B

Asteraceae—Aster family

Baccharis L.

baccharis

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Growth habit, occurrence, and use. The genus *Baccharis* is composed of more than 400 species native to tropical and subtropical America (Barkley 1986; Correl and Johnson 1970). Some species are used as ornamentals, some for erosion control, and some for medicinal purposes (Olson 1974). There are 21 species native to the United States (table 1); 14 of which are found in the far western United States. Baccharis plants are of poor forage value and some are poisonous to livestock and can cause contact dermatitis in humans. On the positive side, baccharis species have metabolites that have antitumor, antimicrobial, and insecticidal properties (Kuti and others 1990). Coyotebrush has a special use in southern California as a fire protection plant (Olson 1974). Desertbroom has been found suitable for copper mine reclamation in Arizona (Day and Ludeke 1980). Eastern baccharis is reported to be an important flower for beekeepers in Queensland, Australia (Westman and others 1975). Many species have good salt tolerance, and saltwater falsewillow and eastern baccharis are known for good growth in soil conditions that range from pure sand to pure clay (Dirr and Heuser 1987).

Growth habit varies considerably among the different species; a few examples follow. Saltwater falsewillow is a small evergreen shrub to 2.4 m high; eastern baccharis is deciduous to 3.6 m in height; Rooseveltweed is also deciduous, growing to 2.7 m or more; coyotebrush is a low evergreen shrub, 15 to 30 cm high, spreading out as much as 3 m; mulefat baccharis is an evergreen shrub to 3.6 m (LHBH 1976). Desertbroom is a shrub to 3.6 m (Sundberg 1993).

Flowering and fruiting. The white or yellowish male and female flowers, borne separately on different plants, are in heads that occur in clusters. In eastern baccharis, the male flowers are yellow and the female are white (Westman and others 1975). The female flowers develop into compressed, usually 10-ribbed achenes, tipped by a pappus of bristly hairs 13 mm long or less (figures 1 and 2). Achenes are dispersed by wind soon after ripening (table 2). Seedcrops are borne annually.

Quantities of seeds produced on an individual plant can be very high in full sunlight. A single plant of eastern baccharis has been estimated to produce over 1 million seeds (Westman and others 1975). Dense shade (3% of full sunlight) reduced seed production dramatically but did not totally eliminate it (Westman and others 1975).

Collection of fruits; extraction and storage of seeds. The ripe fruits of baccharis are either collected by hand or brushed onto cloth or plastic sheets spread beneath the shrubs. The fruits should be spread out to dry in a warm well-ventilated room or in the sun, protected from the wind. When dried, the fruits may be rubbed between the hands or treated in bulk to remove the pappus. Alternatively, full inflorescences can be fed into a brush machine, where the fruit is threshed from the stems and the pappus removed. The seeds can then be cleaned with air, screens, or other equipment described in the seed handling chapter. Sometimes the entire fruits are used without removing the pappus. The number of fruits per weight for coyotebrush is about 180,800/kg (82,000/lb) (1 sample); for mulefat baccharis, about 110,250/kg (50,000/lb) (1 sample) (Olson 1974). Cleaned seeds of baccharis species can be stored dry at 1.7 to 4.5 °C in airtight containers (McBride 1964). Data published by Westman and others (1975) indicate that seeds of eastern baccharis could be stored for 1 to 4 months at room temperature. After 4 months of room temperature storage, the final germination was actually slightly higher than with seeds stored for only 1 month. Panetta (1979) found that seeds stored in an atmosphere of 33% relative humidity maintained their germination of 98% for 12 months at 20 °C but that their percentage germination had dropped to 67% by 24 months. For seeds stored in the laboratory in a constant 70% relative humidity, germination began to drop at 6

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Table 1—*Baccharis,* baccharis: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***B. angustifolia* Michx.**	**saltwater falsewillow,** narrowleaf baccharis	North Carolina S to Florida, W to Louisiana
***B. bigelovii* Gray**	**Bigelow falsewillow**	Arizona, New Mexico, & Texas
***B. brachyphylla* Gray**	**shortleaf baccharis**	Arizona, California, Nevada, New Mexico, & Texas
***B. dioica* Vahl**	**broombush falsewillow**	Florida, Puerto Rico, & the Virgin Islands
***B. douglasii* DC**	**saltmarsh baccharis**	California & Oregon
***B. emoryi* Gray**	**Emory baccharis**	Arizona, California, Nevada, Texas, & Utah
***B. glomeruliflora* Pers.**	**silverling**	North Carolina to Florida, also Mississippi
***B. halimifolia* L.** *B. halimifolia* var. *angustior* DC.	**eastern baccharis**	Connecticut to Maryland, North Carolina to Florida & W to Mississippi, Arkansas
***B. havardii* Gray**	**Harvard falsewillow**	Texas
***B. myrsinites* (Lam.) Pers.**	**Santo Domingo falsewillow**	Puerto Rico
***B. neglecta* Britt.**	**Rooseveltweed**	Arizona, New Mexico, & Oregon
***B. pilularis* DC.** *B. pilularis* ssp. *consanguinea* (DC.) C.B. Wolf *B. pilularis* var. *consanguinea* (DC.) Kuntze	**coyotebrush,** kidneywort baccharis	California, New Mexico, & Oregon
***B. plummerae* Gray**	**Plummer baccharis**	California
***B. pteronioides* DC.**	**yerba de pasmo**	Arizona, New Mexico, & Texas
***B. salicifolia* (Ruiz & Pavon) Pers.** *B. viminea* DC. *Molina salicifolia* Ruiz & Pavon *B. glutiosa* Pers.	**mulefat baccharis**	California E to Texas & Utah
***B. sarothroides* Gray**	**desertbroom**	Arizona, California, Nevada, & Utah
***B. sergiloides* Gray**	**squaw waterweed baccharis**	Arizona, California, Nevada, & Utah
***B. texana* (Torr. & Gray) Gray** *Linosyris texana* Torr. & Gray	**prairie falsewillow**	New Mexico, Oklahoma, & Texas
***B. thesioides* Kunth**	**Arizona baccharis**	Arizona & New Mexico
***B. vanessae* Beauchamp** *B. glutinosa*	**Encinitis falsewillow**	California
***B. wrightii* Gray**	**Wright baccharis**	Arizona & Utah, E to Kansas, Oklahoma, & Texas

Sources: BONAP (1996), Olson (1974).

months. By contrast, seeds buried in the soil in the field at a depth of 5 cm maintained their germination rate at 99% for 2 years. Numbers of cleaned seeds per weight (determined from 1 sample, except for coyotobrush, which was determined from 2) for 4 species are as follows (McBride 1964; Mirov and Kraebel 1939; Olson 1974; Panetta 1979):

Species	seeds/kg	seeds/lb
saltwater falsewillow	4,989,600	2,268,000
eastern baccharis	10,000,000	4,500,000
coyotebrush	8,316,000	3,780,000
mulefat baccharis	11,000,000	5,000,000

Germination tests. Tests have been completed in 15 to 30 days at diurnally alternating temperatures of 30/20 °C (table 3). When comparing germination at constant 10, 15, 20, 25, 30, and 35 °C, Westman and others (1975) found that eastern baccharis germinated most quickly above 20 °C but germinated at higher numbers between 15 and 20 °C. Light was necessary for germination of eastern baccharis and mulefat baccharis. Without light, no or minimal germination was obtained. In another experiment with eastern baccharis (Panetta 1979), alternating temperatures of 19/22 °C partially compensated for the lack of light. However, in this same experiment, it was shown that an 8-hour photoperiod produced twice as much germination as constant light. Alternating temperatures were used and the effective range was from 19/22 °C to 19/24 °C. The ratio of red to far red light was also examined by Panetta (1979), but it was found to be important only when constant light was used. Therefore, either incandescent or fluorescent light for 8 hours each day would give good germination results for eastern baccharis. No pregermination treatments are needed (Emery 1964; McBride 1964; Mirov and Kraebel 1939), although prechilling at 5 °C for 1 week gave higher germi-

Figure 1—*Baccharis angustifolia,* saltwater falsewillow: achene with pappus (**top**); achenes with pappus removed (**bottom**).

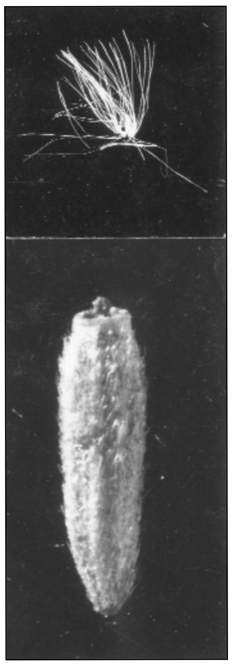
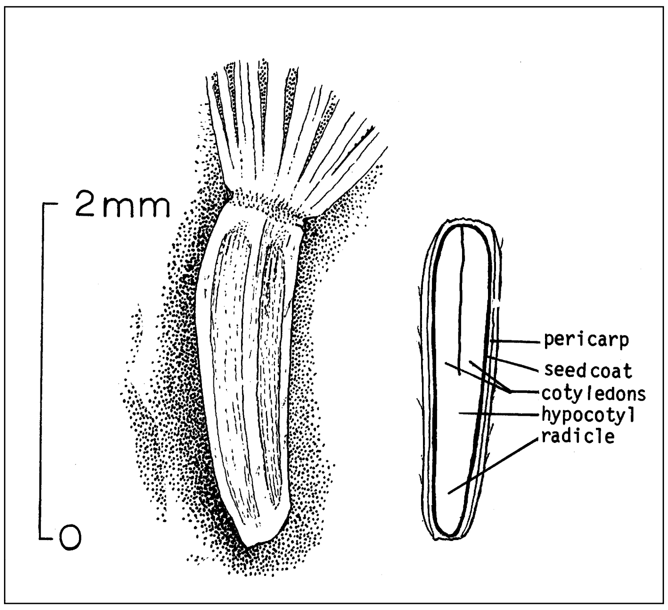


Figure 2—*Baccharis viminea,* mulefat baccharis: achene with pappus (**left**) and longitudinal section through an achene (**right**).



nation than no prechilling or prechilling at 0 °C when eastern baccharis was germinated at 10, 15, or 20 °C with continuous light. In a greenhouse test of eastern baccharis, there was no apparent reduction in germination under 56.7, 23.6, or 17.4% of full sunlight (Panetta 1990). Embryo excision was found to speed embryo germination in both Encinitis falsewillow and eastern baccharis (Kuti and others 1990), demonstrating that there is some inhibitory effect from the seedcoat.

Nursery practice. Seeds may be sown in the fall or early spring in flats or seedbeds using a sandy soil mixture, or one of the vermiculite, perlite, or sphagnum moss seeding media (Everett 1957). Seeds usually germinate within 7 to 15 days. Plants large enough for 10-cm (4-in) pots can be taken from outside seedbeds within 4 months (Everett 1957) (figure 3). Rooseveltweed seeds sown in 15-cm-deep (6-in-deep) pots germinated slowly, requiring 1 month to establish seedlings (Van Auken and Bush 1990).

Figure 3—*Baccharis pilularis,* coyotebrush: seedling development 60 days after germination.

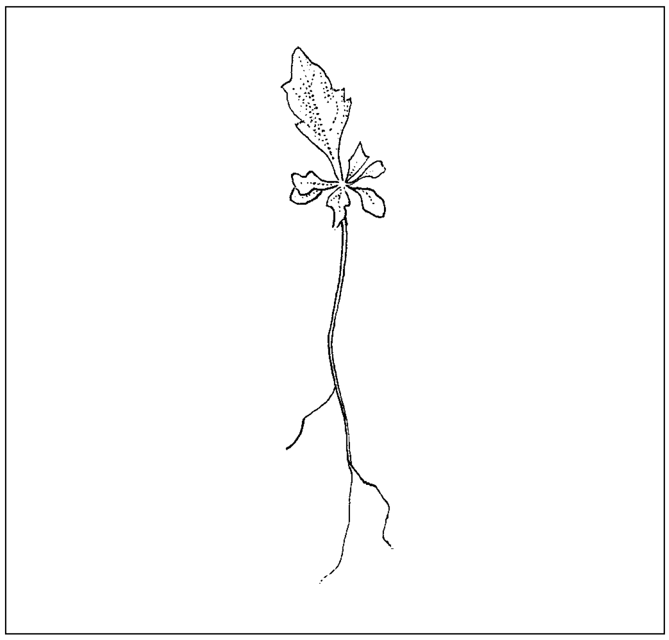


Table 2—*Baccharis,* baccharis: phenology of flowering and fruiting

Species	Flowering	Fruit ripening	Seed dispersal
B. angustifolia	Sept–Oct	Sept–Oct	Oct
B. pilularis	July–Oct	Sept–Dec	Fall
B. salicifolia	May–July	May–July	May–July

Sources: McBride (1964), Mirov and Kraebel (1939), Olson (1974), Radford and others (1964).

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Table 3 —*Baccharis,* baccharis: germination test conditions and resulting germination

		Germination test condition			Germination	
		Temp (°C)			Average	
Species	Medium	Day	Night	Days	(%)	Samples
B. angustifolia	Kimpak	15.6	15.6	55	21	2
B. halimifolia	—	23	19	10	92	1
B. pilularis	Moist paper	22–24	19	10	93	1
	Moist paper	30	17.3	15–30	92	1
	Moist paper	15–25	7.2–25	30	40–54	28
B. salicifolia	—	30	20	15–30	75–82	3

Sources: McBride (1964, 1969), Mirov and Kraebel (1939), Olson (1974), Panetta (1979).

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B

Fabaceae—Pea family

Bauhinia L.

bauhinia

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Growth habit, occurrence, and use. There are about 600 species of the bauhinia genus found in the tropical regions of the world (Larson 1974). The genus includes trees, vines, and shrubs that are frequently planted for their showy flowers and ornamental foliage (Bailey 1941; Neal 1965). Practical usage of the bark of orchidtree as an astringent in tanning and dyeing and of the leaves and flower buds as a vegetable has been reported (Bailey 1941). Seeds of some bauhinia species have served as a human food source (malucreeper, *B. vahlii* Wight & Arn.) (Ramasastri and Shenolikar 1974); a source of vitamin A (butterfly bauhinia) (Essien and Fetuga 1989); and as a possible pest control agent (malucreeper) (Freedman and others 1979). Butterfly bauhinia is used for fuelwood on Puerto Rico and for fences on Jamaica (Little and Wadsworth 1964), but it is considered a weed on Guam (McConnell and Muniappan 1991). Four species, all small evergreen or deciduous trees, have been planted in the continental United States (table 1). Hawaii has 13 species of introduced bauhinias (Neal 1965), whereas Puerto Rico has at least 5 (Francis and Liogier 1991).

Flowering and fruiting. The large 5-petaled orchid-like flowers of bauhinias occur in racemes and range in color from white to deep purple and yellow. The fruits (figure 1) are flat and dark, and dehiscent or indehiscent legumes (pods) varying in length from 8 to 60 cm (Bailey 1941). Flowers of butterfly bauhinias have only 1 fertile

Figure 1—*Bauhinia variegata,* orchidtree: flowers and legumes (from Little and others 1974).

Table 1—*Bauhinia,* bauhinia: nomenclature, occurrence, and uses

Scientific name & synonym(s)	Common name(s)	Occurrence
***B. megalandra* Griseb.** *B. multinervia* (Kunth) DC.	**bauhinia** petite flambouyant	Carribean basin
***B. monandra* Kurz** *B. kappleri* Sagot *Caspareopsis monandra* (Kurz) Britt. & Rose	**butterfly bauhinia,** pink bauhinia, pink orchidtree	Native of SE Asia; planted in Hawaii, escaped & naturalized in Puerto Rico & throughout the West Indies
***B. purpurea* L.** *Phanera purpurea* (L.) Benth. *Caspareopsis purpurea* (L.) Pittier	**purple bauhinia**	Native of SE Asia from India to China; planted in Florida, Hawaii, Puerto Rico, the Virgin Islands, & elsewhere in tropical America
***B. variegata* L.**	**orchidtree,** poor-man's-orchid, mountain-ebony	Native from India to China; planted in Florida & Hawaii; escaped & naturalized in Puerto Rico & the Virgin Islands

Sources: Francis and Liogier (1991), Little and others (1974), Neal (1965).

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Table 2—*Bauhinia,* bauhinia: flower and fruit morphology

Species	Flowering time	Petal color	Fertile stamens/flower	Legume
B. monandra	All year	Pink with red dots	1	15–30 cm long, pointed at apex, twists as opens
B. purpurea	Autumn & winter	Deep pink to purple	3–4	15–30 cm long, black, thin, twists as opens
B. variegata	Autumn to spring	Purple variegated with red & yellow	5–6	13–30 cm long, thin, pointed on both ends

stamen per flower and a calyx splitting along one side (Little and Wadsworth 1964; table 2). Flowers of purple bauhinias have 3 to 4 fertile stamens and a 2-parted calyx, whereas those of orchidtrees have 5 to 6 fertile stamens/flower and a calyx that splits on one side (Little and others 1974; Neal 1965). Information on pollinators is scarce, but Heithaus and others (1982) report that *B. ungulata* L. is pollinated by bats and that 59.4% of flowers examined show evidence of herbivory.

Butterfly bauhinia seeds are elliptic, flat, and 1 cm long; fruits are present throughout the year (Little and Wadsworth 1964). Purple bauhinia seeds are shiny-brown, rounded, flat, and range in length from 1.3 to 1.6 cm; flowering and fruiting occur in autumn and winter months (Little and others 1974). Orchidtree seeds are fairly large, about 1.3 cm in diameter, and the fruits mature in late spring or early summer. *Bauhinia megalandra* seeds are shown in figure 2 and 3. Rugenstein and Lersten (1981) report the presence of stomata on the seeds and pods of purple bauhinias and orchidtrees. In general, bauhinia seeds contain high amounts of linoleic and oleic fatty acids and low amounts of myristic and linolenic fatty acids (Balogun and Fetuga 1985; Ramasastri and Shenolikar 1974; Sherwani and others 1982; Zaka and others 1983).

Collection, storage, and germination. Seeds may be stripped from unopened legumes (pods). Some and others (1990) reported satisfactory germination after 52 weeks when seeds of *Bauhinia rufescens* Lam. were scarified using 97% sulfuric acid (H_2SO_4), washed, dried, sealed into containers, and stored at 4 °C. Another study determined that seeds of orchidtree had a higher germination percentage when stored after cleaning; however, viability was lost within 3 years (Athaya 1985). Because *Bauhinia* is a hard-seeded Fabaceae, dry seeds should store well for many years. Loss of viability after 3 years could be attributable to high moisture content or mechanical damage. Germination studies of orchidtree using excised embryos produced results comparable to experiments using intact seeds (Babeley and Kandya 1986). Francis and Rodrıguez (1993) reported excellent germination of bauhinia without scarification (table 3).

Nursery practices. Bauhinias species grow easily from seeds and bloom within 3 to 4 years (Bailey 1941). Some species can be propagated from suckers but rarely from cuttings.

Figure 2—*Bauhinia megalandra,* bauhinia: seed.

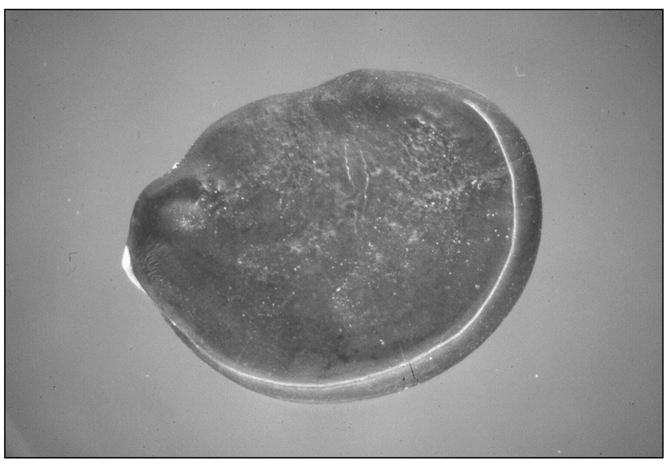

Figure 3—*Bauhinia megalandra,* bauhinia: longitudal drawing of seed section.

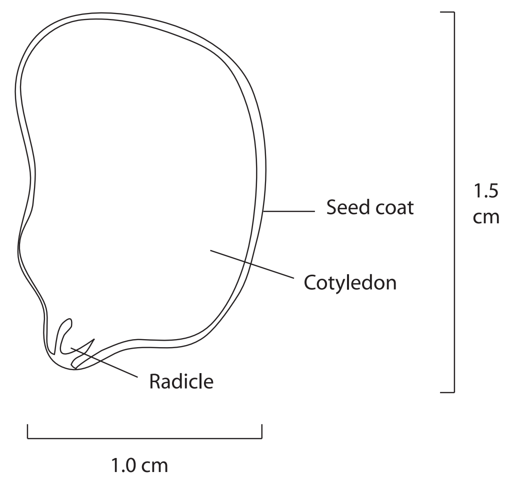

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Table 3—*Bauhinia*, bauhinia: seed and germination data

	Seeds/wt		Germination *	
Species	**/kg**	**/lb**	**Period (days)**	**Percentage**
B. monandra	5,680	2,576	4	100
B. purpurea	4,670	2,118	4	99
B. variegata	4,950	2,245	4	77

Source: Francis and Rodríguez (1993).
* Sample size = 100; germinated on filter paper; germination recorded when radicle emerged from seed

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Berberidaceae—Barberry family

Berberis L.

barberry

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

Growth habit, occurrence, and use. The barberries include about 500 species of spiny or unarmed, evergreen or deciduous shrubs (rarely small trees) native to Asia, Europe, North Africa, and to North, Central, and South America (Ahrendt 1961). Some authorities consider that the genus *Mahonia*, consisting of about 100 species that closely resemble the barberries, should be a section of *Berberis* (Hitchcock and others 1964), whereas others consider *Mahonia* to be a separate genus (Ahrendt 1961). The USDA plant nomenclature system (USDA NRCS 1999) separates them into 2 separate genera, and that is the authority used for this manual (table 1). Thus, *Mahonia* is treated separately in a later chapter. The barberry genus is essentially diploid, with 2n = 28 (Cadic 1992). Many interspecific hybrids are known, such as those between Japanese and common barberries (*B.* × *ottawensis* Scheid.), and Japanese barberry and Julian berberis (Rehder 1940). There are more than 60 crosses within *Berberis*, 6 in *Mahonia,* and 4 "mahoberberis" hybrids (Ahrendt 1961).

Several barberry species are grown as ornamentals because of their handsome foliage and often attractive flowers or fruits (Bailey 1939; Rehder 1940; Schlosser and others 1992). Barberries also are of value for wildlife food (Decker and others 1991), cover, and erosion-control planting. However, Japanese and common barberries, as "invasive aliens," are considered by many to be noxious weeds (Mack 1991). The names, heights, habits, and ripe fruit colors of some common species are listed in table 1.

A yellow dye can be extracted from barberry roots, and the plants contain many alkaloids (Hussain and others 1984;

Table 1—*Berberis,* barberry: nomenclature, height, growth habit, and color of ripe fruit

Scientific name & synonym	Common name(s)	Height at maturity (m)	Growth habit	Color of ripe fruits
B. buxifolia **Lam.**	**boxleaf barberry**	0.6–2.1	Deciduous	Pruinose blue
B. candidula **(C.K. Schneid.) C.K. Schneid.**	**paleleaf barberry**	0.6–1.2	Evergreen	Purplish, bloomy
B. circumserrata **(C.K. Schneid.) C.K. Schneid.**	**cutleaf barberry**	0.6–0.9	Deciduous	Pale red
B. darwinii **Hook.**	**Darwin barberry**	1.5–2.4	Evergreen	Pruinose blue
B. gagnepainii **C.K. Schneid.**	**black barberry**	0.9–1.8	Evergreen	Pruinose blue
B. gilgiana **Fedde**	**wildfire barberry**	1.8–2.4	Deciduous	Reddish
B. julianiae **Schneid.**	**Julian barberry,** wintergreen barberry	1.8–3.0	Evergreen	Bluish-black
B. koreana **Palibin.**	**Korean barberry**	1.2–1.8	Deciduous	Bright red
B. sargentiana **C.K. Schneid.**	**Sargent barberry**	1.8–2.7	Evergreen	Black
B. thunbergii **DC.** *B. trifoliata* Moric.	**Japanese barberry**	0.9–1.8	Deciduous	Bright red
B. tricanthophora **Fedde**	**threespine barberry**	0.9–1.5	Evergreen	Bluish-black
B. vernae **C.K. Schneid.**	**Verna barberry**	0.9–1.2	Deciduous	Pale red
B. verruculosa **Hensl. & E.H. Wilson**	**warty barberry**	0.9–1.8	Evergreen	Violet-black
B. vulgaris **L.**	**common barberry,** European barberry	1.8–3.0	Deciduous	Scarlet or purple

Sources: Ahrendt (1961), Dirr (1990), Dirr and Heuser (1987), Garrett (1969), Hitchcock and others (1964), McMinn (1951), Rehder (1940), Rudolf (1974), Vines (1960).

Ikram 1975; Kostalova and others 1986; Pitea and others 1972). Some of those alkaloids (for example, berberine and jatrorrhizine) are used for medicinal purposes (Ikram 1975; Liu and others 1991). Other barberry extracts may significantly reduce infection with fireblight—*Erwinia amylovora* (Burrill) Winslow et al.—infection when applied as bactericides (Mosch and Zeller 1989). Three species that have been used for conservation planting but are now often considered invasive are listed in table 2. Many of the barberries are alternate hosts for the black stem rust—*Puccinia graminis* Pers:Pers.—of grains, but common barberry is the most susceptible species (LHBH 1976). Some species (for example, Korean barberry and Japanese barberry) are resistant (Rehder 1940).

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 (Fleurat-Lessard and Millet 1984; Lebuhn and Anderson 1994; Millet 1976, 1977). Fruit set and fruit weight are improved by spraying with 200 ppm gibberellic acid (GA_3) at full bloom and again 15 and 30 days later (Malasi and others 1989). The fruit is a berry with one to several seeds (figure 1). Late-fruiting plants often contain more seeds per berry than early-fruiting plants in common barberry; and late-fruiting, large-berried plants may disperse seeds more efficiently than early-fruiting plants with smaller berries (Obeso 1989). Predation by fly larvae (diptera: Tripetidae) tends to increase with increasing number of seeds in the fruit, however, and individual developing seeds have a greater average probability of escaping predation when they occur singly in fruits (Herrera 1984). Fruits having the least number of seeds contain the highest amounts of edible pericarp (Malasi and Paliwal 1984). Starch is not present, but polyfructans are characteristic of barberry fruits (Srepel and Mijatovic 1975). Soluble sugar and anthocyan levels increase while those of chlorophyll and berberine decrease during the ripening of those fruits (Chandra and Todaria 1983).

Good fruit crops are borne almost annually. They ripen in the summer and autumn (table 2). In New Zealand, the proportion of mature flowers that survive to produce ripe fruit and the proportion of ripe fruit taken by birds may be higher in introduced, naturalized barberry species than in most other species with similar reproductive ecology that are growing within their natural range (Allen and Wilson 1992). As a result, establishment of seedlings of Darwin barberry may exceed that of native shrub and tree species in New Zealand (Allen 1991). The presence of a waxy bloom does

Figure 1—*Berberis thunbergii*, Japanese barberry: longitudinal section through 2 seeds in a berry.

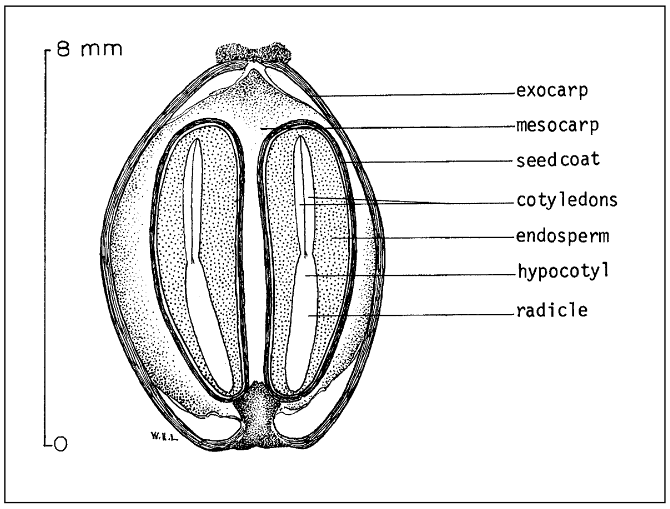
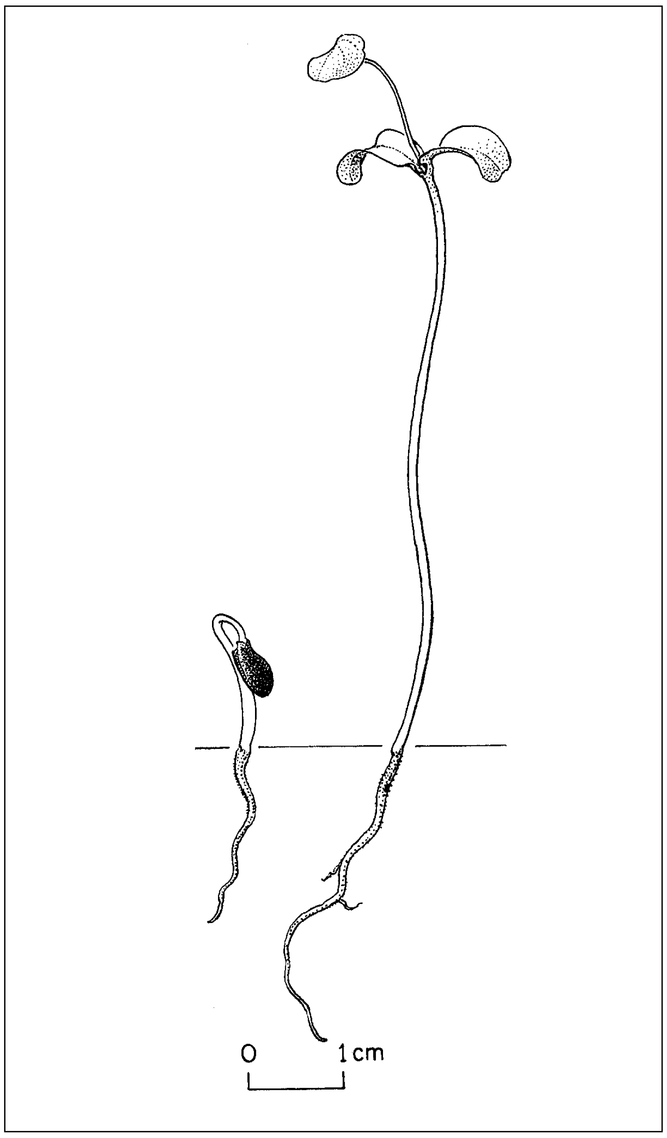


Figure 2—*Berberis thunbergii,* Japanese barberry: seedling development at 1 and 16 days after germination.



B

Table 2—*Berberis,* barberry: phenology of flowering and fruiting for 3 species

Species	Origin	Location	Flowering	Fruit ripening
B. koreana	Korea	NE US & Carver Co., Minnesota	May–early June	Sept–Oct
B. thunbergii	Japan	Japan	Apr–June	Oct
		SE US	Mar–Apr	May–Sept
		NE US & Germany	May–June	Sept–Nov
B. vulgaris	Europe †	NE US & W Europe	Apr–June	Sept–Oct

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).
* Fruits of these 3 species often remain on bushes over winter.
† To 1,525 m in the Alps.

not increase fruit attractiveness, but physical alteration of the fruit surface reduces fruit selection by birds (Allen and Lee 1992). Seed dispersal by both birds and mammals is widespread (Rudolf 1974; Vines 1960).

Collection of fruit; extraction and storage of seeds. Ripe barberry fruits may be picked by using protective gloves, or they may be flailed onto cloths or receptacles spread beneath the bushes. The ripe 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 1967a; NBV 1946; Rudolf 1974). Seed purity and soundness for the species included here have been as high as 90 to 99% (Davis 1927; Rafn and Son nd; Rudolf 1974). Seeds of Japanese and common barberries remained viable for at least 4 years when held at 1 to 3 °C in sealed containers (Heit 1967b), which indicates that these species are orthodox in storage behavior. Fruit yields, seed yields, and numbers of seeds per weight for 3 species are listed in table 3.

Pregermination treatments. Seeds of some barberry species have embryo dormancy that requires cold stratification to provide prompt germination. Dirr and Heuser (1987) recommend 1 to 2 months for wildfire and Japanese barberries, and 2 to 3 months for boxleaf, paleleaf, cutleaf, Darwin, Julian, and Korean barberries. Germination data for 3 species are found in table 4. However, a simple cold stratification is not always successful. Immature or improperly developed embryos may be present in some barberry seeds, and maximum germination may require warm incubation, followed by cold stratification as in the closely related *Mahonia* genus (Dirr and Heuser 1987; McLean 1967). Under natural conditions, barberry seeds germinate in the spring following seed dispersal (Kern 1921).

Germination tests. Germination of seeds from several barberry species 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. Results are summarized in table 4. For 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 be satisfactory for other barberry species.

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), and seedlings develop rapidly (figure 2). In a sowing of common barberry, 22% of the seeds survived to produce shrubs (Swingle 1939). Barberries may be field-planted as 2+0 stock (Rudolf 1974).

The barberries can be propagated from rooted stem cuttings. Several deciduous species are best rooted when propagated from softwood cuttings collected in the summer, but many of the evergreen species root better when hardwood cuttings are collected in the autumn or winter (Dirr and Heuser 1987). Both should be treated with indole butyric acid (IBA) rooting hormone in talc or in solution.

Table 3—*Berberis,* barberry: seed yield data

Species	Place collected	Fruit wt/fruit vol		Seed wt/fruit vol		Cleaned seeds(x 1,000)/weight				
						Range		Average		
		kg/hl	lb/bu	kg/hl	lb/bu	/kg	/lb	/kg	/lb	Samples
B. koreana	Carver Co., MN	39	30	4	3	—	—	84	38	2
B. thunbergii	US	9–15	16–25	—	—	55–82	25–37	64	29	5+
B. vulgaris	US	—	—	—	—	75–90	34–41	84	38	2

Source: Rudolf (1974).

Table 4—*Berberis,* barberry: stratification periods, germination test conditions, and results for 3 species

Species	Cold strati-fication* (days)	Daily light (hrs)	Germination test conditions				Germination rate		% germination		Purity (%)	Soundness (%)
				Temp (°C)								
			Medium	Day	Night	Days	Amount (%)	Days	Avg (%)	Samples		
B. koreana	60	16	Sand or perlite	16	16	20	64	6	88	1	97	95
B. thunbergii	90	—	Wet paper or sand	24†	13†	40	—	—	90	4	93	95
B. vulgaris	40	—	Wet paper or sand	24†	13†	40	—	—	91	2+5	—	96

Sources: Davis (1927), Heit (1968a,b), McLean (1967), Mirov and Kraebel (1939), Morinaga (1926), Plummer and others (1968), Rafn and son (nd), Rudolf (1974), Swingle (1939), Vines (1960).
* Cold stratification temperatures ranged from -1 to 5 °C.
† Twenty-one to 27 °C during the day and 10 to 16 °C during the night.

B

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Betulaceae—Birch family

Betula L.

birch

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Growth habit, occurrence, and use. The birch-genus—*Betula*—consists of about 40 to 50 species of deciduous trees and shrubs occurring in the cooler parts of the Northern Hemisphere (Weaver 1978). Several species produce valuable lumber. Other species are useful for ornamental plantings because of their attractive growth habit, foliage, and bark. Nearly all species provide food and cover for wildlife, and some are valuable because they seed-in promptly on harvested or burned lands. The 14 species native to the Unites States are listed in table 1, along with several species that are introduced or are referenced in the seed literature.

Flowering and fruiting. The flowers are monoecious and borne in catkins. Staminate catkins are formed in late summer or autumn, remain naked during winter, and open after considerable elongation in the spring (table 2). The pistillate catkins, which are cone-like with closely overlapping scales, are born terminally on short, spur-like lateral branches and appear with the leaves (table 2). When the female catkins (strobiles) ripen in late summer or autumn (table 2), they become brown and woody and are either erect or pendulous (figure 1). Each scale may bear a single small, winged nut (seed) (figures 2 and 3) that is oval, with 2 persistent stigmas at the apex. The seeds turn from greenish tan to light brown or tan when mature (Brinkman 1974). Seeds disperse from late fall until the following spring (Houle and Payette 1990; Matlack 1989). Although seeds can begin to disperse in late summer, these early-shed seeds may be of poor quality. Seeds of yellow birch shed in August were found to not be viable. Viable seeds were not released in meaningful amounts until September, with the maximum of good seeds being released in October (Houle and Payette 1990). After seedfall, the strobiles slowly disintegrate on the trees, with the axes persisting on the branchlets.

Seed production. Birch tends to flower at the relatively young age of 10 to 15 years (Lepisto 1973) (table 3). Some individuals are precocious in flowering and this appears to be under genetic control (Huhtinen and Yahyaoglu 1974). Clausen (1980) reported on a progeny test of 147 open-pollinated yellow birch families from 21 stands. He found that some female-flowering began at 6 years from seed, but this occurred in only 1% of the trees. By age 9, 14% of the trees were producing seeds. Male-flowering commenced 1 year later than female-flowering. Seedlings from northern sources tended to flower earlier than those from southern sources. In greenhouse conditions with irrigation, fertilization, and CO_2-enriched air, European white birch seedlings have produced male catkins as early as 9 months and commercial quantities of seed at 5 years (Lepisto 1973).

Birches are known to hybridize readily. These hybrids appear to be at least partially fertile, allowing for the production of second generation hybrids and backcrossing to the parent species (Barnes and others 1974).

The holartic lygaeid—*Kleidocerys resedae* (Panzer)—feeds on the seeds of European white birch and cause premature drop of catkins and seed failure. The feeding does not affect the vigor of the parent plant, even though the insects can be quite numerous and visible (Wheeler 1976).

Seed production is usually regular and abundant. Bjorkbom and others (1965) reported that paper birch produced a higher proportion of viable seeds in good seed years than it did during poor seed years. The percentage of viable birch seeds can be estimated by examining the seeds on a light table (Patterson and Bruce 1931). The seeds are primarily dispersed by wind as they are shed from the catkins. Wind can also blow seeds along the surface of the snow up to 80 m from the mother tree. This secondary dispersal may be the more effective method; it has been predicted to increase sweet birch seed dispersal by a factor of 3.3 over that of aerial dispersal alone (Matlack 1989). Ford and others (1983) trapped about 5% of the total seed-fall from round-leaf birch at nearly 100 m from the parent tree.

B

Table 1—*Betula,* birch: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
***B. alleghaniensis* Britt.** *B. lutea* Michx. F.	**yellow birch**	Newfoundland to SE Manitoba, S to NE Iowa N Illinois & Delaware; mtns to Tennessee
***B. borealis* Spach**	**northern birch**	Massachusetts, New Hampshire, Vermont, Maine, N to Nova Scotia, Newfoundland, Quebec, & Labrador
***B. davurica* Pall.**	**Dahurian birch**	Temperate China, Japan, & Russian Federation
***B. ermanii* Cham.**	**Erman birch**	NE China, Japan, Korea, Russian Federation in Chita, Kamchatka, Sakhalin, Yakutia-Sakha, & Bryansk
***B. lenta* L.**	**sweet birch,** black birch, cherry birch	S Maine to S Ontario, S to E Ohio & Delaware; mtns to N Alabama & Georgia
***B. mandshurica* var. *japonica* (Miq.) Rehder** *B. alba* var. *japonica* Miq. *B. japonica* Siebold ex H.J.P. Winkl. *B. japonica* var. *Kamtschatica* (Regel) H.J.P. Winkl. *B. platyphylla* var. *japonica* (Miq.) H. Hara *B. platyphylla* var. *kamtschatica* (Regel) H. Hara	**Japanese white birch,** Asian white birch	Japanese islands of Hokkaido & Honshu; Russian Siberia in Kamchatka, Magadan, & Sakhalin
***B. maximowicziana* Regel**	**monarch birch**	Japanese islands of Hokkaido & Honshu; Kurile Islands, Russia
***B. minor* (Tuckerman) Fern.** *B. saxophila* Lepage *B. papyrifera* var. *minor* (Tuckerman) S. Wats. & Coult.	**dwarf white birch**	New York, New Hampshire, Maine, New Brunswick, N to Ontario, Quebec, Newfoundland, & Labrador
***B. murrayana* Barnes & Dancik**	**Murray birch**	Michigan
***B. nana* L.** *B. gladulosa* Michx. *B. exilis* Sukatschev *B. michauxii* Sarg. *B. glandulosa* var. *hallii* (T.J. Howell) C.L. Hitchc. *B. glandulosa* var. *sibirica* (Ledeb.) Schneid. *B. nana* ssp. *exilis* (Sukaczev) Hutten *B. nana* var. *sibirica* Ledeb.	**bog birch,** swamp birch, dwarf birch	Newfoundland to Alaska, S to higher mtns of California, Colorado, & Maine
***B. neoalaskana* Sarg.** *B. papyrifera* var. *neoalaskana* (Sarg.) Raup	**Alaska birch**	Alaska, Alberta, N British Columbia, Manitoba, W Northwest Territory, NW Ontario, Saskatchewan, & Yukon Territory
***B. nigra* L.**	**river birch,** black birch, water birch	Connecticut to E Iowa & SE Kansas, S to E Texas, E to N Florida
***B. occidentalis* Hook.** *B. beeniana* A. Nels *B. fontinalis* Sarg. *B. papyrifera* Marsh. ssp. *occidentalis* (Hook.) Hulten *B. occidentalis* var. *inopina* (Jepson) C.L. Hitchc. *B. papyrifera* var. *occidentalis* (Hook.) Sarg.	**water birch**	Alaska, Canada, W US, E to the Dakotas, Nebraska, Colorado, & New Mexico
***B. papyrifera* Marsh.** *B. cordifolia* Regel *B. alba* var. *cordifolia* (Regel) Regel	**paper birch,** canoe birch, silver birch, white birch	Newfoundland to Canada, S to Washington & E to North Dakota, NE Iowa & New England; locally in other states in N
***B. pendula* Roth** *B. verrucosa* Ehrh.	**European white birch**	Europe to Japan
***B. populifolia* Marsh.**	**gray birch,** white birch, wire birch	Nova Scotia to S Ontario, S to N Ohio, Pennsylvania, & Delaware

Table 1—*Betula,* birch: nomenclature and occurrence (Continued)

Scientific name & synonym(s)	Common name	Occurrence
B. pubescens **Ehrh.** *B. alba* L. *B. tortusa* Ledeb.	**downy birch**	N & central Europe to E Siberia
B. pumila **L.** *B. pumila* var. *glandulifera* Regel (Gleason) *B. glandulifera* (Regel) Butler *B. nana* var. *glandulifera* (Regel) Boivin *B. glandulosa* var. *glandulifera* (Regel) Gleason	**swamp birch**, glandulose birch, bog birch, swamp birch	W Quebec to British Columbia, S to Montana, E to North Dakota & N New York
B. uber **(Ashe) Fern.**	**roundleaf birch**	Smyth Co., Virginia
Betula x utahensis **Britt. (pro sp.)** *B. andrewsii* A. Nels. *B. piperi* Britt.; *B. (commixta* Sarg. *B. occidentalis* var. *fecunda* Fern. *B. papyrifera* var. *subcordata* (Rydb.) Sarg.	**northwestern paper birch**	Yukon Territory, S through British Columbia, Alberta, Saskatchewan, Washington, Idaho, Montana, Oregon, Wyoming, & Utah

Source: Brinkman (1974)

Table 2—*Betula,* birch: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening	Seed dispersal
B. alleghaniensis	Mid-range	Apr–May	Aug–Oct	Sept–Spring
B. davurica	Japan	May	Oct	—
B. lenta	Mid-range	Apr–May	Aug–Sept	Sept–Nov
B. nana	Mid-range	June–Aug	Aug–Oct	Sept–Mar
B. nigra	N part of range	Apr–May	May–June	May–June
B. papyrifera	Mid-range	Apr–June	Aug–Sept	Aug–Spring
B. pendula	Russia & Finland	Apr–June	July–Aug	July–Sept
B. populifolia	Mid-range	Apr–May	Sept–Oct	Oct to mid-winter
B. pubescens	Germany & Finland	May–June	Aug–Sept	Fall–Winter
B. pumlia	Mid-range	May–June	Sept–Oct	Oct–Mar

Sources: Ahlgren (1957), Brinkman (1974), Damberg (1915), Fernald (1950), NBV (1946), Sarvas (1952), Van Dersal (1938), Wappes (1932).

Although an abundance of seeds can be found in the forest soil, these seeds are short-lived. Most seeds are nonviable after the second or third year (Granstrom 1987; Granstrom and Fries 1985; Johnson 1975; Moore and Wein 1977; Perala and Alm 1989; Steijlen and Zackrisson 1986). The abundance of seeds in the forest soil is, therefore, likely supported by regular replenishment from new crops (Komarova 1986). A rare case of excessive seed production has been observed to lead to crown deterioration and reduced growth of the parent trees (Gross 1972).

Seed collection. Birch seeds are collected by picking or stripping the strobiles from standing trees or shrubs or from trees recently felled in logging operations. This is best done while strobiles are still green enough to hold together. Because ripe strobiles shatter readily, they are usually put directly into bags rather than allowed to fall onto the ground or tarps, which can result in loss of the seeds. However, seeds can also be collected from paved surfaces in urban areas.

Seed extraction. Freshly collected strobiles can be subject to heating because they usually are at least somewhat green. They should be spread out to dry for several weeks until they begin to disintegrate. Low relative humidity is the most important factor in drying the strobiles. Matlack (1989) found that sweet birch strobiles released their seeds at low humidity anywhere in the temperature range of –14 to 16 °C. Once the strobiles begin to fall apart, they can be shattered by rubbing or shaking, and the seeds can be separated from most of the scales and debris by screening and fanning. Round-hole screens of the following sizes have

Figure 1—*Betula*, birch: ripe female strobiles; *B. pendula*, European white birch (**top right**); *B. populifolia*, gray birch (**bottom left**); *B. papyrifera*, paper birch (**bottom middle**); and *B. lenta*, sweet birch (**bottom right**).

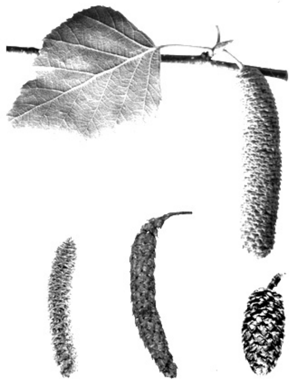
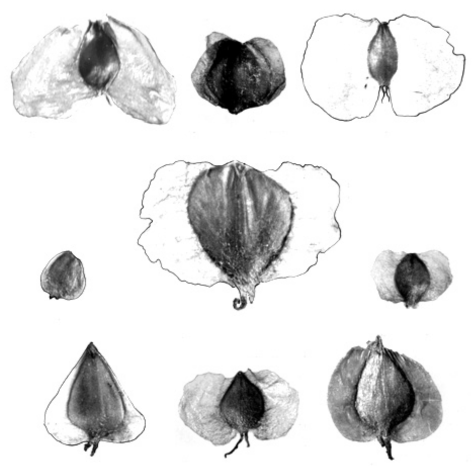
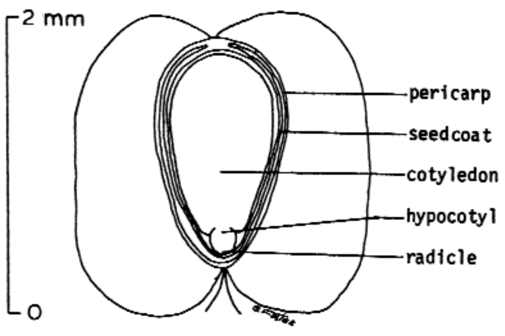


Figure 2—*Betula*, birch: winged nuts of *B. pendula*, European white birch (**top left**); *B. pumila*, low birch (**top center**); *B. populifolia*, gray birch (**top right**); *B. nana,* bog birch (**middle**); *B. nigra*, river birch (**middle center**); *B. pubescens,* hairy birch (**middle right**); *B. lenta*, sweet birch (**bottom left**); *B. papyrifera*, paper birch (**bottom center**); and *B. alleghaniensis*, yellow birch (**bottom right**), enlarged.



proved satisfactory for the following species: glandulose birch, 2.38 mm (#6); yellow birch, 3.2 mm (#8); river birch, 4 mm (#10); paper birch, 3.2 mm (#8); European white and downy birches, 2.6 mm (~#7). The remaining scales can be removed by fanning (Brinkman 1974). Any stems can be removed with an indent cylinder. Very careful adjustment

Figure 3—*Betula nigra*, river birch: longitudinal section through a nut (seed).



with a column blower or a specific gravity table can upgrade the seedlot. Birch seeds are very small and light, with the number per weight and yield per volume varying considerably among species (table 4).

Seed storage. Heit (1967) reported that birch seeds apparently stored best at 1 to 3% moisture content and temperatures of 2.2 to 3.3 °C. Other tests with sweet, paper, and gray birches are in basic agreement with this position, thus indicating that birch seeds are orthodox in storage behavior. Seeds of these 3 species were found to keep for $1\ ^{1}/_{2}$ to 2 years at room temperature if the moisture content was between 1 and 5%. If the moisture content was much higher, germination dropped even though the seeds were stored at 1.7 to 4.4 °C (Brinkman 1974). Slightly higher moisture content seems possible if freezer storage is used. One lot each of yellow, sweet, and paper birch seeds was successfully stored in the USDA Forest Service's National Tree Seed Laboratory seed bank for about 15 years with moisture contents between 5 to 9% at –8 °C (table 5). A lower moisture content would probably have been better, because the paper birch seeds began to deteriorate at 15 years and were discarded at 17 years. Liquid nitrogen storage also appears to be an option for the birch seeds (Iriondo and others 1992).

Pregermination treatment. It has been known for over 50 years that prechilling (that is, stratification) improved germination of birch seeds (Brinkman 1974). Several sources (Brinkman 1974; Heit 1967; ISTA 1996) state that light during germination is able to reduce or replace the need for prechilling to obtain complete germination. The barriers to germination in European white birch are removed by light or stratification (Black 1956; Black and Wareing 1954, 1955). However, prechilling can still be an important procedure. For example, Vanhatalo and others

Table 3—*Betula,* birch: height, seed-bearing age, and seed crop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yr)	Years between large seedcrops
B. allenghaniensis	30	1800	40	2
B. davurica	19.5	1883	—	2
B. lenta	24	1759	40	1–2
B. nana	1.8	1880	—	—
B. nigra	30	1736	—	—
B. papyrifera	21	1750	15	2
B. pendula	19.5	Long	15	2–3
B. populifolia	12	1750	8	1
B. pubescens	19.5	1789	15	2–3
B. pumila	3	1762	—	1–2

Sources: Brinkman (1974), Wappes (1932), Yelenosky (1961).

Table 4—*Betula,* birch: seed yield data

			Cleaned seeds (1,000)/weight				
	Seeds/fruit vol		Range		Average		
Species	kg/hl	lb/bu	/kg	/lb	/kg	/lb	Samples
B. alleghaniensis	1.3–4.5	1.0–3.5*	612–1,995	278–907	990	450	24
B. davurica	—	—	1,518–1,672	690–760	1,595	725	2+
B. lenta	—	—	975–2053	443–933	1,421	646	13
B. nana	—	—	6,547–11,253	2,976–5,115	8,446	3,839	3
B. nigra	—	—	631–1,206	287–548	825	375	13
B. papyrifera	2.6–9.4	2.0–3.4*	1,342–9,064	610–4,120	3,036	1,380	28
B. pendula							
(de-winged)	—	—	3,332–11,088	1,510–5,040	5,317	2,417	154+
(winged)	—	—	1,606–1,892	730–860	1,749	795	10
B. populifolia	—	—	7,878–10,846	3,581–4,930	9,363	4,256	2
B. pubescens	—	—	1,650–9,900	750–4,500	3,784	1,720	45
B. pumila	—	—	3,072–7,634	1,396–3,470	5,328	2,422	4

Sources: Brinkman (1974), NBV (1946), Rafn & son (1928).
* De-winged seeds.

(1996) found that not only did prechilling result in faster and higher germination, but it also improved the ability to germinate at temperatures below the optimum.

Furthermore, the birch genus is divided into 2 groups in regards to prechilling: those that will germinate in the dark with adequate prechilling and those that require light. For example, European white birch (Black and Wareing 1955, Vaartaja 1956) and paper birch (Bevinton and Hoyle 1981) can germinate in the dark, whereas monarch and Japanese white birches and Erman birch require light regardless of prechilling (Nagata and Black 1977; Nagata and Tsuda 1975; Odani and Anma 1986). Giberellic acid (GA_3) in concentrations of 50 to 100 ppm could substitute for the light with Erman birch (Odani and Anma 1986). However, in the light-obligatory group, the sensitivity to light is markedly increased by providing prechilling (Nagada and Black 1977). Therefore, prechilling can reduce the requirement for light when growing plants under artificial conditions. This might provide some cost savings during the germination phase by reducing lighting expense. Reducing the light requirement might also allow birch to be germinated in a greenhouse with other plants that had low light requirements. On the other hand, if there is not time for pregermination chilling, then light sufficient to keep dark periods less than about 6 hours may fully replace the need for prechilling.

It is important to know a seedlot's characteristics well when making the refined manipulations of light and prechilling suggested above, for prechilling beyond 3 weeks can lead to increased dormancy and obligatory use of light

B

Table 5—*Betula,* birch: germination of 3 seedlots stored for 8 years at the USDA Forest Service's National Tree Seed Laboratory, Dry Branch, Georgia

Species	Moisture content (%)	Prechilling (days)	Percent germination
B. alleghaniensis			
1974	—	—	—
1977	5.0	0	45
1983	—	63	70
1988	7.0	63	67
1991	—	0	32
1992	—	0	56
1992	—	21	58
B. lenta			
1974	—	30	54
1977	—	—	
1983	—	63	72
1988	7.9	63	67
1991	—	—	—
1992	—	0	45
1992	—	63	37
B. papyrifera			
1974	—	—	—
1977	7.0	0	76
1977		63	82
1983	—	63	87
1988	8.9	—	—
1991	—	0	4
1991	—	63	16
1992	—	0	18

in some sources of paper birch (Bevington 1986; Bevington and Hoyle 1981). Although light use was obligatory in these sources of paper birch, the seeds were well sensitized to the light and germination was prompt and complete. Bevington (1986) further found that seeds from different sources varied in the range of temperatures at which they would germinate. Seeds from northern sources were able to germinate over a wider range of temperatures than those from southern sources, mostly because they could germinate at cooler temperatures. Sensitivity to light did not seem to be related to geographic source but was universally enhanced in proportion to the length of prechilling, at least up to 6 weeks as demonstrated by faster and higher germination (Bevington 1986).

Prechilling temperatures need to be close to 2 or 3 °C. A rise in temperature to even 5 °C can increase the time needed to effectively overcome the dormancy (Bevington and Hoyle 1981; Vanhatalo and others 1996).

Germination tests. The use of light during the test can reduce or eliminate the need for prechilling. However, because some seedlots may benefit from prechilling, a test with and a test without prechilling are frequently recommended (AOSA 1998; ISTA 1996). Tests should be made on germination paper or sand at alternating temperatures of 30 °C for 8 hours and 20 °C for 16 hours with light supplied during the 30 °C period. Testing by AOSA rules requires planting 4 dishes of 100 seeds each. Should the seedlot be less than 98% pure, then a partial purity analysis must be done to acquire the needed pure seeds for the germination test. Because catkin bracts are not removed from many seedlots, the seedlots have low purity and ISTA prescribes testing by weighed replicate. In the weighed replicate test, 0.10 g of seed are planted in each of the 4 replicates. The number of normal seedlings per weight of seeds is then reported instead of a germination percentage. The results of some published test data are presented in table 6.

Nursery practice. Birch seeds can be sown after collection in the late summer or fall, or in the spring after prechilling for 4 to 8 weeks. Seeds are broadcast and covered as lightly as possible, with about 3 mm ($^1/_{16}$ to $^3/_{16}$ in) of soil. The seeds can be sown without covering (Brinkman 1974) if adequate irrigation can be supplied, which provides more light to the seed. Germination is epigeal (figure 4) and usually complete in 4 to 6 weeks after spring-sowing. Birch seedlings require light shade for 2 to 3 months during the first summer. Tree percent is low; only 15 to 20% of European white birch and downy birch seeds will produce 1+0 seedlings (Deasy 1954; Wappes 1932). A seedling density of 278 to 500/m^2 (25 to 45/ft^2) is desirable (Heit 1964). Stock usually is field planted as 1+0 or 2+0 seedlings. Birch seeds have shown marked sensitivity to herbicides and insecticides (Weinberger and others 1978; Weinberger and Vladut 1981).

In a study of open-pollinated families of yellow birch (Wearstler and Barnes 1977), heavier seeds produced taller seedlings immediately after germination. Seeds from mountain and more northern sources germinated earlier, but the seedlings tended to be shorter. The shorter seedlings and faster germination were generally associated with shorter growing season.

Cherry leaf roll virus is known to be transmitted through seeds. Transmission of this pathogen is highly variable and not generally strong. Two generations were estimated to be enough for the disease to be lost from a population of European white birch (Cooper and others 1984).

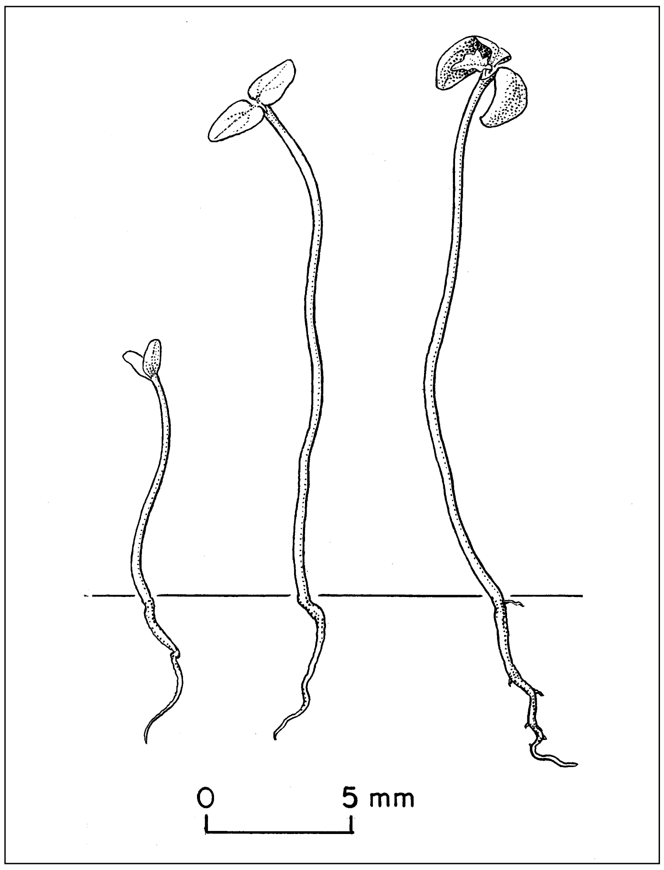
Germination on adverse sites. Environmental disturbances caused by mining operations and air pollution create conditions that have been suspected of interferring with normal seed germination for birch. The germination of European white and downy birches was found to be inhibited by high zinc concentrations (Brown and Wilkins 1986). Such heavy metal concentrations were thought to be a major reason for lack of colonization of these 2 species on mine

Table 6—*Betula,* birch: germination and purity test data

Species	Prechill period (days)	Daily light (hr)	Germination conditions: Medium	Temp (°C): Day	Temp (°C): Night	Germination: Days	Avg (%)	Samples	Purity (%)
B. alleghaniensis	30–0	8+	Sand	32	15	30–40	27	22	56
	None	8+	—	30	20	14–28	59	3	60
B. davurica	None	8+	—	30	20	14–8	18	4	—
B. lenta	40–70	8+	Sand	32	15	30	43	13	72
B. nana	(over winter)	—	Sand	30	20	30	24	1	—
	None	20	Perlite	24	18	30	3	5	—
B. nigra	30–60	8+	Sand	30	20	30	34	13	42
	None	20	Perlite	24	18	30	73	35	—
B. papyrifera	60–75	8+	Sand	32	15	30–40	—	—	24
	None	8+	Paper pads	—	—	40	47	6	—
B. pendula	30–40	8+	Sand	—		—	30	10+	68
	None	8+	—	30	20	30–40	36	143	—
B. populifera	60–90	8+	Sand	30	20	40	64	3	—
B. pubescens	30–60	8+	—	30	20	30	40	44	69
	None	8+	—	25	15	30	87	17	—
B. pumila var. glandulifera	None	20	Perlite	24	18	30	31	4	38

Sources: Black and Waring (1954, 1955), Brinkman (1974), Heit (1968), Gorshenin (1941), Yelenosky (1961).

Figure 4—*Betula populifoliaa*, gray birch: seedling development at 1, 10, and 40 days after germination.



spoil in Wales. On the other hand, Scherbatskoy and others (1987) found that heavy metals and low pH did not reduce germination of yellow or paper birch seed samples taken in Vermont. Reduced regeneration of these 2 species had been associated with low soil pH and increasing concentrations of heavy metals believed to be caused by air pollution. In fact, pH of 3 produced germinations higher than controls or pH values of 4 or 5. Growth of gray birch on coal mine spoils in Pennsylvania is likely to be inhibited by the high temperatures of the soil surface(Pratt 1986).

B

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