

Oleaceae Olive family

Fraxinus L.

ash

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

Geographic races and hybrids. Both green and white ashes exhibit ecotypic variation, but no patterns have been consistent enough to firmly establish geographic races (Kennedy 1990; Schlesinger 1990). White ash and Texas ash (*F. texensis* (Gray) Sarg.) intergrade in Texas (Schlesinger 1990). Oregon ash becomes very similar to velvet ash south of the Kern River in California (Owston 1990), which suggests intergrading of these 2 species. There is also some evidence that pumpkin ash is a true-breeding natural hybrid of white ash and green ash (Kennedy 1990). Several large provenance tests are underway with white ash (Clausen 1984; Clausen and others 1981) and green ash (Hendrix and Lowe 1990; Steiner and others 1988; Van Deusen and Cunningham 1982.), and their results should provide more information about the variation in these species.

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

Collection of fruits. Ash fruits are usually collected in the fall when their color has faded from green to yellow or brown (Bonner 1974; Vines 1960). Collection of European and flowering

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

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

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

Extraction and storage of seeds. Samaras should be spread in shallow layers for complete drying, especially when collected early. Dried clusters may be broken apart by hand, by flailing sacks of clusters, or by running the clusters through macerators or brush machines dry (Bonner 1974). Stems and trash can then be removed by fanning or with air-screen cleaners. Screen openings of 1 by 1 cm are good for white and green ash. De-winging of samaras is not necessary for storage or sowing, but many nurseries prefer to do so. Large amounts of samaras can be de-winged by dry maceration in a Dybvig⁷ or similar macerators and in brush machines (Karrfalt 1992), but they must be completely dry for the process to be successful. Smaller lots, such as those used for research or testing, can be de-winged in laboratory blenders operated at low speeds about half-full of water. Seed yield data for ashes are summarized in table 4.

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

Pregermination treatments. Most species of ash exhibit a complex dormancy that is due to both seed coat and internal factors. The seed coat effect apparently is based on restriction of moisture and oxygen uptake, and scarification or removal of pericarp, seed coats, or both will lead to quick germination of several species of ash (Arrillaga and others 1992; Bonner 1974; Gendel and others 1977; Marshall 1981). Karrfalt (1992) reported that de-winging white ash with a brush machine led to quicker germination, apparently because the brushes scarified the seed coats. Internal dormancy appears to be related to germination inhibitors or their balance with germination promoters (Kentzer 1966; McBride and Dickson 1972; Sondheimer and others 1974; Stinemetz and Roberts 1984; Tinus 1982; Tzou and others 1973). European and black ashes also have immature embryos that must complete development during afterripening for good germination (Nikolaeva 1967; Suszka and others 1996; Vanstone and LaCroix 1975; Walle 1987). This condition has led to the use of warm incubation of imbibed seeds prior to cold stratification for

overcoming dormancy in these species. For European ash, Tylkowski (1990, 1993) has recommended 16 weeks at 15 or 20 °C, followed by 16 weeks at 3 °C. Seed moisture content should be from 55 to 60% during this period, and a 1-hour re-soak in water should be carried out weekly in the warm phase and every 2 weeks in the cold phase. The warm phase can be less than 16 weeks if periodic examinations of longitudinal cuts of seeds show the embryo to have reached 80 to 90% of the seed length (Suszka and others 1996). In many cases, the same warm/cold treatment approach has been beneficial to green and white ashes from the northern portions of their ranges (Bonner 1974; Cram 1984; Tinus 1982). Cold stratification alone is usually sufficient for sources of these 2 species from the southern portion of their ranges (Bonner 1973, 1975). The degree of dormancy also seems related to seed age: older stored seeds appear more dormant than freshly collected ones (Bonner 1974; Tinus 1982). Shamel ash does not require pretreatment for prompt germination (Francis 1990). Pretreatment recommendations for dormant ashes are summarized in table 5. Germination is epigeal (figure 4) and may occur the spring following seedfall, or seeds may lie dormant in the litter for several years before germinating.

Germination tests. Official germination recommendations for ashes call for either 56 days (ISTA 1993) or 28 days (AOSA 1993) with stratified seeds on blotter paper with diurnally alternating temperatures of 30 °C in light and 20 °C in the dark. Prescriptions for individual species and some representative results of tests with stratified seeds under or near these conditions are given in table 6. Recent research in Italy with European and flowering ashes suggests that alternating temperatures of 25 °C for 8 hours and 5 °C for 16 hours (both in the dark) are better than 30/20 °C because of the greater amplitude of temperature change (Piotto 1994).

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

Nursery practice. Ash seeds may be sown in the fall without stratification, especially in the northern part of the United States. Seeds should be planted as soon as collected, preferably by mid-October (Eliason 1965). European ash is usually sown unstratified in August or September or stratified for 16 to 18 months and sown in March or April in England. Fall-sown seeds of this species will germinate the following spring, but yield is erratic (Aldhous 1972). Seeds treated with warm incubation, followed by cold stratification, as described earlier, can be stored non-dormant at -3 °C for up to 8 weeks before sowing, or dried up to 8 to 10% moisture at 20 °C and stored for up to 2 years before sowing (Suszka and others 1996). Fall-sown beds should be mulched with burlap or straw, and the mulch removed as soon as germination starts in the spring. For spring sowing, stratified seeds should always be used. Seeds of most species should be drilled in rows 15 to 30 cm (6 to 12 in) apart at rates of 80 to 100 seeds/m² (25 to 30/ft²), or broadcast to achieve a bed density of 105 to 160 seedlings/m² (10 to 15/ft²) (Bonner 1974; Williams and Hanks 1976).

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

or in some cases 2+0. European ash stock is ordinarily outplanted as 1+1 or 2+0.

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

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Figure 1 *Fraxinus americana*, white ash: cluster of samaras, $\times 1$.

Figure 2 *Fraxinus*, ash: single samaras, $\times 1$.

Figure 3 *Fraxinus pennsylvanica*, green ash: longitudinal section through the embryo of a samara, $\times 2$.

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

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

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

Source: Little (1979).

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

Species	Location	Flowering dates	Flowering habit	Fruit ripening dates	Seed dispersal dates
<i>F. americana</i>	C	AprBMay	Dioecious	OctBNov	SeptBDec
<i>F. caroliniana</i>	C	FebBMar	Dioecious	AugBOct	C
<i>F. dipetala</i>	California	AprBMay	Perfect	JulyBSept	C
<i>F. excelsior</i>	C	AprBMay	Polygamous	AugBSept	WinterBearly spring
<i>F. latifolia</i>	C	AprBMay	Dioecious	AugBSept	SeptBOct
<i>F. nigra</i>	C	MayBJune	Polygamous	JuneBSept	JulyBOct
<i>F. ornus</i>	NE US	MayBJune	Polygamous	C	C
<i>F. pennsylvanica</i>	C	MarBMay	Dioecious	SeptBOct	OctBspring
<i>F. profunda</i>	C	AprBMay	Dioecious	SeptBOct	OctBDec
<i>F. quadrangulata</i>	C	MarBApr	Perfect	JuneBOct	C
<i>F. uhdei</i>	Hawaii	MarBMay	Dioecious	JulyBSept	JulyBSept
	Puerto Rico	NovBJan	C	Aug	C
<i>F. velutina</i>	C	MarBApr	Dioecious	Sept	C

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

Table 3C *Fraxinus*, ash: height, seed-bearing age, and seed crop frequency

Species	Height at maturity (m)	Minimum Year first cultivated	Interval between seed-bearing age (yrs)	large seed crops (yrs)
<i>F. americana</i>	21B24	1724	20	3B5
<i>F. caroliniana</i>	6B12	C	C	C
<i>F. dipetala</i>	2B6	C	C	C
<i>F. excelsior</i>	29B38	Long ago*	15	1B2
<i>F. latifolia</i>	18B24	C	30	3B5
<i>F. nigra</i>	12B24	1800	C	C
<i>F. ornus</i>	6B20	pre-1700	20	C
<i>F. pennsylvanica</i>	21+	1824	C	1
<i>F. profunda</i>	37	C	9	C
<i>F. quadrangulata</i>	4B9	1823	25	3B4
<i>F. uhdei</i>	37	1900	15	1
<i>F. velutina</i>	15	1900	C	C

Sources: Bonner (1974), Krinard (1989).

* Cultivated for many centuries (Rehder 1940).

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

Species	Place fruit collected	Seeds/vol		Range	Cleaned seeds/weight			Samples	Seed moisture (%)
		kg/hl	lb/bu		/kg	Average	/lb		
<i>F. americana</i>	Midwest	16*	12.4	12,220B40,100	5,540B18,185	28,930	13,120	7	C
	Mississippi	16*	12.5	12,600B24,900	5,712B11,288	18,680	8,470	2	11
<i>F. caroliniana</i>	Arkansas	C	C	C	C	13,660	5,744	1	13
<i>F. dipetala</i>	California	C	C	11,025B19,400	5,000B8,800	C	C	3+	C
<i>F. excelsior</i>	Europe	18	14	10,470B15,430	4,750B7,000	C	C	C	7-8
	USA	C	C	8,800B15,430	4,000B7,000	13,000	5,900	10+	C
<i>F. latifolia</i>	C	C	C	22,000B31,000	10,000B14,060	C	C	C	C
<i>F. nigra</i>	Great Lakes region	C	C	13,450B20,950	6,100B9,500	17,860	8,100	4	C
<i>F. pennsylvanica</i>	Midwest &								
	Great Lakes region	C	C	24,250B54,250	11,000B24,000	38,850	17,260	51	C
	Arkansas &								
	Mississippi	9H	7.2	35,060B74,150	15,900B35,630	46,200	20,950	9	10
<i>F. profunda</i>	Mississippi	C	C	6,830B7,270	3,000B3,300	7,050	3,200	5	C
<i>F. quadrangulata</i>	C	C	C	13,000B15,430	5,900B7,000	C	C	2+	C
<i>F. uhdei</i>	Hawaii	C	C	34,200B38,600	15,500B17,500	36,380	16,500	10	C
<i>F. velutina</i>	C	C	C	28,850B61,740	13,000B28,000	45,420	20,600	6	C

Sources: Bonner (1974), Owston (1990).

* Number of seeds per volume: Midwest = 394,500/hl (139,000/bu); Mississippi = 326,540 (115,000/bu).

H Number of seeds per volume: ArkansasBMississippi = 416,620/hl (146,800/bu).

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

Species	Medium	Warm period		Cold period	
		Temp. (°C)	Duration (days)	Temp. (°C)	Duration (days)
<i>F. americana</i>	Sand	20B30	30	5	60
	Plastic bag*	C	C	3	56B84
<i>F. caroliniana</i>	Plastic bag*	C	C	3	60
<i>F. dipetala</i>	Sand, peat	C	C	2-5	90
<i>F. excelsior</i>	SandH	C	C	Cooll	480B540
	Sand, peat, or plastic bag*	20	60B90	4-5	60B90
<i>F. nigra</i>	Sand	20B30	60	5	90
	Peat	21	126	4	90
<i>F. ornus</i>	Soil	Warml	30	Coldl	90
<i>F. pennsylvanica</i>	Moist substrate	20	60	0B5	210
	Plastic bag*	C	C	2B5	60B150'
<i>F. profunda</i>	Moist paper	C	C	5	60
<i>F. quadrangulata</i>	Sand	20B30	60	5	90
<i>F. uhdei</i>	C	C	0	C	0
<i>F. velutina</i>	Sand, soil	C	C	2B5	90

Sources: Bonner (1974), Bonner (1975), Francis (1990), Mirov and Kraebel (1939), Soljanik (1961), Steinbauer (1937), Vanstone and LaCroix (1975), Walle (1987).

* Naked stratification in plastic bags.

H In outdoor pits.

l Exact temperatures not given.

' For seeds from southern sources, 2 or 3 months is enough, but for seeds from northern sources, 5 months is needed. The warm period is helpful but not essential for southern sources (Bonner 1974; Eliason 1965).

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

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

Sources: Bonner (1974), Bonner (1975), Cram (1984), Mirov and Kraebel (1939), Soljanik (1961), Tinus (1982).

NDL = Natural daylength in a greenhouse.