Fabaceae—Pea family

Delonix regia (Bojer ex Hook.) Raf.

flamboyan

J. A. Vozzo

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Other common names. royal poinciana, flametree.

Occurrence and growth habit. A popular ornamental throughout the tropics, flamboyan—*Delonix regia* (Bojer ex Hook.) Raf.—is a small to medium-sized tree, typically 7 to 16 m high and up to 60 cm in diameter (Little and Wadsworth 1964). The champion Puerto Rican flamboyan, however, is 32 m high and 105 cm in diameter (Francis 1994). It grows well in moist soil derived from limestone, where it is common and reproduces well, but it is also tolerant of well-drained and somewhat droughty conditions (Francis and Liogier 1991). The species is briefly deciduous. Flamboyan has prominent buttresses and a broad, flat crown when grown in full sun. Its shallow but spreading root system limits the sites where it may be planted. The tree is susceptible to termites, shoot borers, and heart rot (Webb and others 1984). Although the genus is reported to have 3 species, flamboyan is the most cosmopolitan. A native of Madagascar, it has been planted in nearly every country in frost-free areas and is perhaps the most important flowering ornamental tropical tree of the world (Meninger 1962).

Use. This is a beautiful tree in form, shade, and flower. The flowers are predominantly red, although yellow and orange forms are cultivated; they are relatively short-lived as cut flowers. Trees remain in flower for several weeks, however. They are often seen planted along roadsides as living fence posts or as shade trees on both sides of the road that arch over the entire road. The wood is yellow-brown, weak, brittle, and soft, with a specific gravity of about 0.3. Although the species is not a good timber source, the wood is widely used as firewood. The legume (pod) is edible (Little and Wadsworth 1964; Menninger 1962; Webb and others 1984).

Flowering and fruiting. Showy flowers follow a dry season when the tree is almost leafless. The 5-pointed calyx is hairy and borne on racemes 15 to 25 cm long. Flowers are commonly red but may be white, yellow, orange, or yellow and vary from 8 to 25 cm across. Although flowers form after the dry season and during the wet season, they persist during leaf emergence so that the crown appears feathery green while the colorful flowers are dominant. The hard legumes are 35 to 50 cm long, 6 cm wide, and 5 mm thick, and they hang tenuously on trees year-round. When mature, the legumes split into 2 parts lengthwise and are dark brown to black (Little and Wadsworth 1964); seeds (figures 1 and 2) are shed at that time. There are about 4,500 seeds/kg (2,040/lb) from Puerto Rican sources (Marrero 1949), whereas Colombian sources report only 2,000 to 3,000 seeds/kg (900 to 1,360/lb) (Navarette nd).

Collection, extraction, and storage. Pruning poles should be used to collect dark brown to black legumes. Legumes open naturally on trees after about 6 months. If unopened legumes are collected, they should be dried in the sun for 1 month; then the woody legumes should be forced open and the seeds removed. Seeds are relatively loosely attached in lateral grooves inside the legume. Dry seeds store very well in either open or closed containers and do not require refrigerated storage (Francis 1994). Seeds stored for 12 months at 26 °C germinated at 60% (Marrero 1949). Webb and others (1984) reported viability after 4 years storage but do not give germination rate or percentage germination.

Figure 1—*Delonix regia*, flamboyan: mature seed.

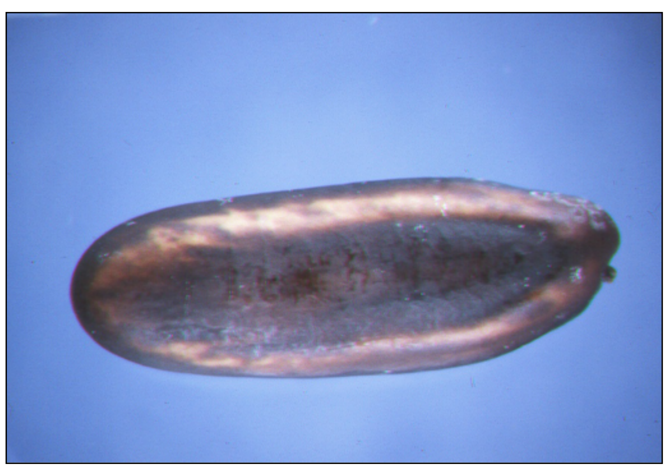
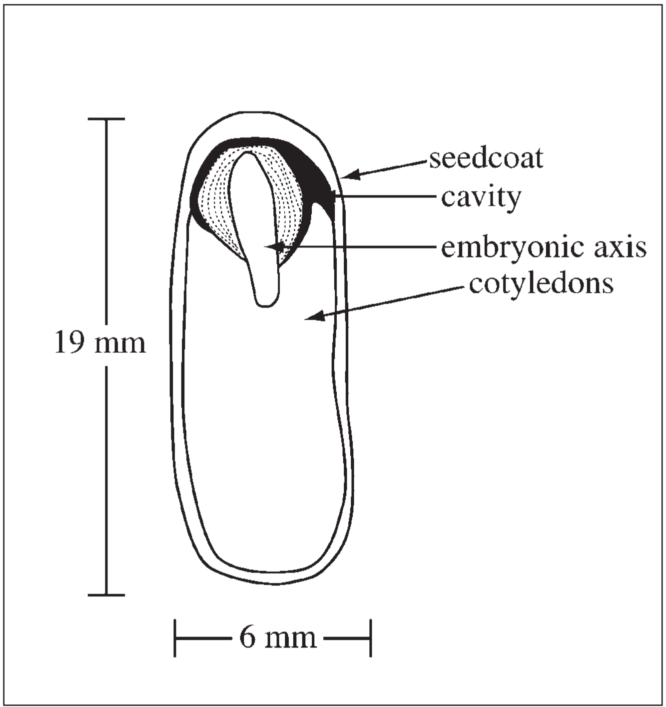


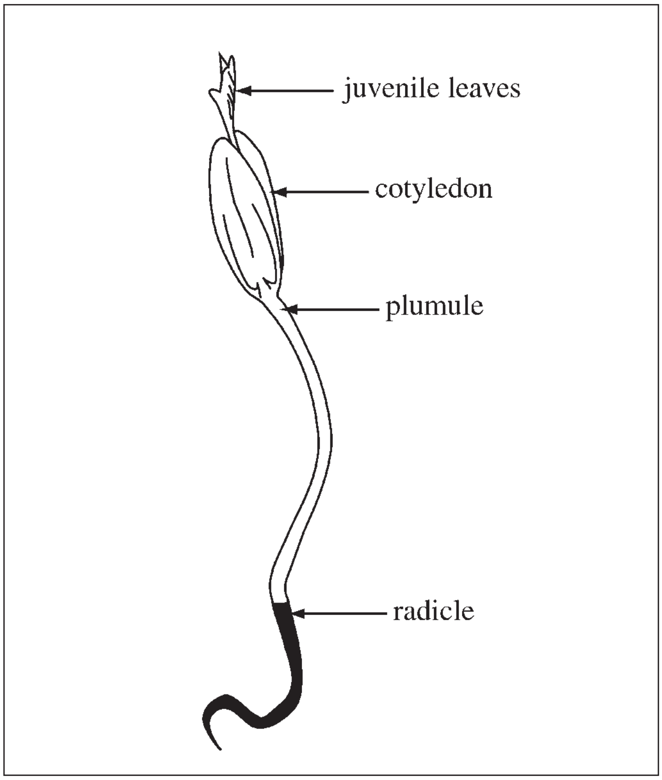
Figure 2—*Delonix regia*, flamboyan: longitudinal section through a seed.



Germination. Scarification—with either hot water, sulfuric acid, or abrasion—is required for germination. Millat-E-Mustafa (1989) recommends 90 °C water for 10 seconds followed by 24 hours of imbibition. A concentrated sulfuric acid soak for 0.5 to 5 hours improved germination for Duarte (1974), whereas a hot-wire scarification proved superior to other means described by Sandiford (1988). Seeds subjected to the various scarification treatments reported here had germination values superior to those of their respective controls. Within 8 days of fresh collections, expect 76% germination after 9 weeks.

Nursery practice. Seedlings (figure 3) are ready for outplanting after 3 to 4 months of growth in plastic nursery bags during the wet season. Saplings are also grown to 2 m, then "balled and burlaped" for large ornamental potted plants. Mature flowering and fruiting trees may be grown in 3 to 5 years in good sites (Francis 1994).

Figure 3—*Delonix regia*, flamboyan: seedling at 10 days after germination.



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Papaveraceae—Poppy family

Dendromecon Benth.

bushpoppy

W. Gary Johnson and Donald L. Neal

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Growth habit, occurrence, and use. Bushpoppies (also known as treepoppies) are openly branched, evergreen shrubs from 0.6 to 2.5 m high, sometimes to 6 m. They have a woody base with gray or white shreddy-barked stems. The 2.5- to 10-cm-long leaves are mostly lanceolate, 3 to 8 times longer than wide (LHBH 1976). Environmental factors and shoot growth pattern affect leaf size (Bullock 1989). The 2 species considered here grow on dry chaparral slopes, ridges, and washes below 1,830 m. One species is found in California's Channel Islands and the other in the coastal range, from Sonoma County to the Sierra San Pedro Martir, Baja California, Mexico, and in the west foothills of the Sierra Nevada, from Shasta County to Tulare County (table 1). Bush-poppies rely on seed production to propagate. No lignotuber is formed on sprouts that appear after burning, so regrowth after fire is rare (Bullock 1989). The genus is useful for watershed protection (Sampson and Jespersen 1963) and for forage. Goats are especially fond of bushpoppies, and deer (*Odocoileus* spp.) and sheep eat the sprouts after fire.

Flowering and fruiting. Flowers are bisexual, yellow, showy, and solitary on stalks. At several locations, the shrubs first flowered in their second spring (Bullock 1989). Flowers appear in April through June and sometimes into August (Munz and Keck 1959). Bullock (1989) reports that the shrubs flower profusely from February through April in the Santa Monica Mountains. Several populations produce a few flowers throughout the year. Fruits are linear, grooved capsules measuring 5 to 10 cm long, with 2 valves that separate incompletely at maturity. Ripe fruits (those that explode when grasped) may be collected in May, June, and July (Neal 1974). Fruits are dehiscence, scattering the seeds (figure 1) up to several meters from the shrub, and ants disperse the seeds, some below and others above the ground. Concentrations of seeds can be found around the entrances of harvester ant—*Pogonomyrmex* and *Veromessor* spp.—nests (Bullock 1989).

Collection, cleaning, and storage. The black seeds are almost spherical, 2 to 4 mm in diameter, with a slightly

Figure 1—*Dendromecon harfordii*, island bushpoppy: seeds.

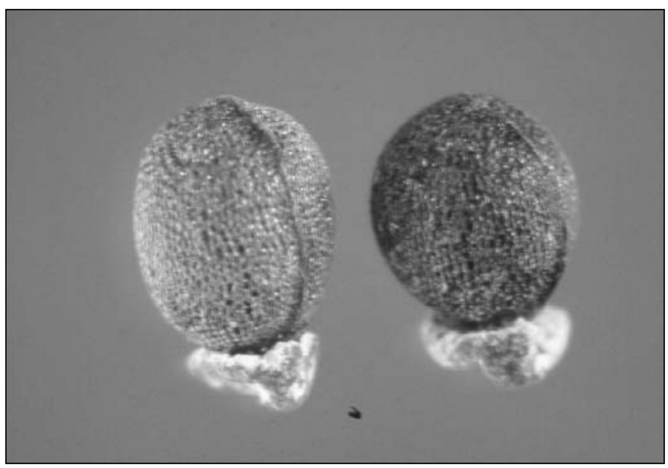


Table 1—*Dendromecon*, bush-poppy: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
D. harfordii **Kellogg** *Dendromecon rigida* ssp. *harfordii* (Kellogg) Raven *D. rigida* spp. *rhamnoides* (Greene) Thorne	**island bushpoppy,** Harford tree-poppy	Channel Islands, California
D. rigida **Benth.**	**stiff bushpoppy**, tree-poppy	Central California to N Baja California

Source: Munz and Keck (1959).

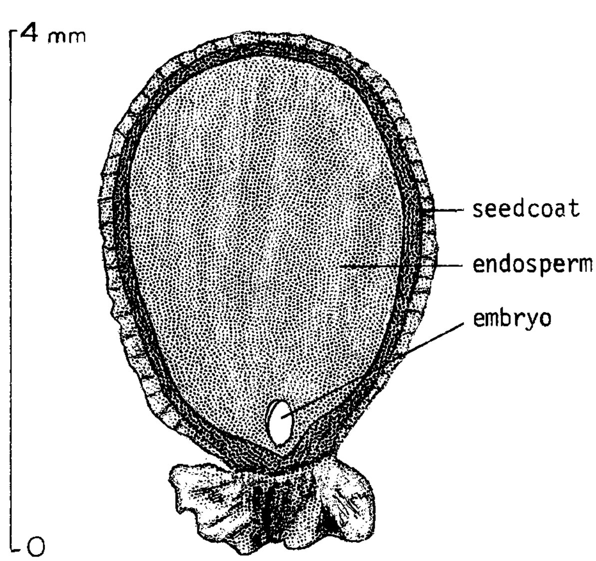
pitted, hard, brittle testa. The seeds are dispersed by ants; the prominent caruncle is removed and used by the ants for food. The endosperm is oily, and the minute embryo rudimentary (Berg 1966) (figure 2). The mean number of seeds per fruit ranged from 2.9 to 10.7 in 14 populations (Bullock 1989). In 2 samples of cleaned seeds, purity was 77% and soundness was 97%. There were 92,400 to 114,400 seeds/kg (42,000 to 52,000/lb) (Neal 1974). Four other samples had purities of 99.4 to 99.9%, with an average of 99.4%, and 100,300 to 106,300 seeds/kg, with an average of 103,200/kg (45,600 to 48,300/lb, average 46,900/lb) (Vivrette 1996). Bullock found that seed weights varied greatly among the 14 populations studied, ranging from 10.1 to 15.8 mg (Bullock 1989). Vivrette reported seed weights ranging from 9.38 to 9.90 mg, average 9.70 mg, on 4 samples (Vivrette 1996). Bullock's slightly heavier fresh seeds may have had attached caruncles or a higher moisture content than Vivrette's laboratory samples.

There are no reports of seed storage of these species, but they likely can be stored at low moisture contents and near-freezing temperatures.

Germination pretreatments. Bushpoppy seeds have been sown in a moist medium at temperatures alternating diurnally from 4.5 °C (night) to 21 °C (day). Germination started after 50 days at these temperatures and reached 21% at 102 days after sowing (Mirov and Krabel 1939; Neal 1974). Vivrette reported no germination in of 9 samples tested for 21 days at 15 °C. A few seeds germinated on blotters moistened with 400 ppm GA_3 (gibberellic acid). Total viable seeds as determined by staining in tetrazolium chloride ranged from 11 to 50%, average 27% (Vivrette 1996). Emery recommended fire treatment or 1 $^1/_2$ to 2 months of stratification and stated that 3 months of stratification with a diurnal fluctuation from 8 to 21 °C may improve germination (Emery 1988).

Nursery practice. Fire-treated bushpoppy seeds give the most reliable germination in nurseries (Emery 1988; Everett 1957). Seeds to be fire-treated should be sown in the fall in a slightly moist nurserybed. The seeds should be then covered with a layer of milled peat or sand 1 to 2 times as thick as the seeds' diameter and not watered. Then, a 10- to 15-cm (4- to 6-in) layer of dry pine needles or excelsior should be placed over the bed and burned. The seedbed should be watered after it has cooled. If wooden flats are being used, 2 layers of aluminum foil will protect the wood during the burning (Emery 1988).

Figure 2—*Dendromecon harfordii*, island bushpoppy: longitudinal section through a seed.



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Ebenaceae—Ebony family

Diospyros L.

persimmon

David F. Olson, Jr., R. L. Barnes, and W. Gary Johnson

Drs. Olson and Barnes retired from the USDA Forest Service's Southeastern Forest Experiment Station;
Mr. Johnson retired from the USDA Forest Service's National Seed Laboratory

Growth habit, occurrence, and use. Nearly 200 species of persimmons—*Diospyros* L.—are widely distributed, mostly in tropical regions. Only 2 persimmons—common persimmon and Texas persimmon—are native to the 48 contiguous states. Two others are grown in mild regions: Japanese persimmon for fruit and date-plum for root stock (table 1). Other persimmons are native to the tropical regions of the United States—*Diospyros hillebrandii* (Seem.) Fosberg and *D. sandwicensis* (A. DC.) Fosberg in Hawaii (Little and Skolman 1989) and *D. revoluta* Poir. and *D. sintenisii* (Krug & Urban) Standl. in Puerto Rico (Little and others 1974).

Common persimmon is a small to medium-sized deciduous tree, normally attaining a height of 9 to 18 m at maturity (Sargent 1965). It occurs in open woods and as an invader of old fields from Connecticut west through southern Ohio to eastern Kansas, and south to Florida and Texas (Sargent 1965). Common persimmon develops best in the rich bottom lands along the Mississippi River and its tributaries and in coastal river valleys. In these optimum habitats, common persimmon trees often attain heights of 21 to 24 m and diameters of 51 to 61 cm (Morris 1965).

In past years, persimmon wood was used extensively for weaver's shuttles, golf club heads, and other products requiring hard, smooth-wearing wood (Olson and Barnes 1974). At present, such uses have diminished because of the use of laminates and other substitute materials.

The fruits are exceedingly astringent when green, but delicious when thoroughly ripe (Harlow and Harrar1958); they are eaten by humans, animals, and birds. The common persimmon is a valuable honey plant and has been cultivated for its handsome foliage and fruit since 1629. Several varieties have been developed for fruit production (Harlow and Harrar 1958).

Texas persimmon is a shrub or small tree of south Texas and northeast Mexico, usually 1.8 to 3 m tall but sometimes reaching 12 m, with 4-cm-long leaves (Everitt 1984; LHBH 1976). The fruits are important wildlife food, but the shrub is considered as undesirable in rangelands of the Southwest (Everitt 1984).

Japanese persimmon (*kaki*) and date-plum are small persimmons from Asia grown commercially in the milder regions of the United States. Japanese persimmon grows to 14 m, with 18-cm-long leaves and large delicious fruit; many varieties are listed. Date-plum grows to 14 m, with leaves 13 cm long; it is often used as a rootstock for Japanese persimmon (LHBH 1976).

Table 1—*Diospyros,* persimmon: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
D. kaki **L.f.** *D. chinensis* Blume	**Japanese persimmon,** *kaki,* keg fir, date-plum	NE Asia & Japan
D. lotus **L.** *D. japonica* Siebold & Zucc.	**date-plum**	NE Asia & Japan
D. texana **Scheele**	**Texas persimmon,** black persimmon	SE Texas to central & trans-Pecos Texas
D. virginiana **L.** *D. mosieri* Small	**common persimmon,** eastern persimmon	S Connecticut to SE Nebraska, S to Gulf of Mexico

Sources: LHBH (1976), Sargent (1965).

Flowering and fruiting. Male and female flowers are borne on different plants, but a few plants have bisexual flowers. The female flowers are solitary, with 4 to many staminodes. The male flowers are in cymes or clusters with 4 to many stamens. The fruits are juicy, 1- to 10-seeded berries with enlarged, persistent calyxes at the base (LHBH 1976).

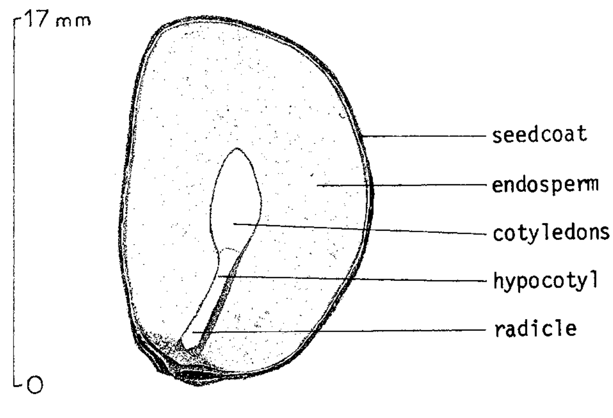
Common persimmon has small, dioecious, axillary flowers borne after the leaves from March to mid-June, depending on the latitude (Little and Delisle 1962; Morris 1965; Olson and Barnes 1974; Radford and others 1964). Flowers are most common in April and May and are pollinated by insects.

The fruits are green before ripening and may vary in color when ripe from green, yellow, orange, and yellowish brown to dark reddish purple and black (Olson and Barnes 1974; Sargent 1965) (figure 1). The fruit is a 2- to 5-cm plumlike berry, glaucous and with a conspicuous, persistent calyx, that contains 3 to 8 seeds (Olson and Barnes 1974; Sargent 1965). The fruits ripen from September to November; the flat, brown seeds, about 15 mm long, are dispersed from the time of ripening until late winter (Little and Delisle 1962; Olson and Barnes 1974; Morris 1965; Radford and others 1964) (figures 1 and 2). The seeds are disseminated by birds and animals that feed on the fruits, and to some extent, by overflow water in low bottom lands (Morris 1965).

Seed bearing may begin at age 10, but the optimum seed-bearing age is 25 to 50 years (Little and Delisle 1962; Morris 1965; Olson and Barnes 1974). Good seedcrops are borne about every 2 years, with light crops in intervening years (Olson and Barnes 1974).

Figure 1—*Diospyros virginiana*, common persimmon: mature fruit and a single seed.

Figure 2—*Diospyros virginiana*, common persimmon: longitudinal section through a seed.



The small Texas persimmon flowers have 5 lobes. The black, globe-shaped fruits are 2.5 cm in diameter and have dark flesh (LHBH 1976). Animals and birds eat the fruits and disseminate the seeds (Everitt 1984).

Japanese persimmon flowers are yellowish white, about 2 cm long. Male flowers have 16 to 24 stamens and female flowers have 8 staminodes. The orange to reddish fruits are variable in shape, to 7.6 cm in diameter, with orange flesh (LHBH 1976).

Date-plum flowers are reddish to greenish, 7.5 mm long, with 4 lobes. Male flowers have 16 stamens. The small, yellow, globe-shaped fruits are 12.5 mm in diameter and turn blackish as they ripen (LHBH 1976).

Collection of fruits; extraction and storage of seeds. The fruits of common persimmon may be collected by picking them or shaking them from the trees as soon as they are ripe and soft in texture. They may also be picked from the ground after natural fall. If the fruits have started to dry, they should be softened by soaking in water (Myatt and others 1988). The seeds are easily removed by running the fruits with water through a macerator and allowing the pulp to float away or by rubbing and washing the pulp through 6.4-mm ($^1/_4$-in) mesh hardware cloth (Olson and Barnes 1974). For small quantities, ripe fruits can be placed in plastic bags and left until the pulp turns to juice, which can then be drained away before drying the seeds (Dirr and Heuser 1987).

After being cleaned, the seeds should be spread out to dry for a day or two. Spreading the seeds on screens to dry is common (Myatt and others 1988). Prolonged storage requires thorough drying. After the seeds are dried, they should be passed over a 9.9-mm (#25) screen on an air-screen cleaner to remove trash and twigs. Use of a gravity table with high air may also be necessary (Myatt and others 1988). The seeds can then be safely stored in sealed dry containers at 5 °C (Engstrom and Stoeckler 1941).

One hundred kilograms (220 pounds) of fruit of the common persimmon will yield 10 to 30 kg (22 to 66 lbs) of cleaned seeds (Olson and Barnes 1974); the number of seeds per weight ranges from 1,460 to 3,880/kg (665 to 1,764/lb), with an average of 2,640 seeds/kg (1,200/lb) (table 2) (Aroeira 1962; Engstrom and Stoeckler 1941; Olson and Barnes 1974). Seedlots of 96% purity and 90% soundness have been obtained (Olson and Barnes 1974).

Japanese persimmon has about 3,400 seeds/kg (1,550/lb). Seeds stored at 0 °C at 45% moisture content retained the greatest viability after 18 months. Viability decreased rapidly as the seeds were dried, regardless of the speed of drying, with almost no germination at moisture contents below 10% (Kotobuki 1978). Date-plum has about 8,910 seeds/kg (4,040/lb).

Pregermination treatments. Natural germination of common persimmon usually occurs in April or May, but 2- to 3-year delays have been observed (Blomquist 1922; Olson and Barnes 1974). The main cause of the delay is the seed covering, which caps the radical, restricts the embryo, and causes a decrease in water absorption (Blomquist 1922). After removal of this cap, 100% germination was secured with mature seeds collected in the autumn (Blomquist 1922). Seed dormancy also can be broken by stratification in sand or peat for 60 to 90 days at 3 to 10 °C (Aroeira 1962; Crocker 1930; Olson and Barnes 1974; Thornhill 1968). Sulfuric acid scarification for 2 hours proved to be less effective in breaking dormancy than did stratification (Aroeira 1962).

Japanese persimmon does not have strong dormancy. Oh and others (1988) have shown that, although stratification was not essential, it improved germination. Rate of germination of date-plum seeds increased as the stratification length increased to 10 weeks (Oh and others 1988). No pretreatment is needed to germinate Texas persimmon seeds (Vora 1989).

Germination tests. Germination of stratified common persimmon seeds was tested in sand or peat flats at diurnally alternating temperatures of 20 to 30 °C. Germinative energies ranging from 54 to 94% were obtained in 20 to 34 days; and germinative capacities at 60 days varied from 62 to 100% (Olson and Barnes 1974). Payne achieved 90% uniform germination on common persimmon and date-plum by stratifying the seeds for 60 to 90 days in wet vermiculite after lightly dusting them with a fungicide. Scratching the seedcoat can shorten the stratification period (Payne 1996).

Fresh Japanese persimmon seeds taken from ripe fruits and sown immediately germinate best. Germination ranged from 20 to 77% in a study of 18 cultivars with fresh seeds sown immediately (Dirr and Heuser 1987). Date-plum seeds germinated best without light at alternating 18 to 30 °C with 10 weeks stratification at 5 °C. Germination of seeds stratified for 2 weeks was increased by treating them with 500 ppm gibberellin (GA_3) (Oh and others 1988). Fresh Texas persimmon seeds sown immediately after extraction germinated 33%. Germination was reduced with all other treatments (Dirr and Heuser 1987).

The tetrazolium chloride staining test is often used to estimate the viability of common persimmon and date-plum seeds due to the long stratification period needed to overcome dormancy. Clipping the radicle end of a seed with toenail clippers and soaking the seed for several days in water or 500 ppm GA_3 will soften it. Then it should be cut lengthwise to expose the embryo and storage tissue for staining.

Nursery practice. Common persimmon seeds may be fall-sown or stratified and sown in the spring. In Missouri, fall-sowing at a depth of 5 cm (2 in) is the normal practice, and seedbeds are mulched. Steavenson (Olson and Barnes 1974) reported a tree percent of 50%; an average tree percent of 25 to 33% is easily attainable. Seedlings of this

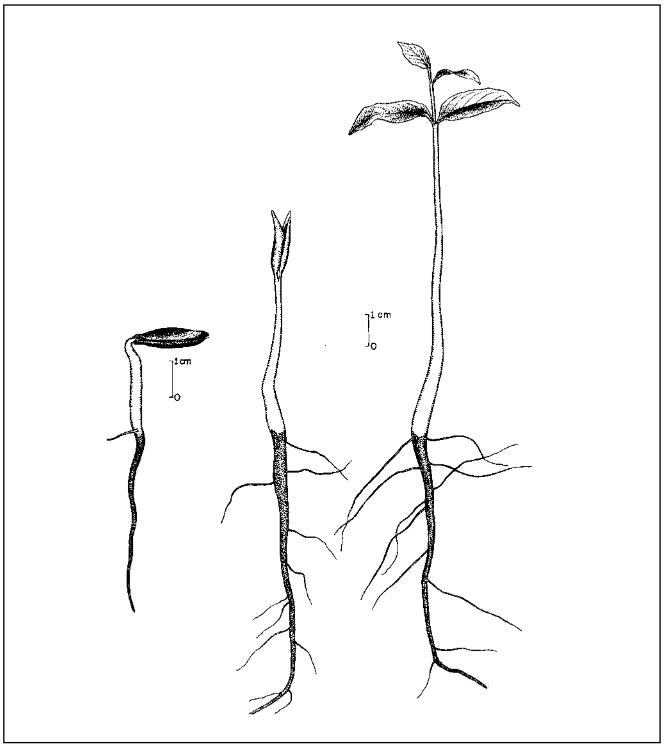
Table 2—*Diospyros,* persimmon: seed yield data

	Cleaned seeds/weight				
	Range		Average		
Species	/kg	/lb	/kg	/lb	Samples
D. kaki	3,015–3,790	1,370–1,720	1,550	3,400	2
D. lotus	—	—	8,910	4,040	1
*D. virginiana**	1,460–3,880	665–1,765	2,640	1,200	—

Source: Olson and Barnes (1974).
* Seed weight to fruit weight ratio (in kilograms/100 kg or pounds/100 lb) = 10 to 30.

species have a strong taproot (figure 3) and should be field-planted at the end of the first season. Root wrenching will cause the seedlings to form a compact, fibrous root system (Myatt and others 1988).

Figure 3—*Diospyros virginiana*, common persimmon: seedling development at 4, 6, and 8 days after germination.



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Thymelaeaceae—Mezereum family

Dirca palustris L.

eastern leatherwood

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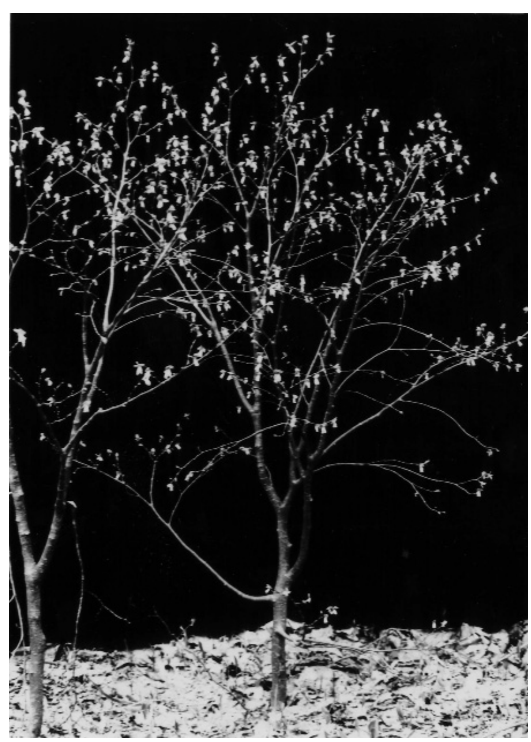
Growth habit, occurrence, and use. Eastern leatherwood—*Dirca palustris* L.—is also known as moosewood, rope-bark, and wicopy. Its natural distribution extends from New Brunswick to Ontario in the north and from northern Florida to Louisiana in the south (Fernald 1950). Within this range, the distribution is restricted to very specific site conditions. It is found almost exclusively in mesic, relatively rich hardwood forests or mixed conifer–hardwood forests (Alban and others 1991; Curtis 1959; Fernald 1950; Ferrari 1993; Jones 2000; Kotar and others 1988; Meeker and others 1993; Neveling 1962; Rooney 1996; Soper and Heimberger 1982; Voss 1985; Weir-Koetter 1996). In aspen ecosystems across the upper Great Lakes region, leatherwood is present in stands with a relatively high aspen site index and a significant northern hardwood component (Alban and others 1991). In Ontario, the northern limit of distribution is similar to that of beech (*Fagus grandifolia* Ehrh.) and sugar maple (*Acer saccharum* Marsh.)(Soper and Heimberger 1982). The distribution of plants on a particular site can vary from apparently random to aggregated (Jones 2000). Forests in which leatherwood is common are characterized by a dense overstory that permits relatively little light to reach the forest floor during the growing season. It is often the only true understory shrub in these stands; the other woody understory species are tolerant to mid-tolerant trees—for example, sugar maple, ironwood (*Ostrya virginiana* (Mill.) K. Koch.), white ash (*Fraxinus americana* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), and balsam fir (*Abies balsamea* (L.) Mill.)—having the capacity to grow into the overstory (Alban and others 1991; Buckley 1996; Ferrari 1993; Jones 2000).

Western leatherwood—*D. occidentalis* Gray—is very similar to eastern leatherwood (Neveling 1962). Its distribution is limited to the wooded hills of the San Francisco Bay region (Vogelman 1953). Flower descriptions and morphological comparisons of the 2 species are provided by Vogelman (1953). A related species in the Thymelaeaceae—*Daphne mezereum* L.—is an introduced species that has become established in some areas. The information presented here is for eastern leatherwood; some of it may also apply to western leatherwood.

In its natural habitat, eastern leatherwood reaches a height of 3 to 4 m and basal diameters of 5 to 10 cm. Crown width and depth of larger plants can be as much as 2 to 3 m; the largest crown volumes that we have measured are in the range of 15 to 25 m^3. Crown architecture can be fairly complex, with frequent branching and numerous apical growing points (figure 1). The largest individuals that we have observed are in old-growth northern hardwood forests where logging is prohibited and in older hardwood stands managed under a single-tree selection system. The maximum age attained by leatherwood is not known, but 30- to 50-year-old plants occur in older hardwood forests.

Figure 1—*Dirca palustris*, eastern leatherwood: mature forest-grown plant in full flower, with plant about 1.3 m tall.



Annual height growth varies considerably (Jones 2000). On mature plants, elongation of an individual apical meristem ranges from 1 to 25 cm, but cumulative annual growth over the many apical meristems comprising the crown may be 0.5 to 1 m or more. Complete removal or reduction of canopy cover to less than 50% seems to reduce the frequency of leatherwood, but more work is needed to understand effects of disturbance on the survival, growth, and reproduction of leatherwood. This reduction, however, may be more the result of physical damage during harvesting than to the change in the physical environment resulting from harvesting. In plants that have had branches completely or partially separated, callus growth covers the wound relatively quickly, giving wounded stems a distinct appearance. The flexible nature of the stem and branches is the result of a relatively low level of lignification in the wood (Neveling 1962). The specific gravity of the wood is 0.41, ranking it among the least dense woods of deciduous broadleafed species, comparable to poplar and basswood species (Alden 1995; Neveling 1962).

There is poor sprouting in leatherwood after the main stem is cut or broken. Layering of branches has been observed, but usually it does not occur, even on branches in good contact with an apparently suitable substrate layer. Seedling regeneration seems to be the most common way that the species is maintained in forests.

The only current documented use of eastern leatherwood is for landscaping. Even for this, it is not used to the extent possible, particularly in more northern areas (for example, in the northern Great Lakes region and northern New England), where the choice of plants is limited by climate. Although leatherwood provides a very early flowering, medium-sized shrub for these northern areas (Esson 1949), unfortunately its leaves are often infected by a rust and leaf miners in mid-summer, turning yellow prematurely and falling early. It can be planted and does best in moist, shaded areas. If the plant is naturally present in areas where development is planned, efforts should be made to protect it and provide conditions that favor growth, as older plants provide interesting form and structure to managed landscapes such as yards and gardens (del Tredici 1991; Dirr 1990). The plant appears to be browsed very little by deer (*Odocoileus* spp.), even in forests where other woody plants are repeatedly and severely browsed throughout the year (Weir-Koetter 1996). The lack of browsing could be due to the plants' diuretic qualities (Meeker and others 1993); the stem also contains large quantities of calcium oxalate crystals (Holm 1921). Ramsewak and others (1999) have described novel phenolic glycosides in leatherwood. The strong pliable bark (the source of the common name) was used by Ojibwa for making bowstrings, baskets, and fishing lines (Holm 1921; Meeker and others 1993; Weir-Koetter 1996). The wood is very easy to slice with a sharp knife.

Flowering and fruiting. Leatherwood is monoecious. The pale yellow, fragrant flowers are perfect and borne in clusters of 2 to 7 (figures 1 and 2) (Neveling 1962; Soper and Heimberger 1982; Vogelman 1953; Zasada and others 1996). The buds from which flowers develop are small and conical, with 4 distinct dark, silky scales that persist after flowering (figure 2). Clusters of 3 flowers are most common in northern Wisconsin–Michigan; clusters of 4 are somewhat less common, and clusters of 5 to 7 uncommon or rare. Mature plants commonly produce 300 to 1,500 flowers; the greatest number we observed on a plant was about 4,500 flowers (Zasada and others 1996). [Note: in the following discussion, we refer to unpublished data on fruits and seeds collected on or in the vicinity of the Ottawa National Forest in Michigan's Upper Peninsula and the Nicolet and Chequamegon National Forests in northern Wisconsin.]

Flowering occurs in April–May, 2 to 3 weeks before the overstory leafs out and generally before the spring ephemeral species flower. In 1994 and 1995 in northern Wisconsin-Michigan, fairly average years in terms of spring weather, pollination was mostly completed by May 11–15. In 1996, a relatively cold, wet spring, flowering began on May 14 on warm, south-facing aspects and several days later on north aspects. Flower buds opened as late as May 25 and some

Figure 2—*Dirca palustris*, eastern leatherwood: 3-flower cluster, subtending structures are silky bud scales.

anthers still contained pollen in early June. Flower parts drop quickly if pollination/fertilization is not successful but remain attached to developing fruits for a longer period (figure 3). Fruits ripen in June and July, with one report of ripening as late as September–October (Vogelman 1953). About 1 month (mid-June) after the first flowers appear in northern Wisconsin–Michigan, 75% of seeds contained embryos that filled 80% or more of the seed; 5% of the seeds were less than 50% filled. When fully ripe, the endosperm is a minor component of the seed (figure 4) (Neveling 1962; Zasada and others 1996). The outermost fleshy portion of the fruit cannot be separated easily from the seed coat until mid-late June.

Immature fruits are green and change to a very light green; some fruits are almost white when they fall from the plant. There are some reports that fruits turn reddish when mature (McVaugh 1941; Meeker and others 1993; Neveling 1962). However, McVaugh (1941) summarized the literature and concluded that although the reddish fruit color can be observed in dried herbarium specimens, his own and other's observations led to the conclusion that mature fruits are light to yellowish green. We found no evidence in the 8 stands studied in Wisconsin and Michigan that fruits were reddish in color when mature. The fleshy outer fruit wall (figure 5) of naturally dispersed fruits turns black within about 24 hours in some fruits, but in others it remains light green for several days.

Each flower has the potential to produce 1 single-seeded fruit, and hence fruits can be in clusters of 3 to 7 if all flowers produce fruits. Fruits with 2 seeds were observed, but they were very rare. Clusters with 1 to 3 fruits were most common, as many flowers do not produce fruits. Clusters of more than 4 fruits are uncommon or rare. Number of flowers, fruit set, and number of fruits per cluster varies annually and among stands in the same year (table 1).

Figure 3—*Dirca palustris*, eastern leatherwood: fully developed but immature fruits. Flower parts are still attached to some fruits. Fruit length varies from 6.5 to 15 mm in the northern Wisconsin–Michigan area where fruits were collected.

Figure 4—*Dirca palustris*, eastern leatherwood: ripe fruits collected shortly after dispersal.

The fruit (figure 3) is a drupe and described as "bilaterally symmetrical, somewhat spindle-shaped....circular in cross-section at the widest point...and (having) a narrow, slightly elevated ridge...from the base of the style down the whole length of the fruit" (McVaugh 1941). Fruits are reported as 9 to 12 mm long for Ontario populations (Soper and Heimberger 1982), 12 to 15 mm long by 7 mm wide (Vogelman 1953) for Michigan and Indiana populations, and 12.5 to 15 mm long (McVaugh 1941) for New York populations. Average dimensions for fruits from 6 northern Wisconsin–Michigan populations were 8.5 to 9.5 mm long by 5.5 to 6.5 mm wide. Range in length was from 6.5 to 15.0 mm and width 4.5 to 7.5 mm for these latter populations (Zasada and others 1996). The fresh weight of individual fruits containing fully developed seeds varied from 0.08 to 0.23 g. Moisture content of whole fruits was 100 to 175% (dry weight basis) for dispersed fruits and those about to be dispersed.

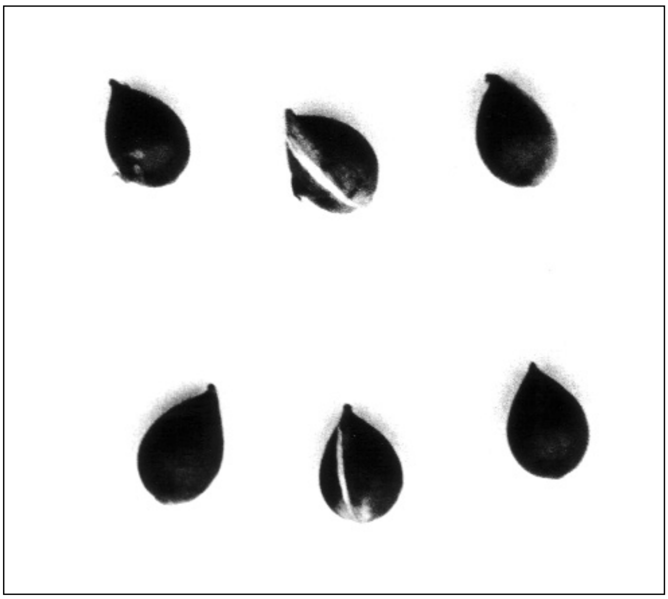
Individual seeds, with their fleshy coats removed (figure 4), were 5.5 to 8.5 mm long and 3.5 to 5.0 mm wide for northern Wisconsin–Michigan populations. Fresh seed weight varied from 0.04 to 0.08 g and percentage moisture content was 40 to 55% (dry weight basis; seeds dried to a constant weight at 65 °C) for seeds collected from the ground shortly after dispersal; individual seeds on plants

Table 1—*Dirca palustris,* eastern leatherwood: flowering and fruit production in 2 forest types in northern Wisconsin

	No. 3-flower clusters/shrub†		% cluster w/1–3	% of all clusters with fruits			Fruits/plant	
Stand type*	**Mean**	**Range**	**fruits**	**1 fpc**	**2 fpc**	**3 fpc**	**Mean**	**Range**
Hardwood forest								
1995	153	5–515	23	22	48	30	40	0–386
1995	198	21–695	—	—	—	—	194	13–840
1996	—	—	55	20	41	19	—	
Pine forest								
1995	59	0–255	2	0	77	23	3	0–45
1995	85	0–325	—	14	57	29	—	
1996	—	—	23	—	—	—	36	0–260

Note: fpc = fruits per cluster; these populations did not have 4-flower or 4-fruit clusters in the 2 years of observation.
* Based on 15 randomly selected shrubs in each stand.
† To obtain total number of flowers, multiply by 3.

Figure 5—*Dirca palustris*, eastern leatherwood: seeds with fleshy outer fruit wall removed. All seeds have a light-colored area along which the ovular trace is located; the 2 seeds in the center are positioned to show this area.



from which seeds were being dispersed but still firmly attached to the peduncle had moisture contents of 100 to 125% (Zasada and others 1996). Mature seeds are dark brown-black with a well-developed lighter longitudinal strip (figure 5). The strip is the point of attachment of the seed to the fruit wall in the area of the elevated ridge, which is a noticeable aspect of the shape of the fruit; the ovular trace is attached to the seed in this strip (figures 3 to 6) (McVaugh 1941; Neveling 1962).

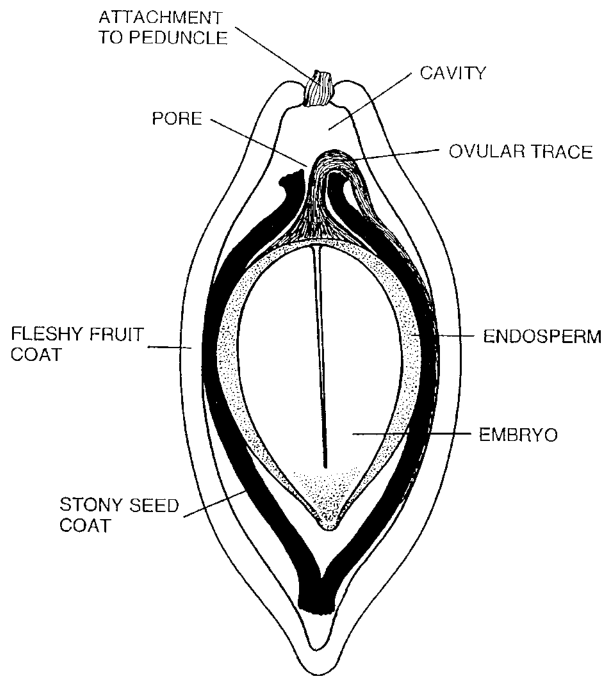
Embryo length varied from 4 to 6 mm and from 2 to 4 mm in width in the Wisconsin–Michigan populations. At maturity, the embryo fills 95% or more of the seed; a small cavity develops at both poles of the seed (figure 6). Multiple embryos, all poorly developed, occurred in less than 0.5% of the seeds (Zasada and others 1996).

The general anatomical features of a seed are illustrated in figure 6. The ovular trace and the pore through which it passes are an interesting feature of the seed (Neveling 1962). The pore appears filled with a fibrous material in seeds that have fallen from the plant. The black, stony seedcoat does not appear to completely seal the pore, even at maturity.

Collection of fruits; extraction and storage of seeds. Fruits ripen in June and July. McVaugh (1941) observed that dispersal for plants in New York was completed by the following dates during a 3-year period—June 20, July 1–3, and later than July 7. In northern Wisconsin–Michigan populations, fruits have been observed on plants as late as July 16, but as observed by McVaugh (1941), dispersal was completed by July 1 in some years. The seeds disappear fairly quickly once they are fully mature but are fairly obvious on the soil surface for several days after dispersal (Dirr and Heuser 1987; McVaugh 1941; Nevling 1962; Soper and Heimberger 1982). During windy periods, deposition rates were as high as 27 fruits/m^2/hr under 1 shrub. Timing of fruit abscission and fruit drop vary among plants in a stand, among branches within a plant and among fruits in a cluster (Zasada and others 1996). In an area where dispersal was followed on a daily basis, seeds from the entire population were dispersed over about a 2-week period; some plants shed all of their seeds in 2 to 3 days, whereas others dispersed seeds over a 6- to 8-day period.

Birds do not seem to be a critical factor in seed removal, but they do consume some seeds and may be more important than our observations suggest. They may remove entire fruits, but, in some cases, they remove only the seed, leaving the fleshy fruit coat attached to the plant. Although the level of fruit use by rodents after dispersal is not known, it seems that this might be an important way in which seeds are

Figure 6—*Dirca palustris*, eastern leatherwood: generalized longitudinal section of mature seed, based on Neveling (1962) and Buckley (1996).



removed from the seed pool. Remnants of the black, stony seedcoat are fairly common under plants about 1 month after dispersal.

If seeds are needed, we recommend keeping a close watch on shrubs with fruits and collecting the fruits soon as they are ripe. Once some fruits fall naturally, all fruits have fully developed seeds. Embryo development is easily checked by cutting seeds longitudinally; those that are fully developed will appear as in figure 6.

Fruits can be picked by hand from the plant. However, when fully ripened, they readily fall when the plant is shaken and could be collected from the ground. Because each fruit contains only 1 seed, the number of seedlings desired (plus additional seeds as insurance against poor germination) will determine the number of fruits required. Based on cutting tests, 90 to 100% of developed fruits contained seeds with apparently viable embryos.

The pulp can be removed by hand or mechanically. When the seeds are fully mature, a cavity, with the exception of the attachment between the ovular trace and fruit wall, develops between the fleshy fruit wall and the hard inner seed coat, making it fairly easy to hand-clean small quantities of seeds. The stony seedcoat is easily broken with the pressure of a fingernail and the seed can be squashed by squeezing between the thumb and forefinger with moderate pressure. Consequently, any type of mechanical cleaning must be done with care.

No information was found on the best ways to handle fruits or store seeds. Seeds remain viable in the forest floor from the time of dispersal until they germinate in the spring (del Tredici 1984), suggesting that storage for at least 8 to 10 months is possible. Seeds are exposed to a fairly wide range of temperature and moisture conditions between dispersal and germination.

Germination. Detailed information on the effects of environmental conditions on germination was not found. del Tredici (1984) used a number of standard methods to stimulate gemination, but untreated seeds planted in a nursery bed soon after they were collected were the only ones that produced seedlings (67% germination). Dirr and Heuser (1987) reported that both cleaned and uncleaned (fleshy fruit wall removed) seeds produced seedlings. In controlled environment studies, a seedlot was observed to produce germinants over at least a 3-year period (Zasada and others 1996).

Nursery. Based on the limited information available, we recommend planting seeds soon after collection with and without the fleshy fruit wall in order to provide the range of conditions under which seeds appear to germinate naturally; seeds sown this way will germinate the next spring (del Tredici 1984; Dirr and Heuser 1987). Dirr and Heuser (1987) reported finding a number of young plants under a mature plant growing in a landscaped area, indicating that it might be possible to obtain some small seedlings from these situations. The growth rate of seedlings under open conditions is not documented. In its natural habitat, seedlings grow to a height of 20 to 30 cm in 5 to 10 years.

There has been little or no success in stimulating rooting in stem cuttings (Dirr and Heuser 1987). Layering occurs under natural conditions, suggesting that air-layering is a potential option for propagating leatherwood. However, Hendricks (1985) reported that air-layered stems did not produce roots or callus during an 8-week period. Our observations of layering of branches and the main stem under natural conditions suggest that it might take longer than 8 weeks for rooting to occur.

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