Fabaceae—Pea family

Ulex europaeus L.

common gorse

George P. Markin

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Growth habit, occurrence, and use. Gorse is a leafless, spined shrub introduced from western Europe. In its homeland, it grows 1 to 2 m tall and is primarily a non-aggressive invader of disturbed areas that is recognized as useful for wildlife protection, soil stabilization, and revegetation. It has also been cultivated as an ornamental and as forage for livestock, which feed on the soft, new growing shoots. Its major use in the past, however, was for hedgerows to contain livestock before barbed wire (Jobson and Thomas 1964). As a useful plant, European settlers carried gorse to many parts of the world where it quickly escaped from cultivation and formed aggressive feral populations. These feral plants grow 3 to 5 m tall in dense, spiny, impenetrable stands that exclude desirable vegetation in pasture lands (Hill 1983; Sandrey 1985) and, in open forests, interfere with reforestation and forest management (Balneaves and Zabkiewicz 1981; Zabkiewicz 1976). Gorse is presently recognized as one of the worst weeds in New Zealand, Chile, and Tasmania and is recognized as a weed in at least 15 other countries or island groups around the world (Holm and others 1979).

In North America, gorse is still used to a limited extent as an ornamental for its dense yellow flowers. In the eastern United States, scattered feral populations have been recorded, but apparently these are not of an aggressive nature. By contrast, along the Pacific Coast, gorse is found scattered along the coastline from San Francisco, California, north to Vancouver, British Columbia (Markin and others 1994). Through most of this area, it is found in small, scattered populations that are usually targeted for intensive control programs to keep them from expanding. The major outbreak along the southwestern coast of Oregon covers at least 15,000 ha and is a major problem in forest management. This gorse population interferes with reforestation and, because of the plant's highly flammable nature, creates an extreme fire hazard (Herman and Newton 1968). Gorse also infests 14,000 ha at higher elevations on the islands of Hawaii and Maui in Hawaii (Markin and others 1988).

As a useful agricultural and ornamental plant in its native range, methods for propagating gorse have been developed in Europe (Rudolf 1974). As a major weed through the rest of the world, no effort has been made to propagate it for sale or outplanting. However, very extensive work has been done in studying the regeneration, reproduction, and propagation of this plant for research purposes and to develop control methods, particularly in New Zealand. A more recent need has been to propagate gorse to be used as food for insects being tested as potential biocontrol agents (Markin and Yoshioka 1989).

Flowering and fruiting. The small, bright yellow, pea-like flowers (Whitson and others 1991) are very similar in size and appearance to those of the closely related Scotch broom—*Cytisus scoparius* (L.) Link—with which it shares much of its range on the Pacific Coast. In Europe, gorse blooms in late spring, usually for 1 month; depending upon the latitude, this can occur from late February to early June. On the Oregon coast, gorse blooms from February to early May; in Hawaii, it blooms from December to May, peaking in February and April. Flowers may be solitary or in clusters, but because they are often synchronized in blooming, an entire plant will sometimes be covered with thousands of blooms. The flowers are insect-pollinated and require a large insect that, while probing for nectar, can trip and release the stamens held in the keel on the lower surface of the flower. The major pollinator in North America and Hawaii is the common honey bee (*Apis mellifera* L.). When massive blooms occur in areas where feral bees are scarce, poor pod set may be seen in limited areas (a desirable feature for land managers). Beekeepers, however, recognize the bloom as an excellent source of early spring pollen that can be used to build up their hives, and they usually move hives in to take advantage of the bloom, resulting in adequate pollination (Sandrey 1985). One method of control that has been used in Hawaii is restricting commercial bees in an effort to reduce seed production.

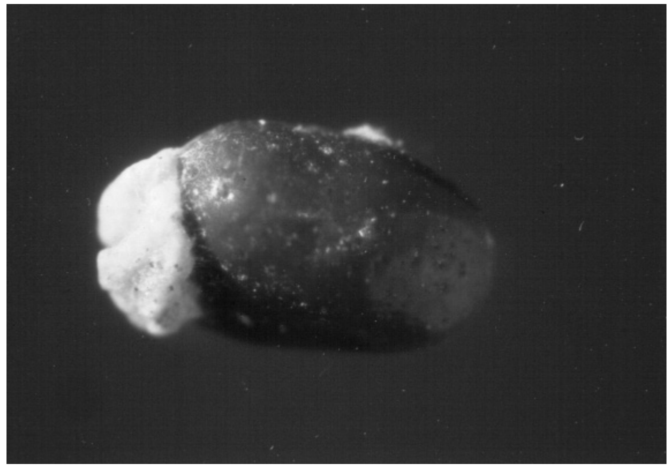
The mature fruit is a typical, small (1 to 1.5 cm), black legume (pod) that contains 1 to 12 seeds, although the average is 4 to 5. After pollination, a legume requires 2 months to mature, so peak legume set occurs 2 months after peak flowering. In Oregon, this is mid-May through July; in Hawaii, peak legume set is in May and is finished by the first of July. On maturing and drying, the legumes open violently (dehisce), naturally dispersing the seeds 1 to 3 m out from the parent plant. In Oregon and Hawaii, natural germination usually occurs during the wetter winter and spring months.

Fruit collection; seed extraction and storage. As an aggressive, noxious weed, there is no demand for the commercial collection of seeds. Researchers obtain the seeds they need by collecting the mature black legumes individually or by cutting a branch containing them. When allowed to dry out in a cloth sack at room temperature, the legumes naturally dehisce, releasing the seeds. The mature brown seeds are generally spherical, 1.25 to 2 mm in diameter (figure 1). Each seed initially contains an elaiosome, a yellow, fleshy appendage, rich in oil and protein (Pemberton and Irving 1990) that attract ants; this is another method of seed dispersal (Weiss 1909). The gorse seedcoat is notorious for its hardness (it is water impermeable), which gives the seeds a very long field life and has created major problems in managing this weed (Butler 1976; Chater 1931; Moss 1959). Seed numbers range from 145,000 to 159,000/kg and average about 150,000/kg (66,000 to 72,000/lb and average about 68,000/lb) (Rudolf 1974). The seeds are orthodox in storage behavior and can be kept indefinitely in ordinary cool, dry storage.

Pregermination treatments. Germination of mature, well-dried seeds varies greatly according to the literature but can be as low as 10 to 30% in 6 months. In the field, the seeds have a long life; it has been estimated that they can remain viable for up to 26 years or more (Moss 1959).

Because of the seedcoat's hardness, a number of different pregermination treatments have been tried. In the field, the most common method to trigger germination is fire. When a gorse area burns, the seeds in the top centimeter or two of duff are destroyed, but the deeper seeds survive and most of these are often triggered into germinating (Rolston and Talbot 1980; Zabkiewicz and Gaskin 1978). In the laboratory, this can be duplicated by heating the seeds from 60 to 80 °C for 30 minutes in an oven (Butler 1976; Moss 1959). Placing gorse seeds in boiling water for 30 seconds and then cooling them in cold water can increase germination to over 90% (Millener 1961).

Figure 1—*Ulex europaeus*, common gorse: seed.



Other methods of germination include soaking in concentrated sulfuric acid for $^1/_2$ to $1^1/_2$ hours, and mechanical scarification (Buttler 1976), most simply done with emery paper (Moss 1959).

Germination tests. Because of the noxious nature of gorse in North America, standardized germination tests for quality control have not been developed. In Europe, where gorse is a beneficial native plant, germination tests at one time were apparently developed in which seeds were tested in germinators or sand flats at 20 °C for 30 days using 400 pretreatment seeds/test (Rudolf 1974). Researchers have reported no problem in obtaining germination by planting scarified seeds 1 cm deep in different media. First signs of germination are usually seen within 10 days of planting. In 15 to 25 days, seedlings are small rosettes with true leaves, approximately 1.5 cm in diameter. Small leaves continue to form until the plant is approximately 5 cm tall, at which time the first spines are produced. During the remainder of its life, the plant produces no more leaves, only spines. The juvenile stage of the plant, from seed germination until spines begin to form, requires 4 to 6 months in the field. In Europe, large-scale germination in pots and direct seeding into the field have been practiced in the past (Rudolf 1974).

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Ulmaceae—Elm family

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 1930s, 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

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

Scientific name & synonym(s)	Common name(s)	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).

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 Scots 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

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

Species	Location	Flowering	Fruit ripening	Seed dispersal	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).

Figure 1—*Ulmus*, elm: samaras of *U. alata*, winged elm (**top left**); *U. americana*, American elm (**top right**); *U. parvifolia*, Chinese elm (**middle left**); *U. pumila*, Siberian elm (**middle center**); *U. rubra*, slippery elm (**middle right**); *U. crassifolia*, cedar elm (**bottom left**); and *U. thomasii*, rock elm (**bottom right**).

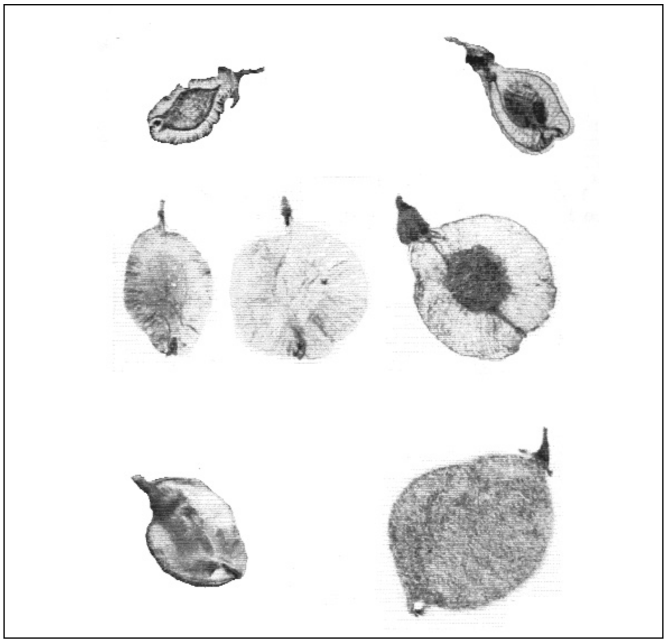

Figure 2—*Ulmus alata*, winged elm: longitudinal section through a seed.

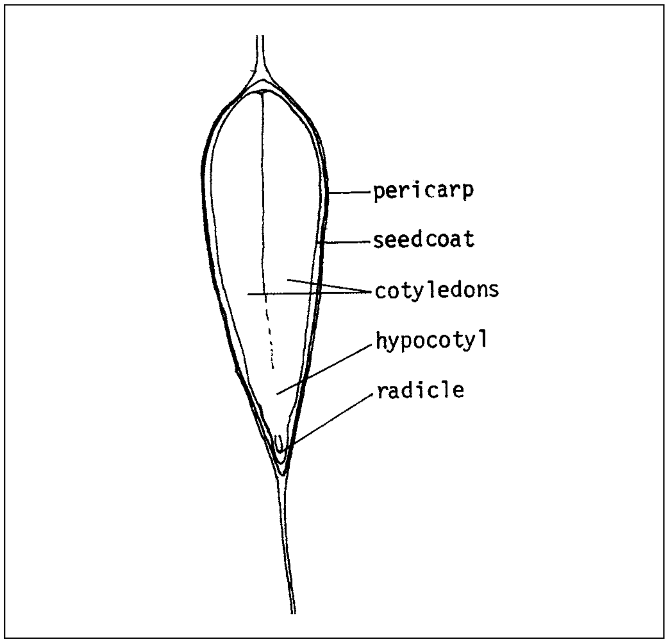

Table 3—*Ulmus*, elm: height, seed-bearing age, seed crop frequency, and fruit ripeness criteria

Species	Height at maturity (ft)	Year first cultivated	Minimum seed-bearing age (yr)	Years between large seedcrops	Ripe 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).

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 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

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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 °C. Smoothleaf elm seeds stored at 22% moisture content (fresh-weight basis) died after 7 days at –75 C°, but seeds stored at 19% moisture content lost no germination ability. Lowering the storage temperature from –13 to –75 °C did not increase seed longevity. Tompsett (1986) found that a 5% moisture content and a temperature of –20 °C 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 °C 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 °C in sealed containers for 8 years (Dirr and Heuser 1987). Air-dried Scots elm seeds stored at 1 to 10 °C were only viable for 6 months (Dirr and Heuser 1987).

Dried American elm seeds stored at 0, 10, and 20 °C 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 °C 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 °C 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

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

Species	Seed moisture (%)	Storage temp (°C)	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	0.5
U. laevis	Air-dried	22	0.5
U. parvifolia	10–15	0	0.5
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	Cleaned seeds (x1,000)/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

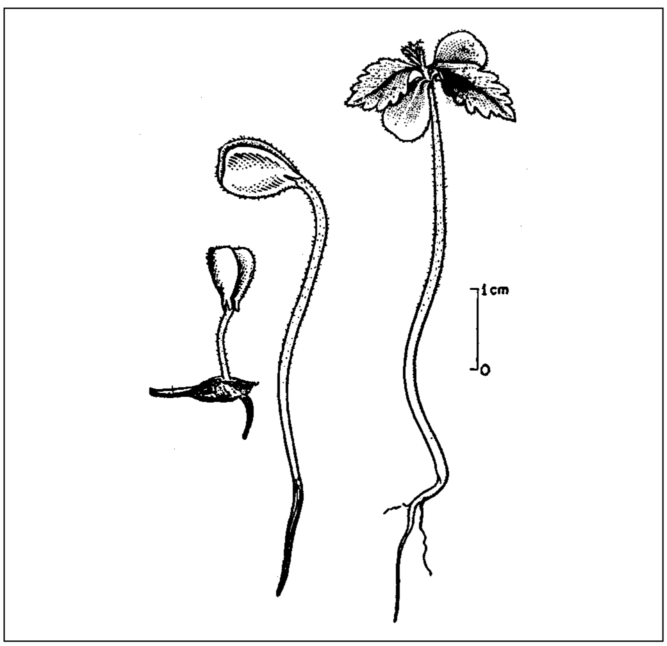
Sources: Asakawa (1969), Brinkman (1974), Engstrom and Stoeckeler (1941), Goor (1955), Gorshenin (1941), Heit (1969), Rafn and Son (1928), Stoeckeler and Jones (1957), Sus (1925), Swingle (1939), Taylor (1941), Van Dersal (1938), Wappes (1932).

months (Dirr and Heuser 1987). Seeds of slippery elm, especially from northern sources, also may show dormancy; 70% of fresh seeds germinated and 57% germinated after 2 months of cold, moist stratification (Dirr and Heuser 1987). Stratification at 5 °C 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 °C (day) for 8 hours and 20 °C (night) for 16 hours for 14 days on wet blotters and 10 days at a constant 20 °C for Chinese and Siberian elms (AOSA 2001). American elm seeds can also germinate well at alternating temperatures of 21 °C (day) and 10 °C (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 °C (day) and 20 °C (night). Rock elm seeds germinated 70 to 80% in a peat moss medium (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).

Figure 3—*Ulmus americana*, American elm: seedling development at 1, 3, and 21 days after germination.



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).

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

Species	Germination test conditions* Medium	Temp (°C) Day	Temp (°C) Night	Days	Germinative energy Amount (%)	Germinative energy Period (days)	Germinative capacity Avg (%)	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	21–30	20–25	30–60	—	—	44	72+	—
U. laevis	Germinator or sand	21	21	30	—	—	65	22+	85
U. parvifolia	Paper pads	20–29	20	10–60	—	—	55	2+	64
U. pumila	Paper pads	—	—	10	—	—	—	—	—
	Kimpak	30	20	28	—	—	81	1	—
	Germinator or sand	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), and Chinese and Siberian elms (AOSA 2001; ISTA 1999).

Table 7—*Ulmus*, elm: nursery practice

Species	Sowing season*	Seedlings/area /m²	Seedlings/area /ft²	Sowing depth mm	Sowing depth in	Tree percent	Out-planting age (yrs)
U. alata	Summer	—	—	0–6.4	0–1/4	—	1
U. americana	Spring	5	2	6.4	1/4	12	1
U. crassifolia	Spring	—	—	0–6.4	0–1/4	—	1
U. glabra	Summer	—	—	0–6.4	0–1/4	—	—
U. laevis	Summer	—	—	0-6.4	0–1/4	6	1–2
U. parvifolia	Spring	25–30	2–3	4.8–6.4	3/16–1/4	12–20	1–2
U. pumila	Summer	—	—	6.4	1/4	3–7	1–2
U. rubra	Spring	25	2	6.4	1/4	—	1
U. serotina	Spring	—	—	0–6.4	0–1/4	—	1
U. thomasii	Spring	15–38	1–4	6.4	1/4	—	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 °C for 60 days.

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Lauraceae—Laurel family

Umbellularia californica (Hook. & Arn.) Nutt.

California-laurel

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Growth habit, occurrence, and uses. The genus *Umbellularia* contains a single species—*Umbellularia californica* (Hook. & Arn.) Nutt.—that has many common names (Coombes 1992; Stein 1990), the best known being California-laurel, California-olive, Oregon-myrtle, myrtlewood, bay, laurel, and pepperwood. California-laurel is a broad-leaved evergreen that matures either as a shrub or tall forest tree. Over much of its range, it attains heights of 12 to 24 m and diameters of 46 to 76 cm, but near the ocean, in the chaparral, and on other severe or rocky sites it is confined to prostrate or shrub sizes (Harlow and others 1979; Jepson 1910). In the protected bottomlands of southern Oregon and northern California, mature trees are 91 to 305 cm in diameter and 30 or more m tall (Harlow and others 1979). A maximum circumference of 1,387 cm at 137 cm above ground (AFA 2000) and a maximum height of 53.3 m have been reported (Sargent 1961).

Several racial variations are recognized. *Umbellularia californic*a forma *pendula* Rehd. is an uncommon, broad-spreading tree distinctive for its pendulous branchlets that contrast strongly with typically ascending branch growth (Jepson 1910; Rehder 1940). *U. californica* var. *fresnensis* Eastwood has fine white down on the lower surfaces of leaves and branches of the panicle (Eastwood 1945). Several forms that Jepson (1910) describes—gregarious, rockpile, dwarf, and prostrate—may indicate other varietal differences.

The range of California-laurel spans more than 11 degrees of latitude, from near the 44th parallel in the Umpqua River Valley of Douglas County, Oregon, south beyond the 33rd parallel in San Diego County, California, nearly to the Mexican border. California-laurel is widely distributed in the coast ranges and less abundantly in inland valleys and the Siskiyou and Sierra Mountains (Sudworth 1908). It may be found from sea level to 1,220 m in much of its range, and from 610 to 1,520 m in southern California (Jepson 1910). Pure, dense stands of California-laurel develop in some areas, but more often it is intermixed with other tree and shrub species. It grows in many kinds of soils under both cool-humid and hot-dry atmospheric conditions (Stein 1990). In xeric climates, it is most prominent where soil moisture is favorable—on alluvial deposits or protected slopes, along watercourses, near springs and seeps—but in its shrub form, it also is found on dry slopes and is a common component of chaparral (Sampson and Jespersen 1963).

All parts of the tree have served human needs. Wood of this species compares favorably in machining quality with the best eastern hardwoods (Davis 1947) and is used for woodenware, interior trim, furniture, paneling, veneer, and gunstocks. Burls and other growths with distorted grain are especially prized for making the gift and novelty items that are marketed extensively as "myrtlewood." Dried leaves are used for seasoning meats and soups (McMinn 1970). In an earlier day, Hudson Bay Company trappers brewed a comforting tea from the leaves to overcome chill (Ross 1966). David Douglas learned that hunters made a drink from the bark and declared it "by no means an unpalatable beverage" (Harvey 1947). Native Americans ate substantial quantities of the fruit and seeds, made a drink from the bark of the roots, and used the leaves for several internal and external medicinal purposes, including vermin control (Chesnut 1902).

Extracts of the leaves, seeds, and wood have strong chemical properties and should be used with caution. Vapor from the aromatic leaves can cause sneezing, headache, sinus irritation, other severe discomforts, and even unconsciousness (Drake and Stuhr 1935; Peattie 1953). The leaves contain considerable menthol (Stein 1974) and the ketone umbellulone, which when extracted from the leaf oil, interferes strongly enough with respiration, heartbeat, and blood circulation to cause death in laboratory animals (Drake and Stuhr 1935). Umbellulone also has fungicidal and germicidal properties (Drake and Stuhr 1935). Oils from the wood, leaves, and seeds have been sold for pharmaceutical purposes such as treating catarrh, nervous disorders, rheumatism, meningitis, intestinal colic, and dyspepsia (Peattie 1953; Sargent 1895; Stuhr 1933).

California-laurel is used to a moderate extent as an ornamental evergreen. It has thick, glossy, medium-to-dark green persistent leaves that turn orange or yellow before they drop individually and contrasting pale yellow flowers. The very dense aromatic foliage often shapes naturally into a pleasing, symmetrical, rounded crown. Since it was first cultivated in 1829 (Rehder 1940), it has demonstrated the ability to grow well far outside its natural range (Stein 1958). It can be grown as a decorative potted plant for lobbies and patios and will tolerate moderate pruning (Kasapligil and Talton 1973).

California-laurel also has wildlife values—young sprouts are choice browse in spring and summer. Year-long use is rated by Sampson and Jespersen (1963) as good to fair for deer (*Odocoileus* spp.) and fair to poor for cattle, sheep, and goats. Longhurst and others (1952) list it as a principal browse species for deer in the north coastal ranges of California. Silver gray-squirrels (*Sciurus griseus*), dusky-footed wood rats (*Neotoma fuscipes*), and Steller's jays (*Cyanocitta stelleri*) feed on the seeds extensively (Bailey 1936; Van Dersal 1938). Hogs eat both seeds and roots (Jepson 1910; Van Dersal 1938).

Flowering and fruiting. California-laurel flowers regularly and often profusely. The small, pale yellow, perfect flowers grow on short-stemmed umbels that originate from leaf axils or near the terminal bud (figure 1). Flower buds develop early; those for the following year become prominent as current-year fruits are maturing. Within its long north–south range, California-laurel has been reported to flower in all months from November to May, beginning before new leaves appear (Jepson 1910; Kasapligil and Talton 1973; Rehder 1940; Unsicker 1974). The flowering period may stretch into late spring and summer with the occasional appearance of flowers originating in axils of the current year's developing leaves (Sargent 1895). California-laurel flowers at an early age; flowers have been observed on short whiplike shrubs and on 1-year-old sucker growth that originated on a long broken stub. Small insects appear to be the chief pollinaters (Kasapligil 1951).

Seedcrops are abundant in most years (Stein 1974). Although umbels bear 4 to 9 flowers each, generally only 1 to 3 fruits set (Jepson 1910). The age when a tree first bears fruit, the age for maximum production, and the average quantity produced have not been reported. Seeds are produced in abundance after trees are 30 to 40 years old (Harlow and others 1979). Damage to developing seedcrops by insects, birds, or diseases has not been reported.

Collection, extraction, and storage. The fruits—acrid drupes each containing a single, large, thin-shelled seed—ripen in the first autumn after flowering (Rehder 1940; Sargent 1895; Sudworth 1908). As the drupes mature, their thin, fleshy hulls change from medium green to speckled yellow green (Britton 1908; Sudworth 1908) (figure 1), pale yellow (Eliot 1938), or various other hues, ranging from yellow-green tinged with dull red or purple (Peattie 1953; Sargent 1895) through purplish brown (Jepson 1910; Kasapligil 1951) to purple (Kellogg 1882; Sargent 1892; Torrey 1856). Ripe drupes may be yellow-green on one tree and dark purple on an adjacent tree (Stein 1974).

Drupes fall stemless to the ground in late autumn or winter and are dispersed by gravity, wind, animals, and water (McBride 1969). Seeds are collected simply by gathering fallen drupes—if squirrels and other animals don't get there first. Shaking ripe drupes from the tree should provide a good means for making quick, efficient collections.

When soft, the fleshy hulls are readily removed from the seeds by hand. The hulls can also be removed easily by machines used for de-pulping drupes if quantity processing is required. Mirov and Kraebel (1937) obtained about 300 cleaned seeds (figure 2) from 0.45 kg (1 lb) of drupes. For 8 samples processed at Davis, California (Lippitt 1995), the seed count averaged 547/kg (248/lb) and ranged from 403 to 675/kg (183 to 306/lb).

Figure 1—*Umbellularia californica*, California-laurel: yellow-green mature drupe suspended from its conical capula.

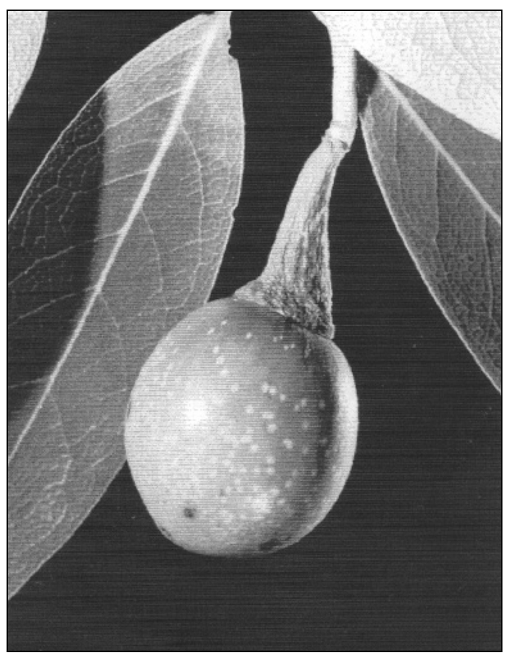


Figure 2—*Umbellularia californica*, California-laurel: exterior views of cleaned seeds.

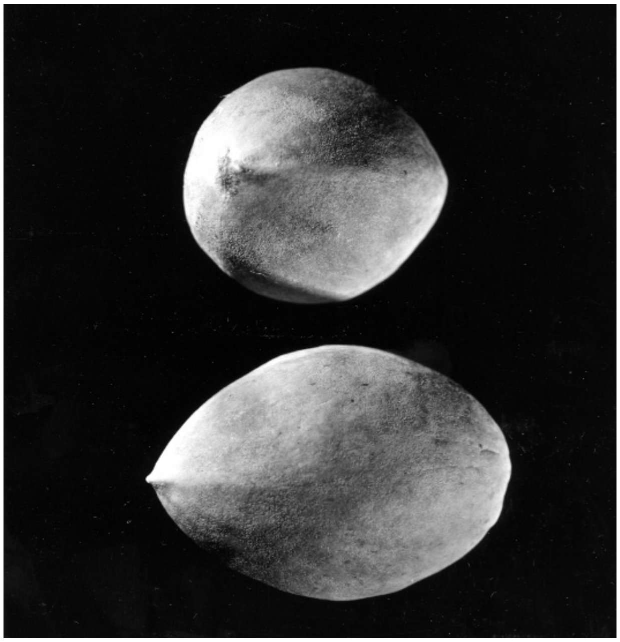
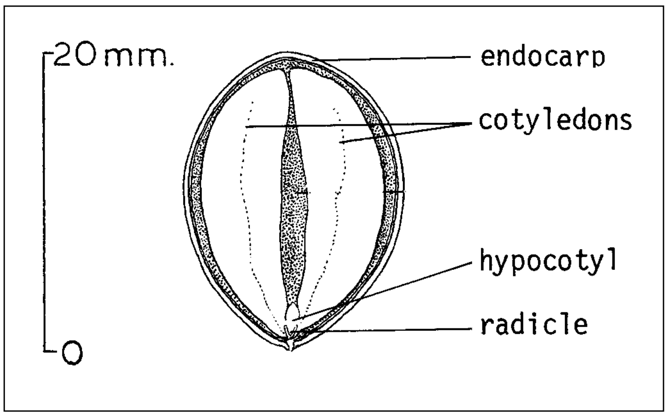


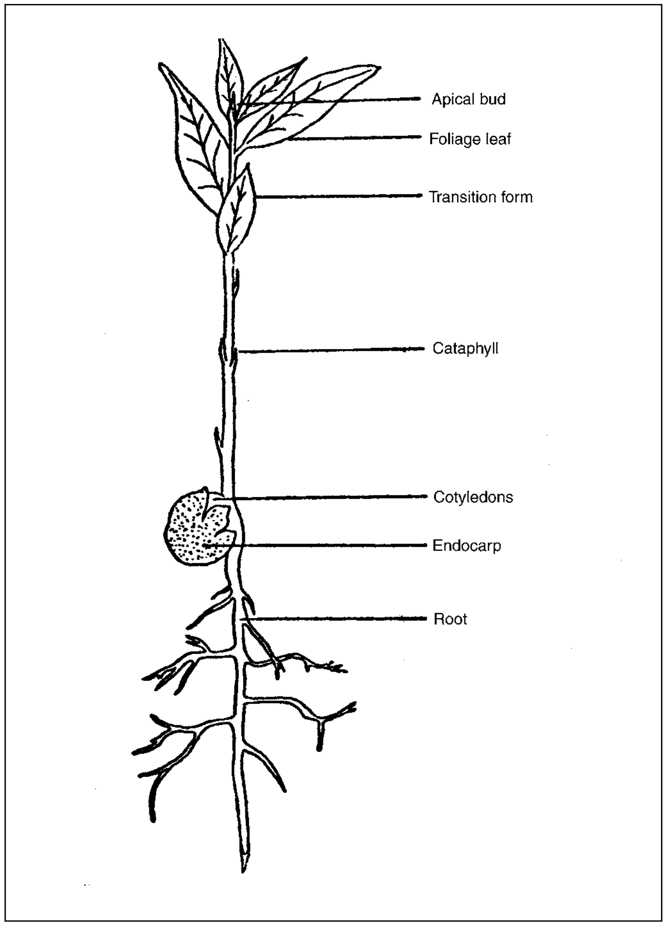
Figure 3—*Umbellularia californica*, California-laurel: tudinal section through a seed.



Seeds of California-laurel have lost viability in storage even at low temperatures, so yearly collection of fresh seeds is advised (Stein 1974). Viability has been maintained for 6 months when seeds were stored at 3 °C in wet, fungicide-treated vermiculite (McBride 1969). Storage trials have been very limited and tests of cool, moist storage at different moisture contents are needed. Highest germination (81%) was obtained from a seedlot with 32% moisture content (Lippitt 1995). Under favorable natural conditions, seeds on the ground retain their viability over winter, but under adverse conditions, viability may prove transient.

Seed treatment and germination. Fresh untreated seeds will germinate under room or outdoor conditions in peat moss, sawdust, vermiculite, or light-textured soil but may require 3 months or longer (Kasapligil 1951; Mirov and

Figure 4—*Umbellularia californica*, California-laurel: 4-month-old seedling (from Stein 1974, courtesy of Baki Kasapligil 1951).



Kraebel 1937; Stein 1974). Germination can be speeded by scarifying, cracking, or removing the endocarp or by stratifying the seeds, but it still may require about 2 months (Kasapligil 1951; McBride 1969; Stein 1974). In light soil, 20 to 25% of untreated seeds germinated; with stratification, germination nearly doubled (Stein 1974). In 16 lots of seeds collected in 1969 from Oregon and California sources, germination by the end of March ranged from 0 to 82% after January planting deep in pots of peat or vermiculite. Parts of seedlots held in a refrigerator at 4.4 °C from November to January germinated somewhat better than those immediately planted outdoors in a peat–vermiculite mixture. The better seedlots germinated equally well in several contrasting test conditions (Stein 1974).

In comparison tests made in petri dishes, California-laurel germination was highest in 30 days under a temperature regime of 16 °C day, 7 °C night, and when evaporative stress was minimal (McBride 1969). Germination did not appear affected by light level but was highest in soil with moisture tension at 4 to 10 atmospheres.

Seedling development and nursery practice. Under forest conditions, germination has been reported to take place in autumn soon after seedfall (Harlow and others 1979; Sargent 1895; Sudworth 1908) or in late winter and spring (Stein 1958, 1974). Covered seeds germinate best, but the large seeds do not bury readily without ground disturbance or silt deposition by high water. Seedling establishment is uncommon in the drier parts of California except in protected areas and where the ground is disturbed (Jepson 1910).

Germination is hypogeal, and the fleshy cotyledons remain within the endocarp and attached to the seedling until midsummer, when the plant may be 15 to 20 cm tall (Kasapligil 1951; Sargent 1895). Generally, there are 2 large cotyledons, sometimes 3, and no endosperm (figure 3) (Kasapligil 1951).

Young California-laurel seedlings appear flexible in their growth requirements. In the first 120 days, seedlings potted in vermiculite grew well at several levels of temperature, evaporative stress, soil moisture, and soil nutrients (McBride 1969). Seedlings grown at 18% or more of full sunlight produced the most dry weight. Seedlings produce leaves of several transitional forms as they develop (figure 4) and do not branch until they are 2 or 3 years old unless so induced by removal of the terminal bud (Kasapligil 1951). They soon develop a moderately stout taproot and are difficult to transplant if more than 1 year old unless grown in containers. Recovery after transplanting is often slow, and height growth may be limited for several seasons.

California-laurel may also be reproduced by cuttings (Stein 1974). Under field conditions, it sprouts prolifically from the root collar, stump, and fallen or standing trunk.

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