

Sequoia sempervirens (Lamb. ex D. Don) Endl.

redwood

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Other common names. coast redwood, California redwood.

Growth habit, occurrence, and use. Redwood is one of the largest trees in the world. It commonly grows to 60 to 84 m in height and 2.4 to 3.6 m in diameter, with the current champion reaching 101 m in height (Van Pelt 2001). Its relatively shallow but wide-spreading root system rises into a buttressed and somewhat tapering trunk that supports a short, narrowly conical crown (Harlow and Harrar 1969). Individual trees can live 2,000 years or longer. It grows naturally in the summer fog belt of the coastal range from Little Redwood Creek on the Chetco River in southwestern Oregon to Salmon Creek in the Santa Lucia Mountains of southern Monterey County, California. This redwood belt is an irregular coastal strip about 725 km long and 8 to 56 km wide (Roy 1966). Elevation ranges from sea level to 915 m and average annual precipitation from 635 to 3,100 mm, most of it falling as winter rain (Olson and others 1990).

Redwoods reach their maximum development in the northern part of their range where the climate is cool and moist and sedimentation from successive floods has created deep fertile alluvial flats. They are smaller and give way to other species as altitude, dryness, and slope increase (Olson and others 1990). Since 1843, redwood has been cultivated outside its natural range, including parts of Europe and New Zealand (Boe 1974; Olson and others 1990).

The wood is used where decay resistance is important. It is made into lumber, plywood, pulpwood, grape stakes, fencing, roof shakes, and other specialized products. Bark is used for insulation and garden mulch (Boe 1974; Harlow and Harrar 1969; Olson and others 1990).

Flowering and fruiting. The tiny male and female flowers grow separately on different branches of the same tree. Ovulate conelets lead to broadly oblong cones with thick scales that are closely packed, woody, and persistent. Each cone scale bears a crescent-shaped row of ovules (Buchholz 1939). Flowering may occur over several months from November to March (Metcalf 1924), but ovules are usually fertilized in May (Buchholz 1939). Dry weather during pollination permits better pollen dispersal and improves seed viability (Olson and others 1990). Cone ripening time can range from late September to mid-January, depending on latitude, elevation, and weather (Lippitt 1996).

Trees begin to bear seeds at 5 to 15 years of age (Boe 1974). Good seedcrops occur every 5 to 7 years (Lippitt 1996), with light crops intervening. Fair to abundant crops occurred for 5 consecutive years in north-coastal California (Boe 1968); however, this is unusual (Lippitt 1996). Further south in the redwood type, some stands produce seed poorly and irregularly,

whereas others frequently have fair to abundant crops (Muelder and Hansen 1961). A mature seed has a brown wing and a slightly darker seedcoat. The wing, which is part of the seedcoat, is about equal in width to the seed (figure 1). Embryos have 2 cotyledons (figure 2). Opened cones often persist through the next growing season (Boe 1974). Cones have the following quantitative characteristics (Lott 1923; Munz 1959; Olson 1990; Roy 1965):

Seeds per cone scale	2-5
Average seeds per cone	60.....
Cone length	1.3-2.8 cm
Cone diameter	1.3-2.5 cm
Average fresh cones per weight	500/kg (227/lb)

Because of the polyploid chromosomal make-up of redwood, care should be taken to avoid in-breeding in seed orchards. Seedlings from self-crossed seeds had lower nursery survival under stress and grew slower in the field than those from out-crossed seeds (Libby and others 1981).

A technique for making controlled pollinations on detached redwood cuttings has become practical. Pollination was most effective when dry pollen was brushed between the open scales of the female strobili. In subsequent years, cuttings that have rooted successfully can be pollinated and will produce viable seeds (Libby and McCutchan 1978; Libby and others 1972).

Collection of cones and extraction of seeds. Seeds are mature when cone color changes from green to greenish yellow or when cone scales slightly separate (Roy 1965). In the northern part of the redwood's range, cone collections should begin in October (Lippitt 1996). Natural seed dispersal proceeds rapidly after October, reaching a peak from November to February (Boe 1968).

Cones can air-dry in 5 to 8 days at 21 to 24 EC with good air circulation (Lippitt 1996). Large nurseries use a kiln set at 38 to 43 EC to open cones in 24 hours (Lippitt 1996). Seeds are extracted with a screen tumbler. At the L.A. Moran Reforestation Center, Davis, California, the seedlots are repeatedly passed through a 4-way air separator to obtain a high percentage of filled seed with high germination rate. Experience with a magnified x-ray makes it possible to distinguish tannin-filled seeds and filled but less viable seeds from seeds that will produce vigorous germinants.

The following seed data have been noted by Lippitt (1996) for cleaned seedlots:

Cleaned seeds per weight	
Low	167,372/kg (75,920/lb)
High	259,297/kg (117,617/lb)
Average (N = 37)	194,000/kg (88,000/lb)
Purity	98%
Germination	60%

Storage of seed. Redwood seeds are orthodox in nature and store well for long periods of time. The L.A. Moran Reforestation Center has stored seeds with 5 to 9% water content at ! 17.8 EC for over 10 years with no loss in viability (Lippitt 1996). Storage of seedlots above

freezing has not been successful (Boe 1974; Metcalf 1924; Olson and others 1990; Schubert 1952).

Germination. A 5-year record of seed dispersal in old-growth redwood showed that of the total seeds dispersed, only 2.5 to 12.4% were sound (Boe 1968). In seeds collected from branch cuttings, Libby and others (1972) measured percentage germination at 5 to 21%. Identification of unsound seeds is often difficult because many seeds that appear to be good are actually filled with tannin (Olson and others 1990). Germination is readily tested in covered petri or plastic dishes on filter paper, vermiculite, or Sponge Roc[®]. Satisfactory germination has been obtained at a constant temperature of 21 EC as well as at temperatures alternating diurnally from 30 to 20 EC. The International Seed Testing Association (ISTA 1993) prescribes the alternating temperatures on the top of moist paper for 21 days; no pretreatment is needed. Germination speed can be increased by soaking the seeds overnight in aerated water (Olson and others 1990). Germination is epigeal.

Germination capacity has typically been low in the past, but this can be corrected by thorough seed processing. Redwood seed germination can be improved by 24 hours of water soaking followed by 4 weeks of stratification (Lippitt 1996).

Nursery practice and seedling care. Redwood seeds may be sown from March to May. Seeds are sown by drilling to a depth of 3 mm (1/8 in) and at a rate calculated to give a density of 323 seedlings/m² (30/ft²) for either 1+0 or 2+0 planting stock. All seedbeds are fumigated as standard practice. Mineral soil provides the best seedbed, but seeds will germinate in duff, on logs, and on most moist surfaces. Seeds can germinate in either shade or sunlight (Olson and others 1990), but frost protection is important (Lippitt 1996). Redwood seedlings need a greater supply of soil water than most associated species (Fritz 1966). The roots lack root hairs and, therefore, are not efficient in extracting water from the soil (Olson and others 1990). If the seeds are sown in fumigated beds, the beds should be inoculated with endomycorrhizae (Lippitt 1996). From 10 to 20% of the seedlings may be culled at the time of lifting (Boe 1974). Redwood seedlings are especially susceptible to damping-off, which is caused by gray mold (*Botrytis cinerea* Pers.:Fr.) and a blight caused by *Cercospora sequoiae* Ellis & Everh. (Sinclair and others 1987).

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Figure 1—*Sequoia sempervirens*, redwood: seeds, H 8.

Figure 2—*Sequoia sempervirens*, redwood: longitudinal section through a seed, H 25.