Rosaceae—Rose family

Oemleria cerasiformis (Torr. & Gray ex Hook. & Arn.) Landon

osoberry

William I. Stein

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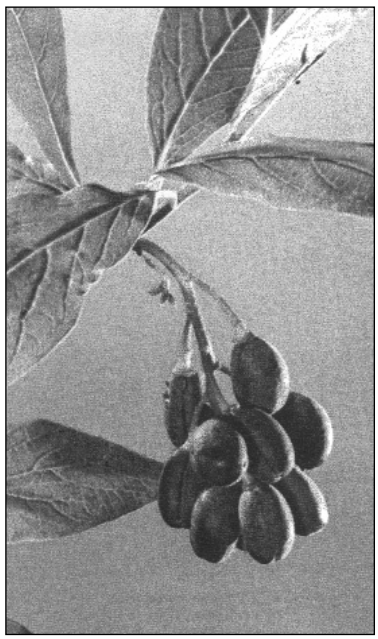
Other common names. Indian plum, squaw-plum, Indian peach.

Growth habit, occurrence, and uses. The genus *Oemleria* contains a single species—osoberry, *Oemleria cerasiformis* (Torr. & Gray ex Hook. & Arn.) Landon. Osoberry was described originally as *Nuttalia cerasiformis,* then identified for decades as *Osmaronia cerasiformis* (Hunt 1970) until an earlier legitimate name was rediscovered about 30 years ago (Landon 1975).

Osoberry is a deciduous, generally multiple-stemmed shrub that is 1.5 to 5 m or taller and sometimes develops into a small tree (Abrams 1944; Hitchcock and others 1961). A plant may have 10 or more stems and can produce new stems throughout its lifetime. Individual stems 7 m tall and 50 years of age have been observed (Allen and Antos 1993). Osoberry's native range is from the Pacific Coast eastward into the Cascade Mountains and the Sierra Nevada from southwest British Columbia southward to California, extending to Tulare County in the Sierras and northern Santa Barbara County in the coastal ranges (Hitchcock and others 1961; McMinn 1970). It is most widely distributed from the Willamette Valley northward to Vancouver Island on stream terraces, alluvial soils, and other moist to moderately dry locations, especially in Oregon white oak (*Quercus garryana* Dougl. ex Hook.) woodlands and open Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests. Based on a sampling of osoberry stands at 56 locations, Antos and Allen (1990b) concluded that its geographical distribution is related to (1) a fairly mild maritime climate, (2) moist areas over much of its range, (3) an inability to tolerate low light levels or wet soils, and (4) a need for disturbance to allow seedling establishment. It is most common at elevations below 250 m but occurs up to 1,700 m in the southern part of its range (Antos and Allen 1990b; Munz and Keck 1959). Two varieties were described in 1905—*lancifolia* in British Columbia and *nigra* in Washington (Hitchcock and others 1961)—but their recognition is now uncertain.

Ripening osoberry fruits are highly attractive to birds such as cedar waxwings (*Bombycilla cedrorum*), and ripe fruits are readily eaten by both birds and mammals (Dayton 1931; Dimock and Stein 1974). The fruits were eaten in small quantities fresh, cooked, or dried by Native American peoples in the Pacific Northwest; twigs and bark were used for several medicinal purposes (Gunther 1945; Mitchem 1993; Pojar and Mackinnon 1994). Flavor of the fruits apparently varies by locality, from sweet to bitter (Dayton 1931). Its attractiveness as an ornamental includes flushing of light green leaves and white flowers much earlier than other plant associates, handsome variegated appearance as scattered leaves throughout the crown turn yellow in early summer, and colorful clusters of fruit (figure 1) that soon disperse or are eaten by wildlife.

Figure 1—*Oemleria cerasiformis*, osoberry: ripe and near-ripe fruits; their color changes from reddish to purple when fully ripe.



Flowering and Fruiting. Anatomical and natural population studies have confirmed strongly that osoberry is dioecious, with male and female plants similar in size, growth form, morphology of vegetative structures, and microhabitats occupied (Allen and Antos 1988, 1993, 1999; Antos and Allen 1990a; Sterling 1964). Flowering period in osoberry is relatively short and varies with latitude and elevation from January to May concurrent with leaf development (Allen 1986; Haskin 1967; Hitchcock and others 1961; McMinn 1970). Both male and female plants flower frequently except in low light; male plants are generally more abundant and may have up to 3 times as many flowers as female plants (Allen 1986; Allen and Antos 1988, 1993). Male plants start flowering earlier than female plants but reach peak abundance and finish flowering later (Allen 1986). First flowering has occurred 2 years after germination on male plants raised from seed (Allen and Antos 1993). The 5-petaled flowers are white, fragrant, and borne on drooping racemes (figure 2). Osoberry pollen is sculptured and distinctive among Rosaceae pollens studied in western Canada (Hebda and others 1991).

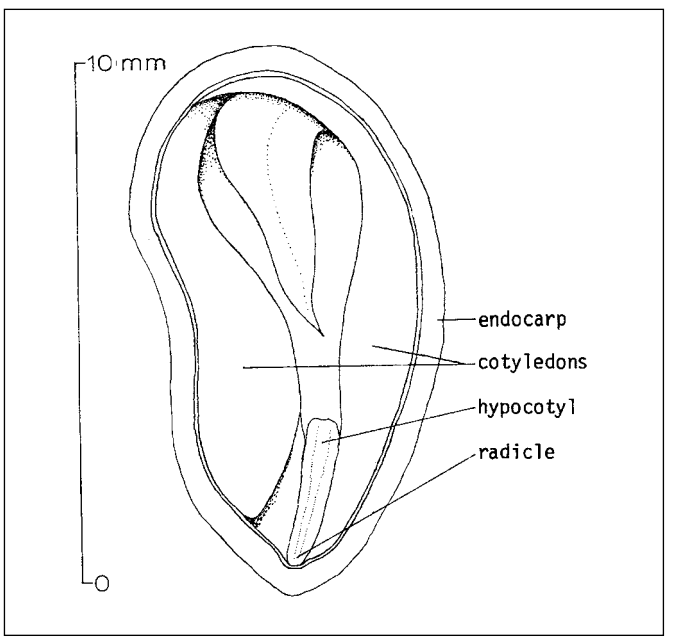
Pistillate flowers may yield up to 5 thin-fleshed, single-seeded drupes per flower, but generally fewer than 60% of pistils on a plant bear fruit; production from 10 to 20 of pistils has been reported (Antos and Allen 1994, 1999). Higher light levels favorably influence fruit set; exposure to light is gained by early flowering before deciduous associates leaf out (Allen and Antos 1988). Fruits develop and ripen in 10 to 12 weeks near Victoria, British Columbia (Antos and Allen 1994). Developing fruits become peach colored, then reddish, and finally deep blue-black under a whitish bloom when ripe (figure 1). In the Pacific Northwest, dispersal by gravity, birds, and mammals may begin in May and be nearly finished in July (Dimock and Stein 1974), substantially earlier than the August 1 to September 15 collection period listed for California by Mirov and Kraebel (1939).

Collection, extraction, and storage. Clusters of the ripe 1-seeded drupes can be stripped readily from the shrubs by hand. Fruits in small collections are de-pulped easily by rubbing them against a submerged screen or by running them through a macerator followed by repeated washings to float off the loosened pulp. Fruit biomass is about half pulp and half seed (ovendry weight); the seeds have a much higher nitrogen concentration (Antos and Allen 1990a, 1994). Osoberry seeds have a bony endocarp (Abrams 1944) and lack endosperm (figures 3 and 4). Air-drying is needed to minimize molding in cool dry storage.

Figure 2—*Oemleria cerasiformis*, osoberry: white flowers are borne on drooping racemes.

Figure 3—*Oemleria cerasiformis*, osoberry: seeds have a bony endocarp.

Figure 4—*Oemleria cerasiformis*, osoberry: longitudinal section through a seed shows folded cotyledons



About 11 kg (25 lb) of seeds (cleaned and air-dried for 24 hours) can be obtained from 45 kg (100 lb) of fresh drupes, based on 7 samples (Dimock and Stein 1974). Cleaned seeds air-dried for 4 weeks averaged 10.2/g (4,630/lb) for 12 samples from western Washington. Heavier seed weights have been reported from other parts of the osoberry's range—4.0/g (1,800/lb) in California (Mirov and Kraebel 1939) and 9.2/g (4,175/lb) in British Columbia (Antos and Allen 1994). Seeds generally are full, 98 to 100% in 4 samples (Dimock and Stein 1974).

Pregermination treatments and germination tests. Lengthy cold moist stratification is needed to overcome dormancy in fresh osoberry seeds (Dimock and Stein 1974; Mirov and Kraebel 1939). In a comparison of stratification periods at 3.3 °C in peat moss followed by 21 days at alternating 30 to 20 °C day/night temperatures, Dimock and Stein (1974) found that 60 days of stratification barely triggered germination, whereas 120 days were required for nearly complete germination. Osoberry seeds are capable of germinating at 3.3 °C during lengthy stratification—84% of total germination in 120 days, full germination in 180 days (table 1). Over 90% germination is obtainable from good seeds. Germination is epigeal (figure 5).

Nursery practice. Osoberry was introduced to cultivation by Theodor Hartweg in 1848 (Hunt 1970). It has been propagated primarily from seeds but also from suckers and cuttings. It lacks rhizomes or stolons, but some layering occurs naturally when woody debris presses stems to the ground (Antos and Allen 1990b). Tips of branches have been propagated vegetatively in a frame with bottom heat (Mirov and Kraebel 1939).

Though fruits ripen and are disseminated naturally by early summer, the seeds rarely, if ever, germinate within the year of dispersal (Dimock and Stein 1974). However, in the following year, they may germinate as early as mid-February. Seeds collected in July, cleaned, and stored at room temperature until sown outdoors in flats in late December began germinating in March in Victoria, British Columbia; second-year germination started in early February and varied from 0 to 70% of total germination for individual seedlots (Allen and Antos 1995). Total germination ranged from 1 to 96% among the 25 lots of 100 seeds each representing 5 plants at each of 5 collection areas in British Columbia and Washington.

Figure 5—*Oemleria cerasiformis*, osoberry: seedlings at 40 and 120 days after germination.

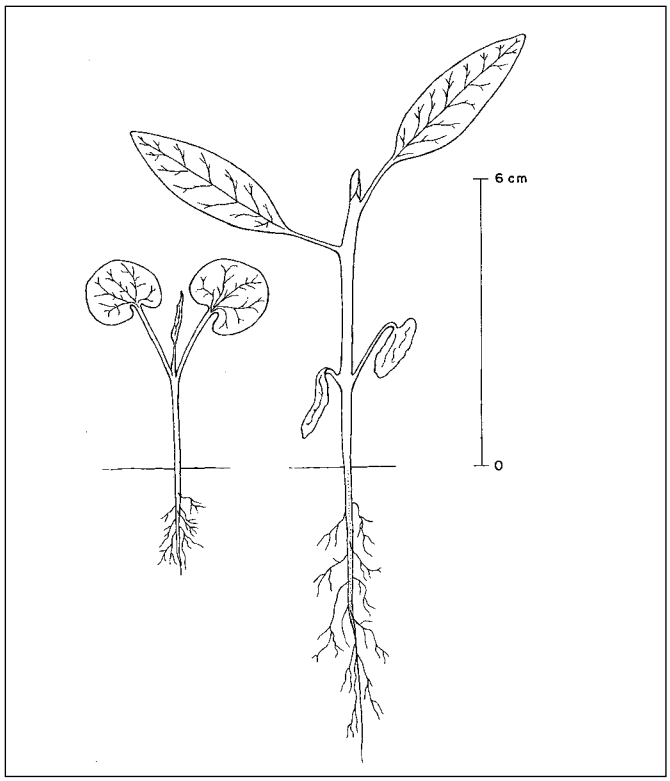


Table 1—*Oemleria cerasiformis*, osoberry: effect of stratification on germination

Stratification at 3.3 °C (days)	Germination during stratification (%)	Additional germination during 21 days at 30/20 °C (%)	Total germination (%)
60	0	1	1
90	21	37	58
120	80	14	94
160	94	0	94
180	95	0	95

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Oleaceae—Olive family

Olea europaea L.

olive

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Growth habit. Olive is a member of the Oleaceae, the family that contains the genera *Fraxinus* (ash), *Forsythia* (golden bell), *Forestiera (F. neomexicana,* the California "wild-olive"), *Ligustrum (*privet), and *Syringa* (lilac) as well as *Olea* (olive). Commercial olives belong to the species *Olea europaea* L. There are about 20 species of *Olea* found in tropical and subtropical regions of the world, but only *O. europaea* L. produces edible fruit.

Olive is a long-lived evergreen tree; some specimens have been reported to live for 1,000 years. The wood resists decay, and when the top of the tree is killed by mechanical damage or environmental extremes, new growth arises from the root system. Whether propagated by seed or cuttings, the root system generally is shallow, spreading to 0.9 or 1.2 m even in deep soils. The above-ground portion of the olive tree is recognizable by the dense assembly of limbs, the short internodes, and the compact nature of the foliage. Light does not readily penetrate to the interior of an olive tree unless the tree is well managed and pruned to open light channels toward the trunk. If unpruned, olives develop multiple branches with cascading limbs. The branches are able to carry large populations of fruit on terminal twigs, which are pendulous and flexible—swaying with the slightest breeze.

Olive leaves are thick, leathery, and oppositely arranged. Each leaf grows over a 2-year period. Leaves have stomata on their lower surfaces only. Stomata are nestled in peltate trichomes that restrict water loss and make the olive relatively resistant to drought. Some multicellular hairs are present on leaf surfaces. Olive leaves usually abscise in the spring when they are 2 or 3 years old; however, as with other evergreens, leaves older than 3 years are often present.

Flower bud inflorescences are borne in the axil of each leaf. Usually the bud is formed on the current season's growth and begins visible growth the next season. Buds may remain dormant for more than a year and then begin growth, forming viable inflorescences with flowers a season later than expected. When each leaf axil maintains a developing inflorescence, there are hundreds of flowers per twig. Each inflorescence contains between 15 and 30 flowers, depending on developmental processes for that year and the cultivar.

The flowers are borne on the inflorescence and are small, yellow-white, and inconspicuous. Each contains a short, 4-segmented calyx and a short-tubed corolla containing 4 lobes. The 2 stamens are opposite on either side of the 2-loculed ovary that bears a short style and capitate stigma. Two types of flowers are present each season: perfect flowers, containing stamen and pistil, and staminate flowers, containing aborted pistils and functional stamens. The proportion of perfect and staminate flowers varies with inflorescence, cultivar, and year. Large commercial crops occur when 1 or 2 perfect flowers are present among the 15 to 30 flowers per inflorescence. As a rule, more staminate flowers than pistillate flowers are present.

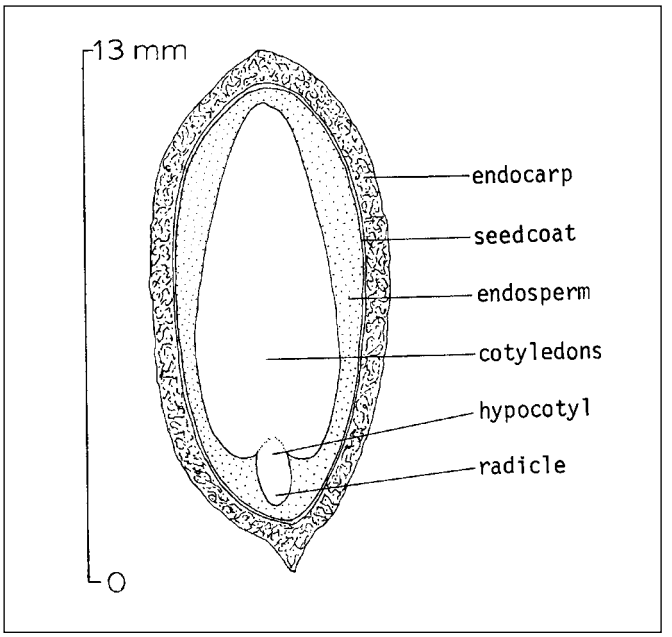
The perfect flower is evidenced by its large pistil, which nearly fills the space within the floral tube. The pistil is green when immature and deep green when open at full bloom. Staminate flower pistils are tiny, barely rising above the floral tube base. The style is small and brown, greenish white, or white, and the stigma is large and plumose as it is in a functioning pistil.

The olive fruit is a drupe, botanically similar to almond, apricot, cherry, nectarine, peach, and plum fruits. The olive fruit consists of carpel, and the wall of the ovary has both fleshy and dry portions. The skin (exocarp) is free of hairs and contains stomata. The flesh (mesocarp) is the tissue eaten, and the pit (endocarp) encloses the seed. Fruit shape and size and pit size and surface morphology vary greatly among cultivars.

The mature seed (figure 1) is covered with a thin coat that covers the starch-filled endosperm (figure 2). The latter surrounds the tapering, flat leaflike cotyledons, short radicle

Figure 1—*Olea europaea,* olive: stone.

Figure 2—*Olea europaea*, olive: longitudinal section through a stone.



(root), and plumule (stem). Seed size and absolute shape vary greatly with cultivar.

The seed undergoes most of its development starting in July and ending in about September. The fruit is horticulturally mature in September or October (ready for the California black-ripe or green-ripe process), and physiologically mature in January or February. The seed is horticulturally mature by October, and if harvested and stratified at that time it will achieve maximum germination (Lagarda and others 1983a). When the fruit is physiologically mature by January, seed germination is greatly reduced.

Occurrence. The origin of olive is lost in prewritten history. The wild olives *Olea chrysophylla* Lam. and *O. europaea* L. var. *oleaster* most probably yielded the domesticated form *O. europaea* L. These wild types are known to have existed in the region of Syria about 6,000 years ago (Zohary and Spiegal-Roy 1975). From the eastern Mediterranean, olive trees were spread west throughout the Mediterranean area and into Greece, Italy, Spain, Portugal, and France. In 1560, the Spanish Conquistadors carried olive cuttings and seeds to Peru. From there or independently, olive was found in Mexico at Jesuit missions. The Franciscan padres carried olive and other fruits from San Blas, Mexico, into California. Sent by Jose de Galvez, Father Junipero Serra established Mission San Diego de Acala in 1769. Though oil production began there in the next decade, the first mention of oil was written in the records of Mission San Diego de Alcala in 1803 as described by Father Lasuen.

Use. By the late 1800s, olive oil production in California was sufficient to supply markets outside of California. By the 1900s, California olive oil production had met the competition from imported olive oil and American vegetable oil and, in an effort to survive, the canning olive industry was born. During the 20th century, the California canning olive occupied a strong market position in America, with olive oil as a salvage industry. Currently, a renewed emphasis in health benefits of monosaturated olive oil has lead to a resurgence of olive oil production in California.

The olive tree has been used widely for shade around homes and as a street tree in cities. Its distribution is only limited by cold weather in the winter, as temperatures below –9.4 °C are lethal (Denney and others 1993).

Varieties. Several hundred varieties of olive are known and can be found at the World's Olive Variety Collection in Cordoba, Spain (del Rio and Caballero 1994). A smaller collection exits at the United States Germplasm Repository at Winters, California. Varieties differ by features of the tree shape, leaves, and fruit. Canning varieties possess larger fruit than do oil varieties. Any of the varieties are useful for landscape purposes. The varieties grown in California for canning are 'Manzanillo', 'Mission', 'Sevillano', 'Ascolano', and 'Barouni'.

Flowering and fruiting. Floral initiation occurs by November (Pinney and Polito 1990), after which, flower parts form in March. Unlike deciduous fruits with a short induction-to-initiation cycle, induction in olive may occur as early as July (about 6 weeks after full bloom), but initiation is not easily seen until 8 months later in February. Complex microscopic and histochemical techniques reveal evidence of floral initiation by November, but the process of developing all the flower parts starts in March. Some olive cultivars,

such as those grown in Crete, southern Greece, Egypt, Israel, and Tunisia, bloom and fruit heavily with very little winter chilling; whereas those originating in Italy, Spain, and California require substantial chilling for good fruiting.

In experiments with the cultivars grown in California, optimum flowering occurred when the temperature fluctuated daily between 15.5 to 19 °C maximum and 2 to 40 °C minimum. Trees held at a constant temperature of 13 °C also bloomed profusely but had poor pistillate flower formation. If temperatures did not rise above 7.5 °C or fall below 15.5 °C, trees did not bloom. At 13 °C, both chilling and warmth are sufficient for flowering but not for complete flower development. In contrast to flower buds, vegetative buds of olive seem to have little if any dormancy, growing whenever the temperatures are much above 21 °C. In addition to winter chilling, inflorescence formation requires leaves on the fruiting shoots. Therefore, it is important to prevent defoliation. The occasional occurrence of hot, dry winds during the blooming period has been associated with reduced fruit set. Winds or heat increase the amount of natural abscission.

Prolonged, abnormally cold weather during April and May, when the olive flower buds should be developing rapidly, can have a detrimental effect on subsequent flowering, pollination, and fruit set. Such weather occurred in California in the spring of 1967, delaying bloom by several weeks and leading to flower abnormalities and a crop of only 14,000 tons, the lightest in modern California history. In California, fruit on the tree by July 1, as a rule, continue on to maturity.

At full bloom, flowers are delicately poised for pollination, when some 500,000 flowers are present in a mature tree; a commercial crop of 7 metric tons/ha (3 tons/ac) or more can be achieved when 1 or 2% of these flowers remain as developing fruit. By 14 days after full bloom, most of the flowers destined to abscise have done so. By that time, about 494,000 flowers have abscised from a tree that started with 500,000 flowers.

Olives are polygamo-monoecious. The flowers are born axially along the shoot in panicles. The panicles of 'Barouni', 'Manzanillo', 'Mission', and 'Sevillano' carry an average of 12 to 18 flowers; 'Ascolano' average 20 flowers. Perfect flowers, those with both pistillate and staminate parts, normally consist of a small calyx, 4 petals, 2 stamens and filaments supporting large pollen-bearing anthers, and a plum-green pistil with a short thick style and a large stigma. Perfect flowers are borne apically in an inflorescence, and within the typical triple-flower inflorescence the middle flower is generally perfect. Imperfect flowers are staminate, with the pistil either lacking or rudimentary. Flowers with abortive anthers also occur and are common in 'Sevillano'.

Cultivars vary, but most abscission occurs soon after full bloom and final fruit set nearly always occurs within 6 weeks of full bloom. Further fruit abscission can result from pest infestation and environmental extremes. When trees have an inflorescence at nearly every leaf axil a commercial crop occurs with 1 to 2% fruit set; with a small population of inflorescence, a commercial crop may require 10% fruit set.

"Shotberries" (parthenocarpic fruits) occur randomly and for reasons not clearly understood. When shotberries occur, they may be seen in clusters on each inflorescence. Here the interfruit competition for raw materials differs from that of normal olive fruits. Shotberries mature much earlier than normal fruit and may be more prevalent when conditions favor a second large crop in succession.

The endocarp (pit) enlarges to full size and hardens by 6 weeks after full bloom. At that time, the endosperm begins to solidify and embryo development takes place, leading to embryo maturity by September. The mesocarp (flesh) and exocarp (skin) continue their gradual growth. The fruits begin changing from the green color to yellow-white (straw) and accumulate anthocyanin from the distal or base end. The purple to black color eventually bleeds into the mesocarp, signaling fruit overmature for the California black-ripe or green-ripe processing. As has been reported for most other fruit crops, trees with few fruits mature their crops earlier than trees with many fruits.

Collection, extraction, storage, and germination of seeds. For seed production, the fruits should be harvested when ripe, but before they turn black. This period extends from late September to mid-November, depending on the cultivar (Largarda and others 1983a&b). Pits are removed from the flesh of the fruit with macerators. Pits can be stored in a dry place for years or planted directly, but germination is slow and uneven. Pregermination treatments are designed to overcome both seedcoat (mechanical) and embryo dormancies. Mechanical or chemical scarification is used to treat mechanical dormancy. In scarification, the endocarp can be cracked mechanically or clipped at the radicle end, with care taken not to damage the embryo. Clipping just the cotyledonary end of the endocarp does not improve germination. Good germination results can be obtained using a seed cracking device before subsequent handling procedures (Martin and others 1986). Pits may be soaked in concentrated sulfuric acid to soften the endocarp. Soaking time depends on the thickness of the endocarp; typical soaking times for 'Manzanillo' are between 24 and 30 hours. The

Table 1—*Olea europaea,* olive: fruit and seed data

	Fruits/wt		Seed wt/metric ton of fruit		Seeds/weight	
	/kg	/lb	kg	lb	/kg	/lb
Small	706	320	778	353	4,410	2,000
Medium	198	90	584	265	1,654	750
Large	99	45	485	220	992	450

acid bath is followed by 1 to 2 hours of rinsing in water (Crisosto and Sutter 1985).

The pits can be planted directly after the endocarp treatments. Pits should be planted at a depth about 2 to 3 times their diameter. Seeds planted outdoors in December do not germinate until the following spring. Pits can also be planted in pots or seedbeds in a greenhouse maintained at a 21 to 24 °C daytime temperature. Germination takes up to 3 months. It is critical that the seeds do not dry out after germination begins. The number of fruits and seeds per weight for 3 commercial size classes are listed in table 1.

Germination is quicker and more uniform when treatments to overcome internal dormancy are carried out in addition to scarification. The most successful of these treatments on a commercial scale is stratification. Pits are scarified as described above and then soaked in water at room temperature for 24 hours. The pits are mixed with moist sand or vermiculite and then placed in the dark in a controlled environment. The temperature is kept at 15 °C for 30 days. Stratification is thought to reduce abscisic acid (which inhibits germination) within the embryo or seedcoat. After stratification, pits can be planted outdoors if the weather is suitable; severe weather can cause losses. Pits can be planted in a greenhouse maintained at a 21 to 27 °C daytime temperature. Bottom heat is necessary. Germination should occur within 1 month. Transplanting seedlings from the greenhouse to the nursery should include steps to harden the seedlings, such as partial shade provided by a lathhouse. Adequate irrigation and fertilization are recommended to ensure continued rapid growth.

Nursery practice and seedling care. Virtually all olive trees are produced from rooted cuttings. Seed handling difficulties, low germination percentage, and slow initial seedling growth rate make seedling production impractical.

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Fabaceae—Pea family

Olneya tesota Gray

olneya

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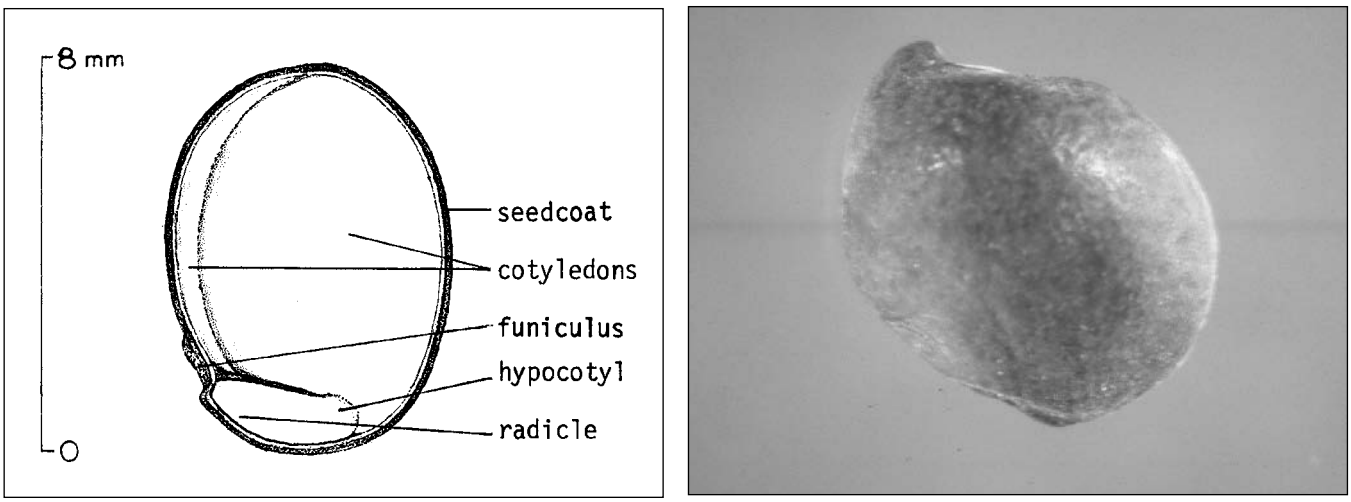
Other common names. ironwood, desert ironwood, *palo fierro, tesota*.

Growth habit, occurrence, and uses. Olneya is a long-lived, multi-trunked, broad-crowned, deciduous tree, 5 to 10 m high, that is commonly found at elevations below 600 m in desert washes and valleys of the Sonora Desert in California, Arizona, Baja California, Baja California Sur, and Sonora (Munz 1974; Shreve and Wiggins 1964). It will grow in areas receiving less water than is required to support mesquite (*Prosopis* spp.) (Felker 1981), has a frost tolerance similar to that of citrus, and will nodulate and fix nitrogen (Felker and Clark 1981). Olneya provides browse for cattle and habitat for native animals; it serves as a nurse plant for cacti and other plants (Nabhan and Carr 1994; Suzan and others 1994). It was also a food source for early cultures of Native Americans (Felger and Moser 1985). The seeds contain large amounts of canavanine, an arginine analog that is a potent growth inhibitor (Becker 1983). The wood is very dark, used for carvings, and will not float, its density being 1.22. The tree is threatened by introduced pasture grasses, urbanization, and illegal harvesting for charcoal and artists' wood.

Flowering and fruiting. Flowering occurs from April to June (Munz 1984; Shreve and Wiggins 1964). The pinkish to pale rose-purple flowers, 8 to 9 mm long, produce a legume (pod) that may contain 1 to 2, or sometimes 3 or 4 or more seeds. The legume is light brown, rounded, and hairy, and measures 4 to 6 cm in length (Munz 1984; Shreve and Wiggins 1964). The seeds are chestnut brown to blackish, shiny, ovoid, and 8 to 9 mm long (figure 1) (Irving and Becker 1985).

Collection and storage of fruits. Legumes on the tree may be picked in June or July or fallen legumes and seeds may be hand-gathered. The legumes dehise easily (Felker 1981). Many seeds are infested with insect larvae when collected, so the seeds should be stored cold or fumigated. Seed

Figure 1— *Olneya tesota*, olneya: longitudinal section through a seed (**left**) and exterior view (**right**).



counts on 2 samples were 4,400 and 4,850 seeds/kg (2,000 and 2,200/lb) (Krugman 1974), with a reported yield of 8 kg (17.6 lbs) of seeds/tree (Felker 1981).

Germination and nursery practice. Fresh seeds germinate readily when soaked for 12 to 24 hours in water; stored seeds may require longer soaking. Mild scarification before soaking is often helpful (Emery 1964; Krugman 1974). Seeds can be broadcast sown in the spring and covered with 6 mm ($^1/_2$ in) of soil or sand. Small seedlots can be germinated in planting flats or small containers and then transplanted. Seeds will rot easily, so extra care must be taken in watering (Everett 1957; Krugman 1974). Initial germination is prompt when soaked or watered, often occurring within 18 to 24 hours of sowing (Everett 1957; Krugman 1974). Seedlings appear within 6 days after sowing (Krugman 1974).

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Betulaceae—Birch family

Ostrya virginiana (P. Mill.) K. Koch

eastern hophornbeam

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Other common names. hophornbeam, American hophornbeam, hornbeam, leverwood, ironwood.

Growth habit, occurrence, and uses. Three of the 8 species of the hophornbeam genus—*Ostrya*—are native to the United States; of these, eastern hophornbeam is the most common (Little 1979). It is a small deciduous tree that attains a maximum height of about 18 m and occurs throughout the eastern half of North America, ranging from Nova Scotia and southeastern Manitoba in Canada south to eastern Texas and northern Florida. It also occurs in the mountains of Mexico, El Salvador, and Honduras (Little 1979). Small trees often occur in the understory on a wide variety of sites ranging from deep, moist soils to dry and gravelly or rocky slopes (Metzger 1990).

The heavy, hard, durable wood has been used for fence posts, tool handles, and other specialty items (Schopmeyer and Leak 1974). Eastern hophornbeam also provides food and cover for many birds and some mammals. The seeds are a preferred food for sharp-tailed grouse (*Pedioecetes phasianellus*) and wild turkey (*Meleagris gallopavo*), and the buds and catkins are important winter foods for ruffed grouse (*Bonasa umbellus*) (Metzger 1990). This tree is sometimes planted as ornamental because of its attractive foliage and fruit clusters (Brown and Kirkman 1990), but it does not grow very rapidly. It was first cultivated in 1690 (Rehder 1940).

Flowering and fruiting. The flowers are monoecious. Staminate catkins, 2.5 to 4 cm in length, develop on the branch tips in late summer and overwinter in a dormant state. Pistillate catkins are small, inconspicuous, and 6 mm long; they appear with the leaves in the spring. Both flowers mature and open in March and April in the South and May and June in the North (Brown and Kirkman 1990; Metzger 1990). The fruit is a strobile, usually 2.5 to 7.5 cm long (figure 1), consisting of involucres that each enclose a single nut (figure 2) about 7 mm long and 4 mm in diameter (Brown and Kirkman 1990; Sargent 1965). The fruits ripen from the end of August in Michigan to October in the South. Nuts are dispersed after ripening when the strobiles fall apart. The buoyancy of the papery sacs aids dispersal by wind (Metzger 1990). Trees do not produce seeds abundantly until they are about 25 years old (Schopmeyer and Leak 1974). Seed production in the northern part of the range has averaged 124,000 seeds/ha (50,200/ac) (Metzger 1990).

Figure 1—*Ostrya virginiana*, eastern hophornbeam: strobile

Collection, extraction, storage. The strobiles may be hand-picked from the trees when they are a pale greenish brown in color. At this stage, they are not yet dry enough to fall apart. When completely ripe, they are light gray to greenish brown (Schopmeyer and Leak 1974). The fruits should be thoroughly dried before seeds are extracted by thrashing or rubbing the dried fruits over screens. Seeds can be separated from the chaff with air-screen cleaners or fractionating aspirators or by fanning. One hectoliter of fruit will yield about 2.5 kg of seed (1 bu yields 2 lb). The number of seeds per weight (5 samples) ranged from 55,100 to 77,200/kg (25,000 to 35,000/lb), with an average of 66,100/kg (30,000/lb). Purities (percentages) in the high 90s are easily obtained with good cleaning. The proportion of sound seeds will vary widely, especially due to insect dam-

Figure 2—*Ostrya virginiana*, eastern hophornbeam: longitudinal section through a seed (**left**) and intact seeds (**right**).

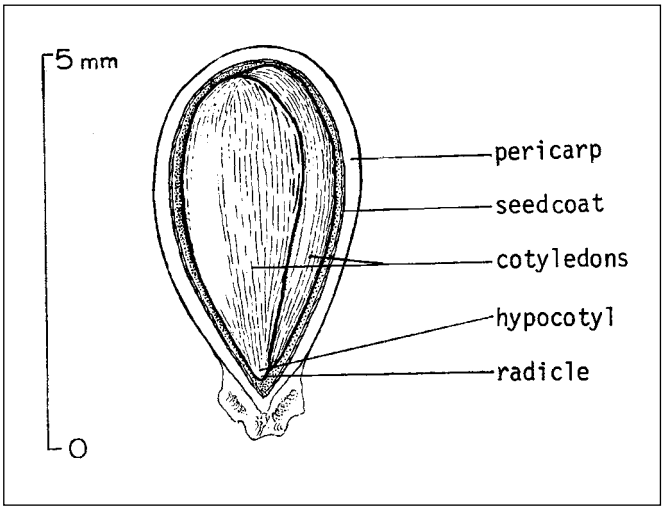
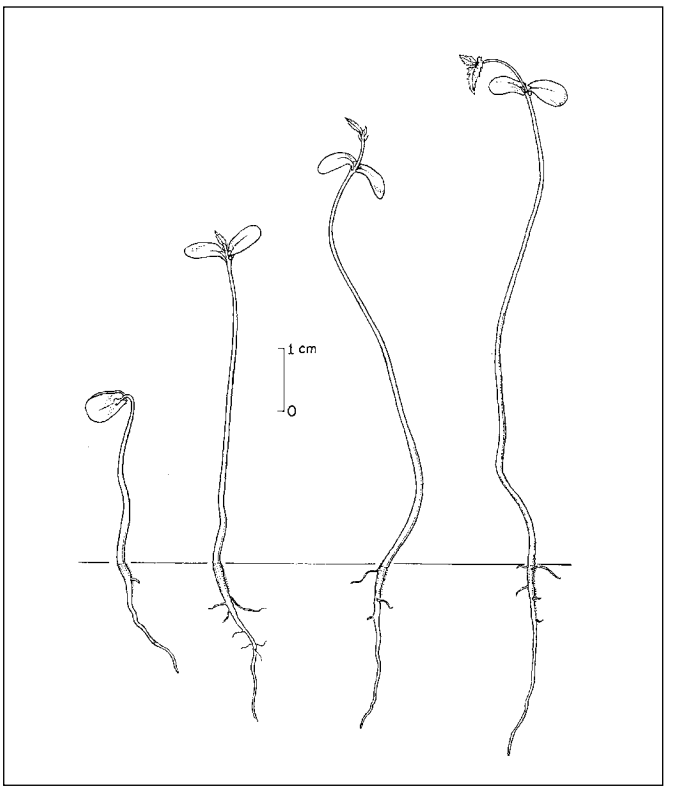


Figure 3—*Ostrya virginiana*, eastern hophornbeam: seedling development at 2, 4, 23, and 27 days after germination.



age, but 80% has been reported (Schopmeyer and Leak 1974). There are no storage test data for eastern hophornbeam, but the seeds have the ability to survive at least 1 year in the soil and should have good storage potential.

Pregermination treatments and germination tests. Seeds have a hard seedcoat and an internal dormancy that is difficult to overcome. Warm incubation, followed by cold stratification may be best. Three months of warm, followed by 3 to 5 months of cold produced germination of 81 to 92% (Dirr and Heuser 1987). Germination is epigeal (figure 3). Tetrazolium staining can be used to estimate viability. Official seed testing organizations do not include eastern hophornbeam in their recommendations.

Nursery practice. Either fall- or spring-sowing is feasible, but fall-sowing should take place soon after seeds are collected. In Iowa, seeds collected when they were slightly immature (August) and sown immediately germinated 100% the following spring (Titus 1940). Seeds should be covered with 6 mm ($^1/_4$ in) of firmed soil. Fall-sown beds should be covered with burlap, straw, or other suitable mulch, and uncovered when germination begins. Stratified seeds may be sown in the spring as soon as the soil can be worked, and the beds should be mulched or watered to keep them moist until germination starts (Schopmeyer and Leak 1974).

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Ericaceae—Heath family

Oxydendrum arboreum (L.) DC.

sourwood

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Synonym. *Andromeda arboreum* L.

Other common names. sorrel-tree, lily-of-the-valley tree.

Growth habit, occurrence, and uses. Sourwood is a medium-sized, deciduous tree that develops a graceful, pyramidal shape when mature (Dirr 1990). The plant typically grows 9 to 15 m tall in the wild but seldom attains such height outside its native range (DeWolf 1987). This species is indigenous to the eastern United States, extending from Pennsylvania southward into northern Florida, and west to Indiana and Louisiana (Rehder 1986). Sourwood often is found on ridges of gravelly soil adjacent to streams and is hardy to USDA Zone 5 (Dirr 1990). The species has several attributes that create an outstanding specimen plant. It has slender, drooping branches of dark green foliage that contrast sharply with pendulous terminal panicles of white flowers in mid-summer, when few other plants are flowering. In addition, the brilliant scarlet fall foliage is without comparison amongst plants indigenous to the United States (DeWolf 1987). Sourwood should be grown in full sun to attain maximum flower production and the most vibrant fall color. However, the tree will also grow in partial shade (DeWolf 1987). Sourwood prefers an acidic (pH 4.0 to 5.5), moist, well-drained soil high in organic matter (DeWolf 1987; Dirr 1990). Sourwood is best suited for suburban or rural landscapes, as it will not tolerate air pollution occurring in urban areas (DeWolf 1987). Lastly, sourwood honey is highly prized, as is the wood, which is used for tool handles and in crafts (Duncan and Duncan 1988).

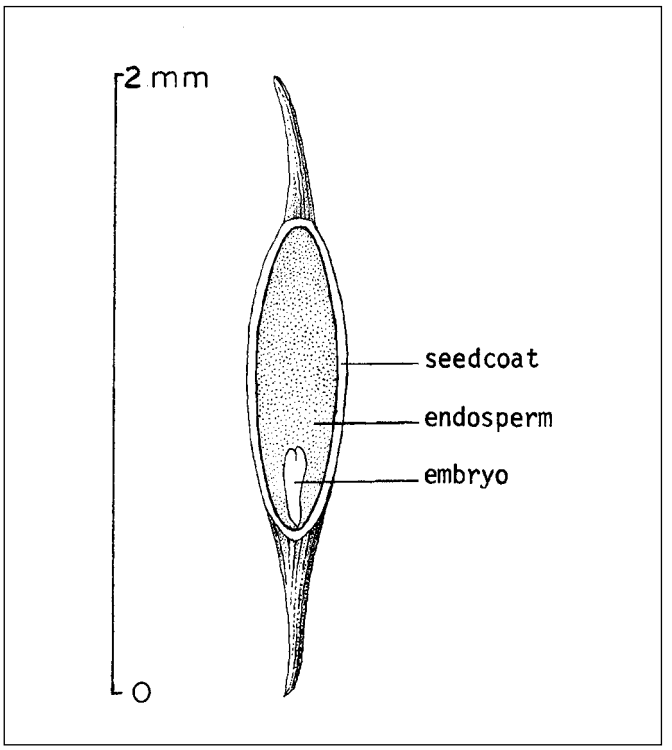
Geographic races and hybrids. Sourwood is monotypic, that is, the only species of its genus. No hybrids are described in the literature.

Flowering and fruiting. Fragrant, 6-mm-wide, white, urn-shaped flowers are borne profusely on 15- to 25-cm, pendulous, terminal panicles (Bridwell 1994; Dirr 1990). Flowers open in late June or July and provide a dramatic, mid-summer show. The floral display can completely shroud the dark green foliage in a white, lacy veil (Dirr 1990). Fruits are ovoid-pyramidal, dry, 5-chambered, dehiscent capsules, borne in clusters, each capsule about 5 to 7 mm long (Bailey 1977; Dirr 1990; Radford and others 1968). Seeds are 2 mm long, 0.5 mm wide, and gray to brown when mature (figure 1) (Olson and Barnes 1974).

Collection of fruits, seed extraction, cleaning, and storage. Capsules and seeds ripen in September and October and can be collected at that time (Olson and Barnes 1974). Capsules are removed from the plant, lightly beaten, and then rubbed to open them completely (Dirr and Heuser 1987). Next, seeds are shaken from the capsules. Viability can be poor if seeds are not graded rigorously. Use of an air-column blower is recommended to remove chaff and empty seeds (Barton and Bonaminio 1986). Lots of cleaned, pure seeds average 8,200 seeds/g (230,000/oz) (Olson and Barnes 1974). The seeds are apparently orthodox in storage behavior and may remain viable for several years if stored dry in a sealed container at 4.5 °C (Blazich 1996).

Pretreatment and germination tests. Seeds germinate readily after harvest and no pretreatments are necessary (Dirr and Heuser 1987; Fordham 1960). Germination is epigeal (figure 2). Seeds of sourwood require light for maximum germination (Barton and Bonaminio 1985). A 30-day test of seeds collected in Yadkin Co., North Carolina, demonstrated that germination in total darkness at 25 °C was minimal (5%) (Barton and Bonaminio 1985). However, a daily photoperiod of $^1/_2$ hour resulted in 29% germination and daily photoperiods ≥ 4 hours resulted in maximum germination (58%). In another test, seeds were placed at 20, 22.5, 25, 28 °C, or at 9/15-hour thermoperiods of 25/15 or 30/20 °C (Barton and Bonaminio 1985). Seeds received 1 hour of light daily at each temperature. After 21 days, the highest germination occurred at 25/15 °C and 30/20 °C, with germination of 50 and 64%, respectively. Germination began faster at 30/20 °C. These studies utilized cool-white fluorescent lamps as the light source, at 4.3 klux (about 55 μmol/m^2/sec). Under particular conditions, stratification (moist prechilling) also may be used to stimulate germination (Barton and Bonaminio 1986).

Figure 1—*Oxydendron arboreum*, sourwood: seeds in longitudinal section (**left**) and external view (**right**).



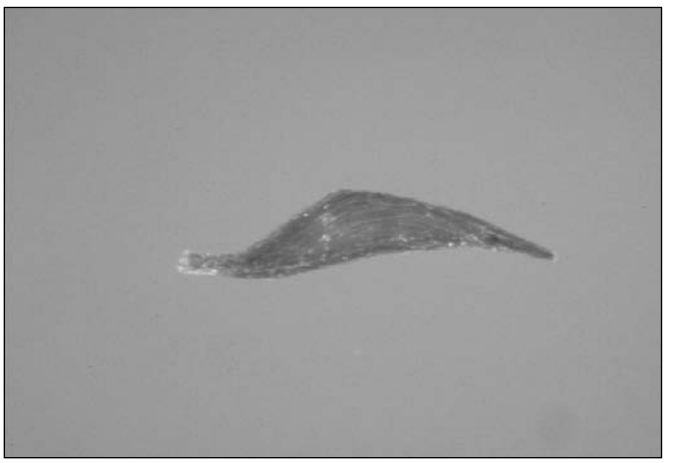
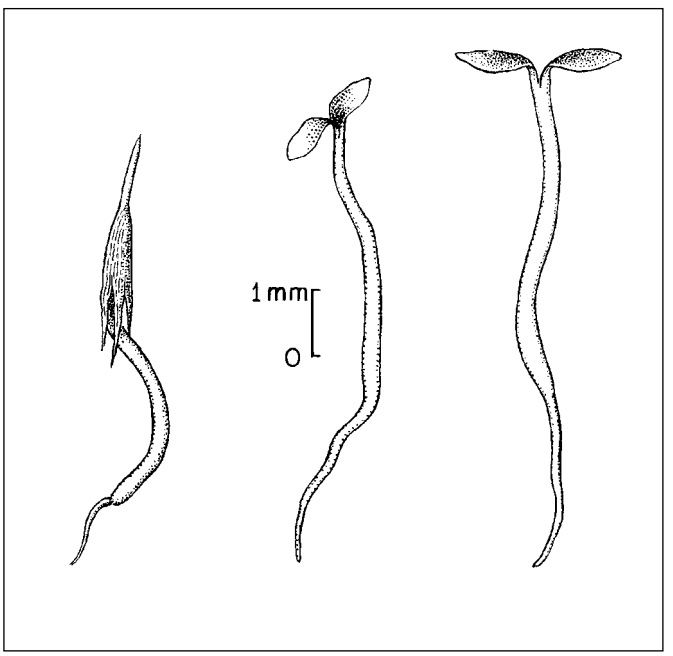


Figure 2—*Oxydendron arboreum*, sourwood: seedlings of sourwood at 2, 6, and 8 days after germination.



Nursery practice. Johnson (1978) described a commercial method for seed propagation, in which seeds are sown in November soon after harvest. Seeds are spread lightly on the surface of a flat containing fine milled sphagnum and vermiculite (1:1, by vol.) and misted. Then, the flat is wrapped in a clear plastic bag, with supports to keep the bag from touching the surface of the medium, and placed under continuous light, provided by cool-white fluorescent lamps. Typically, the germination medium is maintained at 22 °C using bottom heat. The medium surface should never be allowed to dry. Seeds germinate within 2 weeks, and seedlings develop rapidly. At the 2- to 3-leaf stage, seedlings can be transplanted into peat pots or individual containers containing an acidic, organic medium. After 6 months, seedlings can be potted into 3.8-liter (1-gal) containers containing a well-drained, acidic, organic medium. Growth of 0.6 m (2 ft) can be obtained in 9 months following this production protocol. Blazich and others (1994) reported that commercial production of seedlings of sourwood may be accelerated by utilizing a pine bark medium and a day/night cycle of 26/22 °C or 30/26 °C with long-day conditions.

Stem cuttings are reported as difficult to root (Dirr and Heuser 1987). However, sourwood can be propagated vegetatively by micropropagation (Banko and Stefani 1989).

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