Moraceae—Mulberry family

Maclura pomifera (Raf.) Schneid.

Osage-orange

Franklin T. Bonner

Dr. Bonner is a scientist emeritus at the USDA Forest Service's Southern Research Station, Mississippi State, Mississippi.

Synonym. *Toxylon pomiferum* Raf. ex Sarg.

Other common names. *bois-d'arc*, bodark, bowwood, hedge, horse-apple.

Growth habit, occurrence, and uses. Osage-orange—*Maclura pomifera* (Raf.) Schneid.—is native to the bottomlands of southern Arkansas, southeastern Oklahoma, and eastern Texas. It is most abundant in the Red River Valley of Oklahoma but was widely planted in all 48 conterminous states and southeastern Canada as "living fences" on the treeless prairies during the mid-1800s and has now naturalized in many of these locations (Burton 1990; Little 1979; Sargent 1965). Osage-orange is a small deciduous tree chiefly valued for posts and windbreak plantings. Fruits have some value as wildlife food. A typical height at maturity is 9 m, but some individuals have grown to 21 m.

Flowering and fruiting. The small, green, dioecious flowers open from April to June; they are wind-pollinated. The large, globose, yellow-green, aggregate fruit, or syncarp, is composed of many 1-seeded drupelets (figure 1). The fruits ripen in September and October and soon fall to the ground (Bonner and Ferguson 1974). Fruits reach diameters of 7.6 to 15 cm and often weigh more than 1 kg (Burton 1990). Trees bear fruits by age 10, and good crops occur annually (Bonner and Ferguson 1974). Female trees often produce abundant fruit when there are no nearby pollen sources, but these fruits do not contain seeds (Burton 1990).

Collection, extraction, and storage. Fruits should be picked up soon after they fall from the trees but can be collectioned throughout autumn and winter. Seeds (figure 2) may be extracted by macerating the fruits in water and floating off or screening out the pulp. Extraction and cleaning are easier if the fruits are allowed to ferment for several months before maceration. Fruits left in a pile outdoors until late March or early April become very soft and mushy and easy to macerate (Myatt and others 1991). Seeds extracted in this manner have a pronounced purple streak and pleasant fragrance, and they germinate promptly (Bonner and Ferguson 1974.

After extraction, the seeds should be air-dried and cleaned by screening to remove small pieces of fruit tissue. Common air-screen cleaners serve this purpose very well (Myatt and others 1991). Yield data from 22 scattered samples (Bonner and Ferguson 1974) are as follows:

No. of fruits/volume	227/hl	80/bu
No. of seeds/volume of fruit	70,000/hl	24,650/bu
Seed weight/volume	2.9kg/hl	2.25lb/bu
Cleaned seeds weight		
Average	30,900/kg	14,000/lb
Range	15,400–35,300/kg	7,000–16,000/lb

Purity of 96% and soundness of 95% have been attained (Bonner and Ferguson 1974). Long-term storage data are lacking for Osage-orange, but good viability has been reported for clean air-dried seeds stored for 3 years in sealed containers at 5 °C (Engstrom and Stoeckler 1941).

Pregermination treatment and germination tests. Osage-orange seeds typically exhibit a slight dormancy that may be overcome by moist stratification for 30 days at 5 °C or by soaking in water for 48 hours (Engstrom and Stoeckler 1941). Fresh seeds extracted from rotted fruits are not usually dormant and need no pretreatment (Bonner and Ferguson 1974), but stratification or water soaking should probably be used on stored seeds or seeds dried to low moisture contents (10% or below). Tests have been made in flats of sand or soil with pretreated seeds for 40 days at 20 °C nights and 86

Figure 1—*Maclura pomifera*, Osage-orange: aggregate fruit composed of 1–seeded druplets, $^1/_2$ x.

Figure 2—*Maclura pomifera*, Osage-orange: exercised embryo and nutlet (seed) 6 x.

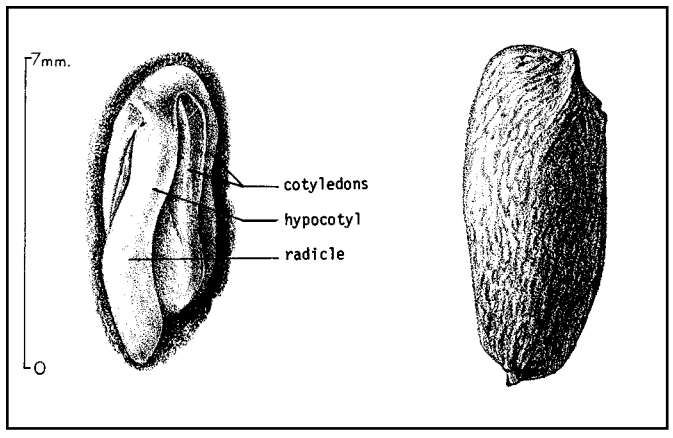
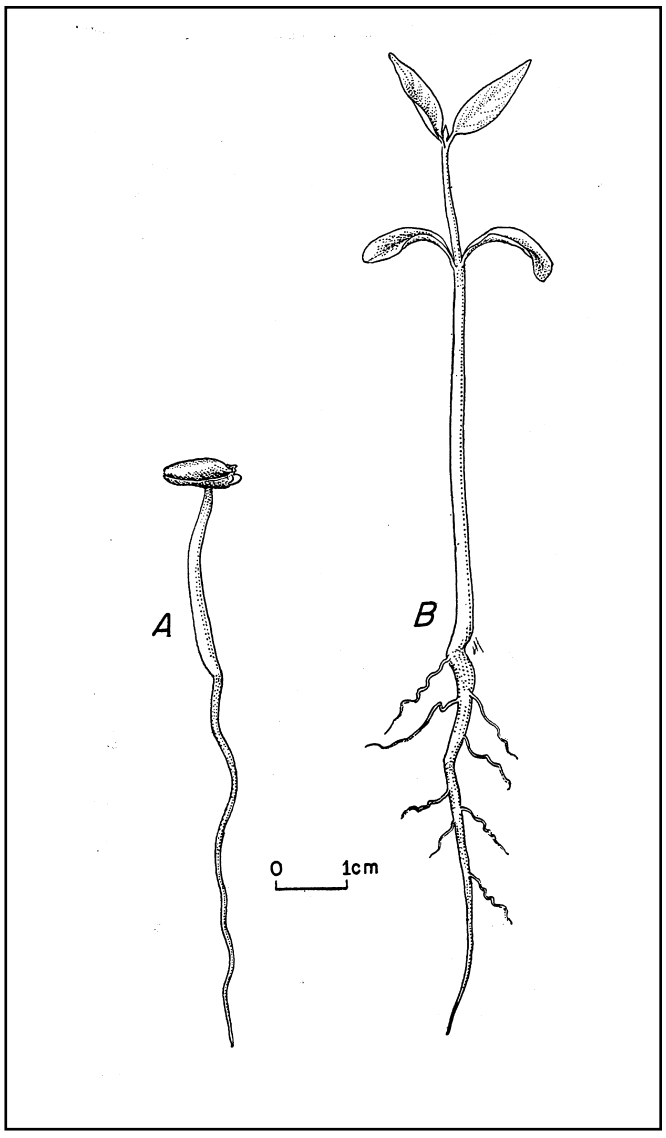


Figure 3—*Maclura pomifera*, Osage-orange: seedling development after 1 and 8 days of germination.



°C days. Average germination for 13 samples under these conditions was 58%. Germination rate was fair: 20 to 79% in 14 to 34 days (Bonner and Ferguson 1974). Germination may also be tested in incubators on paper media. Germination is epigeal (figure 3).

Nursery practice. Untreated seeds may be sown in the fall, but a pregermination treatment should normally be used before spring-sowing. If seeds are freshly extracted from fruits that have been rotting overwinter, however, they have had a "natural" stratification and can be sown without further treatment. Seeds may be drilled in rows 20 to 30 cm (8 to 12 in) apart or sown in bands 7.5 to 10 cm (3 to 4 in) wide if single-row procedures are used. Seeds should be covered with 6 to 13 mm (1/4 to 1/2 in) of firmed soil. Fall-sown beds should be mulched, but not spring-sown beds (Bonner and Ferguson 1974). Recommended bed densities are 100 to 160 seedlings/m^2 (10 to 15/ft^2) (Williams and Hanks 1976).

Osage-orange can also be propagated by softwood cuttings taken in June or by hardwood cuttings taken in January. Cuttings should be treated with indole butyric acid (IBA) at 5,000 or 10,000 ppm and placed in sand under mist (Dirr and Heuser 1987).

References

Barnett JP, Burton JD. 1997. Osage-orange: a pioneering stewardship species. Tree Planters' Notes 48(3/4): 81-86.

Bonner FT, Ferguson ER. 1974. *Maclura pomifera* (Raf.) Schneid., Osage-orange. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 525–526.

Burton JD. 1990. *Maclura pomifera* (Raf.) Schneid., Osage-orange. In: Burns RM, Honkala BH, tech. coords. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service: 426–432.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Engstrom HE, Stoeckler JH. 1941. Nursery practice for trees and shrubs suitable for planting on the Prairie-Plains. Misc. Pub. 434. Washington, DC: USDA. 159 p.

Little EL. 1979. Checklist of United States trees (native and naturalized). Agric. Handbk. 541. Washington, DC: USDA Forest Service. 375 p.

Myatt A, Huffman G, Odell J. 1991. Seed processing manual. Stillwater: Oklahoma Department of Agriculture, Forestry Division.

Sargent CS. 1965. Manual of the trees of North America (exclusive of Mexico). 2nd ed., corrected and reprinted. New York: Dover. 934 p.

Williams RD, Hanks SH. 1976. Hardwood nurseryman's guide. Agric. Handbk. 473. Washington, DC: USDA Forest Service. 78 p.

Magnoliaceae—Magnolia family

Magnolia L.

magnolia

Jill R. Barbour

Ms. Barbour is a germination specialist at the USDA Forest Service's Tree Seed Laboratory, Dry Branch, Georgia

The genus *Magnolia* comprises about 80 species of trees naturally distributed throughout eastern North America and southeastern Asia (Callaway 1994). It is the largest genus in the family Magnoliaceae. There are 10 species and varieties native to the United States (Callaway 1994) and 2 others native to Puerto Rico (table 1) (Figlar 1982, 1984a). Cucumber magnolia is the only species native to Canada. There are no indigenous magnolias in Europe (Johnson 1973). Sweetbay was the first native American magnolia to be cultivated in Europe in 1688 (Hora 1981).

Based on records of early fossil pollen and leaves, the magnolias are considered the most ancient of all flowering plants (FNAEC 1993). These plants are the base from which all other angiosperms have evolved (FNAEC 1993). Fossil records suggest that magnolias once occurred throughout western North America, western Asia, and Europe. Their range became restricted when the continents in the southern hemisphere separated and cold water moved northward, changing the humid tropical paleo-environment to a drier, colder climate (FNAEC 1993). In the past 20,000 years, the warm temperature taxa have not been disrupted and are in dynamic equilibrium (FNAEC 1993)

Magnolia species are widely planted as ornamentals (Dirr 1990). The leaves and flowers of magnolias are highly prized for decoration, and the fruits make excellent food for wildlife (Callaway 1994). Less than 2% of hardwood timber in the southeastern United States is from magnolias and is usually lumped together with that of tuliptree—*Liriodendron tulipifera* L. (Burns and Honkala 1990).

Table 1—*Magnolia,* magnolia: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***M. acuminata* (L.) L.** *Tulipastrum acuminatum* (L.) Small	**cucumber magnolia,** cucumbertree, yellow cucumber magnolia	S Ontario & New York to Illinois, to E Oklahoma & Georgia
***M. ashei* Weatherby**	**Ashe magnolia**	Banks of Apalachicola River in Florida Panhandle & SE Alabama
***M. fraseri* Walt.** *M. auriculata* Lam.	**Fraser magnolia,** mountain magnolia	Mtns of Maryland, West Virginia, & Virginia, S to N Georgia, Alabama, & South Carolina
***M. grandiflora* L.** *M. foetida* (L.) Sarg.	**southern magnolia,** evergreen magnolia, bull bay	Coastal plain from SE North Carolina to central Florida, & to E Texas
***M. macrophylla* Michx.**	**bigleaf magnolia,** greatleaf(ed) magnolia, large-leaf cucumbertree	Ohio & Kentucky S to Georgia, W to Arkansas & Kentucky
***M. portoricensis* Bello**	**Puerto Rico magnolia**	W Puerto Rico
***M. pyramidata* Bartr.**	**pyramid magnolia,** ear-leaf(ed) magnolia, ear-leaf umbrellatree	Banks of the Ochlochnee*, Apalachicola, & Escambia Rivers of the Florida Panhandle, SE Alabama, W to Texas
***M. splendens* Urban**	**shining magnolia**	E Puerto Rico
***M. tripetala* (L.) L.**	**umbrella magnolia**	Streams or swamps from Pennsylvania to Georgia, W to Arkansas & Mississippi
***M. virginiana* L.** *M. australis* Ashe *M. glauca* L.	**sweetbay,** swamp-laurel, sweetbay magnolia, southern sweetbay, evergreen sweetbay	Coastal swamps from Massachusetts to Florida, W to E Texas

Sources: Callaway (1994), Figlar (1984a, b), Fordham (1960), LHBH (1978), Sargent (1965), Wasson (2001)..

* Sometimes spelled Ochlokonee.

Floral biology. The large, perfect flowers of the magnolias are borne singly at the ends of the branches in the spring and summer. The flowers appear after the leaves between April and June, except for cucumber magnolia, which flowers before leaf bud-break. In section Rhytidospermum, the flowers have 6 to 9 tepals (sepals and petals), in section Magnolia, 8 to 12 tepals and in section Tulipastrum, 9 to 12 tepals (table 2) (Fernald 1970). The flowers have a pleasant fragrance, except those of umbrella magnolia, which have an unpleasant odor (Burns and Honkala 1990).

Magnolia flowers are highly specialized for cantharophily—pollination by beetles, which predate the other pollinators, that is, bees, wasps, butterflies, and moths (Peigler 1988). Beetle-pollinated flowers are characterized by their large size, white or pink color, lack of nectar, and abundance of pollen (Peigler 1988). The flowering is protanderous to prevent the flower from being pollinated with its own pollen. Magnolia flowers close at night. The beetles (members of the Mordellidae and Nitidulidae families) chew through the tepals with their strong mandibles to feed on the flower parts (Peigler 1988). While feeding, the beetles get covered with pollen. When the flower opens, the stigmas are no longer receptive, and the stamens have dehisced and detached from the gynandrophore (central axis of flower). The beetles, covered with pollen, leave the flower to feed on another flower, thus effecting cross-pollination (Thien 1974). The self-incompatible species—such as Fraser and pyramid magnolias, sweetbay, and cucumber magnolia—cannot receive pollen from other flowers on the same tree (McDaniel 1963). Nonviable seeds may have been collected from trees that are self-incompatible. It is best to select other trees for future collections.

Seed biology. The fruits develop from the gynandrophore into a follicetum (figure 1) (Callaway 1994). The individual fruits are referred to as follicles and usually contain 1 to 2 seeds. The follicetum contains between 2 and 60 seeds/fruit (Burns and Honkala 1990). Seeds are released from the follicle when ripe and are suspended on a funiculus (Kozlowski 1972). The bright red color of the sarcotesta is adapted to an endozoochorous mode of dispersal (Kozlowski 1972). At maturity, the seeds are 6 to 18 mm long (figure 3). The seeds of cucumber magnolia are 0.7 to 1.5 cm long, 0.3 to 0.6 cm thick, and 0.5 to 1 cm wide (Afanasiev 1937).

The primitive, angiospermous seeds of the magnolias are characterized by having a very small embryo with copious endosperm (figure 3) (Bouman 1977). The underdeveloped embryo is about 1 mm long and 0.4 mm in diameter and is located at the micropyle end of the seed (Afanasiev 1937; Evans 1933). The endosperm is 51% oil with no starch present. The embryo will not start to grow until it undergoes a cold, moist treatment followed by a warm treatment.

Figure 1—*Magnolia*, magnolia: "cones" (multiple follicles) of *M. acuminata*, cucumber magnolia (**top left**); *M. virginiana*, sweetbay (**bottom left**); *M. fraseri*, Fraser magnolia (**middle**); *M. grandiflora*, southern magnolia (**right**).

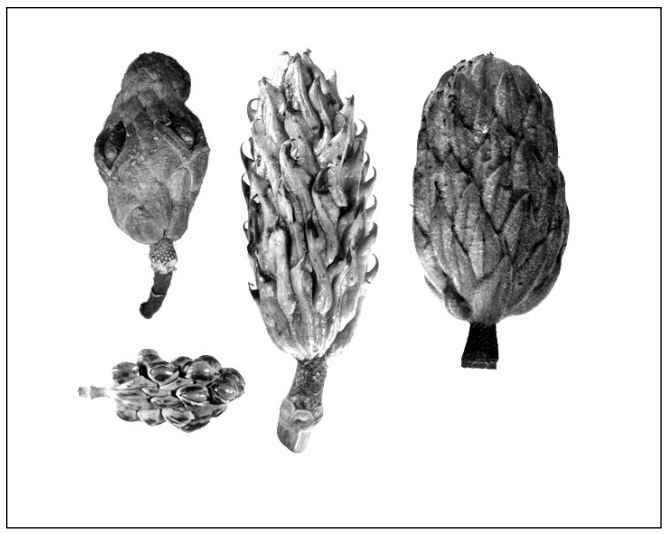


Table 2—*Magnolia,* magnolia: characteristics

Species	Ploidy	Flower color	Leaves, underside color, & hair	Tepals
M. acuminata	2N=76	Yellow-green, yellow	Deciduous, green, & tomentose	9–12
M. ashei	2N=38	White	Deciduous, silver, & pubescent	9
M. fraseri	2N=38	Creamy white	Deciduous, pale green, & glabrous	6–9
M. grandiflora	2N=114	Creamy white	Evergreen, rusty brown, & tomentose	9–15
M. macrophylla	2N=38	White	Deciduous, silver, & pubescent	9
M. portoricensis	2N=114	Creamy white	Evergreen, rusty brown, & glabrous	9–12
M. pyramidata	2N=38	Creamy white	Deciduous, pale green, & glabrous	6–9
M. splendens	2N=114	Creamy white	Evergreen, rusty brown, & pubescent	9–12
M. tripetala	2N=38	White	Deciduous, gray-green, & pubescent	6–9
M. virginiana	2N=38	Creamy white	Deciduous or evergreen, silver, & glabrous	8–12

Sources: Callaway (1994), Johnson (1973), LHBH (1978), McDaniel (1968).

Magnolias have the most primitive seedcoat of the angiosperms. The seedcoat consists of 3 layers (Earle 1962)—the fleshy, outer, red sarcotesta; the parenchymatic middle layer (made up of 57% oil and reducing sugars); and the stony sclerotesta.

Seed crops from magnolia species vary according to environmental conditions. The viability of southern magnolia seedlots averages 50% (Burns and Honkala 1990). Cucumber magnolia reaches seed-bearing age at 30 years (Burns and Honkala, 1990). Seed size ranges from 10,000 to 16,000 seeds/kg (4,550 to 7,530 seeds/lb) (table 3).

Figure 2—*Magnolia*, magnolia: seeds of *M. acuminata*, cucumber magnolia (**top left**); *M. fraseri*, Fraser magnolia (**top right**); *M. grandiflora*, southern magnolia (**bottom left**); *M. virginiana*, sweetbay (**bottom right**).

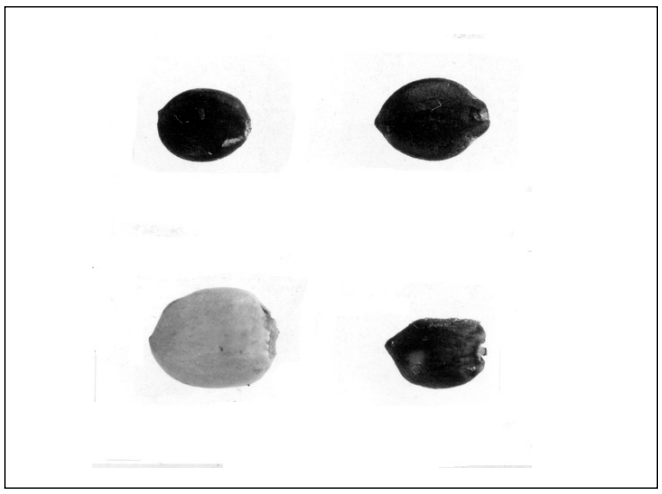
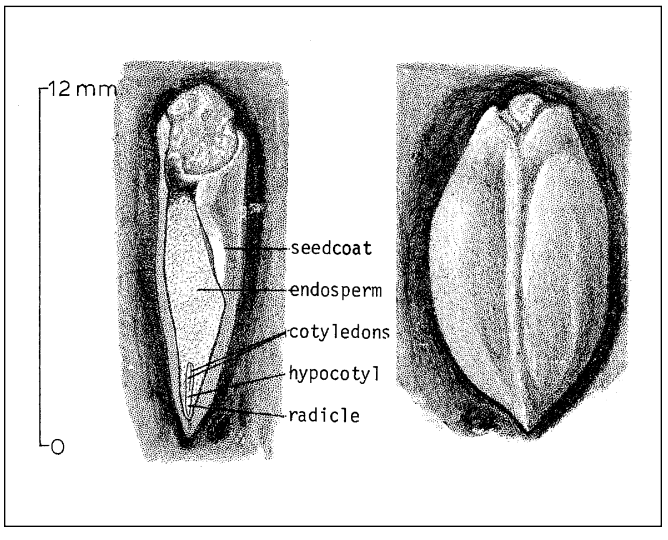


Figure 3—*Magnolia grandiflora*, southern magnolia: longitudinal section through a seed (**left**) and seed with sarcotesta removed (**right**).



Collection of fruits; extraction and storage of seeds. The fruits are usually picked from standing trees or from trees recently felled in logging. The seeds mature in August or September. It is recommended that the fruits be collected before the follicles open to eliminate competition with seed predators (Murphy 1996). The unopened fruit aggregates can be laid on screens to dry (Galle 1953).

The red sarcotesta can be removed by mechanical maceration or by rubbing the seeds over a screen. The oily residue left on seeds can be removed by rinsing them in soapy water, then in clean water (Callaway 1994). The seeds must be kept moist while in storage to retain their viability (Browse 1986; Hanchey and Kimbrough 1954). Saturated sphagnum moss can be added to a plastic bag to keep the seeds moist until sowing (Callaway 1994). Dead and damaged seeds can be removed by floating the seeds in water before storage or planting (Hanchey and Kimbrough 1954). Seeds that float—"floaters"—usually are not viable. Storage of seeds at 0 °C is recommended to reduce the level of infection by fungi (Afanasiev 1937).

Pregermination treatments. Del Tredici (1981) and Evans (1933) found that magnolia seeds exhibit double dormancy. Embryos will not develop until seeds are exposed to warm, moist temperatures after cold, moist temperatures. It takes a minimum of 2 months of cold, moist stratification at 0 to 10 °C to yield the greatest germination (Evans 1933). Stratification medium can be any absorbent material such as sphagnum moss, moss and sand, or vermiculite. During the after-ripening period, the oil and proteins are converted to reducing sugars and the water content of a seed increases from 49 to 61% (Evans 1933). Within 14 days of sowing, the embryo is 50% as long as the seed (Del Tredici 1981).

Other pretreatments such as freezing and sulfuric acid (H_2SO_4) soaks have proved injurious to magnolia seeds (Afanasiev 1937; Hanchey and Kimbrough 1954). Hot water soaks also were not beneficial to seed germination (Hanchey and Kimbrough 1954). Increasing oxygen to the seed had no effect on germination, but eliminating oxygen did inhibit germination (Afanasiev 1937).

Germination tests. Germination is epigeal (figure 4) and occurs rapidly following proper stratification and placement in a standard germination medium (table 4) (Galle 1953). Official tests (AOSA 2001) recommend 45 days of prechilling followed by alternating temperatures of 20/30 °C for 42 days on top of moist blotters. Evans (1933) found that the seeds of southern magnolia germinate most rapidly at 29 °C and give the greatest total germination at 15 to 35 °C. Hanchey and Kimbrough (1954) found that 88% of the seeds of southern magnolia germinated after 2 months of storage in vermiculite at 15 °C. Seeds of sweetbay germinated 93% in 33 days after 58 days of prechilling (Del Tredici

Table 3—*Magnolia,* magnolia: seed data

Species	Cleaned seeds/weight				Samples
	Range		Average		
	/kg	/lb	/kg	/lb	
M. acuminata	6,400–14,500	2,900–6,600	12,020	5,450	15
M. fraseri	5,470–12,460	2,480–5,650	10,030	4,550	12
M. grandiflora	12,800–15,000	5,800–6,800	14,220	6,450	8
M. macrophylla	—	—	9,550	4,330	1
M. portoricensis	—	—	7,410	3,360	1
M. tripetala	—	—	16,540	7,500	1
M. virginiana	—	—	16,600	7,530	5

Sources: Bonner (2002), Dirr and Heuser (1987), Francis and Rodriguez (1993), Heit (1968), Olson and others (1974).

Table 4—*Magnolia,* magnolia: germination test conditions and results for stratified seeds

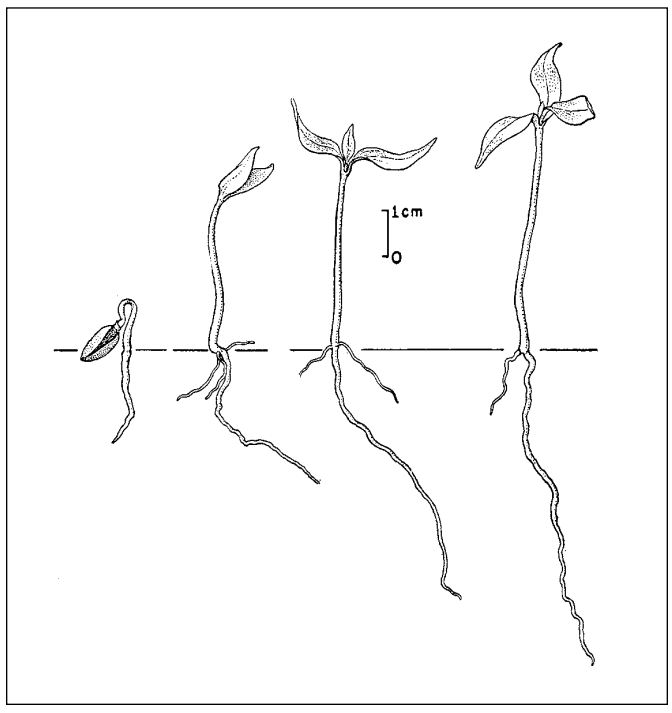
Species	Medium	Germination test conditions			Germinative capacity	
		Temp (°C)				
		Day	Night	Days	Avg (%)	Samples
M. acuminata	Sand–perlite	26–30	15–20	35–60	8–86	4
M. fraseri	Sand–perlite	30	20	40–100	8–21	6
M. grandiflora	Sand–vermiculite	30	20	30–50	43–90	9
M. macrophylla	—	22	22	35	71	35
M. portoricensis	Potting mix	24	30	44	64	—
M. virginiana	Sand–peat	18	18	33	93	1
	Kimpac	30	20	47–61	32–50	4

Sources: Afanasiev (1937), Del Tredici (1981), Francis and Rodriguez (1993), Hanchey and Kimbrough (1954), Jones, (1969), Olson and others (1974), Seitner (1981), Toumey (1942).

1981). For seeds of cucumber magnolia, germination started earliest and progressed most rapidly at a constant temperature of 30 °C, but the highest germination was reached when the temperatures alternated between 15 °C in the dark for 6 hours and 18 hours of light at 26 °C (Afanasiev 1937). At 20 °C, seeds of cucumber magnolia germinated later and more slowly than at the higher temperatures; temperatures above 35 °C resulted in the death and decay of the seeds.

There are 3 viability tests performed on magnolia seeds that correlate with germination. The endosperm of cucumber magnolia will produce green pigment in 2 to 3 days when placed on moist blotting paper at 24 to 30 °C (Afanasiev 1937). The proportion of seeds producing the green pigment is the proportion of viable seeds. Heit (1955) preferred the excised-embryo test for magnolia seeds and recommended soaking them in water up to 4 days to soften their seedcoats. The third viability test is staining with tetrazolium chloride (TZ). Seeds are soaked overnight, then each seed is cut latitudinally to expose the embryo and placed in TZ solution for 18 to 24 hours at 37 °C (NTSL 1997). Embryos that stain red are considered viable.

Figure 4—*Magnolia*, magnolia: seedling development at 1, 5, 13, and 31 days after germination.



Nursery practice. Sowing seeds in a nursery bed is the preferred method of propagating magnolias when a large quantity of seedlings are required for reforestation. The seeds can be planted in October or November in nurserybeds and allowed to naturally stratify over the winter months. The seeds can be sown with or without their sarcotestas if the seeds have not been stored (Papetti 1996). When seed quantities are limited, hand-sowing is the preferred method. Magnolia seeds have been sown with a mechanical seeder at 3 drills/bed and 210 seeds/m (64/ft) (Murphy 1996). A fertilizer distributor has also been used to sow magnolia seeds (Buchanan 1996). It drops a seed every 5 cm (2 in), with 2 passes being made over the nurserybed. When planting in the spring, it is considered common practice to sow cleaned, prechilled seeds.

If rodents or birds are a problem, the seeds need to covered with a ground cloth to prevent predation (Bosch 1996). Coating seeds with Benlate or captan will deter seed fungi (Papetti 1996). For fall-sowing, the seeds should first be covered with 6 to 12 mm ($^1/_4$ to $^1/_2$ in) of mulch, then with the same amount of pine bark or pine straw (Buchanan 1996). For spring-sowing, the seeds need only be covered with the pine mulch.

In more-northern climates, magnolias are grown for 2 years to reach a height of 30 to 60 cm (12 to 18 in) (Murphy 1996). In southern nurseries, a 30-cm (12-in) seedling can be grown in 1 year. Heit (1939) found that shading the newly sprouted plants through the hot summer was beneficial to the survival and development of cucumber magnolia seedlings. Larvae of the black vine weevil—*Otorhynchus sulcatus* F.—are a widespread pest of magnolias. Lamb and Kelly(1985) reported that larvae feed on the roots and kill the plants by eating the bark just below ground and recommend using diazinon as a protectant. Root pruning with a reciprocating blade makes lifting the large, fleshy root system easier (Buchanan 1996). Hand-lifting is the preferred method of lifting magnolias out of the nursery bed, because of the small quantities grown.

Fertilization is needed to stimulate the height growth of magnolias. In Florida nurseries, a blended fertilizer with no additional phosphorus is applied monthly (Buchanan 1996). In a Virginia nursery, a slow-release fertilizer applied just once lasts for 9 months until the lifting season (Papetti 1996).

References

Afanasiev M. 1937. A physiological study of dormancy in seed of *Magnolia acuminata*. Cornell University Agricultural Experiment Station Memoir 208. 37 p.

AOSA [Association of Official Seed Analysts]. 2001. Rules for testing seeds. AOSA. 125 p.

Bonner FT. 2002. Personal communication. Starkville, MS: USDA Forest Service, Southern Research Station.

Bosch L. 1996. Personal communication. Jonesboro, LA: Bosch Nursery.

Bouman F. 1977. Integumentary studies in the Polycarpicae: 4. *Liriodendron tulipfera* L. Acta Botanica Neerlandica 26(3): 213–223.

Browse PM. 1986. Notes on the propagation of magnolias from seed. Plantsman 8(1): 58–63.

Buchanan M. 1996. Personal communication. Day, FL: Central Land and Timber Co.

Burns RM, Honkala BH, tech. coords. 1990. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service. 877 p.

Callaway DJ. 1994. The world of magnolias. Portland, OR: Timber Press. 308 p.

Del Tredici P. 1981. *Magnolia virginiana* in Massachusetts. Arnoldia 41(2): 36–49.

Dirr MA. 1990. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation, and uses. Champaign, IL: Stipes Publishing. 1007 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Durio B. 1996. Personal communication. Opelousas, LA: Louisiana Nursery.

Earle TT. 1938. Origins of the seedcoats in magnolia. American Journal of Botany 25: 221–222.

Evans CR. 1933. Germination behaviour of *Magnolia grandiflora* L. Botanical Gazette 94: 729–754.

Fernald ML. 1970. Gray's manual of botany. 8th ed. New York: Van Nostrand. 1632 p.

Figlar RB. 1982. *Magnolia splendens*: Puerto Rico's lustrous magnolia. Journal of the Magnolia Society 18(1): 13–16.

Figlar RB. 1984a. *Magnolia portoricensis*: Puerto Rico's other magnolia. Journal of the Magnolia Society 19(2): 1–3.

Figlar RB. 1984b. *Magnolia splendens*. Journal of the Magnolia Society 20(1): 23–24.

FNAEC [Flora of North America Editorial Committee]. 1993. Flora of North America, North of Mexico. Volume 1, Introduction. New York: Oxford University Press. 372 p.

Fordham AJ. 1960. Propagation of woody plants by seed. Arnoldia 20: 33–40.

Francis JK, Rodriguez A. 1993. Seeds of Puerto Rican trees and shrubs: second installment. Res. Note SO-374. New Orleans: USDA Forest Service, Southern Forest Experiment Station. 5 p.

Galle FC. 1953. The propagation of magnolias by seed. Proceedings of the International Plant Propagators' Society 3: 105–107.

Hanchey RH, Kimbrough WD. 1954. *Magnolia grandiflora* seed germination tests. In: Proceedings, Association of Southern Agricultural Workers; 1954 Feb. 1–3; Dallas, TX: 140.

Heit CE. 1939. Seed treatment and nursery practice with cucumber (*Magnolia acuminata*). New York State Department of Conservation Notes on Forest Investigations 20. 2 p.

Heit CE. 1955. The excised embryo method for testing germination quality of dormant seed. Proceedings of the Association of Official Seed Analysts 45: 108–117.

Heit CE. 1968. Personal communication. Geneva, NY: New York State Agricultural Experiment Station.

Hora B. 1981. The Oxford encyclopedia of trees of the world. Oxford, UK: Oxford University Press. 288 p.

Jones L. 1969. Personal observation. Atlanta: USDA Forest Service, Southeastern Area, State and Private Forestry.

Johnson H. 1973. The international book of trees. New York: Simon & Schuster. 288 p.

Kozlowski TT. 1972. Seed biology. Volume 1, Importance, development, and germination. New York: Academic Press. 416 p.
Lamb JGD, Kelly JC. 1985. The propagation of deciduous magnolias. Plantsman 7(1): 36–39.
McDaniel JC. 1963. Securing seed production in *Magnolia acuminata* and *Magnolia cordata*. Proceedings of the International Plant Propagators Society 13: 120–123.
McDaniel JC. 1968. *Magnolia* hybrids and selections. In: Proceedings, 6th Central States Forest Tree Improvement Conference. St. Paul: USDA Forest Service, North Central Forest Experiment Station: 6–12.
Murphy K. 1996. Personal communication. Plains, MT: Lawyer Nursery.
NTSL [USDA Forest Service, National Tree Seed Laboratory]. 1997. Unpublished observations. Dry Branch, GA.
Olson DF Jr, Barnes RL, Jones L. 1974. *Magnolia*, magnolia. In: Schopmeyer Ca, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 527–530.
Papetti B. 1996. Personal communication. Melfa, VA: Bobtown Nursery.
Peigler RS. 1988. A review of pollination of magnolia by beetles, with a collecting survey made in the Carolinas. Journal of the Magnolia Society 24(1): 1–8.
Sargent CS. 1965. Manual of trees of North America (exclusive of Mexico). 2nd ed., corrected and reprinted. New York: Dover. 934 p.
Seitner PG. 1981. Factors in the storage of *Magnolia macrophylla* seeds. Journal of the Magnolia Society 17 (2): 13–20.
Thien LB. 1974. Flora biology of magnolia. American Journal of Botany 6(10): 1037–1045.
Toumey JW, Korstian CF. 1942. Seedling and planting in the practice of forestry. 3rd ed. New York: John Wiley and Sons. 520 p.
Wasson E. 2001. Trees and shrubs: illustrated A–Z of over 8500 plants. Willoughby, NSW, Australia: Global Book Publishing: 453–458.

M

Berberidaceae—Barberry family

Mahonia Nutt.

Oregon-grape

Don Minore, Paul O. Rudolf, and Franklin T. Bonner

Dr. Minore retired from USDA Forest Service's Pacific Northwest Research Station, Corvallis, Oregon;
Dr. Rudolf (deceased) retired from the USDA Forest Service's North Central Forest Experiment Station;
Dr. Bonner is a scientist emeritus at the USDA Forest Service's Southern Research Station,
Mississippi State, Mississippi

Growth habit, occurrence, and use. *Mahonia*—the Oregon-grape—is a genus of about 100 evergreen shrubs native to Asia, Europe, North Africa, and the Americas (Ahrendt 1961). Some authorities (Hitchcock and others 1964) place these species in the genus *Berberis,* and that nomenclature was accepted in the 1974 edition of this book (Rudolf 1974). However, most authorities (LBHB 1976; USDA NRCS 1999) now separate the genera by placing the evergreen species with compound leaves in *Mahonia*. The distinction is far from clear, however: "barberry" is a common name for some *Mahonia* species (table 1) and intergeneric hybrids have been reported (Ahrendt 1961).

Several Oregon-grape species are valued as ornamentals because of their foliage, flowers, or fruits (Bailey 1939; Dirr and Heuser 1987; Rehder 1940; Schlosser and others 1992). Like the closely related barberries, Oregon-grapes also are of value for wildlife food (Decker and others 1991), cover, and erosion-control planting. The names, heights, habits, and ripe fruit colors of some common species are listed in table 1. Six species that have potential value for conservation planting are listed in table 2. Like the barberries, some Oregon-grapes are alternate hosts for the black stem rust of grains—*Puccinia graminis* Pers: Pers). Some species, for example, hollyleaf barberry, Cascade Oregon-grape, and Oregon-grape, are resistant (Rehder 1940).

Like the seeds of the genus *Berberis,* seeds of some members of the genus *Mahonia* contain chemical substances of potential commercial value. The seeds of the Beale

Table 1—*Mahonia,* Oregon-grape: nomenclature, height, and color of ripe fruit

Scientific name & synonym	Common name(s)	Height at maturity (m)	Color of ripe fruit
***M. aquifolium* (Pursh) Nutt.** *B. cerberis aquifolium* Pursh	**hollyleaf barberry,** Oregon grapeholly	0.6–3.0	Blue-black, bloomy
***M. bealei* (Fortune) Carr.** *B. bealei* Fortune	**Beale Oregon–grape,** leatherleaf mahonia	1.8–3.0	Light blue, bloomy
***M. fortunei* (Lindl.) Fedde** *B. fortunei* Lindl.	**Chinese mahonia**	1.5–1.8	Purple-black
***M. fremontii* (Torr.) Fedde** *B. fremontii* Torr.	**Fremont mahonia**	0.9–4.6	Bluish black
***M. haematocarpa* (Woot.) Fedde** *B. haematocarpa* Woot.	**red barberry**	0.9–3.7	Blood red
***M. japonica* (Thunb.) DC.**	**Japanese mahonia**	1.8–3.0	Blue
***M. nervosa* (Pursh) Nutt.** *B. nervosa* Pursh	**Cascades Oregon–grape,** Cascades barberry	0.3–1.8	Deep blue, bloomy
***M. nevinii* (Gray) Fedde** *B. nevinii* Gray	**Nevin barberry**	0.9–1.8	Yellowish red to deep red
***M. pinnata* (Lag.) Fedde** *B. pinnata* (Lag.)	**cluster mahonia**	2.4–3.0	Pruinose blue
***M. repens* (Lindl.) G. Don** *B. repens* Lindl.	**Oregon–grape,** creeping barberry	0.3–2.4	Purple, bloomy

Sources: Ahrendt (1961), Dirr (1990), Dirr and Heuser (1987), Hitchcock and others (1964), McMinn (1951), Rehder (1940), Rudolf (1974), USDA NRCS (1999), Vines (1960).

Table 2—*Mahonia*, Oregon-grape: occurrence of species used for conservation planting.

Species	Occurrence
M. aquifolium	British Columbia to Alberta, S to W Montana, W Idaho, through Washington & Oregon to California
M. fremonti	Extreme W Texas, New Mexico, Arizona, California, Colorado, Utah, & Nevada at 1,220 to 2,130 m, & in Baja California & Sonora, Mexico
M. haematocarpa	Dry, sunny sites up to 1,340 m in W Texas, Colorado, New Mexico, Arizona, & adjacent Mexico
M. nervosa	British Columbia S to central California, mainly W of Cascades in Oregon & Washington, E to N Idaho
M. nevinii	California
M. repens	Montana to British Columbia, S to New Mexico & California, including W South Dakota

Source: Rudolf (1974).

Oregon-grape contain alkaloids that are used in folk medicine in Asia (Zhao and others 1991), and seeds of hollyleaf barberry contain tertiary alkaloids of note (Kostalova and others 1986).

Flowering and fruiting. Perfect yellow flowers are borne in the spring in racemes, panicles, umbels, fascicles, or individually, depending on the species (Ahrendt 1961). Stamens are contact-sensitive, and they respond to a tactile stimulus by snapping toward the stigma (Millet 1976, 1977). The fruit (figure 1) is a berry with one to several seeds (figures 2 and 3). A single sample of 100 fruits indicated that most Cascade Oregon-grape berries have about 3 seeds (Minore 1994). Good fruit crops are borne almost annually; the fruits ripen in the summer and autumn (table 3). Seed dispersal by both birds and mammals is widespread (Rudolf 1974; Vines 1960).

Collection of fruit; extraction and storage of seeds. Ripe fruits may be picked by hand (with gloves) or flailed onto cloths or receptacles spread beneath the bushes. The fruits may be run through a macerator or blender with water and the pulp then screened out or floated off. The seeds should then be dried superficially and either sown immediately or stored in sealed containers at temperatures slightly above freezing (Heit 1967; NBV 1946; Rudolf 1974). Seed purity and soundness can be in the 90% range (Rafn and Son nd; Rudolf 1974). Seeds of Fremont mahonia and Oregon-grape did not loose viability for 5 years when stored in unsealed containers in an unheated shed in a temperate climate (Plummer and others 1968). Fruit yields, seed yields, and numbers of seeds per weight are listed in table 4.

Figure 1—*Mahonia nervosa*, Cascade Oregon-grape: a spike of berries.

Pregermination treatments. Seeds of Fremont mahonia and red barberry usually germinate without pretreatment (Dirr and Heuser 1987; Rudolf 1974; Swingle 1939). The seeds of Fremont mahonia have some intermediate embryo dormancy, however, and germination is improved by 6 to 10 weeks of cold stratification at day/night thermoperiods of 5/1 °C (Baskin and others 1993). Beale Oregon-grape and Japanese mahonia should germinate well with only 1 to 2 months of cold stratification (Dirr and Heuser 1987). Seeds of other species also have embryo dormancy that requires cold stratification to overcome (table 5), but simple cold stratification is not always successful. Seeds of cascade Oregon-grape did not germinate after 90 days of cold stratification (Rudolf 1974); up to 5 months of treatment may be required for this species (Dirr and Heuser 1987). Immature or improperly developed embryos are probably present in some species, as maximum germination of hollyleaf barberry was obtained with 4 months of warm stratification followed by 4 months of cold stratification (Dirr and Heuser 1987). A third stratification period (cold + warm + cold) is best for seeds of Oregon-grape (McLean 1967). Under natural conditions, Oregon-grape seeds germinate in the spring after seeds are dispersed (Kern 1921).

Germination tests. Germination of seeds from 4 species of Oregon-grape has been tested in sand-filled flats, in petri dishes, on paper or blotters, or in standard germinators. Day temperatures of 16 to 30 °C, night temperatures of 13 to 21 °C, and germination periods of 20 to 95 days have been used (table 5). Actual germination tests are not prescribed for species of Oregon-grape by the International Seed Testing Association, but germination estimates with tetrazolium chloride (TZ) staining procedures are recommended (ISTA 1993). Seeds should be pre-moistened for 18 hours at 20 °C, cut open by removing a third of the seed at

Figure 2—*Mahonia*, Oregon-grape: seeds of *M. aquifolium*, hollyleaf barberry (**top left**); *M. nervosa*, Cascades mahonia (**top right**); *M. nevins*, Nevin barberry (**bottom left**); and *M. repens*, Oregon-grape (**bottom right**).

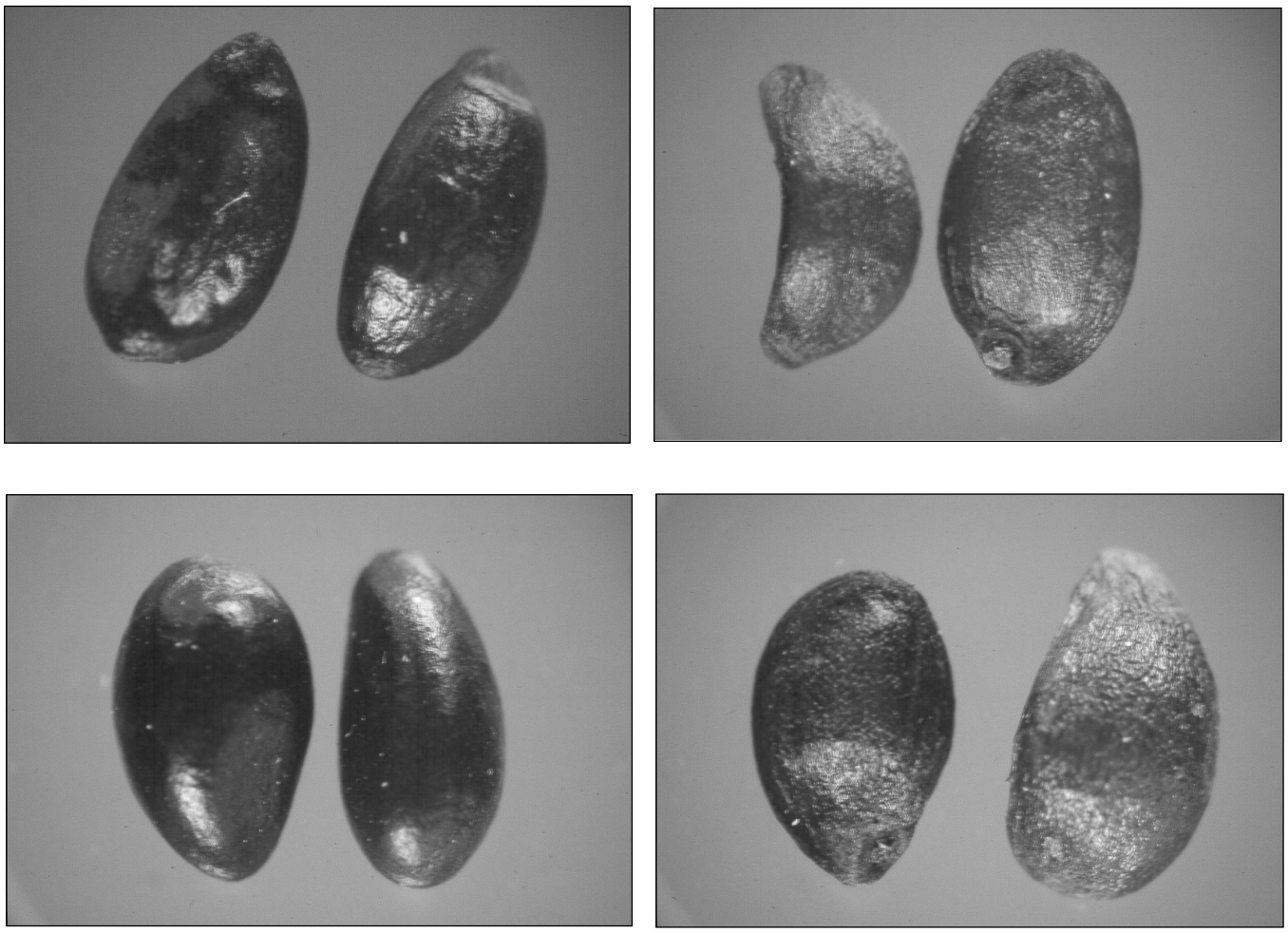


Table 3—*Mahonia*, Oregon-grape: phenology of flowering and fruiting

Species	Location (& altitude)	Flowering	Fruit ripening
M. aquifolium	Mineral Co., Montana (975 m)	Late Apr–early May	Late July–early Aug
	Jackson Co., Oregon (685 m)	Mar–May	Sept–Oct
M. fremontii	Texas, NE US	May–June	Aug–Sept
	Utah & California	May–June	July –Aug
M. haematocarpa	Texas & SW US	Spring	June–Aug
M. nervosa	Clackamas Co., Oregon (90 m)	Early Apr	Mid–Aug
	Jackson Co., Oregon (990 m)	Mid-May	Late Aug
	—	Apr–June	July–Aug
M. nevinii	California	Mar–May	June
M. repens	Black Hills, South Dakota (1,830 m)	May –June	June–July
	—	Apr– May	Aug–Sept

Sources: Bailey (1939), Loiseau (1945), McMinn (1951), Mirov and Kraebel (1939), NBV (1946), Ohwi (1965), Plummer and others (1965), Radford and others (1964), Rudolf (1974), Van Dersal (1938), Vines (1960), Wappes (1982), Wyman (1947).

Table 4—*Mahonia,* Oregon-grape: seed yield data

Species	Place collected	Fruit weight/vol		Seed weight/fruit vol		Cleaned seeds x1,000 /weight				Samples
						Range		Average		
		kg/hl	lb/bu	kg/hl	lb/bu	/kg	/lb	/kg	/lb	
M. aquifolium	Jackson Co., Oregon	44	34	4	3	—	—	73	33	1
	Pacific Northwest	—	—	—	—	84–95	38–43	90	41	2
M. fremontii	Utah	—	—	—	—	—	—	93	42	1+
M. haematocarpa	—	—	—	—	—	—	—	227	103	1
M. nervosa	Clackamas Co., Oregon	39	43*	—	—	—	—	51	23	1
	Pacific Northwest	—	—	—	—	—	—	66	30	2
M. nevinii	California	—	—	—	—	—	—	126	57	1
M. repens	Basin, Montana; & Utah	—	—	—	—	119–157	54–71	136	62	2

Source: Rudolf (1974).

* Data are for berries without stems; data for other species are for berries with stems.

Table 5—*Mahonia*, Oregon-grape: stratification periods, germination test conditions, and percentage germination

Species	Cold stratification* (days)	Daily light (hrs)	Germination test conditions				Germination rate		Percent germination		Purity	Soundness
				Temp (°C)			Amount					
			Medium	Day	Night	Days	(%)	Days	Avg (%)	Samples	(%)	(%)
M. aquifolium	90	8	Sand or perlite	30	20	30	22	12	25	1	95	99
M. fremontii	0	—	—	—	—	—	—	—	85	2+	90	90+
M. nevinii	90	—	Soil	—	—	95	—	—	77	1	—	—
M. repens	196‡	—	Wet paper	21	21	10	62†	150	74	*1*	*90*	—

Sources: Heit (1968a&b), McLean (1967), Mirov and Kraebel (1939), Morinaga (1926), Plummer and others (1968), Rafn and Son (nd), Rudolph (1974), Swingle (1939), Vines (1960).

* Cold stratification temperatures ranged from –1 to 5 °C.

† Maximum germination was obtained with 4 months of warm stratification at 20 °C, followed by 4 months of cold stratification at 2 to 4 °C (Dirr and Heuser 1987).

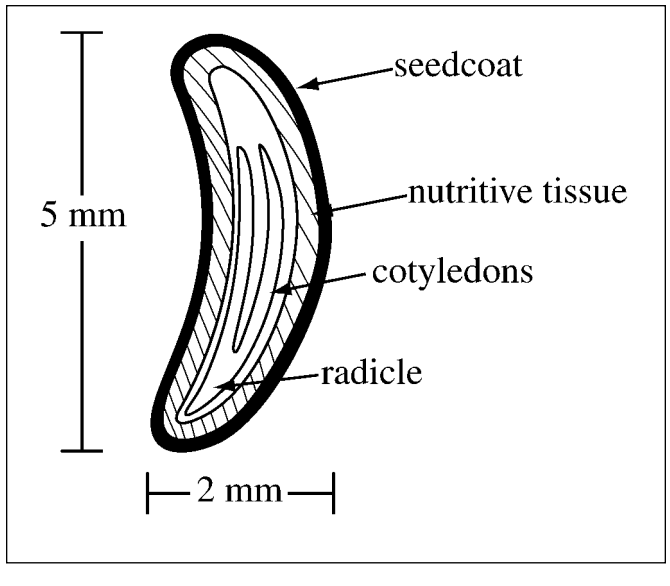
‡ Successive stratification periods were 30 days at 1 °C, 60 days at 21 °C, and 196 days at 1 °C. During the final cold period, 62% of the seeds germinated. An additional 12% germinated after the temperature was again raised to 21 °C for a total of 74%.

the distal end, and incubating in 1% TZ for 18 hrs at 30 °C. All tissues should stain in viable seeds. For the closely related Japanese and common barberries, the Association of Official Seed Analysts (AOSA 1993) recommends germination of excised embryos in covered petri dishes at temperatures of 18 to 22 °C for 10 to 14 days. This method may also be satisfactory for species of Oregon-grape.

Nursery practice. Whole berries or (preferably) cleaned seeds may be sown in the fall, or stratified seeds may be sown in the spring. Injury from molds is more likely if whole berries are used (Chadwick 1936). Fall-sown beds should be mulched until germination begins (NBV 1946). The seeds should be covered with 0.3 to 1.3 cm ($^1/_8$ to $^1/_2$ in) of soil plus 0.6 cm ($^1/_4$ in) of sand (Rudolf 1974). Germination is epigeal (Terabayashi 1987).

Oregon-grapes can be propagated from rooted stem cuttings. Many species root best when hardwood cuttings are collected in the autumn or winter (Dirr and Heuser 1987). They should be treated with indole-butyric acid (IBA) rooting hormone in talc or in solution.

Figure 3—*Mahonia repens*, Oregon-grape: longitudinal section through a seed.



References

Ahrendt T. 1961. *Berberis* and *Mahonia*: a taxonomic revision. Journal of the Linnean Society of London, Botany 57(369): 1–410.

AOSA [Association of Official Seed Analysts]. 1993. Rules for testing seeds. Journal of Seed Technology 16(3): 1–113.

Bailey LH. 1939. The standard cyclopedia of horticulture. New York: Macmillan. 3639 p.

Baskin CC, Baskin JM, Meyer SE. 1993. Seed dormancy in the Colorado plateau shrub *Mahonia fremontii* (Berberidaceae) and its ecological and evolutionary implications. Southwestern Naturalist 38(2): 91–99.

Chadwick LC. 1936. Improved practices in propagation by seed. American Nurseryman 62(8): [3]–4; (9): 5–6; (10): 7–8; (12): [3]–9.

Decker SR, Pekins PJ, Mautz WW. 1991. Nutritional evaluation of winter foods of wild turkeys. Canadian Journal of Zoology 69(8): 2128–2132.

Dirr MA. 1990. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation, and uses. 4th. ed. Champaign, IL: Stipes Publishing Co. 1007 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Heit CE. 1967. Propagation from seed: 8. Fall planting of fruit and hardwood seeds. American Nurseryman 126(4): 12–13, 85–90.

Heit CE. 1968a. Propagation from seed: 15. Fall planting of shrub seeds for successful seedling production. American Nurseryman 128(4): 8–10, 70–80.

Heit CE. 1968b. Thirty-five year's testing of tree and shrub seeds. Journal of Forestry 66(8): 632–634.

Hitchcock CL, Cronquist A, Ownbey M, Thompson JW. 1964. Vascular plants of the Pacific Northwest: 2. Salicaeae to Saxifragaceae. Seattle: University of Washington Press. 597 p.

ISTA [International Seed Testing Association]. 1993. Rules for testing seeds: rules 1993. Seed Science and Technology 21 (Suppl.): 1–259.

Kern FD. 1921. Observations of the dissemination of the barberry. Ecology 2: 211–214.

Kostalova D, Hrochova V, Tomko J. 1986. Tertiary alkaloids of *Mahonia aquifolium* (Pursh) Nutt. III. Chemical Papers 40(3): 389–394.

LHBH [Liberty Hyde Bailey Hortorium]. 1976. Hortus third: a concise dictionary of plants cultivated in the United States and Canada. New York: Macmillan. 1290 p.

Loiseau J. 1945. Les arbres et la forêt. Paris: Vigot Freres. 204 p.

McLean A. 1967. Germination of forest range species from southern British Columbia. Journal of Range Management 20(5): 321–322.

McMinn HE. 1951. An illustrated manual of California shrubs. Berkeley: University of California Press. 663 p.

Millet B. 1976. Kinetic study of the curve of *Mahonia aquifolium* (Pursh) Nutt. stamens electrically stimulated. Annales Scientifiques de l'Universite de Besancon Botanique 3(17): 75–80 [Biological Abstracts 68(5): 3095, Ref. 31123].

Millet B. 1977. A scanning electron microscope survey of the surface of the staminal filament in some Berberidaceae: Comparison with other sensitive organs. Comptes Rendu des Seances de la Societe de Biologie, et de Ses Filiales 171(3): 580–584 [Biological Abstracts 65(8): 4336, Ref. 44154].

Minore D. 1994. Personal observation. Corvallis, OR: Pacific Northwest Research Station.

Mirov NT, Kraebel CJ. 1939. Collecting and handling seeds of wild plants. For. Pub. 5. Civilian Conservation Corps. 42 p.

Morinaga T. 1926. Effect of alternating temperatures upon the germination of seeds. American Journal of Botany 13: 141–158.

NBV [Nederlandsche Boschbouw Vereeniging]. 1946. Boomzaden: Handleiding inzake het oogsten, behandelen, bewaren en uitzaaien van boomzaden. Wageningen, The Netherlands: Ponsen and Looijen. 171 p.

Ohwi J. 1965. Flora of Japan. Washington, DC: Smithsonian Institution. 1067 p.

Plummer AP, Christensen DR, Monsen SB. 1968. Restoring big-game range in Utah. Pub. 68-3. Salt Lake City: Utah Division of Fish and Game. 182 p.

Radford AE, Ahles HE, Bell CR. 1964. Guide to the vascular flora of the Carolinas. Chapel Hill: University of North Carolina Book Exchange. 333 p.

Rafn J and Son. No date. Skovfrökontoret's Fröanalyser gennem 40 Aar, 1887–1927. Copenhagen: Udfört paa Statsfrökontrollen i Köbenhavn. 5 p.

Rehder A. 1940. Manual of cultivated trees and shrubs hardy in North America. 2nd. New York: Macmillan. 996 p.

Rudolf PO. 1974. *Berberis*, barberry, mahonia. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 247–251.

Schlosser WE, Blatner KH, Zamora B. 1992. Pacific Northwest forest lands potential for floral greenery production. Northwest Science 66(1): 44–55.
Swingle CF, comp. 1939. Seed propagation of trees, shrubs, and forbs for conservation planting. SCS-TP-27. Washington, DC: USDA Soil Conservation Service. 198 p.
Terabayashi S. 1987. Seedling morphology of the Berberidaceae. Acta Phytotaxonica Geobotanica 38(0): 63–74 [Biological Abstracts 85(7): AB-121, Ref. 65180].
USDA NRCS [USDA Natural Resources Conservation Service]. 1999. The PLANTS database [website available at http://plants.usda.gov/plants]. Baton Rouge, LA: USDA National Resources Conservation Service, National Plant Data Center.
Van Dersal WR. 1938. Native woody plants of the United States: their erosion control and wildlife values. Misc. Pub. 303. Washington, DC: U.S. Department of Agriculture. 362 p.
Vines RA. 1960. Trees, shrubs, and woody vines of the Southwest. Austin: Texas Press. 1104 p.
Wappes L. 1932. Wald und Holz ein Nachschlagebuch für die Praxis der Forstwirte, Holzhändler und Holzindustriellen. Volume 1. Berlin: J. Neumann. 872 p.
Wyman D. 1947. Seed collection dates of woody plants. Arnoldia 7(9): 53–56.
Zhao TF, Wang XK, Rimando AM, Che CT. 1991. Folkloric medicinal plants: *Tinospora sagittata* var. *cravaniana* and *Mahonia bealei*. Planta Medica 57: 5, 505.

M

Rosaceae—Rose family

Malus Mill.

apple

Paul D. Anderson and John A. Crossley

Dr. Anderson is a plant physiologist at the USDA Forest Service's Pacific Northwest Research Station, Corvallis, Oregon; Mr. Crossley retired from the USDA Forest Service's Northeastern Forest Experiment Station

Growth habit, occurrence, and use. The apple genus—*Malus* Mill.—includes about 25 species of deciduous trees or shrubs native to the temperate regions of North America, Europe, and Asia. Taxonomic classification of the native North American apples is the subject of active debate (Green 1996; Yanny 1996). Rehder (1940) recognized 9 native species—*M. angustifolia, M. bracteata, M. coronaria, M. fusca, M. glabrata, M. glaucescens, M. ioensis, M. lancifolia, and M. platycarpa*. Fiala (1994) suggests that, based on chromosome number, there are 3 distinct native species—M. coronaria, M. fusca, and M. ioensis. Other taxonomic structures having intermediate numbers of species have proponents (Green 1996). The nomenclature and occurrence of commonly recognized species are presented in table 1.

Native apples and planted cultivars occur throughout much of North America. In general, apple performs best in full sunlight in deep, well-drained soils. Growth and vigor are best in rich sandy loams, but apple will grow well in heavier clay soils as long as they are well-drained (Fiala 1994). Ideal soil pH ranges from 5.5 to 6.5, but soils with pH in the range of 5.0 to 7.5 will support apple species (Fiala 1994).

The Oregon crab apple, the only native apple in western North America, occurs along the Pacific Coast from northern California to Alaska, occupying mesic to wet habitats at less than 800 m elevation (Hickman 1993). In California and Oregon, it occurs in open forests of the coast ranges and the foothills of the Cascade Range (Hickman 1993). In British Columbia and southern Alaska, its range includes coastal climatic regions as well as zones of gradual transition to continental climate (Pojar 1996; Vierdeck and Little 1972). Oregon crab apple occurs as an early seral species occupying gaps within old-growth forests, as a component of estuarian and riparian complexes in major river valleys, and in upland Sitka spruce–red cedar swamps having locally perched water tables. In tidal marshes, it can form thickets as the dominant canopy species in association with grasses and forbs. It also occurs in the coastal fringe forest as scattered, slow-growing individuals on rocky shorelines and inland passages where it is protected from wind and salt spray. Oregon crab apple is somewhat tolerant of brackish water and short-term inundation.

In the upper mid-West of the United States, prairie and Great Lakes crab apples occur in open areas, on well-drained soils, near forest margins, in abandoned pastures, in oak savannahs, and at prairie margins (Kromm 1996; Little 1980; Yanny 1996). Common associates include shrubs of hawthorn (*Crataegus* spp.) and bur (*Quercus macrocarpa*) and black (*Q. velutina)* oaks. In southeastern Wisconsin, the native crab apples occur with greater frequency on clay and loam soils than on sandy soils. However, in contrast to Oregon crab apple, neither prairie or Great Lakes crab apples occur in wet areas (Kromm 1996).

In the southeastern United States, southern crab apple occurs at low altitudes on moist soils of valley bottoms and lower slopes. It is found in abandoned fields, along fence rows, and at forest margins, often forming dense thickets (Little 1980).

Native apples have served as a supply of food for both wildlife and humans. Indigenous peoples in both the eastern and western regions of North America have consumed crab apples (Pojar 1996; Vierdeck and Little 1972; Yarnell 1964). The occurrence of crab apples may be locally abundant in areas traditionally inhabited by indigenous peoples, but it is not known whether the trees were cultivated or grew from discarded fruit remains (Pojar 1996).

Consumption of fruit by birds and mammals is common. Known consumers include grouse (*Bonasa umbellus*), pheasant (*Phasianus colchicus*), rabbits (*Sylvilagus* spp.), squirrels *(Sciurus* spp.*)*, opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), skunks (*Conepattus* spp.) and foxes (*Vulpes vulpes*) (Little 1980). The abundance of crab apples along fencelines and riparian areas is thought to reflect dispersal by wildlife. However, the large fruit size and retention of the stem upon falling make transport by

Table 1— *Malus*, apple: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***Malus angustifolia* (Ait.) Michx.**	**southern crab apple,** narrow-leaf crab apple	SE US from Virginia to Florida & W to Mississippi
***Malus baccata* (L.) Borkh.** *Pyrus baccata* L.	**Siberian crab apple**	Asia; planted extensively in US
***M. coronaria* (L.) Mill.** *P. bracteata* Baily; *P. coronaria* L. *M. bracteata* (Baily) Rehd.	**American crab apple,** wild sweet crab apple, garland-tree	E US; New York to Alabama, W to E Indiana
***M. coronaria* var. *dasycalyx* Rehd.** *P. coronaria* var. *dasycalyx* (Rehd.) Fern. *P. coronaria* var. *lancifolia* (Rehd.) Fern. *P. lancifolia* (Rehd.) Baily *M. coronaria* var. *lancifolia* (Rehd.) C.F. Reed *M. lancifolia* Rehd.	**Great Lakes crab apple**	S Ontario to Ohio & Indiana
***M. floribunda* Sieb. ex Van Houtte** *M. pulcherrima* (Sieb.) Makino	**Japanese flowering crab apple**	Japan; planted extensively in E US
***M. fusca* (Raf.) Schneid.** *P. rivularis* Dougl. ex Hook. *P. fusca* Raf. *M. diversifolia* (Bong.) M. Roemer	**Oregon crab apple**, Pacific crab apple, western crab apple, wild crab apple	Pacific Coast region from N California to S Alaska
***M. glabrata* Rehd.**	**Biltmore crab apple**	SE US; North Carolina to Alabama
***M. glaucescens* Rehd.** *P. glaucescens* (Rehd.) Baily	**Dunbar crab apple**	E US; New York to North Carolina & W into Alabama
***M. ioensis* (Wood) Britt.** *P. ioensis* (Wood) Baily	**prairie crab apple**, Iowa crab apple, midwest crab apple	Minnesota & Wisconsin to Nebraska & Kansas & to Texas & Louisiana
***M. pumila* P. Mill.** *P. pumila* (P. Mill.) Borkh. *M. communis* Poir *M. domestica* (Borkh.) Borkh.	**common apple,** apple, paradise apple	Europe & W Asia; cultivated horticulturally and agriculturally in US
***M. x robusta* (Carr.)** Rehd. *M. baccata x (M. prunifolia* (Willd.) Borkh.	**red Siberian crab apple**	Asia
***M. sargentii* Rehd.**	**Sargent apple**	Japan
***M. sylvestris* P. Mill.** *P. malus* L. *M. malus* (L.) Britt.	**European crab apple,** apple	Europe & W Asia

Sources: Crossley (1974), Fiala (1994), Little (1980).

most species of frugivorous birds unlikely (Snow and Snow 1988). Observations suggest that deer may be the principal dispersal agent of crab apples in Europe (Snow and Snow 1988) and in southern Wisconsin (Kromm 1996).

Members of the apple genus have traditionally been some of our most important fruit bearers and ornamentals (table 1). Siberian crab apple has been used in shelterbelts. Larger stems of southern crab apple have been used to make tool handles. More recently, propagation of native crab apples has become increasingly important for habitat restoration (Callahan 1996) and apple cultivars have been considered for use in revegetation of minespoil (Brown and others 1983). Seedling propagation of native prairie crab apple as an ornamental is increasing in the mid-West as a means of avoiding the poorly adapted plants that can arise as sprouts from non-native rootstock following shoot girdling or browsing (Yanny 1996). Many cultivated varieties have been developed from the common or cultivated apple and from the Siberian crab apple, but these varieties are usually propagated vegetatively. Common apple and European crabapple are most often used as the rootstock for cultivars of crab apple (Fiala 1994).

Flowering and fruiting. The pink to white perfect flowers appear in the spring with or before the leaves. Flowering time varies among species from March to June (table 2). The fruit is a fleshy pome in which 3 to 5 carpels, usually 5, are embedded. Each carpel contains 2 seeds or 1 by abortion (figure 1) (Sargent 1965). Seeds have a thin lining of endosperm (figure 2), except in the cultivated, or common, apple, which has almost no endosperm (Martin 1946). Depending upon species, fruits ripen as early as August or as late as November (table 2). The fruits drop to the ground soon after ripening. Color of ripe fruit varies among the species (table 2).

Good crops of fruits and seeds generally occur every 2 to 4 years (Crossley 1974); however, good seed production

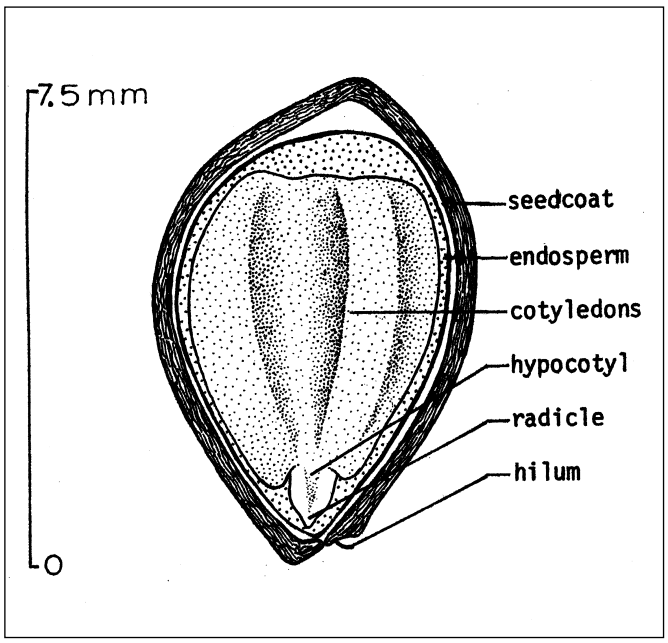
Table 2—*Malus,* apple: phenology of flowering and fruiting, color of ripe fruit, and height of mature trees

Species	Flowering	Fruit ripening	Color of ripe fruit	Height of mature trees (m)	Year first cultivated
M. baccata	May	Aug–Oct	Red or yellow	12.2	1784
M. coronaria	Mar–May	Sept–Nov	Yellow-green	9.2	1724
M. floribunda	May	—	Red or yellow	3.6–10.0	1862
M. fusca	—	Oct–Nov	Green-yellow to yellow & red	8–12.2	1836
M. ioensis	May–June	Sept–Oct	Greenish waxy	—	1885
M. pumila	May	Aug–Oct	Yellow to red	15.4	Ancient times
M. x robusta	Apr–May	—	Red or yellow-green	—	1815
M. sargentii	—	—	Red	1.8–2.5	—

Sources: Callahan (1996), Crossley (1974), Fiala (1994), Krüssmann (1960), Nielsen (1988), Rehder (1940), Sudworth (1908), Van Dersal (1938).

Figure 1—*Malus pumila*, common apple: seeds.

Figure 2—*Malus coronaria*, American crab apple: longitudinal section through a seed.



has been observed annually for select stands of prairie crab apple in Wisconsin (Kromm 1996) and for many crab apple cultivars (Fiala 1994). Seed production may be negatively affected by late-spring frosts. The severity of frost effect on seed production depends on the stage of fruit development at the time of frost. Late-flowering cultivars of apple are less susceptible to fruit damage by late frosts than early and medium flowering cultivars (Nybom 1992). Cultivars of apple exposed to freezing temperatures during the pink to early-bloom stages of fruit development demonstrated seed abortion and fruit pedicle damage, but they continued to produce a smaller, but economically significant fruitcrop (Simons and Doll 1976). A similar phenomenon has been observed in a wild stand of prairie crab apple, where a normal crop of crab apples were produced, yet the fruits bore no seeds (Kromm 1996).

Biennial bearing is a problem for commercial apple production (Williams 1989). Alternate-year fruit production arises from competitive effects of vegetative production, fruit development, and flowering. Trees bearing fruit with a large complement of seeds tend to initiate fewer flowers. Chemical methods, including the post-bloom application of thinning agents or growth regulators, have been used in manipulating fruit set and fruit quality (shape, firmness, russeting, and seed set) in commercial cultivars of apple (Greene 1989; Looney and others 1992; Williams 1989).

Collection of fruits; extraction and storage of seed. Ripe apples may be collected either by picking the fruits

from the tree or by gathering fallen fruits from the ground (Crossley 1974). In contrast to domesticated varieties of apples, crab apples may persist in good condition on the ground for 2 to 3 weeks. Fruits from wild trees need to be collected soon after they ripen, for wildlife may rapidly forage and deplete crops in the wild. Large amounts of seeds from domesticated apple cultivars may be extracted from cores obtained at food-processing plants (Richardson 1966). Seeds from cider mills, however, are often damaged (Crossley 1974) and may have a very low germinative capacity.

Accepted methods for seed extraction from the ripe fruits are cumbersome procedures involving combinations of after-ripening, mashing, and separation of pulp and seeds. After-ripening is the partial fermentation of the fruit. This can be done in a large container where the fruits are maintained at 10 to 18 °C for 2 to 4 weeks to soften (Callahan 1996; Nielson 1988). The softened fruits are then covered with water and mashed. The seeds may be sieved or left to settle out while the pulp is floated over the top with running water (Richardson 1966). Care should be taken to avoid high temperatures or excessive fermentation, as this may injure or kill the seeds (Heit 1967). Seeds may also be extracted by putting the fruits through a mechanical macerator (blender) with water, floating off the pulp, and then screening out the seeds (Nielson 1988). Mechanical macerators or presses must be used with caution, as the seedcoats of apple species are thin and easily damaged, resulting in loss of germinative capacity. Extraction may be enhanced by carefully slitting the endodermis of the fruit before mashing (Yanny 1996). Wisconsin native populations of prairie and Great Lakes apples yield 1 to 2 and 3 to 4 viable seeds per fruit, respectively (Kromm 1996). The numbers of seeds per weight of fruit for various species are listed in table 3.

Seeds extracted in the above fashion can be sown immediately. If there is a need for overwintering, the seeds can be air-dried at room temperature for 3 months and then placed in refrigerator in a 50:50 sand and peat mixture for an additional 3 months. As with seeds of commercial varieties of apple, seeds from native crab apples may germinate in cold storage, resulting in difficult sowing.

Apple seeds are orthodox in storage behavior; long-term storage of seeds can be accomplished by drying the seedlot to lower moisture contents. Seeds dried to a moisture content less than 11% have been stored in a sealed container at 2 to 10 °C for over 2 years without loss of germinative capacity or seedling vigor (Solovjeva and Kocjubinskaja 1955). Decline in seed viability as a function of storage temperature and seed moisture content has been modeled for cultivars of cultivated apple (Dickie and Bowyer 1985). They determined that seedlots dried to 14.5% moisture content (fresh-weight basis) and stored at 6 °C lose half their viability in 323 days. With further drying to 5%, the estimated storage life increases to 37 years at –5 °C storage temperature or 100 years at –18 °C storage temperature (Dickie 1986).

Germination. Apple seeds display dormancy which has been overcome by cold stratification (table 4). Stratification is achieved by placing the seeds in a moist medium and storing at a temperature of 2 to 5 °C. A minimum of about 30 days under stratification conditions is required to remove embryonic dormancy (Zhang and Lespinasse 1991). After stratification, apple seeds exposed to diurnally alternating day/night temperatures of 30/20 °C, germinated in 30 to 60 days (table 4). Germination is epigeal (figure 3).

The application of growth-regulating chemicals, including gibberellin A_3 (GA_3), ethephon (E), and benzylaminopurine (BAP), has been used to obtain germination from non-stratified seeds (AOSA 1965; Litvinenko 1959; Sinska 1989; Zhang and Lespinasse 1991). Chemical treatments often involve soaking excised embryos in growth regulator solutions for periods of 1 to 24 hours. Variations in the concentration of growth substance and duration of soaking have

Table 3—*Malus*, apple: seed yield data

Species	Seeds/fruit wt /100 kg	Seeds/fruit wt /100 lb	Cleaned seeds/fruit weight Range /kg	Range /lb	Average /kg	Average /lb	Samples
M. bacatta	1.2	2.5	10,850–42,000	22,000–85,000	30,000	66,000	5
M. coronaria	0.5	1	—	—	6,350	14,000	1
M. fusca	1.2	2.4	—	—	24,500	54,000	1
M. floribunda	—	—	—	—	26,800	59,000	—
M. ioensis	—	—	—	—	13,600	30,000	1
M. pumila	0.4	0.75	3,460–13,300	7,000–27,000	9,100	20,000	5+
M. x robusta	—	—	—	—	7,700	17,000	—

Sources: Crossley (1974), Swingle (1939).

significant impacts on both the percentage embryo germination and the quality of the resulting plants. Germination of nearly 100% of non-stratified embryos has been obtained with GA_3 applied at concentrations of 12.5 to 50.0 mg/liter for periods of 1 to 24 hours and with BAP applied at 12.5 to 100 mg/liter for periods of 6 to 24 hours. Such treatments have resulted in 50 to 60% germination in less than 10 days and nearly 100% germination in 30 days (Zhang and Lespinasse 1991). Some plants produced from treated embryos demonstrate reduced growth, abnormally thick stems, or poorly developed roots. The percentage of abnormal plants produced tends to increase with increasing growth regulator concentration or increasing period of soaking. Successful application of growth regulator treatments as a substitute for stratification requires careful attention to protocol and is beyond the needs of most propagators as germination percentages of 90% or greater are commonly achieved using the relatively simple cold stratification process.

Nursery practice. Seedlings for use in landscape restoration or as apple rootstocks are often grown from seeds in nurseries (Richardson 1966; Callahan 1996). Untreated seeds have been sown in late fall (Bakke and others 1926; Callahan 1996; Kromm 1996; Yanny 1996) and stratified seeds have been sown in the spring (Crossley 1974; Yanny 1996). In a Washington nursery, seeds are stratified by first soaking them in water for 5 to 7 days, then placing sacks of seeds between layers of ice in a sawdust pit for 6 to 8 weeks. Seeds are subsequently dried only enough to flow freely through a mechanical planter (Crossley 1974). Seeds are sown in rows 20 cm (8 in) wide and 106 cm (42 in) apart (Davis 1940), 1.25 to 2.5 cm ($^1/_2$ to 1 in) deep on loose friable soil. A thin sawdust mulch aids seedling emergence on soils that form a crust after watering. Seedlings may be sprayed weekly with a fungicide to control powdery mildew. By the end of the growing season most of the seedling stems should be pencil-thick and about 38 cm (15 in) high (Richardson 1966). A height of 23 cm (9 in) is regarded as minimum size for grafting (Davis 1940). Most commercial varieties are propagated by budding or grafting onto seedling rootstocks (Crossley 1974; Fiala 1994; Richardson 1966; Solovjeva and Kocjubinskaja 1955).

In Wisconsin, crab apples for landscape use have been produced from seeds sown in the fall at a density of 270/m^2 (5/ft^2) and covered with 2.5 cm (1 in) of sand. Apple seeds are among the first to germinate in the spring, often while

Figure 3—*Malus coronaria*, American crab apple: seedling development at 1, 3, 9, and 16 days after germination.

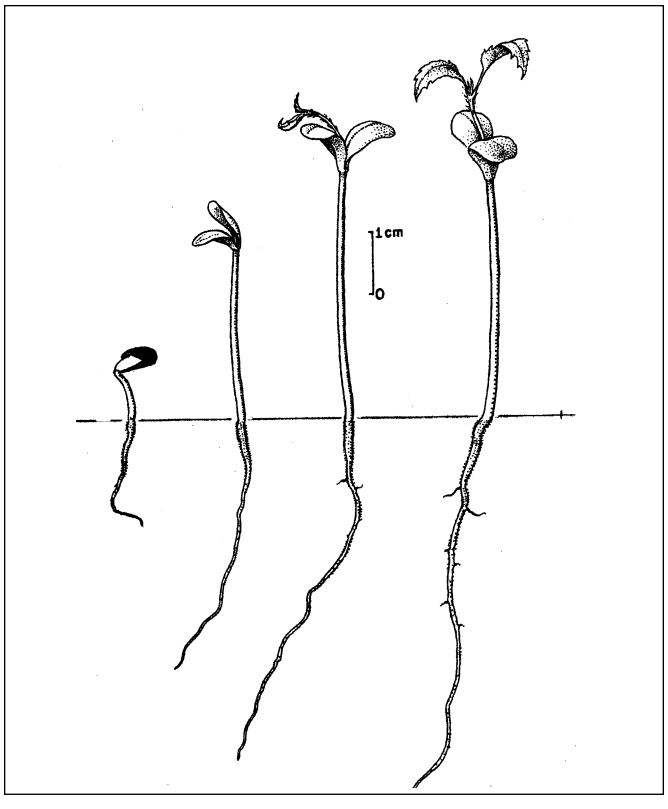


Table 4—*Malus*, apple: effects of cold stratification and germination test conditions on germination results

Species	Cold stratification (days)	Germination conditions: Temp (°C) Day	Germination conditions: Temp (°C) Night	Germination conditions: Days	Germinative energy %	Germinative energy days	Germinative capacity (%)	Samples
M. bacatta	30	30	20	30	48	8	54	2
M. coronaria	120	10	10	30	93	19	96	1
M. fusca	90	—	—	—	—	—	—	—
M. floribunda	60–120	—	—	—	—	—	—	—
M. ioensis†	60	30	20	10	48	4	58	1
M. pumila	60	30	20	60	—	—	65	1+
M. x robusta	60–120	—	—	—	—	—	—	—

Sources: Crossley (1974), Heit (1967), Kallio (1962).

* In a moist medium at temperatures of 2 to 5 °C.

† In another test, fresh seeds from slightly green fruit were sown in a nurserybed without pretreatment and germinated 100%.

soil temperatures are less than 4.5 °C, and the seedlings are generally hardy with respect to spring frost. Seedlings may be grown for 2 years without undercutting, reaching a size of 30 to 60 cm (1 to 2 ft) in height and a caliper of 1.25 cm ($^1/_2$ in) (Kromm 1996).

References

AOSA [Association of Official Seed Analysts]. 1965. Rules for testing seed. Proceedings of the Association of Official Seed Analysts 54(2): 1–112.

Bakke AL, Riches NW, Reeves K. 1926. Germination and storage of apple seeds. Iowa Agricultural Experiment Station Research Bulletin 97: 243–255.

Brown JE, Maddox JB, Splittstoesser WE. 1983. Performance of trees, shrubs, and forbs seeded directly in the fall on minespoil and silt loam soil. Journal of Environmental Quality 12: 523–525.

Callahan F. 1996. Personal communication. Central Point, OR: Callahan Seed.

Crossley JA. 1974. *Malus* Mill., apple. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 531–533.

Davis LL. 1940. Germination and growth of crab apple seedlings as influenced by fungicidal treatment. Proceedings of the American Horticultural Society 37: 359–360.

Dickie JB. 1986. A note on the long-term storage of apple seeds. Plant Genetic Resources Newsletter 65: 13–15.

Dickie JB, Bowyer JT. 1985. Estimation of provisional seed viability constants for apple (*Malus domestica* Borkh. cv. Greensleeves). Annals of Botany 56: 271–275.

Fiala JL. 1994. Flowering crabapples: the genus *Malus*. Portland, OR: Timber Press.

Green T. 1996. Personal communication. Macomb, IL: Western Illinois University.

Greene DW. 1989. CPPU influences 'McIntosh' apple crop load and fruit characteristics. HortScience 24: 94–96.

Heit CE. 1967. Propagation from seed: 11. Storage of deciduous tree and shrub seeds. American Nurseryman 126(10): 12–13, 86–94.

Hickman JC. 1993. The Jepsen manual: higher plants of California. Berkeley: University of California Press.

Kallio TK. 1962. Seed stratification with special reference to apples. Puntarha 65: 62–63 [Horticultural Abstracts 32(4277), 1962].

Kromm D. 1996. Personal communication. Reeseville, WI: Reeseville Ridge Nursery.

Krüssmann G. 1960. Handbuch der Laubgeholze. Volume 1, 495 p.; volume 2, 608 p.

Little EL Jr. 1980. The Audubon Society field guide to North American trees: eastern region. New York: Knopf. 714 p.

Litvinenko SN. 1959. [in Russian: The Ukrainian gibberellin, an effective growth stimulant]. Doklady Akademii Nauk SSSR [Horticultural Abstracts 30(73), 1960].

Looney NE, Granger RL, Chu CL, Mander LN, Pharis RP. 1992. Influences of giberellins A_4, A_4+7 and A_4+iso-A_7 on apple fruit quality and tree productivity: 2. Other effects on fruit quality and importance of fruit position within the tree canopy. Journal of Horticultural Science 67: 841–847.

Martin AC. 1946. The comparative internal morphology of seeds. American Midland Naturalist 36: 513–660.

Neilson KK. 1988. Dormancy in seeds from different positions on individual plants. Acta-Hortica 1 (226): 255-261.

Nybom H. 1992. Freeze damage to flower buds of some apple cultivars. Journal of Horticultural Science 67: 171–177.

Pojar J. 1996. Personal communication. Smithers, BC: British Columbia Ministry of Forests.

Rehder A. 1940. Manual of cultivated trees and shrubs. New York: Macmillan. 996 p.

Richardson BD. 1966. Raising apple seedling rootstock. Tasmanian Journal of Agriculture 37: 15–19.

Sargent CS. 1965. Manual of the trees of North America. New York: Dover. 934 p.

Simons RK, Doll CC. 1976. Morphological and anatomical response of apples to late spring frost in relation to stage of fruit development. Journal of the American Society of Horticultural Science 101: 315–320.

Sinska I. 1989. Interaction of ethephon with cytokinen and gibberellin during the removal of apple seed dormancy and germination of embryos. Plant Science 64: 39–44.

Snow B, Snow D. 1988. Birds and berries: a study of an ecological interaction. Calton, UK: T & D Poyser. 268 p.

Solovjeva MA, Kocjubinskaja VN. 1955. [in Russian: Effect of storage conditions of seed on germination and yield of standard root stocks.] Sadi Ogorod 9: 53–55 [Horticultural Abstracts 26(149), 1956].

Sudworth GB. 1908. Forest trees of the Pacific Slope. Washington, DC: USDA Forest Service. 441 p.

Swingle CF. 1939. Seed propagation of trees, shrubs, and forbs for conservation planting. TP-27. Washington, DC: USDA Soil Conservation Service. 198 p.

Van Dersal WR. 1938. Native woody plants of the United States: their erosion-control and wildlife values. Misc. Pub. 303. Washington, DC: USDA. 165 p.

Viereck LA, Little EL Jr. 1972. Alaska trees and shrubs. Agric. Handbk. 410. Washington, DC: USDA Forest Service. 265 p.

Williams MW. 1989. Control of flowering, fruit set, and seed development in apple (*Malus domestica* Borkh.) with chemical growth regulators. Acta Horticulturae 240:221–228.

Yanny M. 1996. Personal communication. Menomonee Falls, WI: Johnson Nursery.

Yarnell RA. 1964. Aboriginal relationships between culture and plant life in the upper Great Lakes region. Anthropol. Pap. 23. Ann Arbor: University of Michigan, Museum of Anthropology.

Zhang YX, Lespinasse Y. 1991. Removal of embryonic dormancy in apple (*Malus* x *domestica* Borkh) by 6-benzylaminopurine. Scientia Horticulturae 46: 215–223.

M

Meliaceae—Mahogany family

Melia azedarach L.

chinaberry

Franklin T. Bonner

Dr. Bonner is a scientist emeritus at the USDA Forest Service's Southern Research Station
Mississippi State, Mississippi

Other common names. chinatree, bead tree, Indian lilac, pride-of-India, umbrella chinaberry, umbrella-tree, *paráiso*.

Growth habit, occurrence, and use. Chinaberry—*Melia azedarach* L.—is a short-lived deciduous tree, native to southern Asia and Australia, that has been cultivated and naturalized in tropical, subtropical, and warm temperate regions throughout the world. It has naturalized locally in the southeastern United States from Virginia and Oklahoma south to Florida and Texas. It can also be found in California, Hawaii, Puerto Rico, and Virgin Islands (Little 1979). The tree reaches a maximum height of 15 m in the United States, where it is planted as an ornamental, yet has some value for timber and wildlife food. In India the wood is used for furniture, agricultural implements, and the manufacture of writing and printing paper (Guha and Negi 1965). Extracts of the leaves and fruits have insecticidal properties (Al-Sharook and others 1991; Atwal and Pajni 1964), and the fruits are valuable livestock and game food. Birds and animals are common seed dispersal agents (Vines 1960).

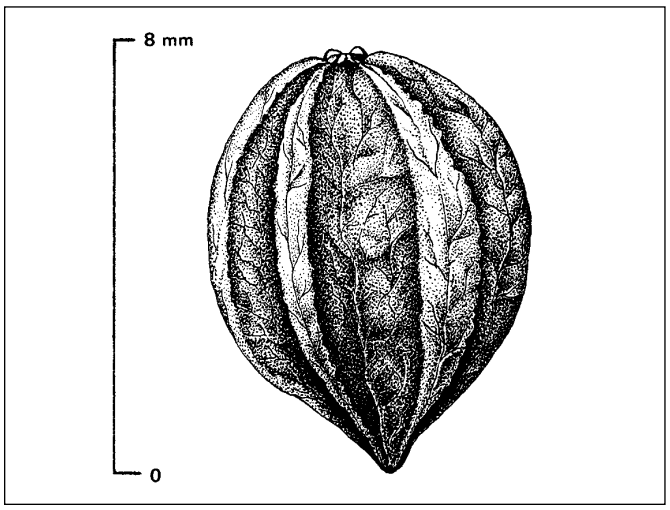
Flowering and fruiting. The flowering habit is either perfect or polygamo-dioecious (Nair 1959). The pretty, lilac-colored perfect flowers are borne in axillary panicles 10 to 15 cm long in March to May. The fruit is a subglobose, fleshy, round, drupe, 13 to 19 mm in diameter, that ripens in September and October and persists on the tree well into winter (Vines 1960). It turns yellow and wrinkled as it ripens (figure 1). Inside the fleshy mesocarp is a single, fluted, light brown or yellowish stone that contains 3 to 5 pointed, smooth, black seeds (figures 2 and 3). Abundant seed crops are borne almost annually.

Collection, extraction, and storage of seeds. Fruits can be collected by hand after the leaves have fallen in late autumn or early winter. Some seeds will germinate when the fruit coats are still green, but it is best to wait until they turn yellow for collection (Moncur and Gunn 1990). The pulp should be removed from the fruits before storage or planting. This can easily be done in mechanical macerators with water, with the pulp floated off or screened out (Amata-Archachai and Wasuwanich 1986). There are about 1,400 fruits/kg (640/lb) (7 samples). Chinaberry is an oily seed of the tropics and subtropics, yet several tests suggest that they are orthodox in storage behavior (Bonner and Grano 1974; Moncur and Gunn 1990). Under refrigerated, dry conditions fruits may be stored for at least a year without loss of viability. Additional research on storage of this species is needed.

Figure 1—*Melia azedarach* L., chinaberry: fruit and stone (**lower left**).

Germination tests. Pregermination treatments are not necessary (Bonner and Grano 1974), but germination is usually improved if the fruit pulp is removed (Moncur and Gunn 1990). In nature, the epigeous germination usually occurs during the spring following dispersal. One fruit may produce up to 4 seedlings. Suggested germination test conditions are 21 °C (night) to 30 °C (day) for 60 days with 200 seeds/test in sand flats. Fresh stones from southeastern Arkansas had a germinative capacity of 81% at 90 days in sand flats in a greenhouse; germination rate was 54% at 30 days (Bonner and Grano 1974). Seeds from tropical sources

Figure 2—*Melia azedarach* L., chinaberry: stone (**left**) and seeds (**right**).



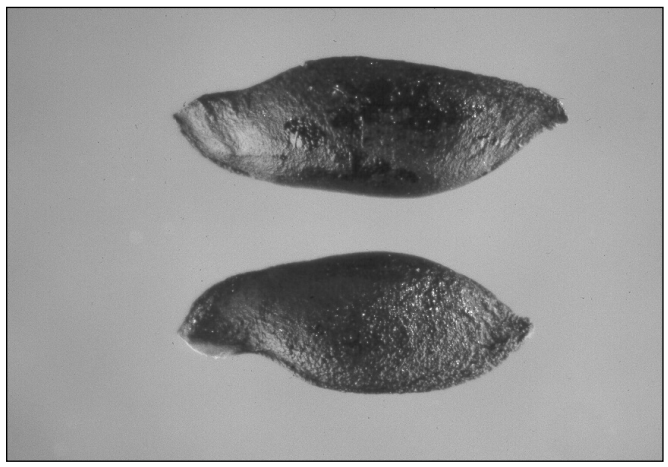
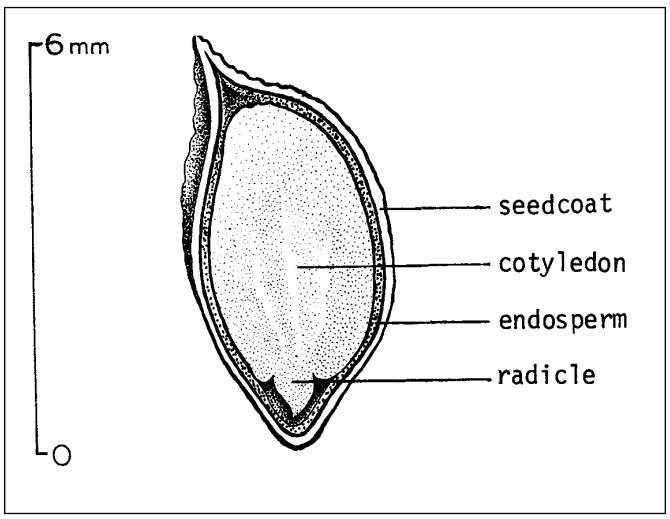


Figure 3—*Melia azedarach* L., chinaberry: longitudinal section through a seed.



seem to require higher temperatures for germination. Moncur and Gunn (1990) reported very little germination below a regime of 30 to 35 °C for Australian collections

Nursery practice. Stones are usually sown intact immediately after collection in the fall or in the following spring. They should be sown 5 to 7 cm (2 to 3 in) apart in drills and covered with about 2.5 cm (1 in) of soil. Germination takes place about 3 weeks after a spring sowing. As planting stock, 1-year-old seedlings are preferred. Older stock should be top-and-root pruned. Chinaberry may also be propagated from cuttings and root suckers and by direct seeding (Bonner and Grano 1974; Dirr and Heuser 1987).

References

Al-Sharook Z, Balan K, Jiang Y, Rembold H. 1991. Insect growth inhibitors from two tropical Meliaceae: effects of crude seed extracts on mosquito larvae. Journal of Applied Entomology 111: 425–430.

Amata-Archachai P, Wasuwanich P. 1986. Mechanical extraction and cleaning of nuts of some tropical species. Embryon 2(1): 1–8.

Atwal AS, Pajni HR. 1964. Preliminary studies on the insecticidal properties of drupes of *Melia azedarach* against caterpillars of *Pieris brassicae* L. (Lepidoptera: Pieridae). Indian Journal of Entomology 26: 221–227.

Bonner FT, Grano CX. 1974. *Melia azedarach* L., chinaberry. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 535–536.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Guha SRD, Negi JS. 1965. Writing and printing paper from *Melia azedarach* Linn. (Persian lilac). Indian Forester 91: 867–869.

Little EL Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handbk. 541. Washington, DC: USDA Forest Service. 375 p.

Nair NC. 1959. Studies of Meliaceae: 2. Floral morphology and embryology of *Melia azedarach* Linn.—a reinvestigation. Journal of the Indian Botanical Society 38: 367–378.

Moncur MW, Gunn BV. 1990. Seed development and germination responses of *Melia azedarach* var. *australasica*. In: Turnbull JW, ed. Tropical tree seed research. 1989 August 21–24; Gympie, Australia. AICAR Proc. 28. Canberra: Australian Centre for International Agricultural Research: 24–28.

Vines RA. 1960. Trees, shrubs, and woody vines of the Southwest. Austin: University of Texas Press. 1104 p.

M

Menispermaceae—Moonseed family

Menispermum canadense L.

common moonseed

Kenneth A. Brinkman and H. M. Phipps*

Drs. Brinkman and Phipps retired from the USDA Forest Service's North Central Research Station

Growth habit, occurrence, and use. Common moonseed—*Menispermum canadense* L.—is a climbing woody vine growing to a height of 3.6 m (Rehder 1940) that is capable of spreading from underground stems (Wyman 1949). It is native from Quebec and western New England to southeastern Manitoba, south to Georgia, Alabama, and Oklahoma (Fernald 1950). The plants are seldom eaten by livestock (Van Dersal 1938), but the fruits are of value to wildlife, although reportedly poisonous to humans (Kingsbury 1964). This species has been cultivated since 1646 for its attractive foliage and fruit (Rehder 1940).

Flowering and fruiting. The dioecious flowers appear from May to July and the bluish-black drupes ripen from September to November (Grimm 1966; Redher 1940). The seeds are flattened stones in the form of a crescent or ring (figures 1 and 2).

Collection of fruits and seed extraction. Fruits may be collected from September to November (Rehder 1940). Seeds may be extracted by washing the macerated fruits in water. One sample showed 16,758 seeds/kg (7,600/lb) (Brinkman and Phipps 1974).

Germination. Stratification of one seedlot at 5 °C for 60 days resulted in 65% germination in 11 days and 98% in 26 days. An unstratified seedlot showed germination of 83% in 28 days and 92% in 60 days (Brinkman and Phipps 1974). Germination was tested in sand under light at alternating temperatures of 30 (day) and 20 °C (night).

Nursery practice. Common moonseed is propagated readily by seeds stratified and sown in the spring or planted as soon as ripe (Bailey 1935). Vegetative propagation also is possible from cuttings.

References

Bailey LH. 1935. The nursery manual, a complete guide to the multiplication of plants. 22nd ed. New York: Macmillan. 456 p.

Brinkman KA, Phipps HM. 1974. *Menispermum*, common moonseed. In: Schopmeyer CS, tech coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 537–538.

Fernald ML. 1950. Gray's manual of botany. 8th ed. New York: American Book Co. 1632 p.

Grimm WC. 1966. Recognizing native shrubs. Harrisburg, PA: Stackpole Books. 319 p.

Kingsbury JM. 1964. Poisonous plants of the U.S. and Canada. Englewood Cliffs, NJ: Prentice-Hall. 626 p.

Rehder A. 1940. Manual of cultivated trees and shrubs. 2nd ed. New York: Macmillan. 2996 p.

Van Dersal WR. 1938. Native woody plants of the United States: their erosion-control and wildlife values. Misc. Pub. 303. Washington, DC: USDA Forest Service. 362 p.

Wyman D. 1949. Shrubs and vines for American gardens. New York: Macmillan. 442 p.

*Note: Review of the literature by Jill R. Barbour, germination specialist at the USDA Forest Service's National Seed Laboratory, Dry Branch, Georgia, found no new information.

Figure 1—*Menispermum canadense* L., common moonseed: fruit (**top**) and seeds (**bottom**).

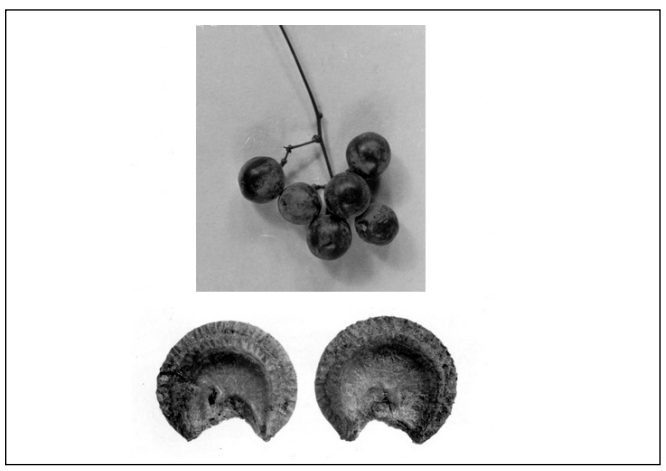
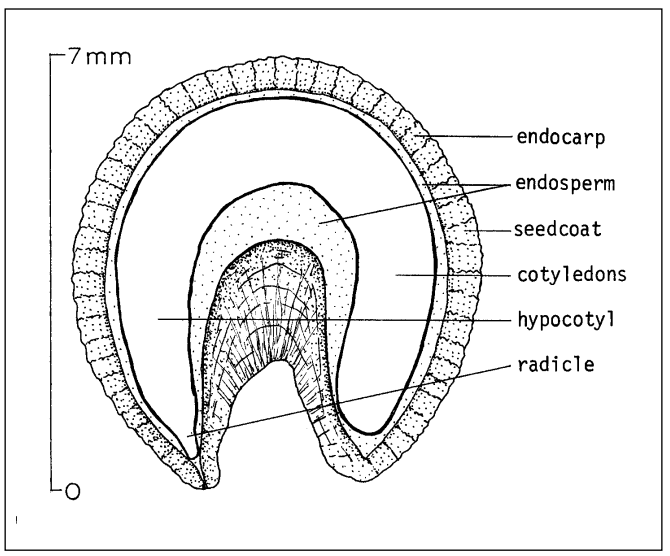


Figure 2—*Menispermum canadense* L., common moonseed: longitudinal section through a seed.



Oleaceae—Olive family

Menodora scabra Gray

rough menodora

Stanley L. Krugman and John C. Zasada

Dr. Krugman retired from the World Bank and the USDA Forest Service's Research and Development National Office, Washington, DC; Dr. Zasada retired from the USDA Forest Service's North Central Research Station

Growth habit, occurrence, and use. Rough menodora—*Menodora scabra* Gray—is a low herbaceous to woody shrub 0.2 to 0.8 m in height. It is native to dry rocky areas and desert grasslands from 462 to 2,155 m in southern California, Arizona, New Mexico, western Texas, Colorado, and Utah (Munz and Keck 1965; Vines 1960). It provides browse for livestock and game animals (Krugman 1974). Due to the type of habitat in which it is usually found, it should grow on strip-mined land (Sabo and others 1979). The genus *Menodora* is represented by 14 species in North America (Turner 1991). Rough menodora is recommended for use as a rock garden plant.

Flowering and fruiting; seed collection and storage. The yellow, often showy flowers of rough menodora appear from May through August (Krugman 1974; Vines 1960). The fruit, a bispherical thin-walled capsule with 2 seeds in each cell, ripens in September to November. Seeds are dispersed during October and November (Krugman 1974; Munz and Keck 1965; Vines 1960). Seeds should be collected from September to November (Krugman 1974). The mature seeds are about 4 to 5 mm in length and 3 mm wide, flat greenish to brownish with a yellowish narrow wing (figures 1 and 2) (Munz and Keck 1965; Vines 1960).

Good seedcrops of rough menodora usually occur annually (Krugman 1974). The number of cleaned seeds per weight in 2 samples was 224,000 and 246,000/kg (102,000 and 112,000/lb). Vines (1960) reported that purity of seedlots was 41% and soundness 98%. Storage in a dry place at room temperature has been satisfactory.

Germination. Sabo and others (1979) reported that germination occurred at alternating and constant temperatures between 14 to 40 °C. The best germination (about 80%) was under alternating temperature regimes of 24 °C for 8 hours and 17 °C for 16 hours and 17 °C for 8 hours and 24 °C for 16 hours. The mean day of germination varied from to about 6 to 10 days under these temperature regimes. Light was not required for germination. Percentage and rate of germination of showy menodora—*M. longiflora* Gray—a

Figure 1—*Menodora scabra*, rough menodora: seed.

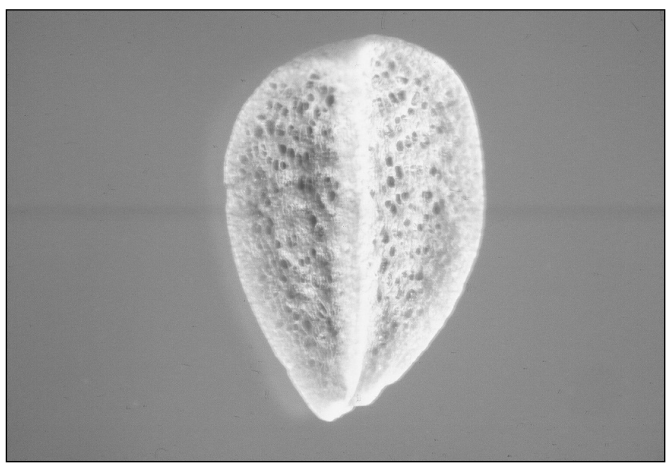
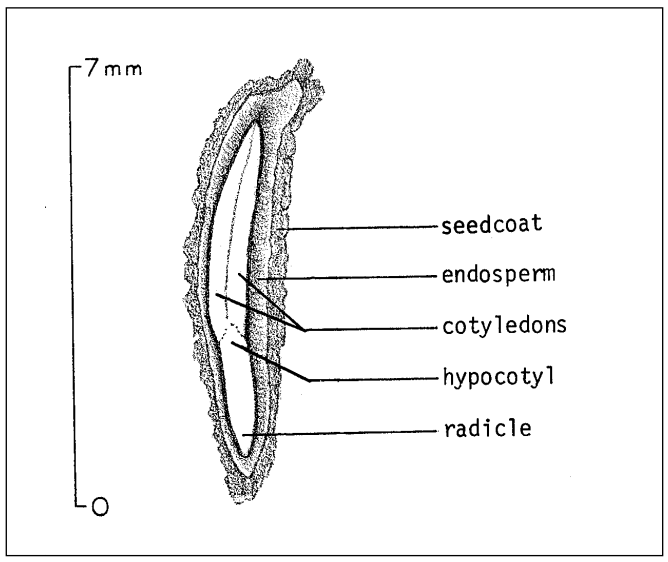


Figure 2—*Menodora scabra*, rough menodora: longitudinal section through a seed.



related sub-shrub, was improved by acid scarification. However, at a temperature regime of 30/20 °C, 60% of unscarified seeds germinated. Germination rate of scarified seeds increased with increasing temperature up to 30/20 ·°C but declined at warmer temperatures. Seeds of showy menodora germinated in the dark, but both germination rate and germination percentage were greater in a light regime with 12 hours light (Fulbright and Flenniken 1986).

References

Fulbright TE, Flenniken KS. 1986. Effects of temperature and presowing treatments on showy menodora seed germination. Journal of Range Management 39(4): 310–313.

Krugman SL. 1974. *Menodora scabra* A. Gray, rough menodora. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States: Agric. Handbk. 450. Washington, DC: USDA Forest Service: 539.

Munz PA, Keck DD. 1965. A California flora. Berkeley: University of California Press. 1681 p.

Sabo DG, Johnson GV, Martin WC, Aldon EF. 1979. Germination requirements of 19 species of arid land plants. Res. Pap. RM-210. Fort Collins, CO: USDA Forest Service. 23 p.

Turner BL. 1991. An overview of the North American species of *Menodora*. Phytologia 71(5): 340–356.

Vines RA. 1960. Trees, shrubs, and woody vines of the Southwest. Austin: University of Texas Press. 1104 p.

Taxodiaceae—Redwood family

Metasequoia glyptostroboides Hu & W.C. Cheng

dawn-redwood

John P. Sloan and LeRoy C. Johnson

Mr. Sloan is at the USDA Forest Service's Lucky Peak Nursery, Boise, Idaho; Mr. Johnson retired from the USDA Forest Service's Pacific Southwest Forest and Range Experiment Station

Growth habit, occurrence, and use. Dawn-redwood—*Metasequoia glyptostroboides* Hu & W.C. Cheng—is the only known living example of its genus (Hu and Cheng 1948). It is often called a "living fossil" because until 1946 it was known only from the fossil record (Hu 1948; Merrill 1945; Shao 1982). The natural range is quite restricted: a few trees are found near the village of Mo-tao-chi in eastern Szechuan Province and the bulk of the native groves are found in Shui-hsa-pa Valley (south of Mo-tao-chi) in the northwestern corner of Hupeh Province, People's Republic of China (Chu and Cooper 1950; Shao 1982). It has been introduced to many other parts of China, as well as the United States and Europe, for a total of 50 other countries (Shao 1982).

Since its introduction into the United States in 1948, this deciduous conifer has mostly been planted as an ornamental, especially at museums and in arboreta. The wood is soft, weak, and brittle, so it has little value as a source of lumber (Wyman 1968), although it is used for building timbers in China (Shao 1982). Pulping characteristics are similar to, and its fibers are stronger than, southern pines (Wyman 1968). In the United States, Wyman (1968) reported height growth was as much as 18 m in 20 years. In China, Shao (1982) described 4-year-old dawn-redwood trees averaging 7 m tall and 11 cm dbh. In its natural range, dawn-redwood grows in the submontane zone at elevations between 100 and 1500 m. The species is hardy in Massachusetts, where the winter temperatures may drop to -34 °C, and thrives in Placerville, California, where summer temperatures often exceed 35 °C and there is usually no summer rainfall (Johnson 1974).

Geographic races. Although great phenotypic diversity exists between planted trees, no geographic races are known to exist. Several cultivars have been described (Broekhuizen and Zwart 1967; DeVos 1963). Of the 6 trees growing at the USDA Forest Service's Institute of Forest Genetics at Placerville, California, half are of the normal single-stemmed conifer shape and the others are bush-shaped with no single branch showing dominance. Johnson (1974) speculates that some of the seeds may have come from self-pollinated trees. According to Shao (1982), dawn-redwood shows a strong apical dominance and produces a straight stem.

Flowering and fruiting. Dawn-redwood is monoecious. Trees that produce female cones begin to do so several years before trees of the same age produce male cones (Em 1972; Li 1957; Wyman 1968). Female trees do not begin to produce seeds until they are 25 to 30 years old and bear heavily until they are 40 to 60 years old, when production diminishes (Shao 1982).

Male cone buds form in leaf axis or on branch tips and become visible in the fall just prior to leaf drop. At this time, they are about 2.5 mm long. Female cones are borne singly, opposite along branches (rarely terminal). Male and female buds begin to grow in late January and are readily seen by early- or mid-February. Pollination takes place in March before the tree puts on needles (Hwa 1945, 1948). This early emergence of the cones makes them susceptible to late winter frosts, which can destroy the cone crop.

Male cone buds are 4 to 6 mm long when closed and 6 to 10 mm long when expanded and shedding pollen. Each staminate strobilus has 20 to 30 distichously arranged microsporophylls with 3 microsporangia per sporophyll. Pollen grains are wingless and covered with a sticky substance that causes them to clump together in masses (Johnson 1968). Female cones have 16 to 26 distichously arranged scales, with 5 to 8 seeds per scale. Mature cones are pendulous (with a 10- to 30-mm peduncle), subquadrangular, and shortly cylindrical; they ripen the same year they are pollinated. Cones ripen in early December and shed their seeds in late December and early January.

Collection, extraction, and storage. Mature cones are light brown, but color is not a good indication of ripeness. Cones should be collected late in the year just before they begin to open. Cones picked when they first turn from green to light brown do not open and the scales must be pried apart. But cones picked when the scales naturally begin to separate will readily open with 1 to 2 weeks of dry-

ing at room temperature. Tumbling is necessary because some seeds are firmly welded to the scales. Because seed wings are minute, de-winging is unnecessary (Johnson 1974).

Seedcoats of dawn-redwood are thin and fragile. Seeds with wings attached are light brown, 5 to 6 mm long, 2 to 4 mm wide, obovate (rarely orbicular-oblong), and notched at the apex (figure 1) (Johnson 1974; Nakai and Furuno 1974). Wings are adnate and appear as tegumentary extensions of the seed (Sterling 1949). Average weight per seed is 8 mg (0.0003 oz) (Nakai and Furuno 1974). Nakai and Furuno (1974) found an average of 70 to 90 seeds per cone, with a range of 50 to 110. One kilogram of cones contains 430,00 to 560,000 seeds (1 lb contains 195,000 to 254,000 seeds) (Shao 1982). Dawn-redwood often produces a high proportion of hollow seeds (CDF 1977). Presumably, seeds can be stored in the same manner as those of other genera in Taxodiaceae such as redwood (*Sequoia*) and arborvitae (*Thuja*). Storage of dry seeds in airtight containers at 1 to 4 °C has been satisfactory for these genera (Johnson 1974).

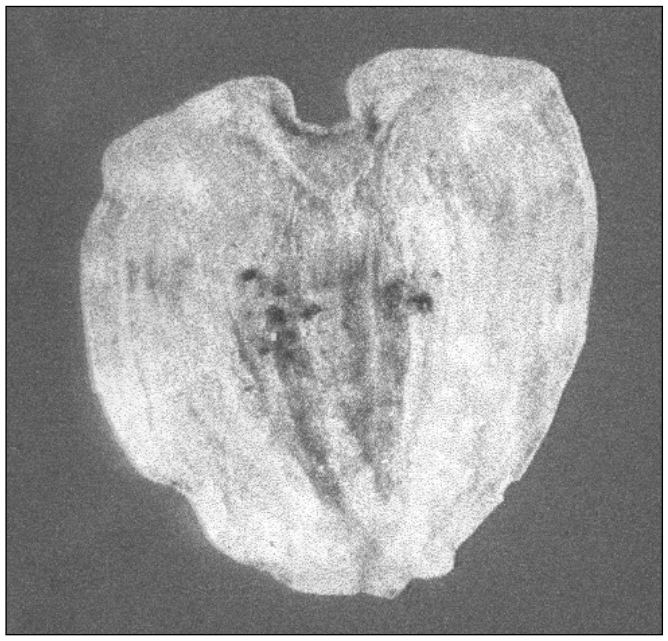
Mechanical separation of seeds is not recommended. Hollow (figure 1) and filled seeds can be identified with x-radiography, but a simpler and more efficient method is to use a light table. The seeds should be scattered 1-layer thick on a light table and then back-lit with the room lights off. The hollow seeds can be picked out with tweezers. However, this method is feasible only on a small scale. If large quantities of seeds become available, all seeds should be stored and then sown, making allowances for seed-fill when the seeding rate is calculating (Johnson 1974).

Germination and nursery practice. Seeds of dawn-redwood do not require chilling (Johnson 1968; Shao 1982; Smith 1950). Germination takes 4 to 8 days (Nakai and Furuno 1974) and is epigeal. After germination, the seedcoat sheds in 3 to 5 days, exposing the cotyledons (Johnson 1974). There are no official testing prescriptions for this species.

Seeds sown directly on soil and mulched with fine sand or Sponge Rok® begin germinating within 5 days (Johnson 1968). During the first 5 weeks of growth, the tender succulent seedlings are particularly susceptible to damping-off (Johnson 1974; Shao 1982). Losses can be minimized by sowing on heat-sterilized or fumigated soil. Young seedlings thrive in high humidity like that found in a greenhouse equipped with automatic overhead sprinklers. In hot climates the young seedlings should be shaded during the first growing season (Johnson 1974).

Because seeds of dawn-redwood are scarce, the species is often propagated from cuttings. Although cuttings are very easy to root (Johnson 1968; Mirov and Blankensop 1955; Shao 1982), growing stock can be produced faster from seeds than from cuttings (Johnson 1974). Cuttings root best when they are taken in early summer through late fall. Rooting is promoted by treatment with 50 ppm of α-naphthalene acetic acid (NAA). Rooting capability of cuttings decreases with increasing age of the mother plant (Shao 1982).

Figure 1—*Metasequoia glyptostroboides*, dawn-redwood: filled seed.



References

Broekhuizen JT, Zwart FN. 1967. A contribution to the knowledge of *Metasequoia glyptostroboides* [English summary]. Agric. Comm. 10. Wageningen, The Netherlands: University of Wageningen Institute of Forest Resources: 439–463.

CDF [China Department of Forestry, Nanking College of Forest Products]. 1977. A preliminary observation on the flowering and seed development of *Metasequoia glyptostroboides* Hu et Cheng. Acta Botanica Sinica 19(4): 252–256.

Chu K, Cooper WS. 1950. An ecological reconnaissance in the native home of *Metasequoia glyptostroboides*. Ecology 31(2): 260–275.

DeVos F. 1963. *Metasequoia glyptostroboides* 'National'. American Horticulture Magazine 42(3): 174–177.

Em H. 1972. *Metasequoia glyptostroboides* and its growth in the Skopje basin. Sumarstvo 24:5–15.

Hu H. 1948. How *Metasequoia*, the "living fossil," was discovered. Journal of the New York Botanical Garden 49(585): 201–207.

Hu H, Cheng W. 1948. On the new family Metasequoiaceae and on *Metasequoia glyptostroboides*, a living species of the genus *Metasequoia* found in Szechuan and Hupeh. Bulletin of Fan Memorial Institute of Biology NS1(2): 153–161.

Hwa CT. 1945. UCB. M 186893. [Herbarium Specimen] *Metasequoia glyptostroboides*. Shui-hsa-pa Valley, 3550 ft. March 10, 1945.

Hwa CT. 1948. UCB. M 186884. [Herbarium Specimen] *Metasequoia glyptostroboides*. In ravine; tree. Li-Chuan, Shui-hsa-pa Valley, 3500 ft. Hupeh Province. March 10, 1948.

Johnson LC. 1968. Crossability of *Metasequoia glyptostroboides*. Genetics Res. File 36105. Placerville, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Institute of Forest Genetics.
Johnson LC. 1974. *Metasequoia glyptostroboides* Hu and Cheng, dawn redwood. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 540–542.
Li H. 1957. The discovery and cultivation of *Metasequoia*. Morris Arboretum Bulletin 5(4): 49–53.
Merrill ED. 1945. *Metasequoia*, another "living fossil." Arnoldia 5(1): 1–5.
Mirov NT, Blankensop CM. 1955. A note on rooting cuttings of dawn redwood. Journal of the California Horticulture Society 20(1): 9–10.
Nakai I, Furuno T. 1974. Flowering and fruiting in *Metasequoia*. Journal of Japanese Forestry Society (Nihon Ringakkai Shi) 56(8): 294–296.
Shao QH. 1982. Silviculture of some important trees species in China. Allgemeine Forst Zeitschrift 11: 314–315.
Smith CM. 1950. Notes on seeds and seedlings of *M[e]tasequoia glyptostroboides*. New Zealand Journal of Forestry 6(2): 145–148.
Sterling C. 1949. Some features in morphology of *Metasequoia*. American Journal of Botany 36(6): 461–471.
Wyman D. 1968. *Metasequoia* after twenty years in cultivation. Arnoldia 25(10/11): 113–123.

M

Rubiaceae—Madder family

Mitchella repens L.

partridgeberry

Kenneth A. Brinkman, G. G. Erdmann, and Jill R. Barbour

Drs. Brinkman and Erdmann retired from the USDA Forest Service's North Central Forest Experiment Station; Ms. Barbour is a germination specialist at the USDA Forest Service's National Seed Laboratory, Dry Branch, Georgia.

Growth habit, occurrence, and use. Partridgeberry—*Mitchella repens* L., also called two-eyed berry or running-fox—is an evergreen vine or herb with fruit valuable as food for birds, raccoons (*Procyon lotor*), and red foxes (*Vulpes vulpes*) (Van Dersal 1938). The natural range is from Texas to Florida, north to southwest Newfoundland, and west to Ontario and Minnesota (Fernald 1950). This attractive plant was introduced into cultivation in 1761 and is often used in rock gardens (Rehder 1940).

Flowering and fruiting. The distylous flowers appear from June to August and can be separated into 2 genetic compatibility groups (Rehder 1940). Plants with short-styled flowers ("thrums") have exserted stamens 15 mm above the ovary and stigmas 10 mm above the ovary; whereas plants with long-styled flowers ("pins") have stamens 11 mm above the ovary and exserted stigmas 16 mm above the ovary (Ganders 1975). The only pollinations that are compatible are those between anthers and stigmas of the same height, that is, between pin and thrum and thrum and pin. The genetic control is by a single gene (S), with thrums the heterozygotes (Ss) and pins the recessive homozygotes (ss) (Allard 1960). Thrums contribute more than three-quarters of all genes transmitted through ovules, and pins more than three-quarters of all genes transmitted through pollen (Hicks and others 1985). Pins and thrums contribute almost equally to gene flow via pollen and ovules.

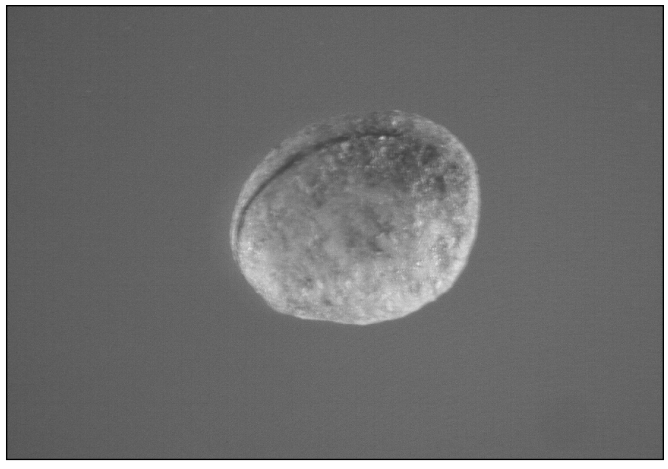
The flowers occur in pairs on a short peduncle with the base of the calyces fused. Each flower has 1 style and 4 stamens (Fernald 1950). Fruit-set occurs when both flowers of a pair have been pollinated. Bumble bees (*Bombus* spp.) are the principal pollinators of partridgeberry. They fly around a patch of partridgeberry for a mean of 2.3 ± 2.3 minutes, visiting 34 ± 43 inflorescences per minute (Hicks and others 1985).

Fruits are scarlet drupaceous berries 7 to 10 mm wide that ripen in July but usually persist overwinter (Petrides 1958). The maximum number of seeds that a single full berry may contain is 8 (Hicks and others 1985). The level of natural fruit-set is near 100% for both pins and thrums. In a flowering study in North Carolina, the overall fruit-set level for pins and thrums was 100%, whereas in New York, the fruit-set was 96.1% for pins and 86.5% for thrums (Hicks and others 1985). A Massachusetts study revealed fruit-set values of 96.8% for pins and 96.3% for thrums (Keegan and others 1979).

Collection of fruits; extraction and storage of seeds. Partridgeberry fruits may be picked in late fall. Fruits should be macerated in water and screened to remove the seeds (figures 1 and 2). About 45 kg (100 lb) of fruit yield about 5.4 kg (12 lb) of cleaned seeds (Swingle 1939). Two samples averaged 427,770 seeds/kg (194,000/lb); 98% of the seeds were sound after cleaning (Brinkman and Erdmann 1974; Swingle 1939). Seeds are orthodox in storage behavior and can be stored for some time in sealed containers at low temperature.

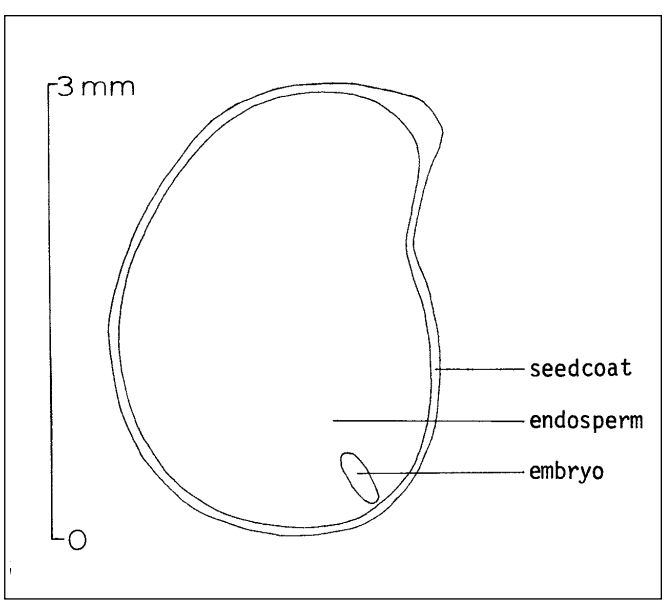
Germination tests. Partridgeberry seeds have internal dormancy, but this can be overcome by 150 to 180 days of stratification at 5 °C (Barton and Crocker 1945). No data are available on results of germination tests.

Figure 1—*Mitchella repens*, partridgeberry: seed.



Nursery practice. Seeds of many other species exhibiting embryo dormancy germinate satisfactorily when sown in the fall, so partridgeberry probably can be handled in the same way. Mulching overwinter should reduce drastic temperature changes and maintain adequate moisture.

Figure 2—*Mitchella repens*, partridgeberry: longitudinal section through a seed.



References

Allard RW. 1960. Principles of plant breeding. New York: John Wiley and Sons. 485 p.

Barton LV, Crocker W. 1945. Twenty years of seed research. London: Faber and Faber. 148 p.

Brinkman KA, Erdmann GG. 1974. *Mitchella repens* L., partridgeberry. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 543.

Fernald ML. 1950. Gray's manual of botany. 8th ed. New York: American Book Co. 1632 p.

Ganders FR. 1975. Fecundity in distylous and self-incompatible homostylous plants of *Mitchella repens* (Rubiaceae). Evolution 29(1): 186–188.

Hicks DJ, Wyatt R, Meacher TR. 1985. Reproductive biology of distylous partridgeberry, *Mitchella repens*. American Journal of Botany 72(10): 1503–1514.

Keegan CR, Voss RH, Bawa KS. 1979. Heterostyly in *Mitchella repens* (Rubiaceae). Rhodora 81: 567–573.

Petrides GA. 1958. A field guide to trees and shrubs. Boston: Houghton Mifflin. 431 p.

Rehder A. 1940. Manual of cultivated trees and shrubs. 2nd ed. New York: Macmillan. 996 p.

Swingle CF, comp. 1939. Seed propagation of trees, shrubs, and forbs for conservation planting. SCS-TP-27. Washington, DC: USDA Soil Conservation Service. 198 p

Van Dersal WR. 1938. Native woody plants of the United States: their erosion-control and wildlife values. Misc. Pub. 303. Washington, DC: USDA. 362 p.

M

Moraceae—Mulberry family

Morus L.

mulberry

Jill R. Barbour, Ralph A. Read, and Robert L. Barnes

Ms. Barbour is a germination specialist at the USDA Forest Service's National Seed Laboratory, Dry Branch, Georgia; Dr. Read retired from the USDA Forest Service's Rocky Mountain Research Station; Dr. Barnes retired from the USDA Forest Service's Southeastern Forest Experiment Station

Growth habit, occurrence, and use. The mulberry genus—*Morus*—comprises about 12 species of deciduous trees and shrubs native to temperate and subtropical regions of Asia, Europe, and North America (Rehder 1956). Seeds of 2 native species and 2 naturalized species are described here (table 1). White (sometimes called "Russian") mulberry was introduced to the United States by Mennonites from Russia in 1875. The United States Prairie States Forestry Project planted an average of over 1 million trees of this species annually from 1937 through 1942 for windbreaks in the Great Plains from Nebraska to northern Texas (Read and Barnes 1974). The high drought resistance of white mulberry makes it well suited for shelterbelt planting (Read and Barnes 1974).

There are 2 mulberries indigenous to North America. Littleleaf mulberry occurs in Arizona, New Mexico, Oklahoma, Texas, and Mexico and has not been cultivated (table 1). Red mulberry has a wide range that covers most of the eastern United States, Great Lakes region, and the southern Great Plains. Though once common, red mulberry is decreasing over its range, possibly because of an unidentified bacterial disease (Moore and Thomas 1977). Its place is being taken by the introduced and naturalized white mulberry (Core 1974).

White mulberry is highly prized in Asia for its leaves, which are eaten by the silkworm—*Bombyx mori* L. The 7 or more forms and varieties of white mulberry differ in their relative drought resistance and in chromosome number and may be climatic races. Both white and red mulberry are diploids (2n=2x=28), but black mulberry has a high polyploidy level (2n=22x=308) (Ottman 1987).

Mulberries are valuable as food for birds and animals. Up to 18 bird species have been recorded eating the fruit in northeastern Kansas, with catbirds (*Dumetella carolinensis*) and robins (*Turdus migratorius*) consuming the most fruit (Stapanian 1982). Opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*), fox squirrels (*Sciurus niger*), and eastern gray squirrels (*S. carolinensis*) eat the fruit in appreciable amounts, and cottontail rabbits (*Sylvilagus floridanus*) feed on the bark in winter (Core 1974).

All the mulberry species have white sap that contains latex (Hora 1981). The heartwood is durable, making it

Table 1—*Morus*, mulberry: nomenclature and occurrence

Scientific name & synonyms	Common name(s)	Occurrence
***M. alba* L.** *M. alba* var. *tatarica* (L.) Ser.	**white mulberry,** Russian mulberry, silkworm mulberry	China; naturalized in Europe & North America
***M. microphylla* Buckl.**	**littleleaf mulberry,** Texas mulberry, mountain mulberry	Arizona, New Mexico, Oklahoma, Texas, & Mexico
***M. nigra* L.**	**black mulberry,** Persian mulberry	Iran; widely cultivated in Europe
***M. rubra* L.**	**red mulberry**	Vermont & Massachusetts to New York, extreme S Ontario, Michigan, & Wisconsin, SE Minnesota, SE Nebraska, central Kansas, W Oklahoma, central Texas, E to S Florida

Sources: Core (1974), Read and Barnes (1974), Wasson (2001).

usable for fenceposts. Other specialty products include farm implements, cooperage, furniture, interior finish, and caskets (Burns and Honkala 1990).

Flowering and fruiting. Mulberry plants are normally dioecious, but they can also be monoecious on different branches of the same plant. The pendulous pistillate (female) and staminate (male) catkins are arranged on spikes and appear in April and May (Rehder 1956). The pistillate catkins in white mulberry are 0.5 to 2 cm long and staminate catkins are 2.5 to 4 cm long (FNAEC 1997; Radford and others 1968). The pistillate catkins in red mulberry are 1 to 3 cm long and the staminate catkins are 3 to 5 cm long (Radford and others 1968).

The green, female flowers have 4 sepals, 1 pistil that is 2-parted at the top, and a 2-locular ovary positioned above the floral organs. The ovary is about 2 mm long (Radford 1968). The style in white mulberry is red-brown and 0.5 to 1 mm long; the styles in red and littleleaf mulberries are whitish and about 1.5 mm long (FNAEC 1997). All mulberries have hairy stigmas. On the average, 44% of the pistillate inflorescences are parthenocarpic, with seedless fruits being somewhat smaller than seeded fruits (Griggs and Iwakiri 1973). Some varieties—such as Illinois everbearing mulberry, a cross between red and white mulberries—do not produce seeds (Reich 1992).

The male flowers are green tinged with red and have 4 sepals and 4 stamens; the filiform filaments vary from 2.7 mm in white mulberry to 3 to 3.5 mm in red mulberry (FNAEC 1997). The anthers open longitudinally (Fernald 1970). The sepals are pubescent and vary from 1.5 mm long in white mulberry to 2 to 2.5 mm in red mulberry (FNAEC 1997).

According to Griggs and Iwakiri (1973), the mulberry ovary is similar to that of other fleshy drupaceous fruits both morphologically and in growth pattern; therefore, the seed should be classified as a drupelet rather than an achene or nutlet. In the development of the mulberry fruit, the calyx adheres to the ovary and becomes an accessory part of the drupelet.

The multiple fruit is composed of many small, closely appressed drupelets (figure 1). Cultivated fruits are about 2 cm long, but fruits from native-grown trees are usually less than 1 cm long and have a cylindrical shape (Hora 1981). White mulberry fruits measure 1.5 to 2.5 x 1 cm, littleleaf mulberry fruits, 1 to 1.5 cm long, and red mulberry fruits, 1.5 to 6 x 1 cm (FNAEC 1997).

Red mulberry bears on the average 50 multiple fruits per branch and yields about 8.6 fruits/g or 8,600 fruits/kg (3,900 fruits/lb) (Burns and Honkala 1990; Griggs and Iwakiri 1973; Halls 1973). Mature trees can produce about 3.7 hl (10 bu) of fruit (Reich 1992). Open-grown trees produce up to about 7 times the amount of fruits per plant than do trees growing in the understory (Halls 1973).

Figure 1—*Morus*, mulberry: fruit and leaves of *M. alba*, white mulberry (**left**) and *M. rubra*, red mulberry (**right**).

Each fruit contains a dozen or more small drupelets (figures 2 and 3) that have thin, membranous coats and endocarps (stones) (Griggs and Iwakiri 1973). White mulberry yields about 10.7 to 32.0 drupelets per fruit, whereas red mulberry yields 10.7 to 30.0 drupelets per fruit (Stapanian 1982). Red mulberry seeds ("stones") are 2.8 mm long and 1.8 mm wide, white mulberry seeds are 2 to 3 mm long, and littleleaf mulberry seeds are about 2 mm long (FNAEC 1997). Red and littleleaf mulberry seeds are yellowish, whereas white mulberry seeds are light brown. Seed yield is up to 22 g/tree for open-grown plants and up to 3 g/tree for understory plants (Halls 1973). Seed embryos are curved, with cotyledon tips nearly touching the radicle (figure 3).

Fruits ripen and drop from the trees during the months of June to August (table 2), though they are often dispersed by birds and animals. Fruiting season can be extended by applying plenty of water during the summer months (Reich 1992). Varieties differ in size and color of ripe fruit (figure 1 and table 3) and vary in taste from insipid to sweet. The fruits stain everything they touch, so that planting mulberries along patios, sidewalks, driveways, and parking lots is NOT recommended (Reich 1992). Large fruit crops appear nearly every year on white mulberry in the Great Plains (Read and Barnes 1974) (table 3). Seed bearing begins at about 5 years of age for white mulberry, 2 years for open-grown red mulberry, and 4 years for red mulberry in the understory (table 3) (Halls 1973). In forest stands, optimum

Figure 2—*Morus alba*, white mulberry: longitudinal section through a seed.

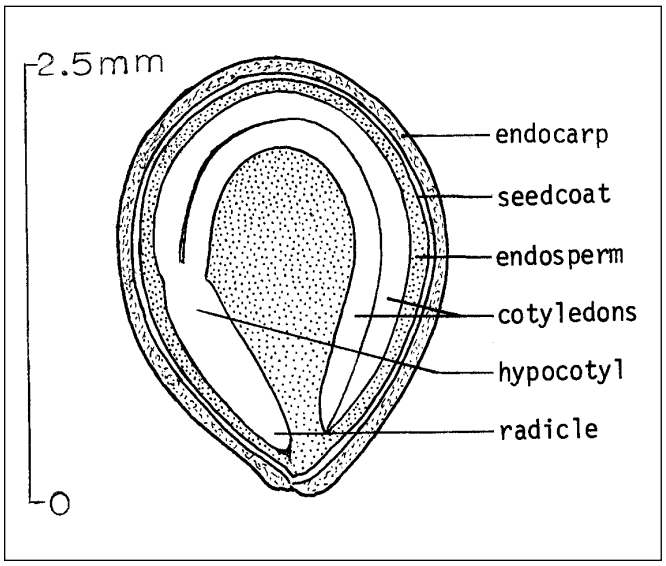
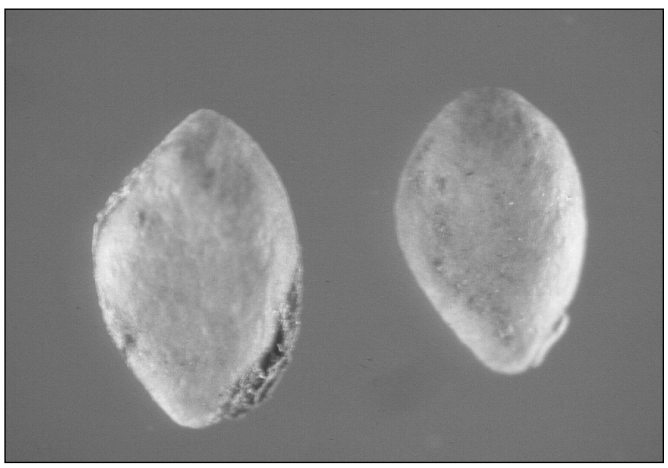


Figure 3—*Morus rubra*, red mulberry: cleaned seeds.



seed-bearing age is 30 to 85 years; the maximum being 125 years (Lamson 1990).

Collection of fruits. Before the fruits are collected, fruits from every tree should be sampled and checked, because mulberry fruits can develop without seeds. Ripe mulberry fruits may be collected by stripping, shaking, flailing, or waiting for them to fall from the tree onto a ground cloth. Fruits should be collected as soon as most are ripe to avoid loss to birds and animals. Seedlots of red mulberry fruits collected 4 to 5 days after falling yielded 89% germination, whereas seeds from fruits collected 1 to 2 weeks after falling reduced germination to 73% (Huffman 1996). Soaking red mulberry seeds in water for 48 and 72 hours reduced germination to 56 and 33%, respectively, making it advisable to not soak seeds for more than 24 hours (Huffman 1996). Seedlots from white mulberry fruits collected in early July that were cleaned and sown immediately showed 75% germination (Dirr and Heuser 1987). Fresh fruits, placed in tubs, can be stored in a cooler at 3 to 5 °C for up to 2 weeks without harming the seeds. Forty-five kilograms (100 lb) of fresh fruit of either species yields from 0.9 to 1.4 kg (2 to 3 lb) of clean seeds (Read and Barnes 1974) (table 4).

Extraction and storage of seeds. Fresh fruits are usually soaked in water and run through a macerator, where pulp and empty seeds are skimmed or floated off. If the fruits are not sufficiently ripe, soaking them in water for 24 hours will aid in the maceration. Fermentation at moderate indoor temperatures for 1 to 2 days before maceration facilitates extraction and improves viability of white mulberry seeds (Taylor 1941). A more efficient method is to spread the fruits on a clean floor, allow them to soften at room temperature for 4 to 5 days and then run them through a seed macerator with the water adjusted so that only the pulp goes through (the plate should be adjusted to 4 mm) (Engstrom

Table 2—*Morus*, mulberrry: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening
M. alba	E US	May	July–Aug
	Nebraska	May	June–Aug
	Oklahoma	Apr	Late May–June
M. microphylla	SW US	Apr–May	June–Aug
M. rubra	E US	Apr–May	June–Aug

Sources: Engstrom (1969), FNAEC (1997), Little and Delisle (1962), Read and Barnes (1974), Rehder (1956).

Table 3—*Morus,* mulberry: height, seed-bearing age, seedcrop frequency, and fruit ripeness criteria

	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yr)	Years between large crops	Fruit ripeness criteria	
					Preripe color	Ripe color
M. alba	3–14	1700s	5	—	White	White, pinkish, or purplish
M. microphylla	7.5	—	—	—	Dark green	Red, purple, or black
M. nigra	10	1548	—	Yearly	Greenish red	Purple to black
M. rubra	12	1629	10	2–3	—	Dark red, dark purple to black

Sources: Little and Delisle (1962), Read and Barnes (1974), Rehder (1956), Sargent (1940), Small (1933).

1969). The now-clean seeds remain. Small samples may be cleaned by rubbing the fruits gently through a 2.4-mm (#6) round-hole screen and floating off the pulp (Read and Barnes 1974). A 1% lye solution can be used to remove any sticky pulp left on the seeds after maceration.

Cleaned seeds should be spread to air-dry in the shade, then cleaned by fanning before storage or use. Lightweight trash and seeds can be removed with a gravity table (Myatt and others 1991). Subfreezing temperatures of –23 to –18 °C are recommended for storage of dry mulberry seeds (Engstrom 1969). Numbers of seeds per weight are listed in table 4.

Pregermination treatments. Germination of untreated seeds in the laboratory may vary greatly because part of each collection may consist of seeds with dormant embryos and impermeable seedcoats (Read and Barnes 1974). Engstrom (1969) found that some seeds that had no pretreatment—but were extracted from fruits that were fermented before the seeds were extracted—did germinate completely under light at low night and high day temperatures. Fresh seeds sown in the fall are usually not pretreated (Lamson 1990). For spring-sowing, stratification in moist sand at 0.6 to 5 °C for 30 to 120 days has improved germination (Afanasiev 1942; Core 1974; Lamson 1990; Read and Barnes 1974; Taylor 1941).

Germination tests. The International Seed Testing Association (ISTA 1999) recommends testing mulberry seeds on top of moist blotters for 28 days at diurnally alternating temperatures of 30 °C (day) for 8 hours and 20 °C (night) for 16 hours. No pretreatment is stipulated in the rules. Germination is epigeal. Red mulberry requires light to germinate under laboratory conditions (Dirr and Heuser 1987). Germination values of red mulberry seedlots obtained from official laboratory tests vary greatly. The germination after 30 days of cold moist stratification was 88% with 95% full seeds; germination after 60 days of cold moist stratification was 1 to 66% and after 90 days it was 3 to 68% (USDA FS 2002).

Tests on pretreated seeds run on wet absorbent paper, wet sand, and mixtures of sand and peat at the same temperature regime for 15 to 45 days with a daily light period of 8 to 16 hours resulted in germination ranging from 20 to 92% (Heit 1968; Read and Barnes 1974; Taylor 1941). In a laboratory study of seeds planted in sand, red mulberry seeds exhibited very high seedling emergence at 25 °C under moderate moisture conditions (4 to 20%) but did not germinate at 5 or 10 °C (Burton and Bazzaz 1991). Seedling emergence was calculated as 75% of the final emerging seedlings divided by the number of days required to achieve 75% emergence (Burton and Bazzaz 1991).

Nursery practice. In fall or spring, properly pretreated mulberry seeds mixed with sand may be broadcast or sown in drills. Rows can be drilled 20 to 30 cm (8 to 12 in) apart, with 164 seeds/m (50/ft) of row, and barely covered with soil. In Oklahoma, white mulberry is sown with 65 to 82 viable seeds/m (20 to 25/ft) in a 7.5- to 10-cm (3- to 4-in) band to produce 33 usable seedlings/m (10/ft) (Engstrom 1969). One Nebraska nursery uses a seedling density of 197 to 262/m of drill (60 to 80/ft) (Korves 1969). Freshly harvested and processed white mulberry seeds have been successfully hand-sown in July at 312 seeds/m^2 (29 seeds/ft^2), lightly raked, rolled, and then covered with straw mulch: germination occurred 2 weeks later (Peaslee 2002).

Beds should be mulched with straw, leaves, or burlap and kept moist until germination begins. Beds should be half-shaded for a few weeks after germination, which usually begins 1 to 2 weeks after spring-sowing (Dirr and Heuser 1987). Twelve to 50% of the seeds of white mulberry should produce usable seedlings. One-year-old seedling stock is used for field planting; seedlings should be dug about 25 cm (10 in) deep with a very sharp blade—main roots are rather stout and tough (Engstrom 1969).

Bacterial canker can be serious threat to white mulberry seedlings in the southern Great Plains; however, treatment of soil with formaldehyde solution before seeding has provided

Table 4—*Morus*, mulberry: seed yield data

Species	Seeds (x1,000)/weight				Samples
	Range		Average		
	/kg	/lb	/kg	/lb	
M. alba	286–770	130–350	517	235	18+
M. rubra	440–1,100	200–500	792	360	4

Sources: Engstrom and Stoeckler (1941), Read and Barnes (1974), Swingle (1939).

adequate control. Mulberry seedbeds should not be located near older mulberry trees (Davis and others 1942). Damping-off may occasionally be a problem, but losses are usually minimal, probably due to nursery cultural methods presently used (Wright 1944). Fungal leaf-spot caused by *Cercospora* spp. and *Mycosphaerella mori* (Fuckel.) E.A. Wolf, as well as bacterial leaf-spot caused by *Pseudomonas mori* (Boy. & Lamb.) Stev. may cause damage.

Mulberries are easy to root from summer softwoods; June and July are optimum months (Dirr and Heuser 1987). When mid-July cuttings were treated with 8,000 ppm IBA in talc and stuck into sand, 100% rooted in 3 weeks (Dirr and Heuser 1987).

References

Afanasiev M. 1942. Propagation of trees and shrubs by seed. Circ.C106. Oklahoma Agricultural Experiment Station. 43 p.

Burton PJ, Bazzaz FA. 1991. Tree seedling emergence on interactive temperature and moisture gradients and in patches of old-field vegetation. American Journal of Botany 78(1): 131–149.

Core EL. 1974. Red mulberry, *Morus rubra* L. In: Gill JD, Healy WM, comp. Shrubs and vines for northeastern wildlife. Gen. Tech. Rep. NE-9. Upper Darby, PA: USDA Forest Service, Northeastern Forest Experiment Station: 106–107.

Davis WC, Wright E, Hartley C. 1942. Diseases of forest-tree nursery stock. For. Pub. 9. Washington, DC: USDA Civilian Conservation Corps. 79 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Dirr MA. 1998. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation and uses. 5th ed. Champaign, IL: Stipes Publishing. 1187 p.

Engstrom A. 1969. Personal communication. Oklahoma City: Oklahoma Department of Agriculture, Forestry Division.

Engstrom HE, Stoeckler JH. 1941. Nursery practice for trees and shrubs suitable for planting on the Prairie-Plains. Misc. Pub. 434. Washington, DC: USDA. 159 p.

Fernald ML. 1970. Gray's manual of botany. 8th ed. New York: Van Nostrand Co. 1632 p.

FNAEC [Flora of North America Editorial Committee]. 1997. Flora of North America North to Mexico. Volume 3, Magnoliophyta: Magnoliidae and Hamamelidae. New York: Oxford University Press: 390–392.

Griggs WH, Iwakiri BT. 1973. Development of seeded and parthenocarpic fruits in mulberry (*Morus rubra* L.). Journal of Horticultural Science 48: 83–97.

Halls LK. 1973. Flowering and fruiting of southern browse species. Res. Pap. SO-90. New Orleans: USDA Forest Service, Southern Forest Experiment Station. 10 p.

Heit CE. 1968. Thirty-five years' testing of tree and shrub seed. Journal of Forestry 66: 632–634.

Hora B, ed. 1981. The Oxford encyclopedia of trees of the world. Oxford, UK: Oxford University Press. 288 p.

Huffman GR. 1996. Seed handling and propagation of hardwood trees and shrubs at Oklahoma Forestry Services' Forest Regeneration Center. In: Landis TD, South DB, tech coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-389. Portland, OR: USDA Forest Service, Pacific Northwest Research Station: 43–48.

ISTA [International Seed Testing Association]. 1999. International rules for testing seeds: rules 1999. Seed Science and Technology 27 (Suppl.) 333 p.

Korves T. 1969. Correspondence. Fremont, NE: Plumfield Nursery.

Lamson NI. 1990. *Morus rubra* L., red mulberry. In: Burns RM, Honkala BH. tech. coords. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk 654. Washington, DC: USDA Forest Service: 470–473.

Little EL Jr, Delisle AL. 1962. Time periods in development: forest trees, North American. In: Altman PL, Dittmer DS, eds. Growth including reproduction and morphological development. Washington, DC: Federation of American Societies for Experimental Biology: 382–386.

Myatt A, Huffman G, Odell J. 1991. Seed processing manual. Washington, OK: Oklahoma Department of Agriculture, Forestry Division, Forest Regeneration Center.

Moore DM, Thomas WP. 1977. Red mulberry, *Morus rubra* L. In: Halls LK, ed. Southern fruit-producing woody plants used by wildlife. Gen. Tech. Rep. SO-16. New Orleans: USDA Forest Service, Southern Forest Experiment Station: 55–56.

Ottman Y. 1987. Rediscovering the realm of fruiting mulberry varieties. Fruit Varieties Journal 41(1): 4–7.

Peaslee A. 2002. Personal communication. Jackson, NJ: New Jersey Forest Tree Nursery.

Radford AE, Ahles HE, Bell CR. 1968. Manual of the vascular flora of the Carolinas. Chapel Hill: University of North Carolina Press. 1183 p.

Read RA, Barnes RL. 1974. *Morus* L., mulberry. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk 450. Washington, DC: USDA Forest Service: 544–547.

Rehder A. 1956. Manual of cultivated trees and shrubs hardy in North America. 2nd ed. New York: Macmillan. 996 p.

Reich L. 1992. Native American fruits. Organic gardening 39(2): 52, 54–57.

Sargent CS. 1940. Manual of the trees of North America (exclusive of Mexico). 2nd ed., corrected and reprinted. New York: Dover. 934 p.

Small JK. 1933. Manual of the southeastern flora. New York: J.K. Small. 1554 p.

Stapanian MA. 1982. A model for fruiting display: seed dispersal by birds for mulberry trees. Ecology 63(5): 1432–1443.

Swingle CF, comp. 1939. Seed propagation of trees, shrubs, and forbs for conservation planting. SCS-TP-27. Washington, DC: USDA Soil Conservation Service. 198 p.

Taylor CA. 1941. Germination behavior of tree seeds. Washington, DC: USDA Forest Service, Prairie States Forestry Project. 64 p.

USDA FS [USDA Forest Service]. 2002. Unpublished data. Dry Branch, GA: National Tree Seed Laboratory.

Wasson E. 2001. Trees and shrubs: illustrated A–Z of over 8500 plants. Willoughby, NSW, Australia: Global Book Publishing: 483–484.

Wright E. 1944. Damping-off in broadleaf nurseries of the Great Plains region. Journal of Agricultural Research 69: 77–94.

Myricaceae—Bayberry family

Myrica L. *and Morella* Lour.

bayberry

Jason J. Griffin and Frank A. Blazich

Dr. Griffin is assistant Professor at Kansas State University's Department of Horticulture, Forestry, and Recreation Resources, Manhattan, Kansas; Dr. Blazich is alumni distinguished graduate professor of plant propagation and tissue culture at North Carolina State University's Department of Horticultural Science, Raleigh, North Carolina

Synonyms and common names. Considerable disagreement exists regarding taxonomy of the Myricaceae, particularly the number and classification of genera within the family. Inclusion of the genera *Myrica* and *Comptonia* L'Hér. ex Aiton in the Myricaceae appears to be universal (Bornstein 1997; Kartesz 1994; Radford and others 1968; Small 1933; Weakley 2000; Wilbur 1994). However, species within the genus *Myrica* and its division into 2 separate genera are still being debated (Bornstein 1997; Weakley 2000; Wilbur 1994). If the Myricaceae are divided into 3 genera, sweet gale *(M. gale* L.*)* and Sierra sweet-bay *(M. hartwegii* S. Wats.*)* are the only species that remain in the genus *Myrica* (Weakley 2000; Wilbur 1994). The other species formerly in the genus *Myrica* are grouped under a third genus which, depending on the authority, is either *Morella* Lour. (Weakley 2000; Wilbur 1994) or *Cerothamnus* Tidestrom (Small 1933). Radford and others (1968) also divide *Myrica* into 2 genera. However, in their view, sweet gale is removed from *Myrica* and placed in the genus *Gale* Adanson.

The newly standardized plant nomenclature of USDA (the PLANTS database of the National Resources Conservation Service), which is being followed in this publication, places the former *Myrica* species into 2 genera—*Myrica* and *Morella*. Both genera are included in this chapter on *Myrica* because the *Morella* nomenclature is not widely known (table 1). The reader should be aware that further division of *Myrica* is possible in the future and the above cited references should be consulted for more information.

Occurrence, growth habit, and uses. Bayberries—both *Myrica* and *Morella*—include about 35 to 50 species of

Table 1—*Morella* and *Myrica,* bayberry and wax-myrtle: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***Morella californica* (Cham. & Schlecht.) Wilbur** *Myrica californica* Cham. & Schlecht.	**California wax-myrtle,** California bayberry, Pacific bayberry	Pacific Coast from Washington to California
***Morella cerifera* (L.) Small** *Myrica cerifera* L. *Myrica pusilla* Raf. *Cerothamnus ceriferus* (L.) Small *C. pumilus* (Michx.) Small *Morella pumila* (Michx.) Small	**southern wax-myrtle,** southern bayberry waxberry, candleberry	New Jersey to S Florida, W to Texas & N to Arkansas (swampy or sandy soils with low pH)
***Morella faya* (Ait.) Wilbur** *Myrica faya* Ait.	**candleberry-myrtle**	Canary Islands, Madeira, & Portugal
***Morella pensylvanica* (Mirbel) Kartesz** *Myrica pensylvanica* *Cerothamnus pensylvanica* (Mirbel) Moldenke *M. caroliniensis* auct. non Mill.	**northern bayberry** bayberry, candleberry	Alaska to Newfoundland, S to Pennsylvania, W to Wisconsin, Washington, & Oregon; isolated areas of Tennessee & North Carolina (swampy soils) Coastal plain from Newfoundland & Nova Scotia S to North Carolina
***Myrica gale* L.** *Gale palustris* Chev. *Myrica palustris* Lam.	**sweet gale,** bog-myrtle, meadow-fern	

deciduous or evergreen shrubs and trees (Bornstein 1997; Huxley 1992; LHBH 1976). Six are native to North America; of these only California wax-myrtle, southern wax-myrtle, sweet gale, and northern bayberry are of any horticultural significance. Another species—candleberry-myrtle, which is native to the Canary and Madeira Islands—was introduced into Hawaii and has achieved considerable ecological impact (Walker 1990).

The evergreen California wax-myrtle and southern wax-myrtle can be maintained as shrubs or allowed to grow to 10.5 m in height, whereas candleberry-myrtle, also evergreen, matures at a shorter height of 7.5 m. The deciduous sweet gale and the deciduous or semi-evergreen, multi-stemmed northern bayberry are species that attain heights of 1.5 and 2.7 m, respectively (LHBH 1976).

Species of bayberry have both ecological and landscape significance. Their ability to associate with symbiotic nitrogen-fixing bacteria—*Frankia* Brunchorst spp.—makes them well adapted for land-reclamation efforts. California wax-myrtle, candleberry-myrtle, and northern bayberry have been used for this purpose, as they establish and grow well in near-sterile soils (Everett 1981; Walker 1990). Candleberry-myrtle performs so well under these conditions that it is now considered a noxious weed in Hawaii, becoming a co-dominant species in areas of the Hawaii Volcanoes National Park (Walker 1990). Southern wax-myrtle and northern bayberry are well suited to coastal marine environments because they will tolerate soils high in salt that may be saturated with water or prone to drought (Bir 1992). Both species are extremely versatile and can be used as shrubs or trained to grow as attractive multi-stemmed small trees.

Bayberries are valued also for their ornamental attributes. California wax myrtle has lustrous dark green foliage and attractive purple fruits (Everett 1981). The foliage of southern wax-myrtle and northern bayberry is pleasantly aromatic when crushed. Birds are attracted to the wax-covered fruits of these species, and the wax is used to scent candles and soaps (Fordham 1983). Medicinal properties as well as ornamental characteristics were the rationale for introducing candleberry-myrtle into Hawaii (Walker 1990). Sweet gale also has been used for medicinal purposes, as well as flavoring beer in Europe (Everett 1981).

Geographic races and hybrids. Individual plants of southern wax-myrtle, which inhabit dry, sandy soils, tend to be more rhizomatous and ultimately attain a smaller size with smaller morphological characteristics than individuals growing in fertile soils (Bornstein 1997). These plants are commonly referred to as *Morella cerifera* var. *pumila* Michx. (*M. pusilla* Raf.) and are usually < 1 m in height; they occur on dry, sandy pinelands and prairies from Texas to North Carolina and Florida (Elias 1971). However, it is uncertain if these differences are genetic or environmentally influenced, and therefore assignment of varietal status is uncertain (Bornstein 1997). Leaf pubescence of sweet gale can be quite variable and is reflected in 2 varieties—*M. gale* var. *subglabra* (Chev.) Fern. and *M. gale* var. *tomentosa* C. DC. (Elias 1971; Kartesz 1994). Other authors, however, do not recognize these as valid varieties (Bornstein 1997). Few selections of particular species have been reported in the literature. However, one—*Morella cerifera* 'Emperor'—is distinguished by elongated, deeply serrate leaves (Brackin 1991).

Flowering and fruiting. Flowers of bayberries are small and inconspicuous. Time of flowering is variable, depending on the species (table 2). Male inflorescences consist of catkins usually < 2 cm long; female inflorescences are ovoid and sessile up to 1 cm in length (Huxley 1992). Fordham (1983) reported that southern wax-myrtle, sweet gale, and northern bayberry are all dioecious. However, there are reports of monoecious forms of sweet gale. Even more interesting is the phenomenon that individual plants of sweet gale have been observed altering their sex from year to year (Everett 1981). Plants of California wax-myrtle are monoecious (Krochmal 1974). Fruit maturation generally occurs in late summer to fall (table 2). Fruits are small spherical drupes usually covered with a wax coating (figures 1 and 2) that ranges in color from gray-green to purple (Huxley 1992). Fruits of sweet gale, however, are surrounded by 2 wing-like bracts and form a catkin by clustering around a central axis (Fordham 1983).

Figure 1—*Morella cerifera*, southern wax-myrtle: wax-coated drupe (**left**) and cleaned drupe (**right**).

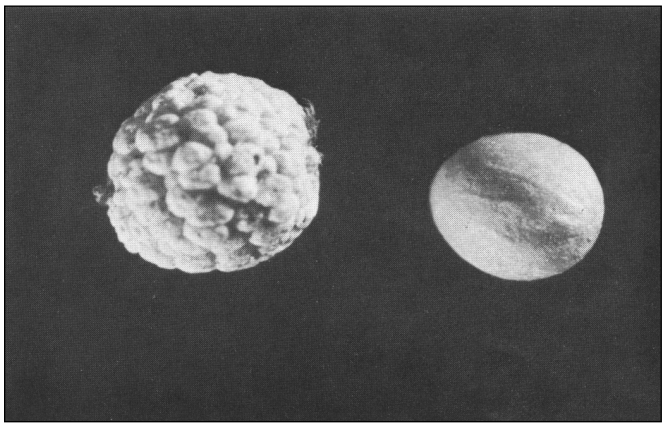
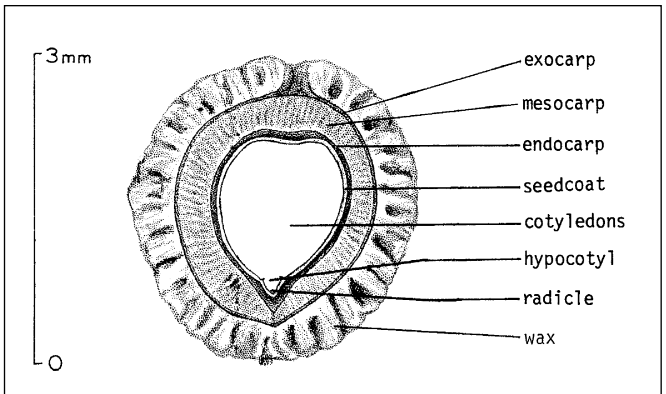


Table 2—*Morella* and *Myrica,* bayberry and wax-myrtle: flowering and fruiting characteristics

Species	Flowering	Fruit ripening	Color of ripe fruit	Diam of ripe fruit (mm)	Cleaned seeds/wt /kg	Cleaned seeds/wt /lb
Morella californica	May–June	Sept	Brownish purple with grayish white wax	6	48,000	22,000
Morella cerifera	Mar-June	Aug–Oct	Light green with pale blue wax	3	185,000	84,000
Morella faya	Variable	Aug–Nov	Red to purple	5	—	—
Myrica pensylvanica	Apr–July	Sept–Oct	Covered with grayish white wax	4	121,000	55,000
Myrica gale	Mar–Apr	Oct	Lustrous & dotted with resin	3	—	—

Sources: Fordham (1983), Huxley (1992), Krochmal (1974), Krüssmann (1984), Schwintzer and Ostrofsky (1989), Walker (1990).

Figure 2—*Morella cerifera*, southern wax-myrtle: longitudinal section of a drupe.



Collection of fruits, seed extraction and cleaning. Ripe drupes can be harvested by stripping branches by hand or shaking them from the branches onto ground sheets. After harvest, they should be handled as seeds (Krochmal 1974). Therefore, seed extraction and cleaning are often unnecessary except as mentioned below.

Seed storage. Fordham (1983) suggested that drupes should be stored intact to avoid desiccation of their seeds; drupes of northern bayberry stored in this manner remained viable for 9 months at room temperature (Krochmal 1974). Most evidence, however, suggests that bayberry seeds are orthodox and should be dried to low moisture contents and stored at low temperatures. Dirr and Heuser (1987) recommend that wax be removed before long-term (10 to 15 years) dry storage at 1 to 3 °C. Seeds of sweet gale air-dried at room temperature for 28 days following collection and stored dry at 5 °C remained viable for 6 years (Schwintzer and Ostrofsky 1989). Optimum moisture contents for storage of bayberry seeds are not known, but similar seeds of other orthodox species store well at 6 to 10% moisture.

Pregermination treatments and germination tests. All species of bayberry discussed herein require pregermination treatments for optimum germination. Those species with wax-covered drupes require that the wax be removed. This can be accomplished by abrasion with a screen or with a warm water soak (Fordham 1983). Following wax removal, stratification (moist-prechilling) for approximately 90 days at 5 °C is necessary to overcome dormancy. However, stratification is ineffective if wax remains (Fordham 1983). Fruits of sweet gale, which lack a wax coating, will germinate in low percentages without stratification. However, best germination occurs following 6 weeks stratification at 5 °C (Schwintzer and Ostrofsky 1989). Seeds of candleberry-myrtle also germinate without any pregermination treatments. However, a fleshy mesocarp and stony endocarp are inhibitory to germination. Removal of the mesocarp and scarification of the endocarp will significantly increase germination (Walker 1990).

Fordham (1983) investigated seed germination of southern wax-myrtle. Seeds were subjected to 4 treatments: no stratification with no wax removal; stratification at 5 °C for 90 days with no wax removal; no stratification with wax removal; and stratification with wax removal. Germination for the first 3 treatments was very poor (6, 17, and 6%, respectively), whereas that for the fourth treatment was significant (data not available).

Schwintzer and Ostrofsky (1989) conducted an extensive study on seed germination of sweet gale. Among factors investigated were the effects of stratification, light, and gibberellic acid (GA) treatment. Some germination (38%) was noted with no stratification or GA treatment. However, stratification for 3, 6, or 12 weeks at 5 °C significantly increased germination with the highest (66%) occurring following 6 weeks of stratification. Without stratification, GA treatment at 500 ppm (0.05%) stimulated germination (48%).

However, germination was reduced when GA was used in combination with stratification. Seeds did not germinate in the dark. Germination was about 12% when seeds were exposed to light for a single 16-hour photoperiod (80 μmol/m²/sec) and then placed in darkness for 28 days. Maximum germination (about 35%) occurred following exposure to 4 such photoperiods.

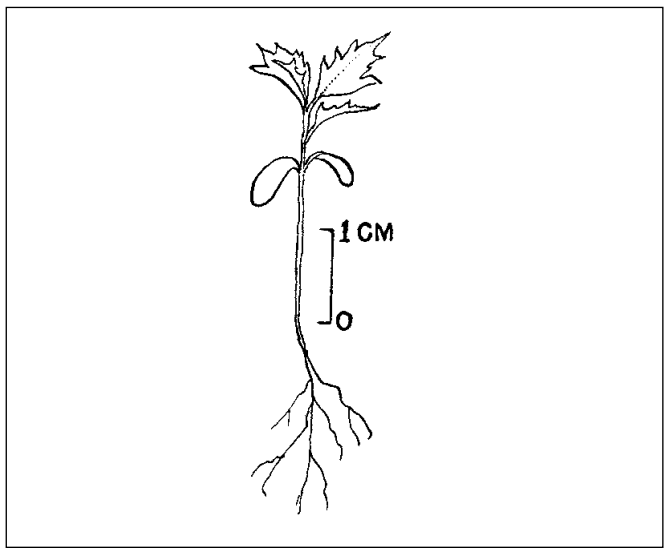
Hamilton and Carpenter (1977) investigated effects of scarification, stratification, and exogenous growth regulator treatment on seed germination of northern bayberry. After their wax was removed, seeds were either scarified with coarse sandpaper or not. Seeds were then soaked in 0, 100 (0.01%), 500 (0.05%), or 900 ppm (0.09%) GA_3 or 6-furfurylamino purine (kinetin) at 0, 25 (0.0025%), or 100 ppm (0.01%) for 24 hours at 22 °C. Following scarification and growth regulator treatments, seeds were sown in flats containing a 1:1 peat/perlite (v/v) medium. Then, flats were placed in sealed polyethylene bags for stratification at 5 °C for 0, 15, or 30 days. After stratification, flats were removed from the bags and placed in a greenhouse at 25 °C for germination periods of 20, 40, 60, or 80 days. Kinetin had no effect on germination unless seeds were scarified and stratified for 30 days. When seeds were scarified and stratified, germination after 80 days was 4, 20, and 28% for seeds treated with 0, 25, or 100 ppm kinetin. Highest germination of scarified seeds followed by stratification for 0 or 15 days was 4 and 8%, respectively. GA_3 proved more effective in promoting germination. Germination after 80 days for scarified seeds was 8, 25, 69, and 65% for seeds treated with 0, 100, 500, or 900 ppm GA_3, respectively. Reducing the length of stratification significantly decreased germination. Germination of nonscarified seeds was similar to scarified seeds following 0 or 15 days of stratification. However, germination was enhanced provided seeds were scarified followed by stratification for 30 days.

Walker (1990) studied the effects of various environmental factors on germination of candleberry-myrtle. He found that storage periods >10 weeks at 20 °C significantly reduced germination. He also noted that germination of seeds collected after passage through the digestive tract of birds (normal method of dissemination) did not differ significantly in comparison to seeds collected directly from trees. Irrigating seeds with water steeped with litter of native woody species and candleberry-myrtle (leachate), densely shading seeds (>55% shade), and covering sown seeds with 0.5 cm of medium all reduced germination. Germination was promoted by removal of the fleshy mesocarp.

Nursery practice and seedling care. For field production, seeds can be sown in fall or spring. Fall-sowing should be sufficiently late to avoid germination before winter, and seedbeds should be mulched. Spring-sowing should follow a period of stratification at 5 °C for 90 days (Krochmal 1974). If container production is desired, seeds may be sown indoors in early spring, and the seedlings repotted before moving outdoors for further growth. Germination is epigeal (figure 3) (Young and Young 1992).

Asexual propagation has been successful to varying degrees depending on species. Blazich and Bonaminino (1984) reported that terminal stem cuttings of southern wax-myrtle, in a transitional growth stage between softwood and semi-hardwood, rooted in high percentages. Cuttings treated with solutions of indolebutyric acid (IBA) at 0, 1,000 (0.1%), 2,000 (0.2%), or 4,000 ppm (0.4%) resulted in rooting of 87, 97, 87, and 90%, respectively. Cutting propagation of northern bayberry is more challenging. However, softwood cuttings can be rooted successfully when treated with a solution of 5,000 ppm (0.5%) IBA (Dirr and Heuser 1987). Most bayberry species produce root suckers and can be propagated by division as well as by root cuttings (Dirr and Heuser 1987).

Figure 3—*Morella californica*, California wax-myrtle: 1-month-old seedling.



References

Bir RE. 1992. Growing and propagating showy native woody plants. Chapel Hill: University of North Carolina Press. 192 p.

Blazich FA, Bonaminio VP. 1984. Propagation of southern waxmyrtle by stem cuttings. Journal of Environmental Horticulture 2(2): 45–48.

Bornstein AJ. 1997. Myricaceae. In: Flora of North America Editorial Committee, eds. Flora of North America north of Mexico. Volume 3, Magnoliophyta: Magnoliidae and Hamamelidae. New York: Oxford University Press: 429–434.

Brackin RL. 1991. Wax myrtle named Lane. United States Plant Patent 7555.

Dirr MA, Heuser Jr. CW. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Elias TS. 1971. The genera of Myricaceae in the southeastern United States. Journal of the Arnold Arboretum 52(2): 305–318.

Everett TH. 1981. The New York Botanical Garden illustrated encyclopedia of horticulture. Volume 7. New York: Garland Publishing: 2131–2492.

Fordham AJ. 1983. Of birds and bayberries: seed dispersal and propagation of three *Myrica* species. Arnoldia 43(4): 20–23.

Hamilton DF, Carpenter PL. 1977. Seed germination of *Myrica pensylvanicum* L. HortScience 12(6): 565–566.

Huxley A, ed. 1992. The new Royal Horticultural Society dictionary of gardening. Volume 3. New York: Stockton Press. 790 p.

Kartesz JT. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. 2nd ed. Volume 1. Portland, OR: Timber Press. 622 p.

Krochmal A. 1974. *Myrica*, bayberry. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 548–550.

Krüssmann G. 1984. Manual of cultivated broad-leaved trees and shrubs. Volume 1. Portland, OR: Timber Press. 624 p.

LHBH [Liberty Hyde Bailey Hortorium]. 1976. Hortus third: a concise dictionary of plants cultivated in the United States and Canada. 3rd ed. New York: Macmillan. 1290 p.

Radford AE, Ahles HE, Bell CR. 1968. Manual of the vascular flora of the Carolinas. Chapel Hill: University of North Carolina Press. 1183 p.

Schwintzer CR, Ostrofsky A. 1989. Factors affecting germination of *Myrica gale* seeds. Canadian Journal of Forest Research 19(9): 1105–1109.

Small JK. 1933. Manual of the southeastern flora. Chapel Hill: University of North Carolina Press. 1554 p.

Walker LR. 1990. Germination of an invading tree species (*Myrica faya*) in Hawaii. Biotropica 22(2): 140–145.

Weakley AS. 2000. Flora of the Carolinas and Virginia: working draft of 15 May 2000. Chapel Hill, NC: Nature Conservancy, Southeast Regional Office, Southern Conservation Science Department [available in draft from the author].

Wilbur RL. 1994. The Myricaceae of the United States and Canada: genera, subgenera, and series. SIDA 16(1): 93–107.

Young JA, Young CG. 1992. Seeds of woody plants in North America. Portland, OR: Timber Press. 407 p.

N

Hydrophyllaceae—Waterleaf family

Nama lobbii Gray
woolly nama

Eamor C. Nord and Andrew T. Leiser

Dr. Nord (deceased) retired from the USDA Forest Service's Pacific Southwest Forest and Range Experiment Station; Dr. Leiser is professor emeritus at the University of California's Department of Horticulture Davis, California

Other common names. Lobb fiddleleaf.

Growth habit, occurrence, and use. There are 2 perennial species in this genus, both low-growing, suffruticose plants native to California, Nevada, and Utah. Only the sub-shrub woolly nama—*Nama lobbii* Gray—has potential for revegetation use, as it can provide a rather persistent, dense groundcover. The other species—Rothrock fiddleleaf, *N. rothrockii* Gray—furnishes only a sparse cover that dies back to the roots each year.

Woolly nama is native to the Sierra Nevada and Cascade ranges in east central and northern California, and western Nevada at elevations of 1,220 to 2,100 m within ponderosa (*Pinus ponderosa* Dougl. ex Laws.) or Jeffrey (*P. jeffreyi* Grev. & Balf.) pine and California red fir (*Abies magnifica* A. Murr.) forests. It occurs in sunny, exposed locations with slightly to moderately acid soils derived mostly from volcanic mud flows and decomposed granites. Plants 15 to 60 cm tall are generally sparse and widely scattered (McDonald and Oliver 1984). However, where the tree or associated shrub overstory is removed, such as by logging or other mechanical means, woolly nama spreads rapidly to form dense crowns up to 1.5 m in diameter on individual plants (McDonald and Fiddler 1995). Fast-growing roots that extend up to 5 m or more in a single year contain a profusion of adventitious buds that sprout to form new plants.

Woolly nama has many characteristics that make it desirable for revegetation on adapted sites. The low growth habit helps reduce fire hazards in brush-cleared areas, and its abundant, aggressive sprouting habit together with dense foliage provides good groundcover. It is known to offer strong competition and thus reduce growth of young conifers within plantations (McDonald and Oliver 1984). Although it is not regarded as a serious weed pest in areas where it occurs naturally, care should be exercised to prevent introduction and possible spread of this plant into cultivated croplands, mainly because of its aggressive rooting habits, which enable the plant to withstand cultivation.

Flowering and fruiting. The numerous small purple flowers are borne in reduced terminal cymes or in axillary angles along slightly erect stems; they appear from May to September. The fruit is a capsule containing 10 to 12 oval, angular, very dark brown seeds up to 1.5 mm long (figures 1 and 2). The capsules mature in late August, September, and October. In a test of a cleaned seedlot, seeds measured 1 to 1.3 mm in diameter; 85% of the seeds in the lot were filled and there were about 2,000 seeds/g (56,875/oz).

Collection, extraction, and storage. Mature seeds may be hand-stripped or flailed directly into containers, or seed heads together with some foliage may be harvested mechanically during late September and thereafter until snow covers the ground. One means is to use a rotary lawnmower equipped with a collection bag and set at maximum height that clips and gathers the material, which is later dried and threshed. The seeds may be extracted by threshers or hammermills, and cleaned with aspirators or air-screen cleaners. A collection made in the Tahoe basin, using this type of equipment, yielded over 1.8 kg (4 lb) of clean seeds from about 59 kg (130 lb) of dry clippings (Nord and Leiser 1974). Only half of the total number of seeds was released from capsules during clipping and drying, and the remaining seeds had to be extracted and separated by a hammermill and South Dakota Seed Blower. No precise data are available on longevity of woolly nama seeds, but they are presumed to be orthodox in storage behavior and should remain

Figure 1—*Nama lobbii*, woolly nama: seed.

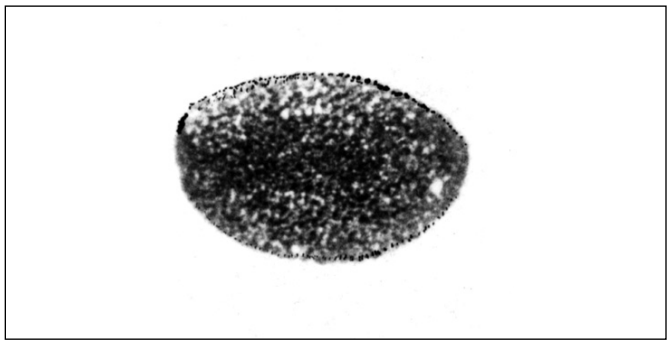
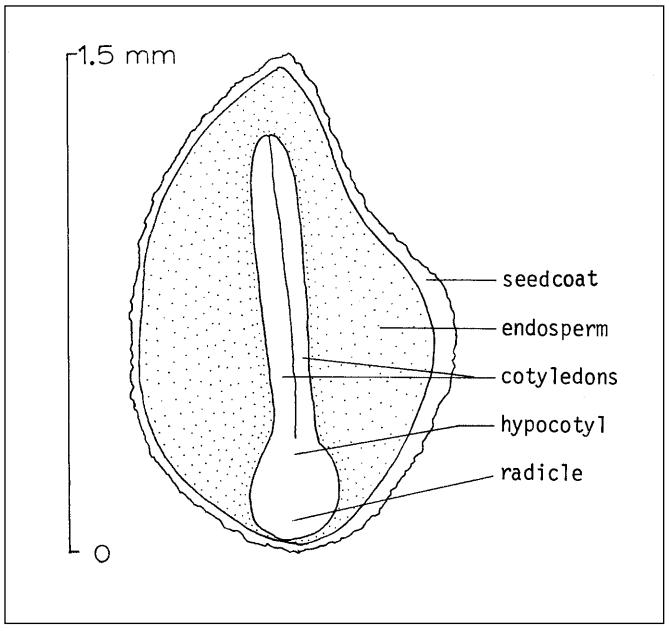


Figure 2—*Nama lobbii*, woolly nama: longitudinal section through a seed.



viable for a number of years when stored dry at low temperatures.

Germination. Woolly nama seeds exhibit what apparently is seedcoat dormancy. Stratification has no effect, but when the seedcoats are removed, up to 60% of the seeds will germinate. The dormancy may be due to a chemical that is found in the seedcoat. Extracts of the colored leachate obtained from seeds kept under intermittent mist contained an anionic polyphenol that may inhibit germination (Nord and Leiser 1974). Leaching woolly nama seeds for 3 days under intermittent mist for 3 seconds at 2-minute intervals, followed by soaking in 200 ppm gibberellic acid, yielded 39% germination. Other treatments in which gibberellic acid was used yielded as much as 30% total germination, but sulfuric acid, thiourea, hydrogen peroxide, and hot water treatments were not effective in improving germination. In laboratory tests , the first observed germination was at 12 days and germination continued intermittently thereafter throughout a 4-month period (Nord and Leiser 1974).

Because of the very low and slow germination, it is most unlikely that woolly nama can establish itself satisfactorily from direct field seeding unless seeds are treated in some manner to break dormancy. This appears to be the case even in native stands, where seedling plants are rarely found; presumably most natural establishment or spread of this species comes from root segments transported during some form of soil disturbance.

Nursery and field practice. The best method known to prepare the seeds for sowing calls for leaching the seeds under intermittent mist or running water for 2 to 3 days, soaking in gibberellic acid that is constantly agitated, and air-drying thoroughly. The seeds should not be rinsed or washed. Soaking for 2 hours in 200 ppm or stronger gibberellic acid solution is suggested if seeds are to be sown within a few days after treatment. If seeding is to be delayed for more than about 10 days and soil moisture conditions are unpredictable, stronger solutions and longer soak times (probably up to 500 ppm for periods up to 24 hours) should be used to reduce risks of leaching should rains occur before seeds germinate. Seeding should be done in the late fall or very early spring to take advantage of the most favorable moisture conditions for germination and seedling establishment. Seeds may be sown separately or mixed with rice hulls as a diluent and carrier at a depth of about 12 mm ($^1/_2$ in) on properly prepared, firm seedbeds where competing vegetation has been previously removed.

The plant makes its best development on medium-textured, well-drained soils that are neutral to moderately acid in reaction. The plants are susceptible to gopher damage to the roots in southern California, but they appear to be immune from damage to the foliage by animals, including rabbits, which often damage or destroy many other shrub or herbaceous species.

Rooting either stem cuttings or root sections of woolly nama has not been too successful. In several trials, only 30% of stem cuttings rooted, and none survived when transplanted into pots. Root cuttings failed to regenerate new plants, although some fresh shoots became green and grew slightly (Nord and Goodin 1970).

References

McDonald PM, Fiddler GO. 1995. Development of a mixed shrub–ponderosa pine community in a natural and treated condition. Res. Pap. PSW-224-web. Albany, CA: USDA Forest Service, Pacific Southwest Research Station. 19 p.

McDonald PM, Oliver WW. 1984. Woody shrubs retard growth of ponderosa pine seedlings and saplings. In: Proceedings, 5th Annual Forest Vegetation Management Conference; 1983 November 2–3; Redding, CA. Redding, CA: Forest Vegetation Management Conference: 65–89.

Nord EC, Goodin JR. 1970. Rooting cuttings of shrub species for plantings in California wildlands. Res. Note PSW-213. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. 4 p.

Nord EC, Leiser AT. 1974. *Nama lobbii* Gray, woolly nama. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 551–552.

Berberidaceae—Barberry family

Nandina domestica Thunb.

nandina

Laura G. Jull and Frank A. Blazich

Dr. Jull is assistant professor at the University of Wisconsin's Department of Horticulture, Madison, Wisconsin; Dr. Blazich is alumni distinguished graduate professor of plant propagation and tissue culture at North Carolina State University's Department of Horticultural Science, Raleigh, North Carolina

Other common names. heavenly-bamboo, sacred-bamboo, *nanten*.

Occurrence, growth habit, and uses. *Nandina* is a monotypic genus indigenous from India to central China (Huxley and others 1992; Krüssmann 1985; Ohwi 1984). It was introduced into Japan from China before the sixteenth century (Coats 1992). The species is a broadleaf evergreen, upright, flat-topped shrub reaching a height of 1.5 to 2.4 m with a spread of 1.0 to 1.5 m that can spread by root suckers into large colonies (Dirr 1990; Whitcomb 1996). Plants are characterized by numerous, unbranched stems with horizontal branches. However, with age, they tend to become leggy and open, unless pruned properly (Flint 1997). The species is hardy to USDA Zone 6 (Dirr 1990) and will remain evergreen in USDA Zones 7–8. It becomes deciduous when exposed to colder temperatures (Gibson 1982).

In Japan, nandina is called *nanten*,"sacred-bamboo," as fruiting twigs are sold in winter to decorate altars, both in temples and private homes (Coats 1992; Krüssmann 1985; Richards and Kaneko 1988). There, nandina is planted close to the entrances of homes because the plant is used to comfort family members who have bad dreams. The wood is aromatic and very close grained; it is considered by the Japanese to be flavorful and suitable for toothpicks (Coats 1992). The plant is reputed to have medicinal properties effective in treatment of various ailments (Ikuta 1994).

Nandina is cultivated commonly in the United States because of several desirable landscape attributes. The new, finely dissected leaves are bronze to red, becoming blue-green with age, and turning a dull purple to bright red in winter (Flint 1997). Flowers occur in large panicles held above the foliage and are followed in the fall by showy, bright red berries produced in clusters that persist throughout the winter. The stems give the appearance of bamboo (Flint 1997). Plants are adaptable to many different soils; they tolerate sun, shade, and drought; and they are pest free (Dirr 1990; Whitcomb 1996).

Geographic races and hybrids. Nandina has been in cultivation for centuries. China and Japan are considered as sources of dwarf selections. Cultivars with fern-like foliage, distorted branchlets, and white, yellow, or crimson fruits occur in the nursery trade (Dirr 1990).

Flowering and fruiting. Nandina will flower and produce fruit in heavy shade to full sun (Dirr 1990). Plants fail to set fruit if planted singly, so it is best to plant groupings of several plants to ensure cross pollination (Gibson 1982). Inflorescences are erect, terminal, 20- to 38-cm-long white panicles that appear from May to June. Individual flowers are perfect, 6 to 13 mm across, and pinkish in bud, opening to white with yellow anthers. The fruits are globular, bright red berries that are 8 mm in diameter with 2 seeds; they ripen in the fall and persist through the winter (Dirr 1990).

Collection of fruits, seed extraction, and cleaning. Fruits should be harvested when mature in the fall. Removal of the fleshy pulp is recommended and is accomplished easily by maceration (Dirr and Heuser 1987; Gibson 1982). After fruits are soaked in water for 24 hours and macerated, the seeds (figures 1 & 2) can be separated from the fleshy pulp (Newman 1991).

Seed storage. Due to the presence of a rudimentary embryo, seeds should be stored under slightly moist conditions at 4 °C, then sown in late spring or summer to obtain uniform and rapid germination (Dehgan 1984; Hartmann and others 1997). Seeds held in cold storage for 9 to 10 months germinate as well as those sown immediately after seed extraction and do so without appreciable loss in viability (Afanasiev 1943; Dirr and Heuser 1987).

Pregermination treatments. Seeds exhibit delayed germination due to a rudimentary embryo and slow rate of embryo development (Dirr and Heuser 1987). The rudimentary embryo is formed after flowering in August and September and during fruit enlargement in winter. However, further development is arrested during spring and summer months (Afanasiev 1943), although embryo maturation can

Figure 1—*Nandina domestica*, nandina: seeds.

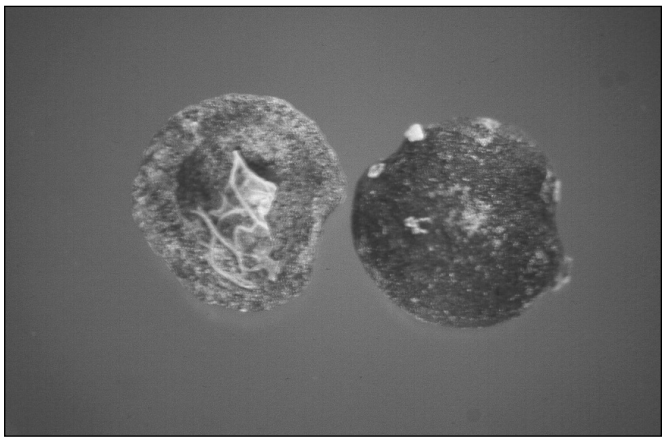
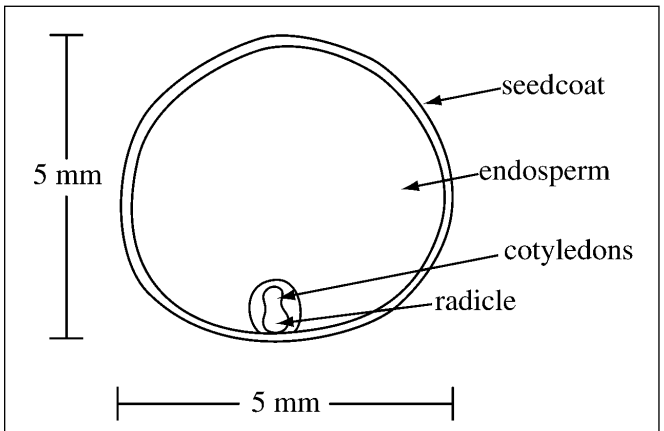


Figure 2—*Nandina domestica*, nanadina: longitudinal section of a seed.



occur during cold storage (Hartmann and others 1997). Embryo development also can occur regardless of whether seeds are stored at high or low temperatures or in moist or dry environments (Dirr and Heuser 1987).

Seeds of nandina have a tendency to germinate only during late fall or early winter, regardless of the sowing date (Afanasiev 1943; Hartmann and others 1997). Attempts to overcome this response—by cold stratification, treatment with various chemical compounds, increased oxygen pressure during germination, or varying the time of planting—have all been unsuccessful (Afanasiev 1943). Afanasiev concluded that cold stratification neither hastened embryo development nor improved germination. To speed embryo development, Dirr and Heuser (1987) recommend warm stratification of seeds for several months, followed by cold stratification for several months. In contrast, Hartmann and others (1997) reported that cold stratification was not necessary for seed germination.

Dehgan (1984) further investigated seed germination of nandina. Seeds were placed under dry or moist conditions at 4 or 30 °C for 0, 6, or 12 weeks. Another group of seeds was first treated with 1,000 ppm (0.1%) gibberellic acid (GA_3) for 24 or 48 hours followed by cold stratification at 4 °C or warm stratification at 30 °C for 0, 6 or 12 weeks. Results demonstrated that cold stratified seeds sown in a greenhouse in February had the greatest germination (78%) with the shortest germination time (3 weeks). Seeds that were cold-stratified for 12 weeks germinated more rapidly and uniformly compared to those stratified for 6 weeks. Neither GA_3 treatment nor warm stratification (30 °C) resulted in greater germination than nontreated seeds. Alternating periods of cold–warm, warm–cold, or warm stratification alone had little effect on increasing germination.

Germination tests. At present, optimum conditions for seed germination of nandina have not been defined. Two years are required for germination if seeds are sown in the fall (Dirr 1990). Dirr and Heuser (1987) reported 65% germination of seeds sown immediately following collection. However, time of actual germination was not reported.

Nursery practice. Although seeds can be germinated, commercial propagation of nandina is typically accomplished by vegetative means. If sexual propagation is desired, nandina seeds should be sown 6 mm ($^1/_4$ in) deep in a moist, sterile medium at 21 °C. The medium needs to be covered with polyethylene film and the container placed in bright light. Germination tends to be slow and generally occurs in about 60 days (Gibson 1982; Hartmann and others 1997). Seedlings tend to be relatively uniform (Whitcomb 1996).

Stem cuttings can be rooted anytime of year (except during the spring flush) with success rates of 80 to 90% (Barr 1987; Hartmann and others 1997). Auxin treatment of cuttings is beneficial (Barr 1987; Dirr and Heuser 1987). However, rooting tends to be slow (Bean 1976). Once stems have hardened, which is indicated by a reddening of the foliage, they become more difficult to root (Dirr and Heuser 1987; Gwaltney 1983). In addition, division of side shoots and removal of suckers that appear at the bases of plants have been successful, especially on dwarf cultivars (Dirr and Heuser 1987; Gwaltney 1983; Hartmann and others 1997). This is best accomplished in spring before growth begins.

Micropropagation protocols for nandina are currently being used commercially (Briggs and McCulloch 1983; Dirr 1990). *In vitro* techniques have been used to eliminate viruses from nandina (Smith 1983).

References

Afanasiev M. 1943. Germinating *Nandina domestica* seeds. American Nurseryman 78 (9): 7–8.

Barr B. 1987. Propagation of dwarf nandina cultivars. Combined Proceedings of the International Plant Propagators' Society 37: 507–508.

Bean WJ. 1976. Trees and shrubs hardy in the British Isles. 8th ed. Volume 3. London: John Murray Co. p. 1.

Briggs BA, McCulloch SM. 1983. Progress in micropropagation of woody plants in the United States and western Canada. Combined Proceedings of the International Plant Propagators' Society 33: 239–248.

Coats AM. 1992. Garden shrubs and their histories. New York: Simon and Schuster. 223 p.

Dehgan B. 1984. Germination of *Nandina domestica* seed as influenced by GA_3 and stratification. Proceedings of the Florida State Horticultural Society 97: 311–313.

Dirr MA. 1990. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation, and uses. 4th ed. Champaign, IL: Stipes Publishing Co. 1007 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Flint HL. 1997. Landscape plants for eastern North America: exclusive of Florida and the immediate Gulf Coast. 2nd ed. New York: John Wiley and Sons. 842 p.

Gibson G. 1982. The bamboo alternative. American Horticulturist 61(10): 4, 7–10, 36.

Gwaltney T. 1983. Propagation of dwarf nandina cultivars. Combined Proceedings of the International Plant Propagators' Society 33: 624–628.

Hartmann HT, Kester DE, Davies Jr FT, Geneve RL. 1997. Plant propagation: principles and practices. 6th ed. Upper Saddle River, NJ: Prentice Hall. 770 p.

Huxley A, Griffiths M, Levy M. 1992. The new Royal Horticultural Society dictionary of gardening. Volume 3. London: Macmillan. 790 p.

Ikuta A. 1994. *Nandina domestica* (heavenly bamboo): *in vitro* culture and the production of jatrorrhizine, berberine, and other alkaloids. In: Bajaj YPS, ed. Biotechnology in agriculture and forestry: Medicinal and aromatic plants VI. Volume 26. Berlin: Springer-Verlag: 259–268.

Krüssmann G. 1985. Manual of cultivated broad-leaved trees and shrubs. Volume 2. Portland, OR: Timber Press. 624 p.

Newman SE. 1991. Germination of doubly dormant woody ornamental seeds. Combined Proceedings of the International Plant Propagators' Society 41: 359–364.

Ohwi J. 1984. Flora of Japan. Washington, DC: Smithsonian Institution. 1067 p.

Richards BW, Kaneko A. 1988. Japanese plants: know them and use them. Tokyo: Shufunotomo Co.: 98–99.

Smith RH. 1983. *In vitro* propagation of *Nandina domestica*. HortScience 18(3): 304–305.

Whitcomb CE. 1996. Know it and grow it: 3. A guide to the identification and use of landscape plants. Stillwater, OK: Lacebark Publications and Research. 802 p.

Aquifoliaceae—Holly family

Nemopanthus mucronatus (L.) Loes.

mountain-holly

John C. Zasada and C. S. Schopmeyer

Dr. Zasada retired from the USDA Forest Service's North Central Research Station; Dr. Schopmeyer (deceased) retired from the USDA Forest Service's Research National Office

Growth habit, occurrence, and use. Mountain-holly is a deciduous, branchy shrub occasionally attaining small tree stature that occurs in swamps, bogs, and poor fens from Newfoundland to Minnesota and south to Virginia and Indiana. Heights at ages 5, 10, 20, 30, and 40 years for plants in a shrub-dominated peatland in New York were 1.4, 2.0, 3.5, 4.0, and 4.5 m, respectively (LeBlanc and Leopold 1992). It is regarded as an obligate wetland species: 99% of the plants grow in wetlands (Begin and others 1990; Curtis 1959; Reed 1988; Vitt and Slack 1975). It is typically found on acidic to mildly acidic soils in the shrub zone adjacent to bog mats (Cram 1988).

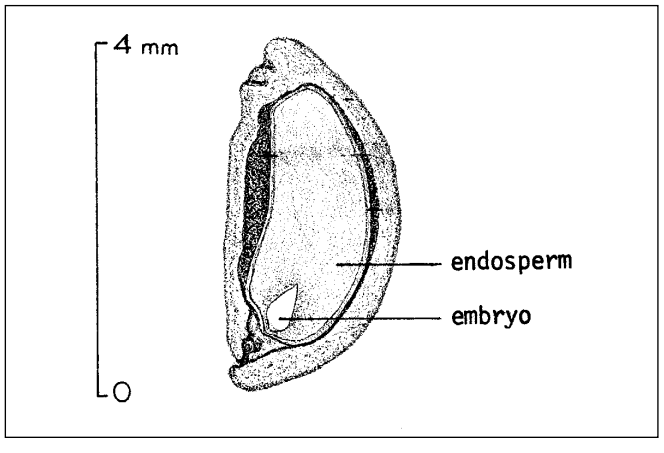
Nemopanthus is a monospecific genus and is closely related to *Ilex* spp. Similarities between *Ilex* and *Nemopanthus* in anatomical characteristics provide a basis for combining the 2 genera, but at this time it is maintained as a separate genus (Baas 1984). Information from Bonner (1974) for *Ilex* seeds is relevant to *Nemopanthus*. The species was introduced into cultivation in 1802.

Flowering, fruiting, and seed collection. This species is mainly dioecious, with some monecious individuals (Farrar 1995). Flowering occurs in early May to June; fruits ripen as early as July, continuing into August; animals disperse the seeds (Gorchov 1990). The fruit is a scarlet, dull-red berrylike drupe, 0.6 to 2.5 cm in diameter, containing 4 to 5 bony nutlets (Rehder 1940), although Gorchov (1990) found a mean of 2.9 seeds/fruit. The latter are somewhat crescent shaped and are bone colored, with 1 rib on the back (figure 1). Because the fruits are somewhat persistent, they may be collected as late as mid-October (Schopmeyer 1974).

Extraction and cleaning of seeds. Seeds in small lots can be prepared by rubbing the fruits through a #10 soil screen (0.7mm) and then floating off the pulp and empty seeds. There are about 1,600 berries in 0.45 kg (1 lb) of fruit. The number of cleaned seeds per weight (3 samples) ranged from 68,355/kg (31,000 to 66,000/lb), with an average of 99,225/kg (45,000/lb). Seed purity in one sample was 96% and average soundness in 4 samples was 80% (Schopmeyer 1974).

Germination. Seeds are doubly dormant and require a period of after-ripening before the immature embryo will develop (figure 1) (Dirr and Heuser 1987). Consequently, germination is very slow. In 3 tests, germination began several months after sowing and continued for about 2 years, when germination capacities of 14 to 66% were observed

Figure 1—*Nemopanthus mucronatus*, mountain-holly: longitudinal section through a nutlet showing small immature embryo (**left**) and nutlet (**right**)



(Adams 1927; Schopmeyer 1974). Cold stratification alone did not increase germination rate (Adams 1927; Nichols 1934). Dirr and Heuser (1987) recommended 5 months of warm followed by 3 months of cold stratification. Propagation by greenwood cuttings is feasible (Bailey 1937; Dirr and Heuser 1987).

References

Adams J. 1927. The germination of the seeds of some plants with fleshy fruits, American Journal of Botany 14: 415–425.

Baas P. 1984. Vegetative anatomy and the taxonomic status of *Ilex collina* and *Nemopanthus* (Aquifoliaceae). Journal of the Arnold Arboretum 65: 243–250.

Bailey LH. 1937. The standard cyclopedia of horticulture. 3 vol. New York: Macmillan. 3639 p.

Begin J, Belanger L, Pfalzgraf J, Pineau M. 1990. Qualite de production dans les erablieres rouges de la plaine Drummondville, Quebec. Forestry Chronicle 66(4): 377–386.

Bonner FT. 1974. *Ilex* L., holly. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington DC: USDA Forest Service: 450–453.

Curtis JT. 1959. The vegetation of Wisconsin: an ordination of plant communities. Madison: University of Wisconsin Press: 655 p.

Cram H. 1988. A focus on peatlands and peat mosses. Ann Arbor: University of Michigan Press. 306 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Farrar JL. 1995. Trees in Canada. Markham, ON: Fitzhenry and White. 502 p.

Gorchov DL. 1990. Pattern adaptation and constraint in fruiting synchrony within verterbrate dispersed woody plants. Oikos 58: 169–180.

LeBlanc CM, Leopold DJ. 1992. Demography and age structure of a central New York shrub-carr 94 years after fire. Bulletin of the Torrey Botanical Club 119(1): 50–64.

Nichols GE. 1934. The influence of exposure to winter temperatures upon the seed germination in various native American plants. Ecology 15: 364–373.

Reed PB JR. 1988. National list of plant species that occur in wetlands. Biol. Rep. 88 (26.1), Northeast Region (region 1). Washington DC: USDI US Fish and Wildlife Service, Northeast Region.

Rehder A. 1940. Manual of cultivated trees and shrubs. 2nd ed. New York: Macmillan. 996 p.

Schopmeyer CS. 1974. *Nemopanthus mucronatus* (L.) Trel., mountain holly. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington DC: USDA Forest Service: 553.

Vitt DH, Slack NG. 1975. An analysis of the vegetation of sphagnum-dominated kettle-hole bogs in relation to environmental gradients. Canadian Journal of Botany 53: 332–359.

Nyssaceae—Sour-gum family

Nyssa L.

tupelo

Franklin T. Bonner

Dr. Bonner is a scientist emeritus at the USDA Forest Service's Southern Research Station, Mississippi State, Mississippi

Growth habit and use. The 4 deciduous, arboreal species of tupelo—the genus *Nyssa*—native to North America (table 1) are valued for pulp, veneer, specialty wood products, wildlife food, and honey production. Water tupelo, black tupelo, and swamp tupelo were cultivated in North America before 1750 (Bonner 1974; Brown and Kirkman 1990).

Flowering and fruiting. The minute, greenish white flowers that appear in spring (table 2) may be either perfect or staminate and pistillate; flowers may be borne separately on different trees. Fruits of the tupelos are thin-fleshed, oblong drupes about 10 to 38 mm long (figure 1). Their colors range from red to blue-black when they ripen in the autumn (table 2). Each fruit contains a bony, ribbed, usually 1-seeded stone (figures 2 and 3). Seeds of water tupelo range in color from white to dark brown or gray, and some are pinkish white. Seeds of all colors have germinated equally well (Bonner 1974). Trees of Ogeechee tupelo will bear fruit when they are about 5 years old (Kossuth and Scheer 1990), and 2-year-old stump sprouts of both swamp

Table 1—*Nyssa,* tupelo: nomenclature, occurrence, and height

Scientific name & synonym(s)	Common name(s)	Occurrence	Height at maturity (m)
***N. aquatica* L.** *N. uniflora* Wangenh.	**water tupelo,** tupelo-gum, sourgum, cotton-gum, swamp tupelo	Coastal Plain from Virginia to N Florida & Texas N to Missouri & S Illinois	24–30
***N. biflora* Walt.** *N. sylvatica* var. *biflora* (Walt.) Sarg. *N. sylvatica* var. *ursina* (Small) Wen & Stuessy	**swamp tupelo,** blackgum, swamp, black-gum	Coastal Plain, chiefly from Delaware to S Florida & E Texas, N to W Tennessee	40
***N. ogeche* Bartr. ex. Marsh.** *N. acuminata* Small	**Ogeechee tupelo,** Ogeechee-lime, sour tupelo, sour tupelo-gum, white tupelo	Coastal Plain from South Carolina to NW Florida	12–15
***N. sylvatica* Marsh.**	**black tupelo,** blackgum, sourgum, tupelo-gum, pepperidge	Maine W to Michigan & Missouri, S to E Texas & S Florida	15–18

Source: Little (1978).

Table 2—*Nyssa,* tupelo: phenology of flowering and fruiting

Species	Flowering	Fruit ripening	Color of ripe fruits	Fruit drop
N. aquatica	Mar–Apr	Sept–Oct	Dark purple	Oct–Dec
N. biflora	Apr–June	Aug–Oct	Blue-black	Sept–Dec
N. ogeche	Mar–May	July–Aug	Red	Nov–Dec
N. sylvatica	Apr–June	Sept–Oct	Blue-black	Sept–Nov

Sources: DeBell and Hook (1969), Kossuth and Scheer (1990), Radford and others (1964), Vande Linde (1964).

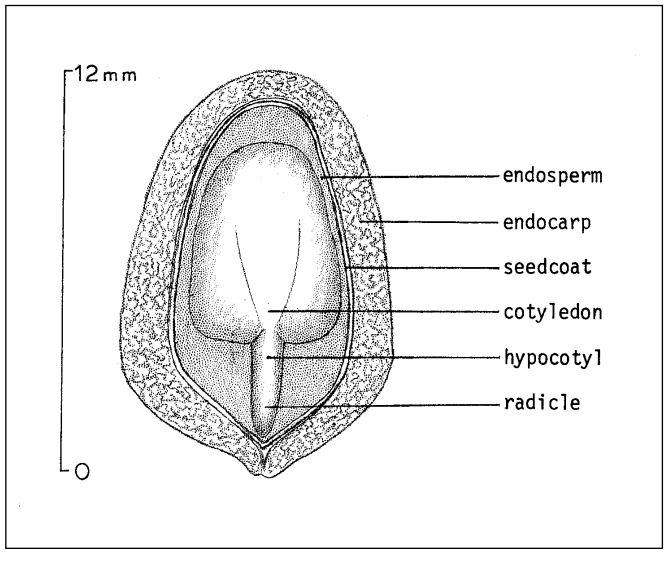
Figure 1—*Nyssa*, tupelo: fruits of *N. aquatica*, water tupelo (**upper left**); *N. sylvatica*, black tupelo (**upper right**); *N. ogeche*, Ogeechee tupelo (bottom).

Figure 2—*Nyssa,* tupelo: stones (seeds) of *N. aquatica*, water tupelo (**upper left**); *N. ogeche*, Ogeechee tupelo (**upper right**); *N. sylvatica*, black tupelo (**lower right**); *N. biflora*, swamp tupelo (**lower right**).

tupelo and water tupelo have produced viable seeds (Priester 1979). Major seed production can be expected when trees reach a dbh of about 20 cm, and all of the tupelos typically fruit abundantly each year (Johnson 1990; Kossuth and Scheer 1990; McGee and Outcalt 1990).

Collection, extraction, and storage. Ripe tupelo fruits may be picked from the ground, from standing trees, or from freshly felled logging tops. Newly shed fruits of water tupelo with exocarps intact will float for as long as 100 days, and they may be skimmed from the top of the water or picked from drift piles (Johnson 1990; Schneider and Sharitz 1988). Ogeechee tupelo fruits that are partially

Figure 3—*Nyssa sylvatica*, black tupelo: longitudinal section through a seed.



dried may float also (Kossuth and Scheer 1990), but fruits of the other tupelos do not (McGee and Outcalt 1990). External fruit color is the best index of maturity in the field (table 2). To extract the seeds, the fruits should be run through a macerator with running water to float off the pulp. Small samples may be de-pulped by rubbing the fruits over a large-meshed screen, such as hardware cloth. For water tupelo, observed numbers of fruits per weight have been from 340 to 600/kg (155 to 270/lb). Fifty kilograms (100 lb) of black tupelo fruits should yield 12 kg (25 lb) of cleaned seeds (Bonner 1974). Seed weights are listed in table 3.

Water tupelo seeds are orthodox in storage behavior. They can be stored for at least 30 months in polyethylene bags at either 3 or –10 °C, if seed moisture contents are <20% or <10%, respectively (Bonner and Kennedy 1973). Seeds of black tupelo can be stored satisfactorily over 1 winter in cold, moist stratification in sand or in just cold storage (Vande Linde 1964). Removal of the pulp did not appear to be essential for retention of viability in either condition. There are no published storage data for other tupelo species, but it is probable that the same methods would be successful for them also.

Pregermination treatment. Tupelo seeds exhibit moderate embryo dormancy, and they benefit from cold, moist stratification. Treatment in moist sand and in plastic bags without medium have been used successfully (Bonner 1974; DeBell and Hook 1969). Good germination has been reported after only 30 days of stratification, but periods up

to 120 days may be needed for some seedlots (Bonner 1974; DuBarry 1963).

Germination tests. Official seed testing prescriptions for tupelos in North America (AOSA 1993) call for a temperature regime of 8 hours at 30 °C in light and 16 hours at 20 °C in the dark. Testing should be on moist blotters or creped cellulose wadding for 21 days (water tupelo) or 28 days (black tupelo). Stratification for 28 to 30 days should precede the test. Germination of stratified seeds has been tested in several other media (table 4), and each of these probably would be satisfactory for seeds of all tupelo species.

Nursery practice. Although untreated seeds may be sown in the fall (Heit 1967) spring-sowing of stratified seeds is recommended, particularly in the South. They may be broadcast or drilled in rows, with 50 seeds/m (15/ft) for water tupelo. Seeds should be planted 12 to 25 mm ($^1/_2$ to 1 in) deep or sown on the bed surface and rolled into the soil and mulched (Bonner 1974; Vande Linde 1964). Mulching with 2 to 3.5 cm (.8 to 1.4 in) of sawdust is recommended for water tupelo and with 6 mm ($^1/_2$ in) of sawdust or 1 cm (.4 in) of pine straw for swamp tupelo. After sowing, the seeds and mulch must not be allowed to dry excessively.

Table 3—*Nyssa,* tupleo: seed weights

Species	Collection place	Cleaned seeds/weight: Range /kg	Range /lb	Avg /kg	Avg /lb	Samples
N. aquatica	—	—	—	1,000	456	—
N. biflora	South Carolina	—	—	5,320	2,415	10
N. ogeche	—	2,300–3,100	1,040–1,420	2,700	1,230	2
N. sylvatica	—	4,100–8,820	1,850–4,000	7,280	3,300	5
	North Carolina	5,750–8,500	2,610–3,860	7,450	3,380	10
	Midwest	—	—	5,500	2,492	2+

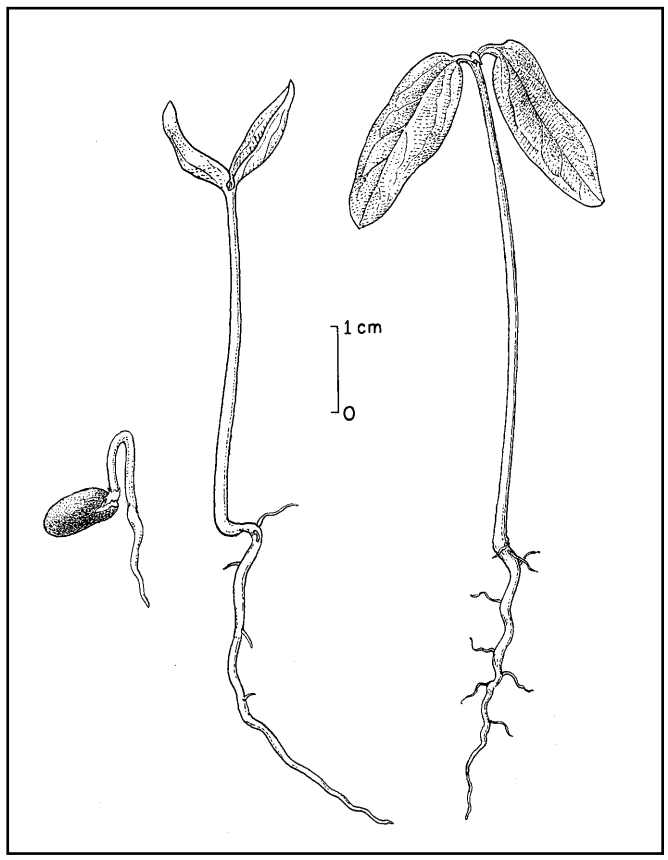
Sources: Bonner (1974), Earle and Jones (1969).

Table 4—*Nyssa,* tupelo: germination test conditions and results on stratified seeds

Species	Daily light (hr)	Germination test conditions: Medium	Temp (°C): Day	Night	Days	Germination rate: Amt (%)	Days	Germination %: Avg (%)	Samples	Purity (%)
N. aquatica	8	Kimpak	30	20	27	87	18	97	5	100
	0	Water in petri dish	29	29	28	57	14	79	24	—
N. biflora	ND	Sand	—	—	60	—	—	51	—	—
N. ogeche	8	Kimpak	30	20	70	69	12	85	1	—
N. sylvatica var. *sylvatica*	8	Kimpak	30	20	27	—	—	71	8	99

Sources: Bonner (1974), Debell and Hook (1969).
ND = natural daylength in a greenhouse.

Figure 4—*Nyssa sylvatica*, black tupelo: seedling development at 1, 4, and 39 days after germination.



Shading with tobacco shade cloth can help keep beds moist and aid the newly emerged seedlings (Vande Linde 1964). Germination is epigeal (figure 4). Desirable seedbed densities for water and black tupelos are 100 to 150 seedlings/m^2 (9 to 14/ft^2) (Williams and Hanks 1976. Vegetative propagation of tupelos is possible by softwood cuttings and grafting (Dirr and Heuser 1987).

References

AOSA [Association of Official Seed Analysts]. 1993. Rules for testing seeds. Journal of Seed Technology 16(3): 1–113.

Bonner FT. 1974. *Nyssa* L., tupelo. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 554–557.

Bonner FT, Kennedy HE Jr. 1973. Storage of water tupelo seeds. Tree Planters' Notes 24(4): 7–8.

Brown CL, Kirkman LK. 1990. Trees of Georgia and adjacent states. Portland, OR: Timber Press. 292 p.

DeBell DS, Hook DD. 1969. Seeding habits of swamp tupelo. Res. Pap. SE-47. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 8 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation. Athens, GA: Varsity Press. 239 p.

DuBarry AP Jr. 1963. Germination of bottomland tree seed while immersed in water. Journal of Forestry 61: 225–226.

Earle FR, Jones Q. 1962. Analyses of seed samples from 113 plant families. Economic Botany 16: 221–250.

Heit CE. 1967. Propagation from seed: 8. Fall planting of fruit and hardwood seeds. American Nurseryman 126 (4): 12–13, 85–90.

Johnson RL. 1990. *Nyssa aquatica* L., water tupelo. In: Burns RN, Honkala BH, tech. coords. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service: 474–478.

Kossuth SV, Scheer RL. 1990. *Nyssa ogeche* Bartr. ex Marsh., Ogeechee tupelo. In: Burns RM, Honkala BH, tech. coord. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service: 479–481.

Little EL Jr. 1978. Checklist of United States trees (native and naturalized). Agric. Handbk. 541. Washington, DC: USDA Forest Service. 375 p.

McGee CE, Outcalt KW. 1990. *Nyssa sylvatica* Marsh., black tupelo. *N. sylvatica* Marsh. var. *sylvatica*; black tupelo (typical), *N. sylvatica* var. *biflora* (Walt.) Sarg., swamp tupelo. In: Burns RM, Honkala BH, tech. coords. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service: 482–489.

Priester DS. 1979. Stump sprouts of swamp and water tupelo produce seeds. Southern Journal of Applied Forestry 3: 149–151.

Radford AE, Ahles HE, Bell CR. 1964. Guide to the vascular flora of the Carolinas. Chapel Hill: University of North Carolina Book Exchange. 1183 p.

Schneider RL, Sharitz RR. 1988. Hydrochory and regeneration in a bald cypress–water tupelo swamp forest. Ecology 69: 1055–1063.

Vande Linde F. 1964. Nursery practices for southern oaks and gums. Tree Planters' Notes 65: 24–26.

Williams RD, Hanks SH. 1976. Hardwood nurseryman's guide. Agric. Handbk. 473. Washington, DC: USDA Forest Service. 78 p.