Ulmus L.

elm

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Growth habit, occurrence, and use. About 20 species of elm—the genus *Ulmus*—are native to the Northern Hemisphere. There are no native elms in western North America but some are found in northeastern Mexico (Johnson 1973). American elms are much loved as street trees for their arching branches and most elms species are valued for their hard, tough wood and many have been planted for environmental purposes. The natural ranges of 13 of the more important species are listed in table 1.

Since the 1930's, however, most elms in North America have been killed by the Dutch elm fungus, *Ophiostoma ulmi* (Buisman) Nannf., or by phloem necrosis, which is caused by a microplasma-like organism (Sinclair and others 1987). The Dutch elm disease was discovered in 1930 in Ohio. Dutch elm disease is transmitted when the European elm beetle, *Scolytus multistriatus* (Marsham), and the native elm bark beetle, *Hylurgopinus rufipes* Eichoff, feed on the tree (Burns and Honkala 1990). Phloem necrosis is spread by the whitebanded elm leafhopper, *Scaphoideus luteolus* (Van Duzee) and root grafts (Burns and Honkala 1990). Only Chinese, Japanese, and Siberian elms (Krüssman 1960) are resistant to these diseases. Although American elms now are only a small percentage of the large-diameter trees in mixed forest stands, beautiful old specimens of American elm still exist in some isolated city parks and along streets, for example, in Central and Riverside Parks in Manhattan (Barnard 2002).

Flowering and fruiting. Elm flowers are perfect. Selfing rarely occurs in elms due to their high degree of self-incompatibility, with the exception of Siberian elm, which is self-compatible (Townsend 1975). American elm has twice as many chromosomes(2n=56) as the other elm species common to North America, making it hard to cross-pollinate different species to impart disease resistance to American elm (Burns and Honkala 1990).

Most of the elms commonly grown in North America have protogynous flowers, where the stigma becomes receptive to pollen before the male anthers dehisce (Burns and Honkala 1990). Three species—rock, Siberian and Russian elms—have protandrous flowers, where the male anthers dehisce before the stigma is receptive. The elms are one of the few tree genera where the normal flowering period varies more than 2 to 3 weeks among species that are sexually compatible (Santamour 1989). Five floral stages have been identified: (1) stigma visible; (2) stigma lobes reflexed above anthers; (3) anthers dehiscing; (4) anther dehiscence complete and stigma wilting; (5) stigma shriveled, ovule green, and enlarged (Lee and Lester 1974). Pollination at stage 2 yielded the most viable seed (81%) followed by stage 1, stage 3, stage 4, and finally stage 5 (Lee and Lester 1974).

The perfect, rather inconspicuous inflorescences usually are borne in the spring before the leaves appear except for cedar, lacebark, and red elms, which flower in the fall (table 2). The inflorescences are fascicles, racemes, or racemose cymes measuring <2.5 up to 5 cm long (Fernald 1970). American, Scots, and rock elms have pendulous inflorescences (FNAEC 1997). Individual flowers are borne on pedicels measuring 0.4 to 1 cm long. The flowers have a calyx with 3 to 9 lobes, 3 to 9 stamens, and white stigmas with 2 styles (Fernald 1970; Radford and others 1968). Most of the elm species have reddish anthers,which gives the trees their characteristic flower color (FNAEC 1997; Johnson 1973).

The fruit is a 1-cell samara that ripens a few weeks after pollination and consists of a compressed nutlet surrounded by a membranous wing (figures 1 and 2). Winged, cedar, slippery, red, and rock elm seeds have pubescent samaras (Hora 1981). The seed is centrally located within the wing for slippery, Siberian, lacebark, and Scotch elms (Hora 1981). The apex of the wing can be shallowly or deeply notched (FNAEC 1997). American elm seeds have 2 inward curving beaks at the wing's apex (Dirr 1998). Elm seeds have no endosperm and are dispersed by wind, water, or animals (Burns and Honkala 1990). Most species produce good seedcrops at 2- or 3-year intervals (table 3).

Collection of fruits. Elm seeds can be collected by sweeping them up from the ground soon after they fall or by beating or stripping the seeds from the branches. The large seeds of rock elm are greatly relished by rodents (Dore 1965), however, and usually must be picked from the trees. American elm samaras fall within 91 m of the parent tree (Burns and Honkala 1990). Rock elm samaras are carried no more than 40 to 45 m from the parent tree, but their buoyant samaras can be carried by water and are frequently found along stream and lake banks (Burns and Honkala 1990). In rock elm, 90 to 100% of the mature seeds are viable and the seeds ripen about 2 to 3 weeks after American elm seeds (Burns and Honkala 1990).

Storjohann and Whitcomb (1977) collected lacebark elm seeds at Oklahoma State University and found that 75 to 80% of the seeds were empty. They also found that found that lacebark elm seeds are the most viable if collected before a hard freeze. Freshly collected fruits should be air-dried for a few days before being sown or stored. The number of seeds per weight varies widely, even within species (table 5).

Extraction and storage of seeds. Although the fruits can be de-winged by putting them into bags and beating with flails, this has been found to damage the seeds of American and Siberian elms (Cram and others 1966; George 1937). Elm seeds can be cleaned with an air-screen cleaner in a reverse procedure—blowing out the seeds, and catching the heavier leaves and twigs (Myatt 1996) with the air vents wide open on both sides of the cleaner. A large round-holed 9.9-mm screen (#25) is placed on top of the cleaner to separate the seeds from the leaves and a small round-holed 2.4-mm screen (#6) is placed on the bottom to separate the twigs from the seeds (Myatt and other 1998). Only 3 to 7% of the seeds blown out of the air chute in the back of the air-cleaner were good seeds (Myatt and others 1998).

Fruits usually are sown or stored with the wings attached. Elm seeds are orthodox in storage behavior and should be stored at low temperatures and moisture contents in sealed containers (table 4). Dessication of smoothleaf elm seeds to 3.3% moisture content did not reduce germination (Tompsett 1986). When the temperature of storage was increased at constant moisture contents, seed longevity was reduced within the range of ! 13 to 52 EC. Smoothleaf elm seeds stored at 22% moisture content (fresh-weight basis) died after 7 days at !75 CE, but seeds stored at 19% moisture content lost no germination ability. Lowering the storage temperature from !13 to !75 EC did not increase seed longevity. Tompsett (1986) found that a 5% moisture content and a temperature of !20 EC or lower maintains the long-term seed viability for smoothleaf elm seeds. Tylkowski (1989) reported that Russian elm seeds dried to 10% moisture could be stored at !1 to !3 EC for 5 years without losing any viability; however, after 6 years of storage, a 20% decrease in germination was observed. Siberian elm seeds with 3 to 8% moisture content have been stored at 2 to 4 EC in sealed containers for 8 years (Dirr and Heuser 1987). Air-dried Scots elm seeds stored at 1 to 10 EC were only viable for 6 months (Dirr and Heuser 1987).

Dried American elm seeds stored at 0, 10, and 20 EC declined from 65 to 70% germination before storage to less than 10% after 10.5 months of storage (Steinbauer and Steinbauer 1932). Another lot of dried American elms seeds stored at 20 EC exhibited a steady, continuous decline in germination when stored for 14 to 51 weeks compared to fresh seed germination values (Steinbauer and Steinbauer 1932). Barton (1939, 1953) found that a 75% germination value for American elm seeds was retained after 15 years of seed storage at ! 4 EC with a 3% seed moisture content .

Pregermination treatments. Under natural conditions, elm seeds that ripen in the spring usually germinate in the same growing season; seeds that ripen in the fall germinate in the following spring. Although seeds of most elm species require no presowing treatment, practically all the seeds in some seedlots of American elm remain dormant until the second season (Rudolf 1937). Dormant American elm seedlots should receive cold stratification for 2 to 3 months (Dirr and Heuser 1987). Seeds of slippery elm, especially from northern sources, also may show dormancy; fresh seeds germinated 70%; and 57% germinated after 2 months of cold, moist stratification (Dirr and Heuser 1987). Stratification at 5 EC for 60 to 90 days before sowing improves germination of cedar, smoothleaf, and September elms (Brinkman 1974; Dirr and Heuser 1987; Maisenhelder 1968).

Winged, Scots, Japanese, English, Russian, Siberian, and rock elms have no pregermination requirements (Dirr and Heuser 1987). Fresh seedlots of Scots elm germinated at 98%, but after 2 months of cold, moist stratification, only 88% germinated (Dirr and Heuser 1987). English elm rarely produces seeds, but fresh seeds will germinate at 100% with or without 2 months of stratification (Dirr and Heuser 1987). Fresh Siberian elm seeds germinated 96% and cold stratification did not improve germination (Dirr and Heuser 1987). Fresh lacebark elm seeds will germinate without pretreatment, but once dried they require 1 to 2 months of cold, moist stratification (Dirr and Heuser 1987).

Germination tests. Official testing rules for American elm call for alternating temperatures of 30 EC (day) for 8 hours and 20 EC (night) for 16 hours for 14 days on wet blotters and 10 days at a constant 20 EC for Chinese and Siberian elms (AOSA 2001). American elm seeds can also germinate well at alternating temperatures of 21 EC (day) and 10 EC (night) (Burns and Honkala 1990). The International Seed Testing Association (1999) suggests testing for 14 days on wet blotters for all 3 species. ISTA also suggests removal of the pericarp if germination is slow. Germination tests of most species may also be made on sand or peat in germinators at alternating temperatures of 30 EC (day) and 20 EC (night). Rock elm seeds germinated 70 to 80% in a peat moss media (Burns and Honkala 1990). Light requirements may vary among species (table 6). American elm can germinate in darkness but germination is increased with the addition of light (Burns and Honkala 1990).

Germination is epigeal (figure 3); it usually peaks within 10 days. Seedlots of stratified seeds complete germination in 10 to 30 days. With American elm seeds, germination can extend up to 60 days; seeds can lay on flooded ground for a month without adversely affecting germination (Burns and Honkala 1990). Radicles of rock elm emerge in 2 to 3 days in a petri dish and are 2.5 to 3.8 cm (1 to 1.5 in) long by the 5th day; cotyledons opened about the 5th or 6th day (Burns and Honkala 1990). Winged elms cotyledons are oval with shallowly notched apexes and heart-shaped bases and may persist 1 to 2 months on the seedling with primary leaves appearing 1 week after germination in natural forest conditions (Burns and Honkala 1990).

Nursery practice. Seeds of elm species ripening in the spring are usually sown immediately after collection, whereas seeds of fall-ripening species or of species requiring stratification are usually planted the following spring (table 7). Beds should be kept moist until germination is complete; shading is not usually necessary. From 5 to 12% of the viable cedar elm seeds sown can be expected to produce plantable stock (Burns and Honkala 1990). One-year-old seedlings usually are large enough for field planting. Rock elm seedlings have a persistent dormant bud, so seedlings rarely develop more than a single pair of true leaves in the first growing season (Burns and Honkala 1990). In northern Wisconsin, rock elm 1.5+0 nursery stock averaged 27 cm (10.6 in) in height 5 years after planting and 52 cm (20.5 in) in height 10 years after planting; first-year survival was 85% and 10th-year survival was 32% (Burns and Honkala 1990). To improve survival in semiarid regions, trees often are transferred into containers after 1 year in the seedbeds (Goor 1955). Slippery elm is commonly used as rootstock when grafting hybrid elms (Burns and Honkala 1990).

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Table 1—*Ulmus,* elm: nomenclature and occurrence

Scientific name & synonym(s)	Common name	Occurrence
***U. alata* Michx.**	**winged elm,** cork elm, wahoo	Virginia to Missouri, S to Oklahoma & E Texas, E to central Florida
***U. americana* L.**	**American elm,** water elm, soft elm, white elm	Quebec to E Saskatchewan, S to North Dakota, Oklahoma, & Texas, E to central Florida
***U. crassifolia* Nutt.**	**cedar elm,** basket elm, red elm, southern rock elm	SW Tennessee, Arkansas, & S Oklahoma to S Texas, Louisiana & W Mississippi
***U. glabra* Huds.** *U. scabra* Mill. *U. montana* With. *U. cammpestris* L. in part	**Scots elm,** Scotch elm, Wych elm	N & central Europe & Asia Minor
***U. japonica* (Sarg. ex Rehd.) Sarg.** *U. campestris* var. *japonica* Rehd. *U. davidiana* var. *japonica* (Rehd.) Nakai	**Japanese elm**	Japan & NE Asia
***U. laevis* Pall.** *U. pedunculata* Pall. *U. effusa* Willd. *U. racemosa* Borkh.	**Russian elm,** spreading elm, European white elm	Central Europe to W Asia
***U. minor* Mill.** *U. carpinifolia* Gled.	**Smoothleaf elm,** field elm	Central & S Europe, England, Algeria, & Near East
***U. parvifolia* Jacq.** *U. chinensis* Pers.	**Chinese elm,** leatherleaf elm lacebark elm	N & central China, Korea, Japan, & Formosa
***U. procera* Salisb.**	**English elm**	S & central England, NW Spain
***U. pumila* L.**	**Siberian elm,** Chinese elm, dwarf Asiatic elm	Turkestan, E Siberia, & N China
***U. rubra* Mühl.** *U. fulva* Michx.	**slippery elm,** grey elm, red elm, soft elm (lumber)	SW & Quebec to E North Dakota, S to W Oklahoma & SE & E Florida
***U. serotina* Sarg.**	**September elm,** red elm	Kentucky and S Illinois, S to N Alabama & NW Georgia; also in Arkansas & E Oklahoma
***U. thomasii* Sarg.** *U. racemosa* Thomas	**rock elm,** cork elm	Vermont to S Ontario, central Minnesota & SE South Dakota, S to E Kansas, E to Tennessee & New York

Sources: Brinkman (1974), Maisenhelder (1966), Rudolf (1937).

Table 2—*Ulmus,* elm: phenology of flowering and fruiting

Species	Location	Flowering dates	Fruit ripening dates	Seed dispersal dates	Seed size (mm)
U. alata	—	Feb–Apr	Apr	Apr	6–8
U. americana	From S to Canada	Feb–May	Late Feb–June	Mid-Mar–mid-June	13
U. crassifolia	SE US	Aug–Sept	Sept–Oct	Oct	6–13
U. glabra	Europe & Asia Minor	Mar–Apr	May–June	May–June	15–25
U. japonica	Japan	Apr–May	June	—	—
U. laevis	Massachusetts	Apr—May	May—June	May –June	10–15
U. parvifolia	NE US	Aug–Sept	Sept–Oct	Sept–Oct	10
U. pumila	E central US	Mar–Apr	Apr–May	Apr–May	10–14
U. rubra	F S to Canada	Feb–May	Apr–June	Apr–June	12–18
U. serotina	SE US	Sept	Nov	Nov	10–13
U. thomasii	NE US	Mar–May	May–June	May–June	13–25

Sources: Asakawa (1969), Brinkman (1974), Burns and Honkala (1990), Dirr (1998), FNAEC (1997), Hora (1981), Little and Delisle (1962), Loiseau (1945), Pammel and King (1930), Petrides (1958), Rehder (1940), Spector (1956), Stoeckeler and Jones (1957), Sus (1925) Vines (1960), Wappes (1932), Wyman (1947).

Table 3—*Ulmus,* elm: height, seed-bearing age, seed crop frequency, and fruit ripeness criteria

Species	Height at maturity (ft)	Year first cultivated	Minimum seed-bearing age (yr)	Interval between large seed crops (yrs)	Fruit color when ripe
U. alata	50	1820	—	—	Reddish green
U. americana	120	1752	15	—	Greenish brown
U. crassifolia	100	—	—	—	Green
U. glabra	130	Long cultivated	30–40	2–3	Yellow-brown
U. japonica	100	1895	—	2	—
U. laevis	100	Long cultivated	30–40	2–3	Yellow-brown
U. parvifolia	80	1794	—	—	Brown
U. pumila	80	1860	8	45	Yellow
U. rubra	70	1830	15	2–4	Green
U. serotina	60	1903	—	2-3	Light green to brownish
U. thomasii	100	1875	20	3–4	Yellow or brownish

Sources: Brinkman (1974), Burns and Honkala (1990), Dore (1965), FNAEC (1997), George (1937), Little and Delisle (1962), McDermott (1953), Van Dersal (1938), Vines (1960), Wappes (1932).

Table 4—*Ulmus,* elm: seed storage conditions

Species	Seed moisture (%)	Storage temp (EC)	Viable period (yr)
U. alata	Air-dried	4	1
U. americana	3–4	!4	15
	Air-dried	4	2
U. crassifolia	Air-dried	4	1
U. glabra	Air-dried	1–10	½
U. laevis	Air-dried	22	½
U. parvifolia	10–15	0	½
U. pumila	3–5	2–4	8
U. thomasii	Air-dried	Cold	—

Sources: Barton (1939, 1953), Brinkman (1974), Heit (1967a&b), Kirby and Santelmann (1964), Rohmeder (1942), Sus (1925).

Table 5—*Ulmus,* elm: seed yield data

Species	Place collected	Fruit/vol kg/hl	Fruit/vol lb/bu	Thousands of cleaned seeds/weight Average /kg	Average /lb	Range /kg	Range /lb	Samples
U. alata	Mississippi	—	—	245	112	222–269	101–119	4
U. americana	—	5.8	4.5	156	71	106–240	48–109	14
U. crassifolia	Mississippi	—	—	147	67	130–135	59–61	5
U. glabra	Europe	4-6.5	3–5	88	40	66–99	30–45	12+
U. japonica	Japan	—	—	12.8	6	—	—	2+
U. laevis	Russia	—	—	140	63	117–205	53–93	20+
U. parvifolia	US, Japan	—	—	265	121	250–372	114–169	6+
U. pumila	—	—	—	158	72	88–261	40–119	35+
U. rubra	—	—	—	90	41	77–119	35–54	10
U. serotina	—	—	—	328	149	—	—	—
U. thomasii	—	7.7–10.3	6–8	15	7	11–15	5–7	5

Sources: Asakawa (1969), Brinkman (1974), Engstrom and Stoeckeler (1941), Goor (1955), Gorshenin (1941), Heit (1969), Rafn and Son (1928), Stoeckeler and Jones (1957), Sus (1925), Swingle (1939), Taylor (1941), Van Dersal (1938), Wappes (1932).

Table 6—*Ulmus,* elm: germination test conditions and results

Species	Medium	Temp (EC) Day	Temp (EC) Night	Duration	Germinative energy Amount (%)	Germinative energy Period (days)	Germinative capacity Ave (%)	Samples	Purity (%)
U. alata	Soil	32	21	15	76	7	91	6	—
U. americana	Paper pads	30	20	14	—	—	—	—	—
	Kimpak	30	20	28	—	—	67	1	—-
	—	—	—	13–60	55	7	64	15	92
U. crassifolia	Soil	32	21	80	56	78	56	2	—
U. glabra	Germinator or sand	70–86 21–30	68–77 20–25	30–60	—	—	44	72+	—
U. laevis	Germinator or sand	21	21	30	—	—	65	22+	85
U. parvifolia	Paper pads	68–85 20–29	20	10–60	—	—	55	2+	64
U. pumila	Paper pads	—	—	10	—	—	—	—	—
	Kimpak	30	20	28	—	—	81	1	—
	Germinator or sand	68–86 20–30	20	30	55	10	76	48	90
U. rubra	Sand	30	20	60	21	10	23	5	94
U. serotina	Soil	32	21	30	68	20	72	1	—
U. thomasii	Sand or petri dish	30	20	30	77	8	81	11	95

Sources: Arisumi and Harrison (1961), AOSA (2001), Engstrom and Stoeckeler (1941), Gorshenin (1941), Heit (1967a&, 1968), ISTA (1999), Johnson (1946), Kirby and Santelman (1964), Maisenhelder (1968), McDermott (1953), NBV (1946), Rafn and Son (1928), Rohmeder (1942), Spector (1956), Stoeckeler and Jones (1957), Sus (1925), Swingle (1939), USDA FS (2002), Wappes (1932).

* Light for 8 hours or more per day is recommended for American elm (AOSA 2001; ISTA 1999; McDermott 1953). Light is neither required nor inhibitory for germination of winged elm (Loiseau 1945), Chinese and Siberian elm (AOSA 2001; ISTA 1999).

Table 7—*Ulmus,* elm: nursery practice

Species	Sowing season*	Seedlings/area /m^2	/ft^2	Sowing depth mm	in	Tree percent	Out-planting age (yrs)
U. alata	Summer	—	—	0–6.4	0–¼	—	1
U. americana	Spring	5	2	6.4	¼	12	1
U. crassifolia	Spring	—	—	0–6.4	0–¼	—	1
U. glabra	Summer	—	—	0–6.4	0–¼	—	—
U. laevis	Summer	—	—	0-6.4	0–¼	6	1–2
U. parvifolia	Spring	25–30	2–3	4.8–6.4	3/16–¼	12–20	1–2
U. pumila	Summer	—	—	6.4	¼	3–7	1–2
U. rubra	Spring	25	2	6.4	¼	—	1
U. serotina	Spring	—	—	0–6.4	0–¼	—	1
U. thomasii	Spring	15–38	1–4 6.4	¼	—	2	

Sources: Baker (1969), Deasy (1954), Engstrom and Stoeckeler (1941), George (1937), Kirby and Santelman (1964), Rohmeder (1942), Stoeckeler and Jones (1957), Sus (1925), Swingle (1939), Toumey and Korstian (1942).
* Spring-sowing was preceded by stratification in sand or in a plastic bag at 4 to 5 EC for 60 days.