). Seeds should not be stored or planted still within the berry. There are about 10,000 seeds/kg (4,550/lb). Forty-five kilograms (99.2 lb) of fruits

Table 1—*Lindera,* spicebush: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***L. benzoin* (L.) Blume** *Benzoin aestivale* (L.) Nees	**common spicebush**, northern spicebush, Benjamin bush, feverbush, wild allspice	Maine to Ontario & Kansas; S to Florida & Texas
***L. melissifolia* (Walt.) Blume** *Benzoin melissifolium* (Walt.) Nees *Laurus melissifolia* Walt.	**pondberry,** southern spicebush, Jove's fruit	North Carolina to Missouri; S to Georgia & W to Louisiana
***L. obtusiloba* Blume** *Benzoin obtusilobum* (Blume) O. Kuntze *L. cercidifolia* Hemsley *L. obtusiloba f. velutina* T.B. Lee	**Japanese spicebush**	Japan, Korea, & China
***L. subcoriacea* B.E. Wofford**	**bog spicebush**	North Carolina S to Florida & W to Louisiana; also New Jersey

Source: Brinkman and Phipps (1974).

Figure 1—*Lindera benzoin*, common spicebush: seed.

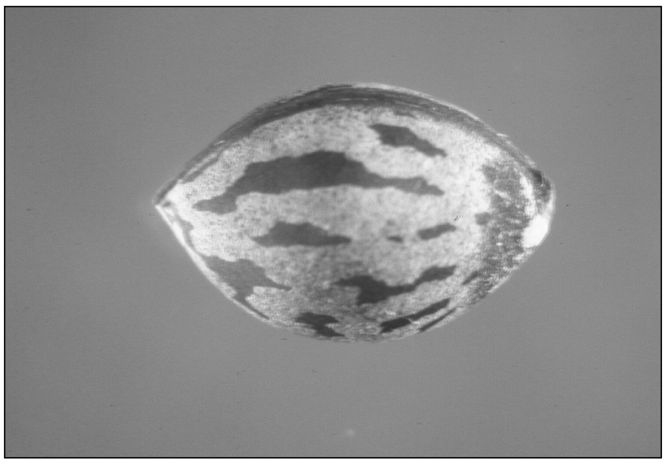
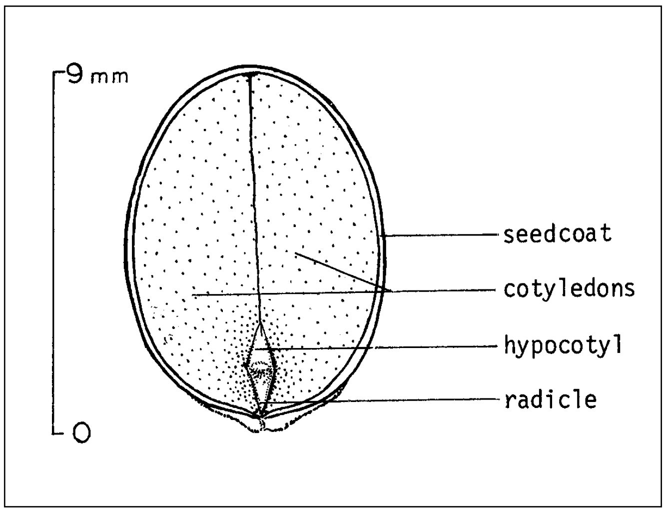


Figure 2—*Lindera benzoin*, common spicebush: longitudinal section through a seed.



of common spicebush yields about 7 to 11 kg (15 to 25 lb) of seeds (Brinkman and Phipps 1974). Common spicebush seeds usually lose their viability soon after maturity, but storage at 1 to 5 °C will prolong viability for 1 to 2 years (Boyle 1997; Murphy 1997).

Pregermination treatment. Common spicebush has a dormant embryo that responds to warm incubation for 30 days at 25 °C followed by 90 days of moist stratification at 1 to 5 °C (Schroeder 1935). Good results were also obtained with 120 days of moist stratification in peat or sand at 5 °C (Barton and Crocker 1948; Brinkman and Phipps 1974). In another test, Olney (1960) reported best results after stratifying seeds for 105 days in sand at 5 °C. Dirr and Heuser (1987) believe that seeds of Japanese spicebush should be stratified cold for 3 months, and they also reported 85 to 90% germination with 3 months of cold stratification for common spicebush. Seeds of pondberry sent to the USDA Forest Service's National Tree Seed Laboratory in 1993 (in accordance with a permit issued by the USDI Fish and Wildlife Service for the purpose of germination and propagation) were germinated using 3 different stratification schemes. Each scheme (table 2) produced good results. Some seeds germinated during the 28-day warm cycle of the warm-cold stratification scheme. This would suggest that the dormancy present in common spicebush may not be present to the same degree in pondberry.

Germination tests. Tests may be made in moist peat or sand at a constant temperature of 25 °C, or at alternating temperatures of 30 °C in the day and 20 °C at night. Germination rate may be 70 to 100% in 14 to 28 days for treated seeds, and total germination should range from 85 to 100% (Brinkman and Phipps 1974). Tetrazolium staining and excised embryo tests will also provide accurate testing information. Excised embryos can develop into seedlings if they are not damaged during excision.

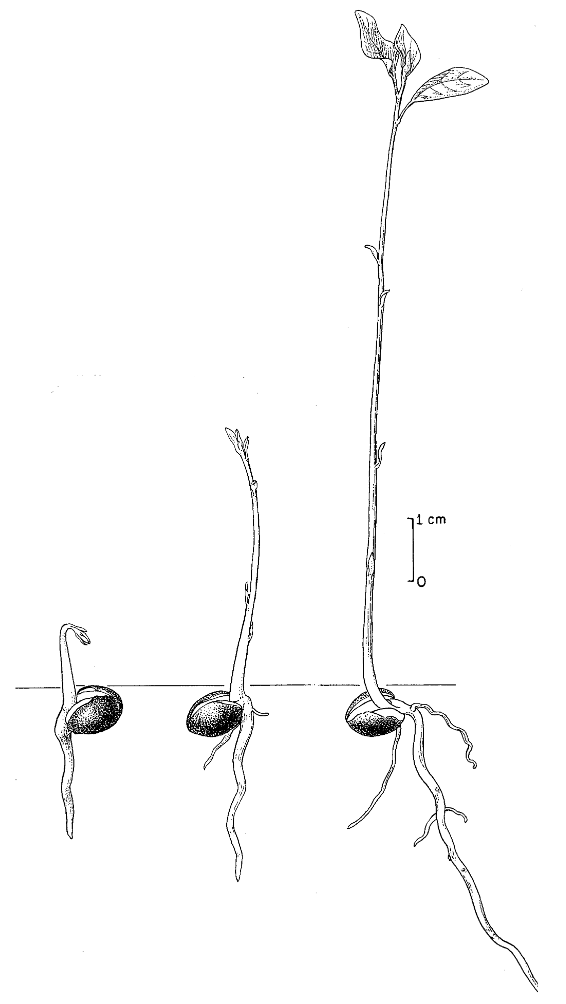
Nursery practice. Common spicebush seeds should be sown in the fall and mulched over winter. The mulch should be removed in April or May before germination begins. Stratified seeds may be sown in the spring. From 70 to 80% of the sound seeds can be expected to produce seedlings (figure 3). Spicebush grows well in sandy soils of pH 4.5 to 6.0 (Brinkman and Phipps 1974; Laurie and Chadwick 1931).

Table 2—*Lindera*, spicebush: stratification treatments and germination

Species	Stratification (days) Warm	Cold*	Percentage germination
L. benzoin	30†	90	—
	—	105	—
	—	120	—
	—	90	85–90
L. melissifolia	28‡	91	100
	—	56	84
	—	119	88
L. obtusiloba	—	90	—

Sources: Barton and Crocker (1948), Brinkman and Phipps (1974), Dirr and Heuser (1987), Olney (1960), Schroeder (1935).
* 1 to 5 °C. † 25 °C. ‡ 20 to 30 °C.

Figure 3—*Lindera benzoin*, common spicebush: seedling development at 2, 3, and 10 days after germination.



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L

Hamamelidaceae—Witch-hazel family

Liquidambar styraciflua L.

sweetgum

Franklin T. Bonner

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Other common names. redgum, American sweetgum, sapgum, bilsted.

Growth habit, occurrence, and use. Sweetgum—*Liquidambar styraciflua* L.—is found on a variety of sites from Connecticut and southeastern Missouri, south to central Florida and southeastern Texas. It also occurs in scattered locations from Mexico south to Nicaragua (Kormanik 1990) and is considered by some to be a very promising species for the American tropics (McCarter and Hughes 1984). This large deciduous tree reaches heights of over 45 m and diameters of 1.2 m at maturity (Brown and Kirkman 1990). Sweetgum has some value for pulp, lumber, and veneer. The seeds are eaten by many species of birds (Van Dersal 1938), and the tree is planted as an ornamental. It was first cultivated in 1681 (Bonner 1974).

Sweetgum exhibits quite a bit of variation over its wide natural range (McCarter and Hughes 1984; McMillan and Winstead 1976; Wells and others 1991; Williams and McMillan 1971). Minor differences in germination and seedling growth and morphology have been reported, but there is no strong evidence for distinct geographic races in the species.

Flowering and fruiting. The small, greenish, monoecious flowers bloom in March to May. The pistillate flowers are borne in axillary, globose heads that form the 22- to 35-mm-diameter multiple heads of small 2-celled capsules (figure 1). The lustrous green color of the fruiting head fades to yellowish green or yellow as maturity is reached in September to November (Bonner 1974; Vines 1960). At the point of color change, moisture content of the fruit head should have dropped below 70% (Bonner 1972). The beaklike capsules open at this time, and the small, winged seeds (figures 2 and 3), 1 or 2 per capsule, are dispersed. Empty fruiting heads often remain on the trees over winter. Fair seedcrops occur every year and bumper crops about every 3 years. The flowers are susceptible to late spring freezes that can greatly reduce seedcrops. Crop reductions of up to 44% have also been reported from damage by seed bugs—*Leptoglossus oppositus* (Say)—in North Carolina (Ebel and Summerville 1983). Some trees have been known to flower and bear fruit 4 and 5 years after planting (Mohn and Randall 1970), but good crops are not common until the tress reach 20 to 30 years of age (Bonner 1974).

Figure 1—*Liquidambar styraciflua*, sweetgum: fruiting head.

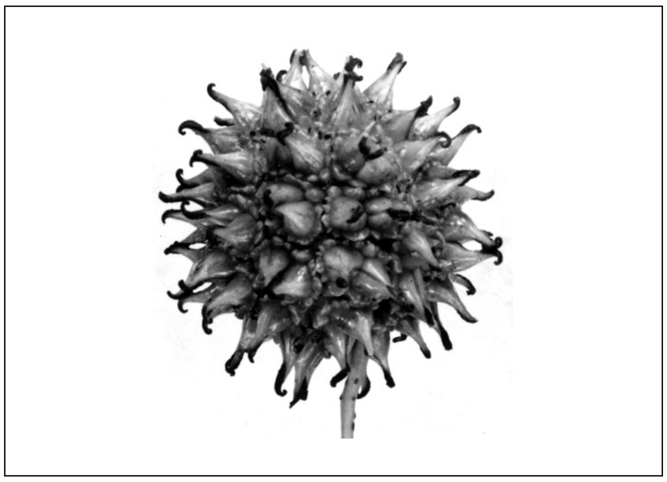
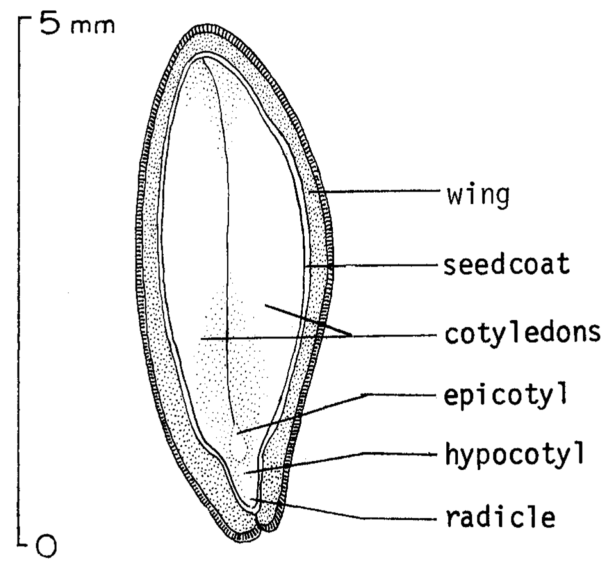


Figure 2—*Liquidambar styraciflua*, sweetgum: seed.

Collection and extraction. Mature fruit heads must be picked from standing trees or logging slash before seed dispersal. The best indicator of maturity is the fading of

Figure 3—*Liquidambar styraciflua*, sweetgum: longitudinal section through a seed.



their green color. Fruit heads should be dried to completely open the capsules so that the seeds can be extracted by shaking or tumbling. Drying may be done indoors on well-ventilated screen racks or outdoors on plastic or canvas sheets in the sun (Bonner 1987). Indoor drying takes approximately 7 to 10 days, whereas outdoor drying in typical fall weather in the South should require only 3 to 5 days. The fruit heads should be stirred daily, and those dried outdoors should be covered at night and during rain (Bonner 1987). Canvas sheets are preferred over plastic, as plastic tears easily and also tends to promote condensation of moisture (Robbins 1984).

Fruit heads picked prematurely may be ripened in moist storage at 5 °C for about a month (Bonner 1970). The fruit heads should then be spread to dry until they open and release the seeds. This operation may take longer than drying fruits that were picked when mature, and the seed yields may be less.

Leaves, twigs, and the sawdust-like aborted seeds can be removed most easily with hand screens and laboratory blowers or with air-screen cleaners, depending on the size of the lot (Bonner 1974). Round-hole screens are best for this job, but variations in seed size due to geographic origin or weather during maturation may require a variety of hole sizes (Bonner 1987). Two passes through an air-screen cleaner should produce seedlot purities of 98%. Seedlots may then be upgraded by removing empty seeds with laboratory blowers or by flotation in water (Bonner 1987). From mostly southern collections, the following yield data were obtained (Bonner 1974):

- Weight per volume of air-dried fruiting heads (1 sample) was 11 kg/hl (or 8.5 lb/bu).
- Weight of cleaned seeds per volume of fruiting heads (3 samples) was 1.0 kg/hl (0.8 lb/bu).
- Number of seeds per fruiting head (144 samples) was 56.
- Range in number of seeds per weight (40 samples) was 143,300 to 217,000/kg (65,000 to 98,400/lb), with an average of 180,000/kg (82,000/lb).

In Mississippi, there were significantly more seeds per fruiting head on trees in the Mississippi River flood plain than on trees from other parts of the state (Kearney and Bonner 1968).

Storage. Sweetgum fits in the storage category of orthodox seeds, that is, its seeds can be stored for a number of years at low temperatures and moisture contents (Bonner 1994). Seed moisture should be maintained in the 5 to 10% range. For storage periods of 5 years or less, temperatures should be kept at 0 to 5 °C; for longer storage, subfreezing temperatures (–18 °C) should be used (Bonner 1987). The ultimate storage potential of the species is not known, but seeds stored at –18 °C for 14 years at the USDA Forest Services's Forestry Sciences Laboratory, in Mississippi State, Mississippi, lost no viability.

Pregermination treatments. Sweetgum seeds exhibit what can be described as only a shallow dormancy (Nikolaeva 1967). Studies of geographic variation in sweetgum have shown that stratification requirement increases from south to north (Wilcox 1968; Winstead 1971), but even the southernmost sources will respond to stratification with increased germination rates (Bonner and Farmer 1966; Rink and others 1979). Moist stratification at 3 to 5 °C for 2 to 4 weeks should produce timely germination both in the laboratory and in nurserybeds (Bonner 1987). Satisfactory treatment has also been achieved by soaking the seeds for 14 to 20 days in water at 3 to 5 °C (Bonner 1974). Older seeds from storage may not require as much stratification, especially if they have been stored above freezing. Stratification of lots stored longer than 7 years under such conditions should be cut in half (1 to 2 weeks) (Bonner 1987).

Germination tests. Satisfactory tests may be obtained with either constant or alternating temperature regimes, but alternating temperatures of 20 °C at night for 16 hours, and 30 °C in the day for 8 hours are recommended for official

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Table 1—*Liquidambar styraciflua,* sweetgum: germination test conditions and results

Stratif-ication* (days)	Daily light (hrs)	Germination test conditions Medium	Temp (°C) Day	Night	Days	Germination rate %	Days	Germination Avg (%)	Samples
0	8	Blotter paper	30	20	28	76	21	85	14
30	8	Kimpak	30	20	25	86	14	95	23
15–45	0	Blotter paper	30	30	30	—	—	85	13

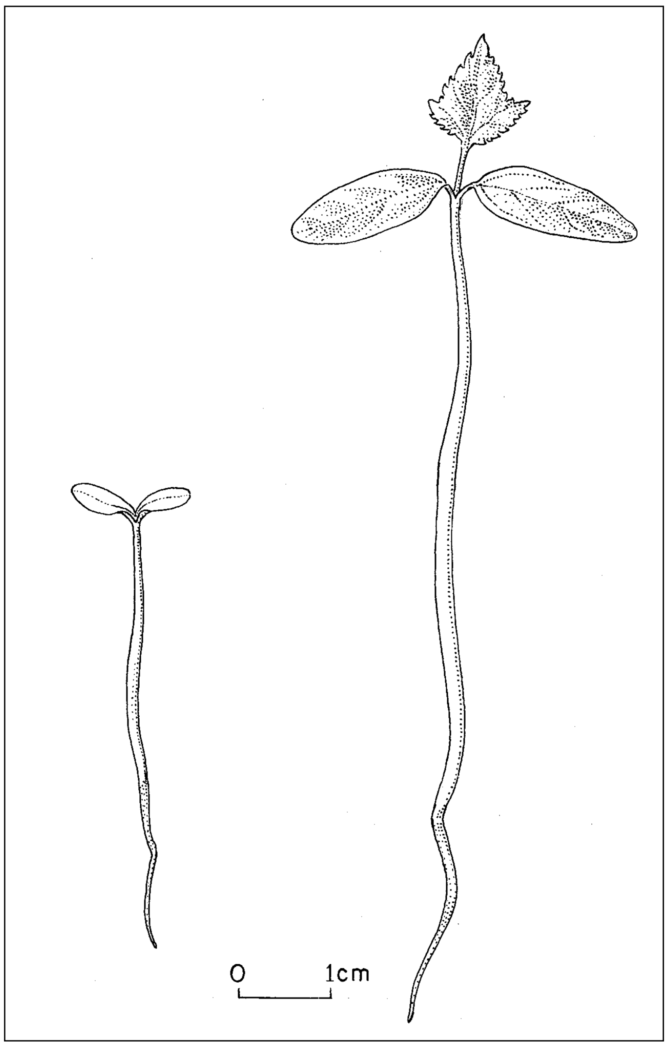
Sources: AOSA (1993), Bonner (1974).
* Stratification at 3 °C.

testing (table 1) (AOSA 1993). Light is not absolutely necessary for germination of stratified seeds (Bonner 1967), but it is normally used in all testing. Tetrazolium staining (Bonner and Gammage 1967), radiography (Belcher and Vozzo 1979), and the excised embryo method (Bonner and Gammage 1967; Flemion 1948) also provide reliable tests of viability. Germination is epigeal (figure 4). For moisture testing, duplicate samples of 4 to 6 g each should be dried for 17 ± 1 hour at 103 ± 2 °C (ISTA 1993), or electric meters can be used for rapid measurements (Bonner 1981).

Nursery practice. Stratified seeds should be broadcast or drilled in the spring to achieve an initial seedling density of 100 to 160/m^2 (9 to 15/ft^2) (Barham 1980). Aluminum powder may be mixed with wet stratified seeds at a rate of 15 ml/45 kg of seeds (4 tablespoons/100 lb) to achieve easy flow in seeders (Bonner 1974). The seeds should be sown on the surface and lightly into the soil with a roller. A 6- to 12-mm ($^1/_4$- to $^1/_2$-in) mulch of sawdust, sand, or chopped pine straw should be applied (Bonner 1974; Coleman 1965; Vande Linde 1964), although some nurseries have reported better results with wood fiber mulches at rates of 1,400 to 2,900 kg/ha (1,250 to 2,600 lb/ac) (Barham 1980).

Ornamental cultivars of sweetgum are usually propagated vegetatively. Cuttings taken in early June will root, and budding is common also (Dirr and Heuser 1987).

Figure 4—*Liquidambar styraciflua*, sweetgum: seedling development at 2 and 30 days after germination.



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Magnoliaceae—Magnolia family

Liriodendron tulipifera L.

tuliptree

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Other common names. yellow-poplar, poplar, tulip-poplar, white poplar, whitewood.

Growth habit, occurrence, and uses. Tuliptree—*Liriodendron tulipifera* L.—occurs naturally throughout the eastern United States from Vermont and southern Michigan south to Louisiana and north-central Florida (Little 1979). It grows under a variety of climatic conditions from sea level to 1,370 m elevation in the Appalachian Mountains and to 300 m in the northern part of its range. This large deciduous tree is among the tallest in the eastern United States and reaches considerable age: tuliptrees planted by George Washington still grow at Mount Vernon (Griswold 1999). It can attain heights of 61 m and diameters of 2.4 to 3.7 m at maturity (Beck 1990). The wood is very valuable for lumber and veneer. It is a good honey tree and is planted extensively as an ornamental. Tuliptree has been cultivated since 1663 (Bonner and Russell 1974).

Flowering and fruiting. The large, perfect, greenish-yellow flowers of tuliptree open from April to June (Little and Delisle 1962). The fruit is an elongated cone composed of closely overlapped carpels that are dry, woody, and winged (figure 1). Each carpel (samara) contains 1 or 2 seeds (figure 2). The cones turn from green to yellow to light brown as they ripen; they mature from early August in the northern part of the range (Guard 1943) to late October in the South (Bonner and Russell 1974). As the mature cones dry on the trees, they break apart and the samaras are scattered by the wind. Peak dissemination occurs in October and November, but a few samaras fall as late as the following March (Carvell and Korstian 1955; Whipple 1968). In South Carolina, seedfall is usually at least 90% complete by early December (Goebel and McGregor 1973).

Good seedcrops occur almost every year; failures, as well as bumper crops, occur infrequently. In North Carolina, 1 large tree produced 29,000 sound seeds, and seedfall of 1.5 million seeds/ha is not uncommon (Beck 1990). In a South Carolina study, 1 of 5 seedcrops was heavy (Goebel

Figure 1—*Liriodendron tulipifera*, tuliptree: cone (**left**) and single samara (**right**).

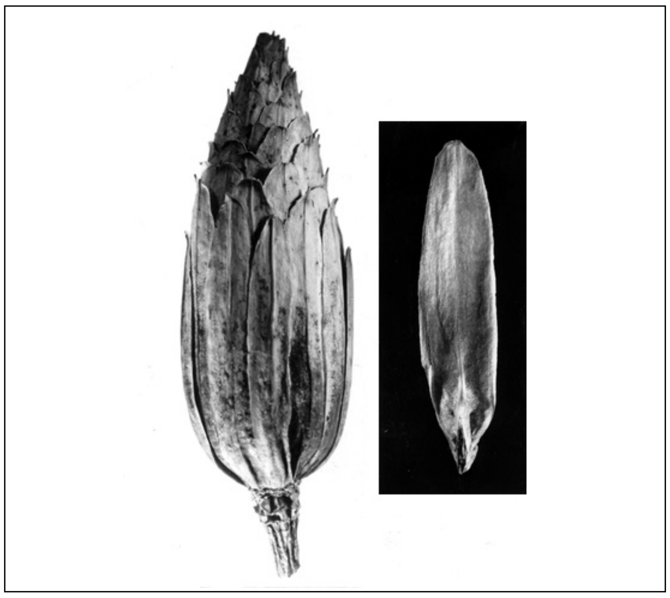
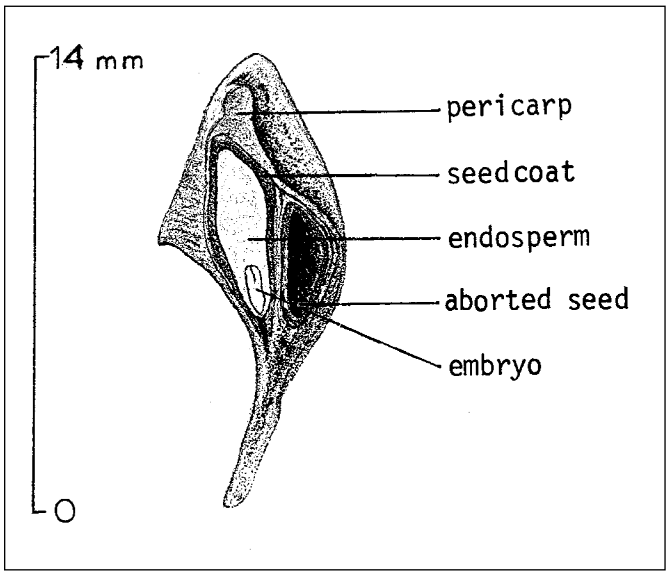


Figure 2—*Liriodendron tulipifera,* tuliptree: longitudinal section through an embryo of a samara.



and McGregor 1973). Although trees as young as 9 years old have been reported to bear fruit, the normal commercial seed-bearing age of tuliptree is 15 to 20 years (Bonner and Russell 1974).

Tuliptree is pollinated by insects, and the number of filled samaras per cone is very low in natural stands (Boyce and Kaeiser 1961). There is considerable variation among trees, but a general average seems to be about 10% (Bonner and Russell 1974; Carvell and Korstian 1955; Heit 1942; Limstrom 1959; Sluder 1964; Swingle 1939; Whipple 1968). At the extreme northern part of the species' range in southern Ontario, the filled samara proportion was 8 to 10% in isolated trees and 20% in old-growth, high-density stands (Kavanagh and Carleton 1990). Filled samara proportions in central Mississippi have ranged from 3.5% in isolated trees to 35% in older stands of mixed hardwoods with numerous large tuliptrees. Controlled pollinations in seed orchards have produced filled seed yields as high as 75% (Houston and Joehlin 1989). Some seed orchard managers have placed hives of honey bees (*Apis mellifera* L.) in their orchards to increase seed production; results have been varied.

Collection of fruits. Mature cones may be picked by hand from standing trees or from logging slash. In the southern United States, cone maturity is first indicated by the color changes in cones from green to yellow, which usually occurs in late October. At this point, cone moisture content is still high (over 60% of fresh weight), and cones must be handled carefully to avoid overheating. Maturity is assured when cones turn dark brown in color, but dry weather can quickly cause cones in this condition to break apart and scatter the samaras (Bonner 1976b). Cones may be collected from logging slash felled as much as 4 weeks before natural maturity, but they must be dried slowly to allow maturation of the seeds. One way to do this is to wait 2 to 3 weeks after felling to pick the cones (Bonner 1976b). Cones and seeds may also be shaken onto canvas or plastic sheets from standing trees in early winter. A mechanical shaker was used successfully to dislodge cones from trees in West Virginia; from 9 to 95% of cones were collected from individual trees without apparent damage (Cech and Keys 1987). Cones from the upper two-thirds of the crown yield more full seeds than cones from the lower one-third (Guard and Wean 1941), probably because of inefficient pollination in the lower branches.

Cones should be spread out to dry immediately after collection. Drying sufficient to separate the samaras usually requires 7 to 20 days, depending on temperature, humidity, and cone moisture content (Bonner and Russell 1974). Cones may be dried more quickly by using the forced air systems of pine cone tray driers, but no heat should be applied.

Extraction, cleaning, and storage of seeds. Thoroughly dried cones can be broken apart by hand by shucking, flailing, or treading, or by running them through a hammer mill or macerator (Bonner and Russell 1974; Steavenson 1940). Tuliptree seeds can be de-winged in macerators or in oat de-bearders. After wing fragments and fruit axes are removed with air-screen cleaners, many of the empty (unfertilized) seeds can be removed with gravity tables or aspirators (Bonner and Switzer 1971). By this process, filled seed percentages of 6 to 10% can be upgraded to 60 or 65%. There are 80 to 100 samaras/cone (Bonner and Russell 1974). Yield data from various locations (table 1) suggest that samaras from southern trees are larger than those from northern trees.

Tuliptree seeds are orthodox in storage behavior; they may be stored at low seed moisture contents (6 to 10%) and low temperatures (2 to 5 °C). No long-term storage data are available, but storage for several years under these conditions without loss of viability is common (Bonner and Russell 1974). Excellent results have also been reported for 3 to 4 years of moist storage in outdoor soil pits (Paton 1945; Williams and Mony 1962) or in drums of moist sand held in cold storage at 2 °C (Bonner and Russell 1974).

Pregermination treatments. Seeds to be sown in the spring and seeds taken from dry storage need pretreatment to overcome dormancy. The traditional method of moist storage in well-drained pits or mounds of mixed soil, sand, and peat, can successfully overwinter seeds for as long as 3 years (Bonner and Russell 1974; Williams and Mony 1962). Cold, moist stratification in plastic bags, both with or without peat moss or other media, in refrigerators for 60 to 90 days is widely used (Bonner and Russell 1974). Recommended temperatures for cold stratification are a constant 2 to 5 °C (Adams 1968; Bonner and Russell 1974), but alternating weekly temperatures of 0 and 10 °C (Chadwick 1936) or 2 and 12 °C (Boyce and Hosner 1963) have also been successful. Percentage and rate of germination of some sources of tuliptree have been significantly increased by soaking seeds in solutions of the potassium salt of gibberellic acid (GA_3) (100 and 1,000 mg/liter), but no practical application of this method has been reported (Bonner 1976a).

Germination tests. Germination tests should be carried out at the common alternating temperature regime of 20 °C in the dark for 16 hours and 30 °C in light for 8 hours. Seeds should be given cold, moist stratification for 60 to 90 days before testing on the top of moist blotters for a

Table 1—*Liriodendron tulipifera,* tuliptree: seed yield data

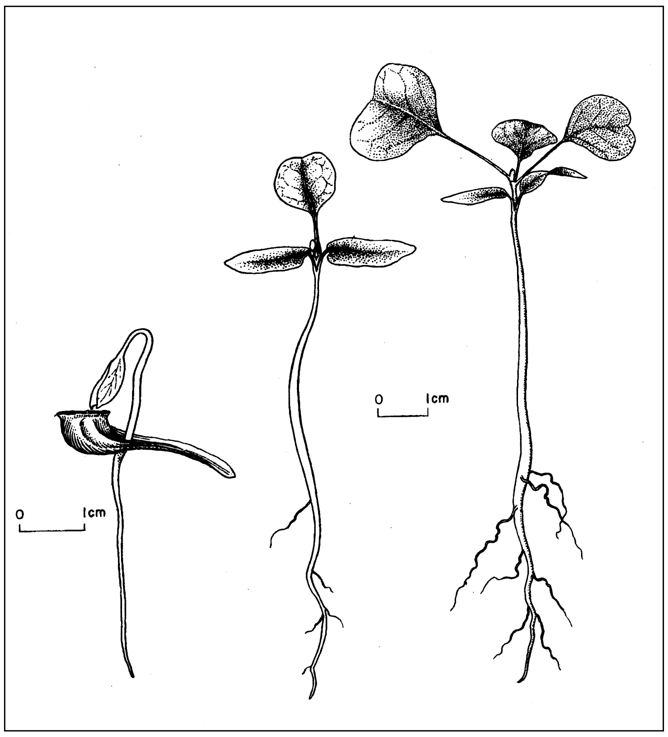
Place collected	Cone wt/ cone vol kg/hl	Cone wt/ cone vol lb/bu	Seed wt/ cone vol kg/hl	Seed wt/ cone vol lb/bu	Cleaned seeds/weight Range /kg	Cleaned seeds/weight Range /lb	Cleaned seeds/weight Average /kg	Cleaned seeds/weight Average /lb	Samples
Mississippi									
Warren Co.	39	30	8	6	9,455–17,200	4,288–7,804	12,680	5,750	3
Oktibbeha Co.	32	25	—	—	—	—	—	—	—
North Carolina*	—	—	—	—	32,430–75,080	14,710–34,050	41,200	18,700	9
E Tennessee	—	—	9	7	—	—	—	—	—
New York	—	—	—	—	15,170–30,980	6,880–14,050	23,440	10,630	9
	—	—	9–24	7–19	22,050–52,920	10,000–24,000	30,870	14,000	—

Sources: Bonner and Russell (1974), Heit (1942).
* Seed moisture content was 10% when the counts were made.

period of 28 days (AOSA 1993). If empty seeds have not been removed from test samples, germination percentages will be quite low because of the naturally low proportion of filled seeds common in this species. Germination of the filled seeds should be good, however; percentages of 80 to 90% are common (Bonner and Russell 1974). Seeds ungerminated at the end of a test should be cut to determine if any embryos are present. Viability can also be estimated by tetrazolium staining (ISTA 1993) and by radiography (Belcher and Vozzo 1979; Kaeiser and Boyce 1962; Taft 1962). Germination is epigeal (figure 3).

Nursery practice. Untreated seeds may be sown in the fall, but stratified seeds must be used for spring sowing. Seeds may be broadcast at rates of 25 to 75 kg/m^2 (1 to 3 lb/ft^2) of bed space or sown in rows 20 to 30 cm (8 to 12 in) apart at a rate of 80 to 100 seeds/m (24 to 30/ft) (Bonner and Russell 1974). Bed densities of 110 seedlings/m^2 (10/ft^2) are recommended (Williams and Hanks 1976). To assure proper bed density, the proportion of filled seeds must be known before sowing. The seeds should be covered with 6 mm ($^1/_4$ in) of soil or 12 to 25 mm ($^1/_2$ to 1 in) of sawdust and beds should be shaded for 1 to 2 months from the start of germination (Bonner and Russell 1974). Fumigation with MC-33 (67% methyl bromide plus 33% chloropicrin) was recommended for control of cylindrocladium root rot—*Cylindrocladium scoparium* Morg. (Affeltranger 1969). Because of the uncertain status of methyl bromide at this time, local extension authorities should be consulted about an appropriate fumigant to use.

Figure 3—*Liriodendron tulipifera*, tuliptree: seedling development at 1, 18, and 48 days after germination.



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Fagaceae—Beech family

Lithocarpus densiflorus (Hook. & Arn.) Rehd.

tanoak

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Occurrence and growth habit. This evergreen hardwood species, the sole representative of its genus in North America, is considered a link between the chestnuts (*Castanea*) and the oaks (*Quercus*) (McMinn 1939). Tanoak (also known as tanbark-oak)—*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.—has flowers that resemble those of the chestnuts, but acorns that resemble those of the oaks. Tanoak is found from just north of the Umpqua River in southwestern Oregon southward throughout the coastal ranges to the eastern end of the Santa Ynez Mountains in western Ventura County, California. Its range then extends eastward to near Grants Pass, Oregon, and the lower slopes of Mt. Shasta, and then intermittently southward along the western slopes of the Sierra Nevada to Mariposa County, California (Griffin and Critchfield 1972).

A striking characteristic of the tanoak species is that, throughout its range, the tree form is found where moisture is present—from the soil, from fog, or from high relative humidity (McDonald and Tappeiner 1987). Another characteristic of the species is that shade is a requirement, but the amount varies by reproductive mode. Seedlings from acorns need shade to become established and grow. Sprouts from root crowns, which are often found in burned or otherwise severely disturbed areas, grow best in full sunlight, but only until the crowns close. From then on, and whether from acorns or sprouts, only toplight is needed. Indeed, full sunlight is then deleterious.

Because partial shade is necessary, tanoak is often found in dense stands, usually in mixture with several conifer and hardwood species. Pacific madrone (*Arbutus menziesii* Pursh) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are its most common associates. The species is particularly abundant in a belt surrounding the redwood forest in northern coastal California and in Yuba and Butte Counties in the Sierra Nevada (Sudworth 1908). But even though abundant, it is reported to "never" form pure stands (Jepson and others 1911). However, extensive pure stands of tanoak, 40 to 50 years old, have developed in northwestern California after logging and fire (Thornburgh 1994). Tanoak often forms part of the overstory, but almost always in a codominant position. It is rarely found in a dominant position, except possibly when part of a ragged overstory with Douglas-fir. Because tanoak cannot withstand sudden exposure to full sunlight, leaving scattered mature tanoak trees after heavy logging is a sure way to cause blighted tops and decreased acorn production (McDonald and Tappeiner 1987). Tanoak also is abundant in the understory in intermediate and suppressed crown positions.

As a codominant forest tree, tanoak has a crown that is shaped much like the tapering cone of its principal conifer associate, Douglas-fir. It has a long, straight bole, often clear of branches for 9 to 24 m (Roy 1974); narrow crown; and slender upright branches. Leaning, forking, and crooked trees are uncommon. In stature, tanoak is best described as medium in height, with most trees growing to a range of 13 to 47 m.

Tanoak also has a recognized shrubby form—*L. densiflorus* var. *echinoides* (R. Br.) Abrams—and possibly another, unrecognized one. The recognized form is reported in northern California in Shasta, Siskiyou, and Trinity Counties and on the lower slopes of Mt. Shasta. In these areas, it is restricted to rocky exposed ridges intermixed with tanoak trees that reach heights of 17 m in protected spots (Griffin and Critchfield 1972). They also describe the shrubby form at the end of the species' southern range in the Sierra Nevada. Roy (1974) states that the northern California variety has a typical shrub form, low stature, and "small, thin" leaves. The unrecognized form is found in the northern Sierra Nevada in a narrow elevational band just above that occupied by the tree form (McDonald and Litton 1987; McDonald and others 1989). Here large clumps, often flattened by heavy snow, are found with stems straggling downslope for 5 m or more (Tappeiner and others 1990). In addition, the thick, dark-green leaves of these plants are as large or larger than those of the tree form. Sudworth (1908) was doubtful about classifying this shrubby form as a variety. He stated that it was "...not to be worth of separation because it is connected with the larger tree forms by numerous intermediate ones."

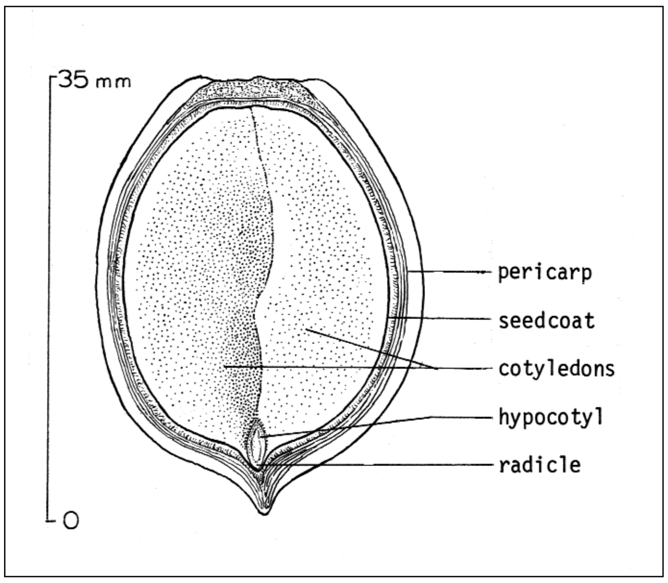
Use. The hard, strong, fine-grained wood has a long but intermittent record of use in California and Oregon (Huber and McDonald 1992). It has been used for flooring, railcar decking, paneling, veneer, plywood, gunstocks, pallets, crossties, baseball bats, pulpwood, and fuelwood (EDA 1968). In the past, tannin was extracted from the bark for tanning heavy leathers (Jepson and others 1911), hence its common names.

Flowering and fruiting. Tanoak produces flowers in the spring and irregularly during autumn. Most flowers arise from the axils of new leaves, occasionally from buds at the base of year-old leaves (Peattie 1953). April, May, and June are the months of heaviest flowering. Pistillate (female) flowers form at the base of the catkins, below the spike of the staminate (male) flowers (Hickman 1993). The pistillate flowers are 5 to 10 cm long and form crowded clusters in such profusion as to conceal the foliage. Initially, their color is white, eventually turning to yellow.

The fruit is a fairly large, heavy acorn (figures 1 and 2), maturing at the end of the second season, and numbering about 242/kg (110/lb) (Mirov and Kraebel 1937). Acorns are borne singly or in clusters of 2 to 4. They ripen in September to November, with peak fall occurring when the relative humidity is low, often when a dry north wind is blowing (McDonald 1978). Generally, the first and last acorns to fall are unsound. The minimum seed-bearing age (from root-crown sprouts) is 5 years, with abundant production occurring after age 30 to 40. On a good site in northern California, annual records showed that, during a 24-year period (1958–1981), tanoak produced 4 medium to heavy and 9 very light to light seedcrops (McDonald 1992). The number of acorns per mature tree is reported to range between 3,900 and 110,000 (Tappeiner and others 1990). Soundness of just-fallen acorns varies from 49 to 79%.

Figure 1—*Lithocarpus densiflorus*, tanoak: acorns.

Figure 2—*Lithocarpus densiflorus*, tanoak: longitudinal section through an acorn.



Collection, extraction, and storage. Although it fairly "rains acorns" in the fall of a bumper seed year, few remain by spring. Consumption by a host of birds, rodents, and other animals typically is heavy. In a study in several clearcuttings in southwest Oregon (Tappeiner and others 1986) and in studies in northwestern California (Thornburgh 1994), consumption after 3 annual sowings was over 99%. Many acorns are killed by insolation and freezing but, even though they are embryo-dead, they are still prime food for birds, rodents, and other animals. Acorns should be gathered during or shortly after the time of maximum seed fall, preferably from shady, covered locations. Those that fall in an exposed environment overheat and become embryo-dead in a few days, possibly even in a few hours. Freezing temperatures also kill embryos of exposed acorns (McDonald 1978).

Tanoak acorns generally are stored without the cups. Storage for any length of time can be risky. Death or germination often occur. Acorns can be stored in sacks in cool shaded places or in plastic bags containing a small amount of moist material at temperatures just above freezing. The most effective and efficient technique is to place sound acorns in wire containers buried near the planting site and covered with soil and dead leaves. Here, they stratify in tune with the local environment and produce tiny radicles in the

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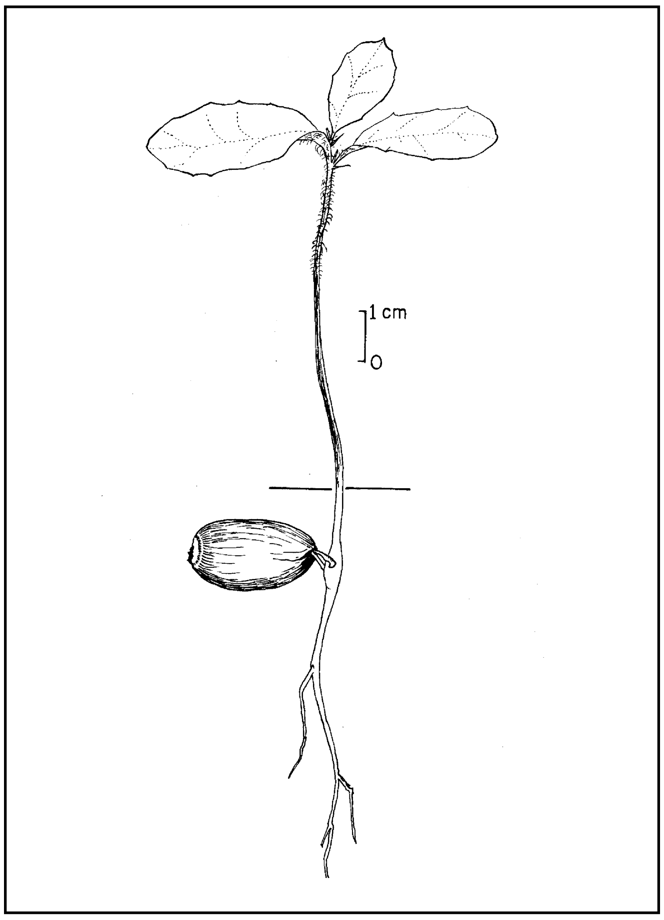
spring. Seeding germinated acorns almost guarantees a high initial seed-to-seedling ratio.

Pregermination treatments. Stratification in moist peat moss at temperatures just above freezing is all that is needed to give high germination values (97% and 6 days). Germination is hypogeal (figure 3).

Germination. Acorn position is a major influence on germination and subsequent seedling survival and development. Reversing polarity (placing acorns so that the pointed end is up) enhances the speed and completeness of germination, as well as seedling development. In a test in a conventional plantation (clearcutting) with 840 acorns placed point-up and 772 point-down, germination was 53% for point-up acorns and 21% for point-down acorns. Germination rate was 12 versus 41 days, respectively (McDonald 1978). Early germination, however, subjected the just-emerged (7-day-old) seedlings to late spring frost and many were frozen. It is of interest that 75% of these seedlings eventually sprouted from the root crown, but with multiple stems. Perhaps shade from the outer stems provides the inner stems with a more favorable environment and is at least part of the reason for this phenomenon.

Figure 3—*Lithocarpus densiflorus*, tanoak: seedling development 2 months after germination



Nursery practice. Tanoak seedlings are difficult to grow in the nursery. The emergent seedling produces a fast-growing taproot that quickly exceeds the depth of conventional containers and should not be clipped.

Seedling care. Extensive trials on a good site in northern California involved seeding sound acorns and outplanting container seedlings. In spite of the utmost care in site preparation—yearly removal of competing plants, loosened soil at each seed spot, careful seeding, use of acorns known to be viable when seeded, rodent protection, fertilization, and irrigation—seedling survival and growth were poor. Survival of 4- and 6-year-old seedlings was about 34% and mean height was 30 cm (12 in). Many plants had multiple stems from repeated dieback and sprouting (McDonald 1978). Most eventually died. The fate of container-grown seedlings that were given extensive care and artificial shading was little better. Survival after 2 growing seasons was 46%; height growth after outplanting was essentially nil (McDonald 1978). Most seedlings eventually died. The clipped taproot did not renew and the seedling's poorly developed root system did not extend beyond the already loosened soil. When that dried out, the seedlings died. Survival and growth of natural tanoak seedlings is best described as fair and slow, respectively. We cannot grow tanoak seedlings in conventional sunlit plantations. An environment of moderate shade and plentiful organic material seems necessary for survival and establishment of both artificial and natural seedlings. How to achieve consistent and reliable seedling growth remains a mystery.

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Caprifoliaceae—Honeysuckle family

Lonicera L.

honeysuckle

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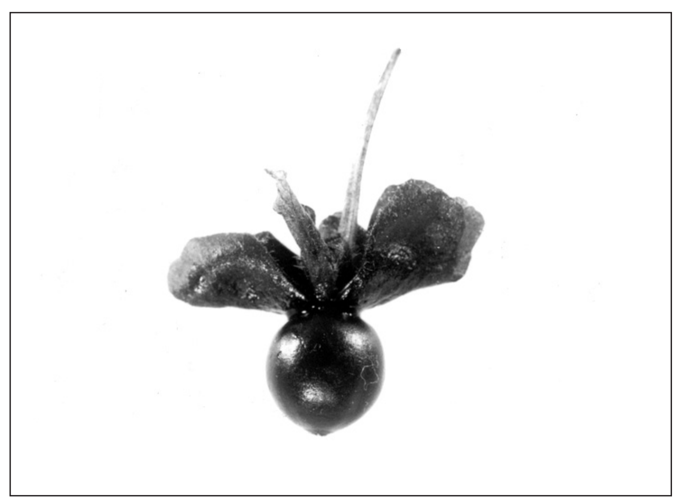
Occurrence, growth habit, and uses. Honeysuckles include about 180 species of deciduous or evergreen, bushy, scandent, twining, or creeping shrubs, found throughout the Northern Hemisphere, south to Mexico and North Africa, Java, and the Philippines (Huxley 1992). Many species are cultivated for their attractive, often-fragrant flowers and for their ornamental fruits. Some species furnish food and cover for wildlife, whereas others are valuable for erosion control and shelterbelt planting (Brinkman 1974; Huxley 1992). They are valued also for their extreme cold hardiness (Herman and Davidson 1997). Many species introduced in the United States have escaped cultivation and have become naturalized within this century (table 1). Japanese, Amur, and Tatarian honeysuckles are now considered invasive weeds (Luken and Thieret 1997)

Scientific and common names. The nomenclature of honeysuckles has been the object of many revisions over time. Many species were once classified as varieties, and vice versa, making synonyms common. The names currently accepted for species native to, naturalized, or in cultivation in the United States are listed in table 1.

Geographic races and hybrids. Erstad (1991) demonstrated extensive genetic variation between black twinberry plants from various northwestern American provenances. Thirty North American honeysuckles have been assigned varietal status (Kartesz 1994). Among the 74 cultivated honeysuckles reported by the Liberty Hyde Bailey Hortorium (1976), 10 species are of hybrid origin.

Flowering and fruiting. The small, perfect flowers vary from white or yellow to pink, purple, or scarlet. They are borne in axillary pairs or sessile, 6-flowered whorls in terminal spikes or panicles. Time of flowering varies not only among species but also by geographic locality within species (table 2). The attractive fruits are berries, white, red, orange, blue, or black at maturity (table 2). They occur often in coalescent pairs that ripen in the spring, summer, or early fall (figure 1). Depending on the species, each berry contains a few to many small seeds that measure about 4 mm in diameter (figures 2 and 3) (Brinkman 1974; Huxley 1992).

Figure 1—*Lonicera involucrata*, black twinberry: fruit (berry).



Bountiful seedcrops of Amur and Tatarian honeysuckles are borne nearly every year. No data are available concerning the age that plants must be to produce a good seedcrop. Seeds are dispersed primarily by birds and other animals. Fruits of Amur, Morrow, and Tatarian honeysuckles persist well into the winter (Brinkman 1974).

Collection of fruits. Fruits should be hand-picked or stripped from the branches as soon as possible after ripening to reduce consumption by birds (Brinkman 1974). Belcher and Hamer (1982) advocate flailing pruned branches of Amur honeysuckle inside a large drum as a time-saving method. Although pruned plants do not bloom the following season, greater quantities of fruits are produced from these plants the second year after pruning.

Fruit color is generally used as an indicator of maturity. Cram (1982) reported, however, that the germination rate of seeds of Tatarian honeysuckle collected several weeks prior to the "color-ripe" stage was not significantly different from that of seeds extracted from ripe fruits. It is generally recommended that fruits be collected from isolated plants or

Table 1—*Lonicera,* honeysuckle: scientific and common names, native occurrence and North American occurrence of introduced species and height at maturity

Scientific name & synonym(s)	Common names(s)	Native occurrence	N Am occurrence of introduced species	Height (m)
***L. albiflora* Torr. & Gray** *L. albiflora* Torr. & Gray var. *dumosa* (Gray) Rehder *L. dumosa* Gray	**western white honeysuckle**	Arizona E to Oklahoma & Texas	—	Scandent to 4 m
***L. arizonica* Rehd.**	**Arizona honeysuckle**	Arizona & New Mexico	—	5.5 m
***L. x bella* Zabel**	**Belle honeysuckle,** whitebell honeysuckle	Wyoming N to Saskatchewan, E to South Carolina & New Brunswick	—	2.5 to 3 m
***L. caerulea* L.**	**bearberry honeysuckle,** sweetberry honeysuckle	Europe to NE Asia	California N to British Columbia, E to Pennsylvania & Newfoundland	2 m
***L. canadensis* Batr. ex Marsh.** *Xylosteon ciliatum* Pursh	**fly honeysuckle**	Tennessee N to Iowa, E to Georgia & Nova Scotia	—	1.5 m
***L. caprifolium* L.**	**Italian woodbine,** Italian honeysuckle	Europe to W Asia	New Jersey to Massachusetts & Nova Scotia	Scandent to 6 m
***L. chrysantha* Turcz. ex Ledeb.**	**coralline honeysuckle,** honeysuckle	NE Asia to Japan	No occurrence except in cultivation	4 m
***L. ciliosa* (Pursh) Poir. ex DC.**	**orange honeysuckle**	California N to British Columbia, E to Utah & Montana	—	5.5 m
***L. conjugialis* Kellogg**	**purple flower honeysuckle**	California N to Washington, E to Nebraska & Idaho	—	1.5 m
***L. dioica* L.**	**limber honeysuckle,** mountain honeysuckle	Arizona N to British Columbia, E to Georgia, Quebec, & Missouri	—	1.5 m
***L. etrusca* Santi**	**Etruscan honeysuckle**	Mediterranean region	California to British Columbia	Scandent to 4 m
***L. flava* Sims** *L. flava* Sims var. *flavescens* Gleason *L. flavida* Cockerell ex Rehder	**yellow honeysuckle**	Oklahoma N to Illinois, E to South Carolina & Ohio	—	2.5 m
***L. fragrantissima* Lindl. & Paxton** *Xylosteon fragrantissimum* (Lindl. & Paxton) Small	**winter honeysuckle,** sweet-breath-of-spring	China	Utah; Louisiana N to Ohio E to South Carolina & North Carolina	2 m
***L. hirsuta* Eat.** *L. hirsuta* Eat. var. *interior* Gleason *L. hirsuta* Eat. var. *schindleri* B. Bovin	**hairy honeysuckle**	Nebraska N to Saskatchewan, E to Pennsylvania & Quebec	—	3.5 m
***L. hispidula* (Lindl.) Dougl. ex Torr. & Gray**	**California honeysuckle**	California to British Columbia	—	—
***L. interrupta* Benth.**	**chaparral honeysuckle**	California to Oregon & Arizona	—	—
***L. involucrata* Banks ex Spreng.**	**black twinberry,** bearberry honeysuckle, inkberry, skunkberry, twinberry honeysuckle	California N to Alaska, E to New Mexico & New Brunswick	—	2 m

Table 1—*Lonicera*, honeysuckle: scientific and common names, native occurrence and North American occurrence of introduced species and height at maturity (continued)

Scientific name & synonym(s)	Common names(s)	Native occurrence	N Am occurrence of introduced species	Height (m)
***L. involucrata var. ledebourii* (Eschsch.) Zabel** *L. ledebourii* Eschsch.	—	Coastal California	—	2 m
***L. japonica* Thunb.** *L. japonica* Thunb. var. *chinensis* (P.W. Wats.) Baker *Nintooa japonica* (Thunb.) Sweet	**Japanese honeysuckle,** gold-and-silver-flower	E Asia	California N to Oregon, E to Texas & N to Nebraska, E to Florida & Maine	Scandent to 10 m
***L. korolkowii* Stapf**	**blueleaf honeysuckle**	Central Asia, Afghanistan, & Pakistan	No occurrence except in cultivation	3 m
***L. maackii* (Rupr.) Herder**	**Amur honeysuckle**	Japan, Korea, Manchuria, N China, Amur, Ussuri	Texas to South Carolina & Ontario	5 m
***L. morrowii* Gray**	**Morrow honeysuckle**	Japan	New Mexico N to Saskatchewan, E to Virginia & New Brunswick	3 m
***L. oblongifolia* (Goldie) Hook.**	**swamp fly honeysuckle**	Michigan N to Manitoba, E to Nova Scotia	—	1.5 m
***L. periclymenum* L.**	**woodbine honeysuckle,** European honeysuckle	Europe, N Africa, & W Asia	British Columbia to Ontario, Maine, Nova Scotia, & Newfoundland	4 m
***L. reticulata* Raf.** *L. prolifera* (Kirchn.) Booth ex Rehder *L. prolifera* (Kirchn.) Booth ex Rehder var. glabra Gleason *L. sullivantii* Gray	**grape honeysuckle**	SE China	Arkansas N to Nebraska, E to Tennessee, Ontario, & Nova Scotia	—
***L. ruprechtiana* Regel** *L.* x *muscaviensis* Rehder	**Manchurian honeysuckle**	NE Asia, Manchuria, & China	Illinois, Indiana, Michigan, & New York	6 m
***L. sempervirens* L.**	**trumpet honeysuckle,** coral honeysuckle	Texas N to Connecticut, E to Florida	—	4 m
***L. standishii* Jacques**	**Standish honeysuckle**	China	Illinois, Kentucky, Maryland, New York, & Pennsylvania	3.5 m
***L. subspicata* Hook. & Arn.**	**southern honeysuckle**	Central & S California	—	2.5 m
***L. tatarica* L.**	**Tatarian honeysuckle**	S Russia to Altai Mtns & Turkestan	California N to Alberta, E to Virginia & Nova Scotia	4 m
***L. utahensis* S.Wats.**	**Utah honeysuckle**	California N to British Columbia, E to New Mexico & Alberta	—	1.5 m
***L. villosa* (Michx.) J.A. Schultes**	**mountain fly honeysuckle**	Alberta E to Pennsylvania & New Brunswick	—	1 m
***L. xylosteum* L.**	**European fly honeysuckle,** dwarf honeysuckle	Europe, Siberia, & China	Missouri N to Ontario, E to Virginia & Quebec	3 m

Sources: BONAP (1996), Brickell and Zuk (1997), Brinkman (1974), Cullina (2002), Dirr (1990), Dwelley (1980), FNPS (2002), Huxley (1992), Kartesz (1994), LHBH (1976).

Table 2—*Lonicera,* honeysuckle: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening	Color of ripe fruit
L. albiflora	—	Spring	—	Orange
L. arizonica	Arizona	June–July	—	Red
L. x bella	—	Early summer	—	Red
L. caerulea	—	Spring	—	Dark blue
L. canadensis	—	Apr–July	July–Aug	Red, orange-red
L. caprifolium	—	—	—	Orange-red
L. chrysantha	NE US	May–June	July–Sept	Coral red, dark red
	Japan	June	July–Aug	—
L. ciliosa	—	—	—	Red
L. conjugialis	—	Early summer	—	Red
L. dioica	—	May–July	July–Sept	Red
L. etrusca	—	Summer	—	Red
L. flava	—	Late spring	—	Red
L. fragrantissima	—	Winter–early spring	—	Red
L. hirsuta	—	May–Aug	Sept–Oct	Yellow, red
L. hispidula	—	Summer	—	Red
L. interrupta	—	Early summer	—	Red
L. involucrata	E US	June	Aug	Purple-black, glossy
	N Rocky Mtns	June–July	July–Aug	—
	W US	Apr–Aug	—	—
L. involucrata var. *ledebourii*	California	Mar–July	—	Black
L. japonica	—	Summer	—	Black
L. korolkowii	—	Late spring	—	Bright red
L. maackii	NE US	June	Sept–Nov	Dark red, black
	Japan	May	Aug–Sept	—
L. morrowii	NE US	May–June	June–Aug	Yellow, red, dark red
	Japan	May	Aug–Sept	—
L. oblongifolia	—	May–June	July–Aug	Orange-yellow to red to deep red
L. periclymenum	—	Summer	—	Red
L. reticulata	—	—	—	Black
L. ruprechtiana	—	Late spring	—	Red
L. sempervirens	—	Summer	—	Red
L. standishii	—	Early spring	—	Red
L. subspicata	—	—	—	Yellow or red
L. tatarica	—	May–June	July–Aug	Yellow, orange, red
L. utahensis	W US	April–June	June–Sept	Red
L. villosa	—	June	July–Aug	Blue-black
L. xylosteum	—	Late spring	—	Dark red

Sources: Bailey (1949), Brickell and Zuk (1997), Brinkman (1974), Dwelley (1980), FNPS (2002), , Hériteau (1990), Huxley (1992), Krüssmann (1985), Las Pilitas Nursery (2002), LHBH (1976), Maisenhelder (1958).

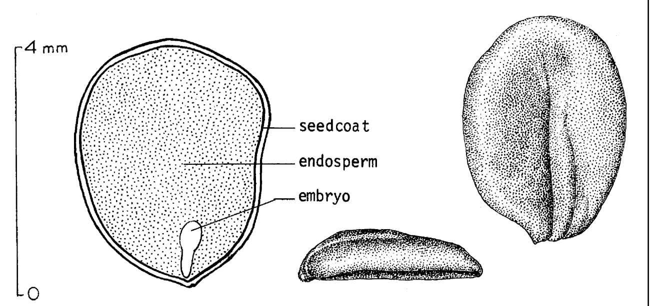
groups of plants, as honeysuckles are believed to hybridize freely (Brinkman 1974).

Seed extraction and storage. Unless seeds can be extracted immediately, fresh fruits should be spread out in thin layers to prevent heating. Extraction is accomplished by macerating the fruits in water and allowing the empty seeds and pulp to float and the viable seeds to sink. Munson (1986) has described the use of modified kitchen and shop implements to facilitate extraction. After a short drying period, seeds are ready for sowing or storage. Data regarding seed yields are presented in table 3. Honeysuckle seeds are apparently orthodox in storage behavior. Storage of air-dried seeds at room temperature results in loss of viability over several years. One study showed that germination of swamp fly honeysuckle decreased 20% after 1 year (Brinkman 1974). In another experiment, seeds of Tatarian honeysuckle stored at 15 to 29 °C showed a more or less continuous decrease in viability with length of storage, with negligible germination after 6 years. In contrast, storage of dried seeds in sealed containers at 1 to 3 °C for 15 years resulted in little loss of viability (Brinkman 1974).

Pregermination treatments. Seeds exhibit considerable variation in dormancy. Some species have both seedcoat and embryo dormancy, whereas others have only embryo dormancy or lack dormancy entirely. This variability also occurs among different seedlots of the same species (Hartmann and others 2002; Romanyuk 1989). Swingle (1939) reported that 75 to 90 days of cold stratification

Figure 2—*Lonicera*, honeysuckle: seeds of *L. dioica*, limber honeysuckle (**top**); *L. maackii*, Amur honeysuckle (**second**); *L. involucrata*, black twinberry (**third**); and *L. tatarica*, Tatarian honeysuckle (**bottom**).

Figure 3—*Lonicera tatarica*, Tatarian honeysuckle: seed in longitudinal section (**left**) and exterior views of seed (**center and right**).



(moist prechilling) were needed for Amur honeysuckle, whereas Luken and Goessling (1995) found that seeds of the same species collected in northern Kentucky showed no dormancy and had a rapid drop in viability after dispersal.

Cold stratification in moist sand or peat for 60 to 90 days at 4 °C is generally recommended to overcome embryo dormancy. Seedcoat dormancy has been reported repeatedly in hairy and swamp fly honeysuckles but has never been confirmed experimentally. When seedcoat dormancy is known or suspected, Brinkman (1974) recommends that cold stratification be preceded by warm moist stratification for 60 days at 20 to 30 °C (table 4). He indicated that without such treatments, germination may be prolonged over a period of 6 months or longer.

Germination tests. Germination is epigeal (figure 4), and germination tests can be conducted in flats or in a germinator. Light is not necessary, at least for Tatarian honeysuckle. For most species, alternating temperatures of 30 and 20 °C yield satisfactory results (table 5). Brinkman (1974) reported conflicting results in 2 studies conducted to determine the optimal germination temperature of Tatarian honeysuckle. One study reported that 20 °C or less was required for complete germination, whereas the other reported that 18 to 20 °C was the minimum needed, with the most rapid germination occurring at 25 to 27 °C. Swingle (1939) reported that tests by the USDA Soil Conservation Service (which is now called the Natural Resources Conservation Service) showed no correlation between seed viability, as estimated by cutting tests, and germination rates as measured by germination tests. There are no official testing protocols for honeysuckle species.

Nursery practice and seedling care. Seeds of species of honeysuckle that only exhibit embryo dormancy can be

Table 3—*Lonicera,* honeysuckle: cleaned seeds per weight

Species	Range /kg	Range /lb	Average /kg	Average /lb
L. involucrata	500,000–1,050,000	227,000–477,000	720,000	326,500
L. maackii	260,000–430,000	116,000–194,000	330,000	148,000
L. morrowii	250,000–440,000	114,000–191,000	335,000	152,000
L. oblongifolia	520,000–530,000	234,000–239,000	520,000	236,000
L. tatarica	260,000–440,000	116,000–198,000	310,000	142,000

Source: Brinkman (1974).

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Table 4—*Lonicera*, honeysuckle: stratification treatments

	Warm period		Cold period	
Species	**Temp (°C)**	**Days**	**Temp (°C)**	**Days**
L. hirsuta	20–30	60	5	60
L. maackii	—	—	0–10	60–90
L. oblongifolia	20–30	60	5	90
L. tatarica	—	—	5	30–60

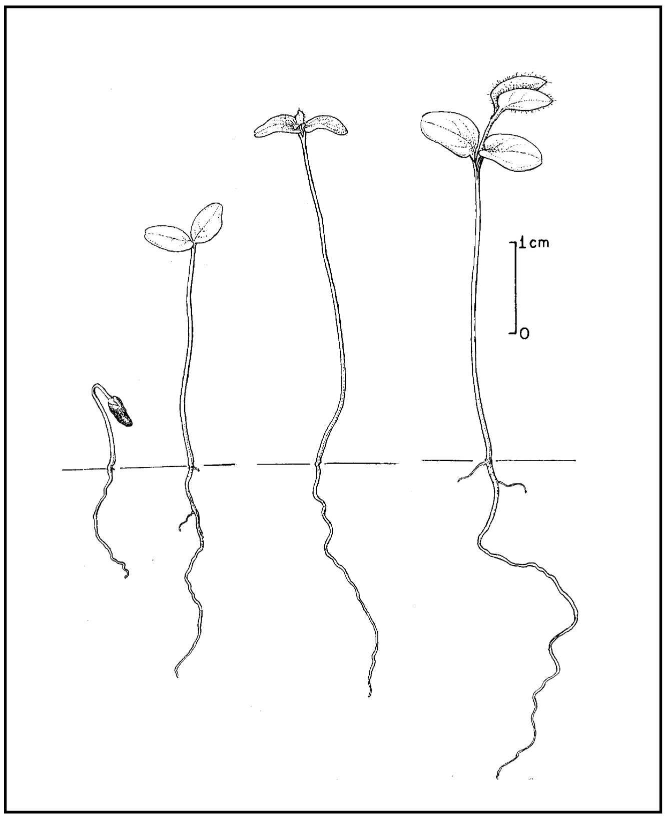
Source: Brinkman (1974).

Table 5—*Lonicera,* honeysuckle: germination test conditions and results

	Germination conditions				Germination rate		Total
		Temp (°C)			Amount		germination
Species	**Medium**	**Day**	**Night**	**Days**	**(%)**	**Days**	**(%)**
L. canadensis	Sand	30	20	90	—	—	100
L. chrysantha	—	—	—	—	—	—	78–91
L. dioica	Sand	30	20	80–100	—	—	95
L. hirsuta	Sand	30	20	100	—	—	43
L. involucrata	—	—	—	—	—	—	83
L. oblongifolia	Sand	30	20	60	33	25	37
L. tatarica	Sand	30	20	60–90	58	33	85

Source: Brinkman (1974).

Figure 4—*Lonicera tatarica,* Tatarian honeysuckle: seedling development at 1, 3, 13, and 31 days after germination.



sown either broadcast or by drills in the fall, or cold-stratified and sown in early spring. Seeds of species believed to have an impermeable seedcoat as well, however, should be sown as soon as possible after collection to ensure germination the next spring. Nondormant seeds may be sown in the spring without pretreatment. Seeds should be covered with 3 to 6 mm ($^1/_8$ to $^1/_4$ in) of nursery soil. Mulching with 5.0 to 7.5 cm (2 to 3 in) of straw prevents excessive drying of the soil and seeds. Germination of Tatarian honeysuckle usually is complete in 40 to 60 days after spring-sowing. This time can be shortened by soaking seeds in water for 2 to 3 days before sowing. About 15% of sown seeds of Tatarian honeysuckle result in usable seedlings. One- or 2-year-old seedlings of this species and Amur honeysuckle are suitable for field planting (Brinkman 1974).

Vegetative propagation of honeysuckles by stem cuttings is also possible. Most species can be propagated readily by softwood, semi-hardwood, or hardwood cuttings (Dirr and Heuser 1987; Hartmann and others 2002).

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Myrtaceae—Myrtle family

Lophostemon confertus (R. Br.) P.G. Wilson & Waterhouse

brushbox

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Synonyms. *Lophostemon australe* Schott., *Tristania conferta* R. Br., *T. subverticillata* Wendl.

Other common names. Brisbane-box, scrub-box, vinegar-tree.

Growth habit, occurrence, and uses. Brushbox is a straight-boled evergreen tree that obtains heights of 35 to 45 m (18 m in Hawaii) (Carlson and Bryan 1959; Francis 1951; Maiden 1904). It is native to the eastern coastal region of Australia and has become naturalized throughout India and Africa as well as in California, Florida, and Hawaii (Bailey 1906; Little and Skolmen 1989; Streets 1962). It has been planted for timber and for ornamental purposes in Hawaii (Little and Skolmen 1989). The wood grown in Hawaii is moderately resistant to decay and termites, whereas wood grown in Australia is considered to be very resistant to both. In Hawaii, the wood is used for pallets, flooring, and pulp chips, whereas in other regions it is used extensively for construction, shipbuilding, bridges, railway crossties, and pallets (Little and Skolmen 1989). This species is a hardy ornamental and shade tree with handsome foliage (Streets 1962)

Flowering and fruiting. The white brushbox flowers appear in clusters of 3 to 7 on short branches at leaf bases and the backs of leaves. Individual flowers are about 2.5 cm wide. The fruits are bell-shaped capsules 1 to 1.5 cm in diameter and light green to brown in color (Little and Skolmen 1989; Neal 1965). Individual seeds are flat, elongated (figure 1), light brown in color, and less than 4 mm long (figure 2). Seeds are produced moderately well at 15 to 20 years of age (Carlson and Bryan 1959). In Hawaii, trees can be found in all stages of the reproductive cycle at any time during the year, depending on the aspect and elevation at which they are growing (Petteys 1974).

Figure 1—*Lophostemon confertus*, brushbox: seed.

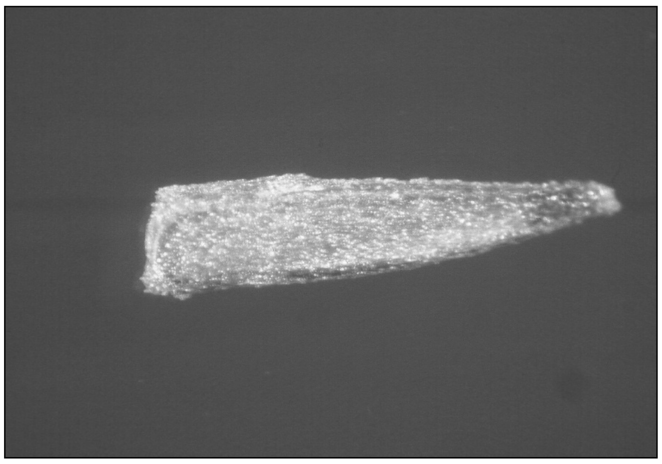
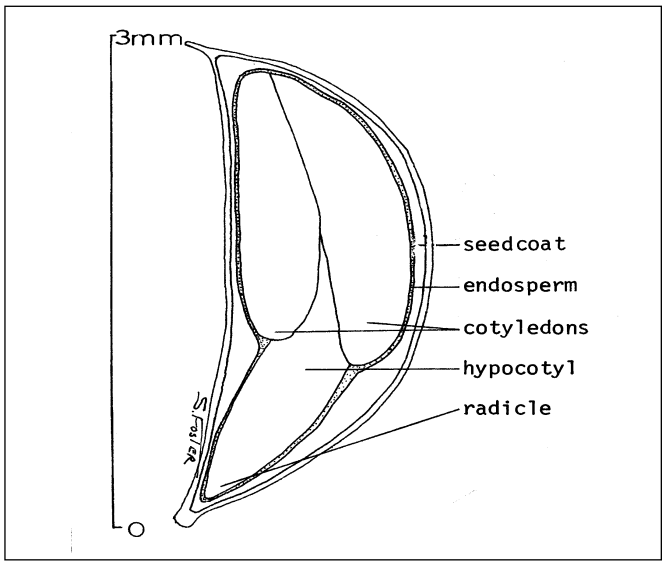


Figure 2—*Lophostemon confertus*, brushbox: longitudinal section through *a* seed.



Collection, extraction, and storage. In Hawaii, the capsules are picked by hand when they turn from green to greenish brown in color. They should be spread out on trays or tables to complete the drying process. Once the capsules are dry, simple agitation will separate the seeds from the capsules. There are almost 5 million seeds/kg (2.2 million/lb), but as few as 2 or 3% of these may be viable (Petteys 1974). The seeds are orthodox in storage behavior,

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as they have stored well in sealed polyethylene bags at low moisture contents and temperatures of –18 to –23 °C (Petteys 1974).

Germination. Brushbox is not dormant and no pregermination treatments are necessary for timely germination. Germination of full seeds for one group of samples averaged about 70% (Petteys 1974).

Nursery and field practice. Brushbox seeds are mixed with fine soil and the mixture is applied to beds with a fertilizer spreader. Germination usually begins in 10 to 14 days. Mulching and shading are not necessary. Seeds are usually sown from November to March and seedlings are outplanted the following winter as 1+0 stock. Bed densities of 215 to 320 seedlings/m^2 (20 to 30/ft^2) are recommended. Seedlings must be treated and planted with care to minimize the high mortality common to this species (Petteys 1974).

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Fabaceae—Pea family

Lupinus L.

lupine

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Growth habit, occurrence, and use. The genus *Lupinus* is a large genus of herbs and shrubs that are distributed worldwide (Christofolini 1989). Only 10 to 14 Old World species, all herbaceous, are recognized (Williams and others 1983). New World lupines are more diverse, with 147 species found in North America (USDA SCS 1982), 200 in Mexico, 30 to 40 in Central America, and about 500 in South America (Christofolini 1989). Four shrub species are considered here (table 1). Three species are commonly planted in California. Pauma lupine can reach a maximum height of about 2.5 m (Hickman 1993). As far as can be determined, Pauma lupine was first cultivated in 1928 and has since proved to be valuable as an ornamental plant and for watershed protection and erosion control. Though some plants may live for 10 years, Pauma lupine is generally short-lived (Everett 1957). Whiteface lupine, a more northerly shrub species in California, often reaches a maximum height of 3 m. Since it was first cultivated in 1927, it has been planted for wildlife purposes, watershed protection, and more recently for environmental forestry. Four varieties of whiteface lupine are recognized: *Lupinus albifrons* var. *collinus* Greene; var. *douglassii* (J.G. Agardh) C.P. Sm.; var. *flumineus* C.P. Sm.; and var. *eminens* (Greene) C.P. Sm. (Hickman 1993; USDA SCS 1982). Bush lupine, a large, fast-growing but short-lived shrub found in the northern coastal scrub of California, has been planted for dune stabilization in northern California (Davidson and Barbour 1977; Gadgil 1971a,b&c). Inyo bush lupine is not positively distinct from whiteface lupine, and they are often grouped together.

Flowering and fruiting. Flowers are bisexual, irregular, blue, purple, and yellow in racemes. Pauma lupine will bear viable seeds at 1 year of age (Everett 1957). It flowers from April to May (Munz and Keck 1959) and its seeds ripen from May to August (Ratliffe 1974). Whiteface lupine flowers from March to June (Hickman 1993) and its seeds mature from early June to late July.

Collection, extraction, and storage. The legumes (pods) of both Pauma and whiteface lupines pop open when ripe and disperse 2 to 12 seeds (figures 1 and 2). Hence, it is necessary to collect the legumes while the seeds are somewhat green (Ratliffe 1974). Immature legumes can be gently air-dried until they open. The coarse material can be removed by screening. The number of clean Pauma lupine seeds per weight in 2 samples was 39,700 to 52,900/kg (18,000 to 24,000/lb) (Mirov and Kraebel 1937). Information on seed weight is lacking for whiteface lupine; however, for the closely related Inyo bush lupine, the num-

Table 1—*Lupinus,* lupine: nomenclature and occurrence

Scientific name	Common name(s)	Occurrence
L. albifrons **Benth ex. Lindl**.	**whiteface lupine,** silver lupine	Coastal range & Sierra Nevada
L. arboreus **Sims**	**bush lupine**	N California coast
L. excubitus **M.E. Jones**	**Inyo bush lupine**	California & Nevada
L longifolius **(S. Wats) Abrams**	**Pauma lupine,** longleaf bush lupine	S California

Sources: Davidson and Barbour (1977), Everett (1957), Gadgil (1971a,b&c), Hickman (1993), USDA SCS (1982).

Figure 1—*Lupinus*, lupine: seeds of *L. albifrons*, whiteface lupine (**left**) and *L. longifolius*, Pauma lupine (**right**).

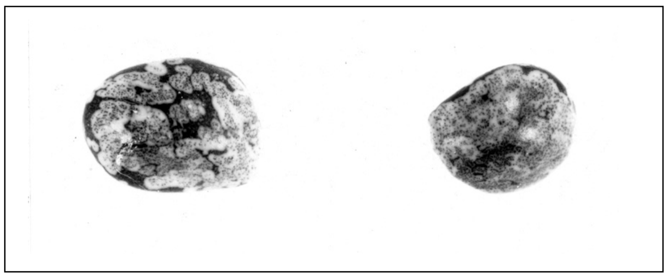
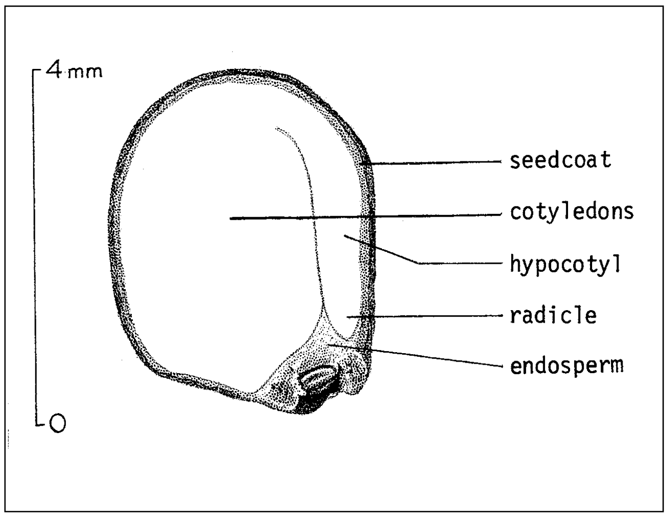


Figure 2—*Lupinus longifolius*, Pauma lupine: longitudinal section through a seed



ber of clean seeds per weight was reported to be 59,500/kg (27,000/lb) (Mirov and Kraebel 1937). In 1 sample, purity was 91% and soundness was 76% (Ratliffe 1974).

When adequately dried, mature seeds of lupine can be stored for extended periods. Seeds stored for 30 years at room temperature were found to be viable, and variations in the color of these seeds had no effect on viability (Everett 1957).

Germination. Stored seeds of the lupines have hard seedcoats that require pretreatment to induce prompt germination. Seeds of the west Australian blue lupine (*L. angustifolius* L.) became impermeable to water when their moisture content was reduced to 10 to 12% (Quinlivan 1962). Each of 3 treatments—mechanical scarification, a hot water soak, and cold stratification for 72 days at 2 °C—induced prompt germination (Ratliffe 1974). In addition, the hard seeds of this lupine became permeable to water when exposed to simulated surface soil temperature fluctuating between 16 and 60 °C (Quinlivan 1962). Ongoing research on sundial lupine (*Lupinus perennis* L.) suggests that seeds from both the northeastern and southwestern United States germinate poorly (10%) without scarification, but that treatment with concentrated sulfuric acid for 30 to 60 minutes (depending on source of seed) improves germination to near 90%. Preliminary comparisons with bush lupine further suggest that seeds from the 2 species respond similarly to acid treatment.

Germination percentage has been variable for both untreated fresh seeds and pretreated stored seeds (table 2), which may reflect species or population-dependent scarification requirements. Current nursery practices for breaking hardseededness in lupines include nicking, sandpaper scarification, and hot water soaking (Kaplow 1996; Wilson 1996).

Nursery and field practices. Container production of shrubby lupines is somewhat difficult. Young seedlings are susceptible to slug and snail damage. Soil temperatures must be kept low; pot-heating in summer greenhouses may cause major mortality. Root systems are delicate and transplant survival is often low (Kaplow 1996). Wilson (1996) recommeded planting seeds directly into large containers and using a well-aerated soil mix. Shrubby lupines may be direct-seeded after scarification to break hardseededness. They do best in poor, rocky, or sandy soils where competition from perennial grasses is minimal.

Table 2—*Lupinus,* lupine: pregermination treatments and germination test results

Species	Storage (yrs)	Wet chilling (days)	Test duration (days)	Germination percentage	Tests
L. albiftons	2	72	—	90	1
L. excubitus	0	0	6	92	1
L. longifolims	0	0	10+	92	1
L. arboreus	0	0	95	4–45	3

Sources: Davidson and Barbour (1977), Mirov and Kraebel (1937), Ratliff (1974).

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L

Solanaceae—Potato family

Lycium L.

wolfberry

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Other common names. matrimony vine, desert-thorn, boxthorn, squawthorn.

Growth habit, occurrence, and use. The wolfberries—*Lycium* L.—include about 100 species of shrubs native to the temperate and subtropical regions of both hemispheres (Rehder 1940). Deciduous or evergreen as well as thorn-bearing and unarmed forms occur in the genus. Species of wolfberry native to the United States tend to be desert shrubs (Benson and Darrow 1954; Wallace and others 1980; Webb and others 1987). Wolfberries are used as ornamental shrubs because of their showy berries, but they also provide wildlife habitat and watershed protection. At least 1 species is grown for shelter hedges. The 2 introduced species—Chinese wolfberry and matrimony vine—have been grown horticulturally for the longest most extensively in this genus. It is likely that geographic races have developed within widely distributed wolfberry species. Some botanical varieties may be geographical races. Hitchcock (1932) mentions apparent racial development in Anderson wolfberry. Natural hybrids occur where species ranges overlap, as is the case with Anderson wolfberry and Torrey wolfberry (*L. torreyi* Gray) and Rich wolfberry (Hitchcock 1932). Information on 5 species (table 1) is included here.

Flowering and fruiting. The perfect flowers, grading by species from white to lavender, usually bloom in the summer (table 2). They are followed by bright red (rarely yellow or black) berries (table 3), each with few to many seeds (figures 1 and 2). Good seedcrops are borne almost every year by matrimony vine (NBV 1946) and probably by other wolfberry species. Arizona desertthorn produces seed abundantly (Van Dersal 1938).

Collection of fruits; extraction and storage of seeds. Ripe berries may be picked from the bushes in the fall. The berries are soft and may be pulped by forcing them through a screen and floating out the pulp (Rudolf 1974). For extraction on a larger scale, berries may be fermented, mashed in water, and then run through a hammermill equipped with screens of suitable sizes (Glazebrook 1941). After extraction, the seeds should be dried and stored in sealed containers at 5 °C (NBV 1946; Rudolf 1974), or stratified in moist sand (Glazebrook 1941; NBV 1946). Stratified seeds of matrimony vine will maintain good viability for 6 months (NBV 1946), but there is no information on long-term storage of dry seeds. They appear to be orthodox, however, so storage should not be a problem. Seed data are listed in table 4.

Germination. Dormancy in wolfberry seeds is variable. Seed samples of Anderson wolfberry and Arizona desert-thorn germinated well without pretreatment. They had germination of 68 and 94% (Swingle 1939). Germination of matrimony vine seeds, however, was hastened and improved by stratification in moist sand for 60 to 120 days at 5 °C. After cold stratification, the average germination capacity for 19 samples was 74% (Glazebrook 1941; NBV 1946; Rudolf 1974). These tests were run in sand flats for 30 to 40 days at diurnally alternating temperatures of 30 to 20 °C. Germination after 18 days was 54%. Seeds of Rich wolfberry probably would benefit from similar pretreatment,

Figure 1—*Lycium barbarum*, matrimony vine: cleaned seed.

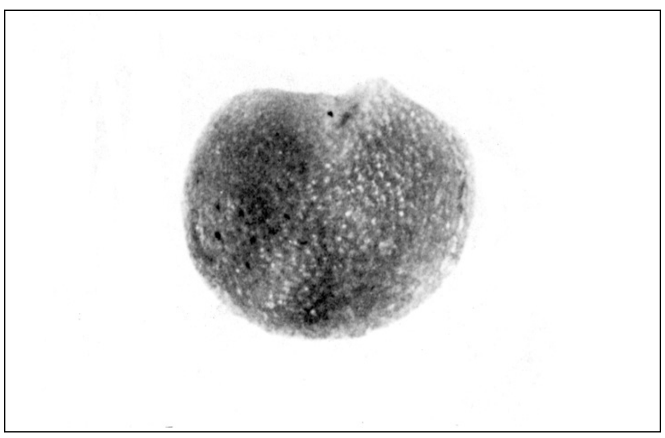


Table 1—*Lycium,* wolfberry: nomenclature and occurrence

Scientific name & synonym(s)*	Common name(s)	Occurrence
L. andersonii **Gray**	**Anderson wolfberry,** Anderson desert thorn, & water jacket, squawberry	New Mexico to California, N to Colorado, Nevada, & Utah, & in Mexico (Sinaloa Sonora) on gravelly washes, & sandy or alkali flats up to 1,524 m
L. barbarum **L.** *L. halimifolium* P. Mill.	**matrimony vine,** boxthorn, European desert thorn	China to SE Europe; commonly cultivated in much of the US, West Indies, & Mexico
L. chinense **P. Mill.**	**Chinese wolfberry**, Chinese matrimony-vine, Chinese desertthorn	In thickets along riverbanks in Japan, Korea, Manchuria, China, Ryukyu Islands, & Formosa
L. exsertum **Gray** *L. fremontii* var. *bigelovii* Gray	**Arizona desert thorn**	Arizona & New Mexico & NW Mexico up to 1,219 m
L. richii **Gray** *L. palmeri* Gray *L. pringlei* Gray	**Rich wolfberry,** Baja desert thorn	S California & Sonora, Sinaloa, & Baja California in Mexico

* See Chiang (1983) for nomenclatural history.

Table 2—*Lycium,* wolfberry: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening
L. andersonii	W US	Apr–June	—
	SW US	Jan–May	—
	California	Nov–Apr	—
	Arizona	Feb–Apr	Aug–Sept
L. barbarum	Holland, NE US	June–Sept	Aug–Oct
L. chinense	NE US	June–Sept	Aug–Oct
	Japan	Aug–Nov	—
L. exsertum	Arizona	Jan–Feb*	—
L. richii	California	May–Sept	June–Oct

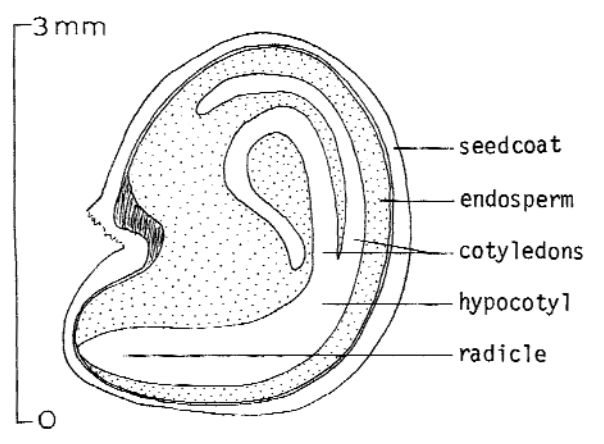
Sources: Bailey (1939), Kearney and Peebles (1942), McMinn (1951), Mirov and Kraebel (1939), NBV (1946), Ohwi (1965), Rehder (1940), Van Dersal (1938), Vines (1960), Wyman (1947).
* Most abundant then, but flowers throughout the year (Kearney and Peebles 1942).

Table 3—*Lycium*, wolfberry: height, length of cultivation, flower color, and fruit characteristics

Species	Height at maturity (m)	Year first cultivated	Flower color	Ripe fruit color	Seeds/fruit
L. andersonii	0.3–3	Before 1935	Light purple, lavender,	Red or white	Very many
L. barbarum	1–6	Long cultivated	Dull, lilac-purple sometimes yellow	Scarlet to orange-red	3–20
L. chinense	1–2*	Before 1709	Purple	Scarlet to orange-red	—
L. exsertum	1–4	Before 1935	Whitish to purple	Orange or red	20–30
L. richii	1–4	Before 1935	Lilac	Bright red	30–50

Sources: Bailey (1939), Benson and Darrow (1954), Hitchcock (1932), Kearney and Peebles (1942), McMinn (1951), Rehder (1940), Standley (1924), Vines (1960).
* Up to 4 m long as a prostrate rambler.

Figure 2—*Lycium barbarum*, matrimony vine: longitudinal section through a seed.



because germination was only 11% without pretreatment (Mirov and Kraebel 1939).

Nursery practice. One recommendation is to sow the seeds in the fall as soon as the fruits ripen (Laurie and Chadwick 1934). Another suggestion is to sow stratified seed in the spring and cover them lightly by sifting-on about 6 mm ($^1/_4$ in) of soil (NBV 1946). Tree percent has been from 10 to 15 for Chinese wolfberry and matrimony vine (Swingle 1939). Two-year-old seedlings may be outplanted.

Table 4—*Lycium,* wolfberry: seed data

	Seed soundness	Cleaned seeds/weight				
		Range		Average		
Species	(%)	/kg	/lb	/kg	/lb	Samples
L. chinense	99	—	—	377,000	171,000	1
*L. barbarum**	98	555,600–586,400	252,000–266,000	573,000	260,000	3
L. richii	—	—	—	3,022,600	1,371,000	1

Sources: Glazebrook (1941), Mirov and Kraebel (1939), Swingle (1939).
* Seed purity was 92% in one sample (Rudolf 1974).

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