Alnus P. Mill.

alder

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Growth habit and occurrence. AlderCthe genus *Alnus*Cincludes about 30 species of deciduous trees and shrubs occurring in North America, Europe, and Asia and in the Andes Mountains of Peru and Bolivia. Most alders are tolerant of moist sites and thus are commonly found along streams, rivers, and lakes and on poorly drained soils; in addition, some species occur on steep slopes and at high elevations. The principal species found in North America are listed in table 1. Many changes in the taxonomy of alder have been made over the years; in this summary, species are referred to by their currently accepted names although in many cases the information was published originally under the synonyms (and alternative common names) listed in table 1.

Although some cultivated European alder is used commercially in the eastern United States, red alder is the largest native species. It is also the most extensively utilized of the native species. Management interest and research activity on red alders have increased dramatically during the past 2 decades, and the resulting information accounts for the majority of new information added to the previous summary on alder seeds prepared by Schopmeyer (1974).

Alders are pioneer species favored by high light levels and exposed mineral soils; in addition, their ability to fix atmospheric nitrogen facilitates establishment on geologically young or disturbed sites with low levels of soil nitrogen (Harrington and others 1994). Dense stands of naturally regenerated red alders were established quickly on mudflows associated with the eruption of Mount St. Helens. The trees grew rapidly and soon overtopped other pioneer species such as poplars in the nitrogen-deficient soils (Heilman 1990). Sitka alder plays a similar role in primary succession following deglaciation in Alaska.

Use. Seedlings have been planted successfully for reforestation of spoil banks (Lowry and others 1962). Soil fertility is improved through fixation of atmospheric nitrogen by microorganisms in the root nodules (Tarrant and Trappe 1971). Alders also have been planted for wildlife food and cover (Liscinsky 1965) and for ornamental use. European and red alders have been considered for use in biomass plantings for energy (Gillespie and Pope 1994) and are considered excellent firewood. In recent years, harvest and utilization of red alder has expanded greatly on the Pacific Coast of North America where the species is used for paper products, pallets, plywood, paneling, furniture, veneer, and cabinetry (Harrington 1984; Plank and Willits 1994). Red alder is also used as a fuel for smoking or curing salmon and other seafood and its bark is used to make a red or orange dye (Pojar and MacKinnon 1994). The soft, even-grained wood lacks odor or taste and has been traditionally been used by native peoples, and more recently other woodworkers, to make bowls, eating utensils, and other items (Pojar and MacKinnon 1994). In addition, alder exports have grown from almost nothing in 1990 to more than 153,000 m^3 (or 65 million) board feet of lumber annually (Tarrant and others 1994). Several options exist for managing alder in both mixed (Miller and Murray 1978) and pure stands (Tarrant and others 1983), and a summary of management principles and alternative strategies are available for red alder (Hibbs and DeBell 1994).

Geographic races and hybrids. Considerable geographic variation exists among populations of red (Ager and others 1993; Ager and Stettler 1994; Dang and others 1994; Hamann and others 1988; Lester and DeBell 1989), speckled ((Bosquet and others 19988), American green (Bosquet and others 1987), and European alders (Funk 1990; Hall and Maynard 1979). Disjunct populations of red alder have been located in Idaho (Johnson 1968), and growth of such populations and those at the extremes of species= range differs markedly from that of most populations (Lester and DeBell 1989). Natural hybridization is common in alder, and zones of introgression between some species can occur where ranges overlap (Ager and Stettler 1994). Artificial hybridization has been conducted with numerous species, including hybrids of red alder with European or mountain alders (Chiba 1966; Hall and Maynard 1979; Ljunger 1959).

Flowering and fruiting. Species in the genus are typically monoecious, with clusters of separate male and female flowers in close proximity (figure 1). Flower initiation probably occurs during late June or July for both red and European alders (Ager and others 1994; Brown 1986; McVean 1955). The male and female flowers develop into catkins that elongate in late winter or early spring and mature on the previous year=s twigs (table 2). For red alders, peak pollen shedding precedes peak female receptivity by only 2 to 4 days (Stettler 1978). For a specific description of staminate and pistillate catkins, see Brayshaw (1976). The strobiles of most species are 10 to 15 mm long when mature (figure 1), but those of Nepal, red, and Sitka alders are larger, having lengths of 12 to 24 mm (Carlson and Bryan 1959; Funk 1990; Harrington 1990; Krstinić 1994; Townsend and Douglass 1994). They are produced in abundance before trees reach 10 years of age in at least 2 species. European alders can produce flowers by their second growing season, and individual red alder trees are sexually mature at 3 or 4 years. Most dominant trees in a red alder stand will produce seeds by age 6 to 8 years (Harrington and DeBell 1995; Stettler 1978). Although the majority of seeds produced are probably the result of outcrossing, both selfing and apomixis occur in red alder (Stettler 1978). Seed production resulting from selfing has been reported for European and mountain alders; however, in many cases self-fertilization results in aborted ovules (Krstinić 1994). Information on the effects of management practices on reproductive processes is limited. In young red alder plantings in western Washington, flowering varied by half-sib family but overall was reduced in close spacings and by summer irrigation (Harrington and DeBell 1995). However, dry weather in spring reduced germination rates of European alder seeds, making irrigation early in the year desirable when precipitation is below normal (Hall and Nyong 1987).

Seed production varies from year to year, site to site, and tree to tree (Ager and others 1994; Brown 1985, 1986; Lewis 1985; Koski and Tallquist 1978; Krstinić 1994; McGee 1993), but good crops are borne at least once every 4 years (table 3). LaBastide and van Vredenburch (1970) reported that seed crops for European alder follow an annually alternating pattern. McVean (1955) concluded that seed crops of European alder could vary substantially from year to year, but that

Aboom-and-bust@ patterns of seed production were not typical. Complete failure of a seed crop is rare, but after a severe freeze in November 1955, almost no red alder seeds were produced in 1956 (Worthington 1965).

Seeds are small nuts (Anutlets@) borne in pairs on the bracts of the strobiles. The nuts of red, Siberian, and Sitka alders have broad wings about as wide as or wider than the body of the nut. In the other species included here, the wings are reduced to a narrow border (figure 2) (Fernald 1950; Sargent 1965). Seeds are without endosperm and contain only small cotyledons (figure 3). For additional information on reproductive biology of red alders, see Ager and others (1994).

The factors regulating the timing of seed dispersal in alders have not been investigated, but they are probably similar to those regulating the release of seeds from the cones of conifers; that is, once strobiles are mature, dispersal is determined by the occurrence of weather that dries them, thus opening scales and allowing the seeds to be released (Harrington and others 1994). In general, wet weather following dry weather closes the strobiles, thus terminating a dispersal event. Nonetheless, heavy seedfall can occur during wet weather under certain conditions (Lewis 1985), but dispersal will not occur if ice freezes the seeds in the strobile. Although most seed dispersal occurs from September or October through February to April (table 2), some red alder seedfall has been observed in all months (Lewis 1985). American green alder strobiles do not release many seeds if the weather is wet during the autumn; substantial seed dispersal onto snow can occur throughout the winter (Densmore 1979). Alder seeds are very light, and when released they are dispersed long distances by wind, and in some species by water. Seeds of European alder have remained viable after floating for 12 months in still water (McVean 1955). In Alaska, seeds of thinleaf alder have corky, thick wings and float for long periods of time, whereas seeds of American green alder have thinner wings and sink rapidly (Densmore 1979). Birds or other animals also act as dispersal agents when moving through alder crowns and when extracting seeds from the strobiles (Harrington and others 1994).

Information on damaging agents is limited. Fungal diseases of alder catkinsCcaused by *Taphrina occidentalis* Ray and *T. alni* (Berk. & Broome) GjaerumCcause enlargements of the bracts of female catkins (Mix 1949) and thus prevent or hinder normal fertilization and seed development. Jumping plant liceC*Psylla alni* (L.)Clay eggs in alder catkins in western North America (Furniss and Carolin 1977). Alder seeds are an important source of food for some bird species (White and West 1977), and presumably seed predation by birds could have significant impacts when seed crops are small.

Collection of fruits, extraction and cleaning, and storage of seeds. Seed crops can be assessed in mid-summer by obtaining a count of mature strobiles and filled seeds (Ager and others 1994). Filled seed count should be determined from the upper third of the crown where viability is highest (Brown 1985). Seed quality can be assessed by cutting the strobile longitudinally and counting the filled seed on one of the cut faces. Although the number of filled seeds on a cut face can vary from 0 to 20 or more in red alders, less than 3 or 4 seeds per cut face indicate a marginal crop (Ager and others 1994). Strobiles may be collected from standing or recently felled trees when the bracts (scales) start to separate on the most mature strobiles. In red alders, ripeness can be judged by twisting the cone along the long axis; if it twists easily and the scales part slightly, the seeds are sufficiently mature for collection (Hibbs and Ager 1989). Color is also a good indicator of maturity; immature cones are green whereas mature cones are mottled shades of green, yellow, gray, or brown (Hibbs and Ager 1989). Strobiles should be collected as soon as they are ripe, for the largest seeds with the best germinability are usually released first. Thus, both seed quality and seed yield are higher if collections are made in the fall rather than in the winter or spring (Lewis 1985; Krstinić 1994). Alder cones will open after being dried on screens or in fine mesh bags in a well-ventilated room for several weeks at ambient air temperature. They can be opened in a shorter time (2 to 7 days) by drying them in a kiln at 16 to 27 °C. Higher temperatures should not be used as the strobiles will dry too quickly, harden and not open completely. Most of the seeds fall out of the strobiles during the drying process. The remainder, if needed, may be extracted by shaking or tumbling. Overall seed yields can be improved by either wetting cones again, placing them in a cooler for 24 hours, or spraying them with a fine water mist and then redrying (Ager and others 1994). Seeds may be cleaned by screening to remove large trash and further processing with an air column to remove small extraneous material.

Purity as high as 90% has been attained with European alder by fanning and screening seeds. Quality, however, may be low because the light weight of alder seeds makes it difficult to separate and remove empty seeds (Ager and others 1994). Soundness in most cleaned seedlots has been between 30 and 70% (table 4). Number of seeds per weight ranges from 660,000 to 2,816,000/kg (or 300,000 to 1,277,000/lb) in lots of average quality (table 4). Except for seeds of American green alder, higher numbers may indicate a low percentage of filled seeds. Numbers ranging from 1,800,000 to 4,400,000 seeds/kg (800,000 to 2,000,000/lb) have been found in samples of Nepal, red, and thinleaf alders, but less than 5% of the seeds in these samples were full (Schopmeyer 1974). One red alder seedlot, however, was 70% sound and had 2,700,000 seeds/kg (1,224,000/lb). In a trial with red alder, the percentage of filled seeds determined by x-radiography was highly correlated ($r^2 = 0.91$), with the actual germination percentage (Ager and others 1994).

Air-dried seeds have been stored in sealed containers at 0 ± 2 °C. Under these conditions, viability has been maintained for 2 years in seeds of European alder (Holmes and Buszewicz 1958) and for 10 years in speckled alder (Heit 1967). For long-term storage, however, further drying of seeds to moisture content of less than 10% has been recommended for red alder (Ager and others 1994). This can be accomplished by kiln-drying or placing seeds in a room at 27 °C with less than 25% relative humidity. Red alder seed can then be placed in moisture-proof containers and stored at < –12 °C for 10 to 20 years without substantial losses in viability (Ager and others 1994).

Pregermination treatments and germination tests. The degree of dormancy appears to vary among alder species and among provenances (geographic origins) within species. Thus, percentage germination of fresh seeds of white and thinleaf alders was equally good for stratified and nonstratified seed (Schopmeyer 1974). Fresh seeds of European and mountain alders also germinated promptly without stratification; but dried seeds, at a moisture of content of 8 to 9%, were dormant (table 5) (Schalin 1967). Germination capacity of the dried seeds, after stratification for 180 days at 5 °C was higher than that of fresh seeds. Maximum germination capacity, however, was obtained only when the stratification period was followed by a 3-day period at –20 °C (table 5) (Schalin 1967). A more recent study found that fresh mountain alder seeds initially exhibited some dormancy (that is, only about half of the filled seeds germinated in the incubator), but no dormancy was observed after one winter in the soil (Granstrom 1987). Dormancy also has been encountered in occasional seedlots of speckled (Heit 1968) and American green alders (Schopmeyer 1974). Stratification for 30 to 60 days at 1 to 5 °C has been recommended for these dormant lots

(Schopmeyer 1974). Stratification for 30 to 90 days also has been recommended for Sitka alder (Emery 1988).

Although physiological seed dormancy is not widespread in red alder, it can exist (Elliot and Taylor 1981). Stratification at low temperature (0 to 5 °C) has little or no effect on the rate or completeness of germination of red alder seeds when tested at warm germination temperatures (Elliot and Taylor 1981; Radwan and DeBell 1981; Tanaka and others 1991). Under cool temperatures similar to those likely to prevail during outdoor sowings in early spring, however, 2 to 4 weeks of stratification substantially enhanced rate of germination and total germination (Tanaka and others 1991) and such a period is therefore recommended (Ager and others 1994). Thinleaf and American green alder seedlots collected near Fairbanks, Alaska, also germinated well without stratification at 25 °C but only germinated well at lower temperatures (10 to 15 °C) when combined with 72 days of stratification (Densmore 1979). Studies have also indicated the potential of 3 quick pregermination treatments for red alder seeds: gibberellin (Berry and Torrey 1985), 1% captan (Berry and Torrey 1985), and 30% hydrogen peroxide (Neal and others 1967). The results from these pregermination treatments, however, were obtained under warm germination conditions and need to be tested under the cooler conditions encountered in spring sowings. The captan and peroxide treatments may have a beneficial effect by reducing the amount of disease organisms present on seed coats. Pretreatment with gibberellic acid improved greenhouse germination (21 °C day/13 °C night) of thinleaf alder seeds from 2 sources but did not affect germination of Arizona alder seeds from a single source (Dreesen and Harrington 1997).

For germination testing, both constant temperatures and diurnally alternating temperatures have been used (table 5). Official tests of the International Seed Testing Association (ISTA 1993) call for a 21-day test at alternating temperatures of 20/30 °C, with light during the 8 hours at 30 °C. Although seeds of European alder germinated as well in continuous darkness as under normal day length (McVean 1955), recent work indicates that seed germination of many alder species is markedly affected by light regime (Berry and Torrey 1985; Boojh and Ramakrishnan 1981; Bormann 1983; Densmore 1979; Khan and Tripathi 1989). Such effects in red alder are mediated by phytochrome: red light stimulates seed germination, far-red light inhibits it, and the effect of each light treatment can be reversed by the alternative treatment (Bormann 1983). Seeds of red alder are also sensitive to amount and quality of light under field conditions, and these factorsCalong with soil moistureCcontrol germination success on disturbed sites (Haeussler and Tappeiner 1993; Haeussler and others 1995).

Nursery practice. Alder seedlings have been produced by bareroot nursery (open field or bedhouse) and container methods, as well as combinations thereof (Ahrens 1994; Ahrens and others 1992; Funk 1990; Radwan and others 1992). Successful stock types for red alder are grown in 1 year and include 1+0 open-bed bareroot, 1+0 bedhouse bareroot, 1+0 plug, and +0.5 (or plugBtransplant). Most nurseries sow in the spring when growing alder species (Ahrens and others 1992; Schopmeyer 1974), but fall-sowing is mentioned by Heit (1968). Spring-sowing is sometimes delayed until late spring to reduce seedling size. Sowing depths of 2 to 5 mm (.1 to .2 in) have been used for seeds of European alder and red alder (Schopmeyer 1974). In California, seeds of red alder have been mixed with 10 parts of vermiculite and drilled 1 cm (.4 in) deep (Schopmeyer 1974). In Oregon, seeds of red alder have also been sown on the soil surface and covered with peat. Seeds of Nepal alder have been mixed with sand and spread over the nursery beds. The number of plantable seedlings obtained from 1 kg (2.2 lb) of seed was 22,000 (10,000/lb) for European alder and 88,000 (40,000/lb) for hazel alder (Van Dersal 1938). Germination is epigeal (figure 4).

Alder seedlings, particularly those of red alder, grow rapidly and seedling densities should be lower than those used for conifers. Seedlings grown at open-bed densities of 60 to 180 seedlings/m^2 (or 5 to 15 seedlings/ft^2) or in large containers result in much better outplanting performance than those grown at greater densities or in small Styroblocks7 (Ahrens 1994). Inoculation of beds or container media with the nodulating actinomycete *Frankia* can improve establishment and early growth in the nursery (Berry and Torrey 1985; Hilger and others 1991) and may enhance outplanting performance (McNeill and others 1990). Diluted suspensions of pure *Frankia* cultures and homogenates of crushed, fresh root nodules have been used for inoculation (Ahrens and others 1992; Perinet and others 1985). Detailed methods of preparation and application are available (Martin and others 1991; Molina and others 1994; Zasada and others 1991).

Development of nitrogen-fixing nodules is promoted by fertilization with low to moderate applications of nitrogen; phosphorus and lime are likely to be necessary for production of high-quality stock (Hughes and others 1968; Radwan 1987; Radwan and DeBell 1994). Although alder seedlings are produced operationally, optimum combinations of fertilizer source, amount, and timing of application have not been completely worked out; some combinations have had detrimental effects on alder seedlings or their root associates. Frequent irrigation may be necessary to prevent desiccation and heat damage of surface-sown seed or germinants during germination and early establishment (Ahrens 1994).

Direct seeding in the field has been done successfully with 2 species. Speckled alder has been established in Pennsylvania by broadcast sowing on disked areas and on sod. Seeds were collected in the fall and broadcast during the following February and March. Seeding rates were 0.28 liter/10 m^2 (or 0.5 pint/100 ft^2) on bare soil and 0.38 liter (0.7 pint) for the same area of sod (Liscinsky 1965). In England, better stocking was obtained on a shallow blanket bog with spot sowing of European alder than with broadcast sowing. About 15 viable seeds were sown in each spot and fertilized with about 60 g of rock phosphate (McVean 1959).

Seedling care. Information to guide lifting dates is very limited, even for red alder (Ahrens 1994; Ahrens and others 1992); current recommendations based on experience in southwest Washington are to lift seedlings in January. They are then stored at either +2 °C or –2 °C; the lower temperature is recommended because it prevents budbreak during storage (and possible *Botrytis* infection associated with budbreak during storage) and reduces the tendency for planted alders to break bud too soon after planting. Storage in sealed bags will prevent desiccation. Because alder stems are brittle and sensitive, seedlings must be handled carefully during storage, transport, and outplanting to avoid damage to stems, branches, and buds. At low elevations (< 300 m) in western Washington, it has been recommended that seedlings be planted between mid-March and mid-April. The spring planting period should begin when the probability of severe frost is low and end before there is appreciable soil drying (Dobkowski and others 1994).

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Figure 1C*Alnus,* alder: mature female catkins (strobiles), × 2.

Figure 2C*Alnus,* alder: nuts (seeds), × 8.

Figure 3C*Alnus rubra,* red alder: longitudinal section through a nut, × 16.

Figure 4AC*Alnus glutinosa,* European alder: seedling development at 1 and 7 days after germination. **Figure 4BC***Alnus tenuifolia,* thinleaf alder: 2 older seedlings.

Table 1C*Alnus,* alder: nomenclature and occurrence

Scientific name(s) & synonyms	Common name(s)	Occurrence
***A. glutinosa* (L.) Gaertn.** *A. alnus* (L.) Britt. *A. rotundifolia* Mill.; *A. vulgaris* Hill *Betula alnus* var. *glutinosa* L.	**European alder,** black alder, European black alder	Native of Europe, northern Africa, & Asia; naturalized locally in parts of E Canada & NE US, cultivated in E, central, & S US
***A. incana* (L.) Moench** *Betula alnus* var. *incana* L.	**mountain alder,** European speckled alder, hoary alder, gray alder	Native of Europe & the Caucasus area; occurs in North America only under cultivation
***A. incana* ssp. *rugosa* (Du Roi) Clausen** *A. incana* var. *americana* Reg. *A. glauca* Michx. *A. rugosa* (Du Roi) Spreng. var. *americana* (Reg.) Fern *A. rugosa* var. *tomophylla* (Fern.) Fern. *Betula alnus* var. *rugosa* Du Roi	**speckled alder,** tag alder, swamp alder, aulne blanchâtre	E & central Canada, N central US & in Appalachian Mtns to West Virginia & Maryland
***A. incana* ssp. *tenuifolia* (Nutt.) Breitung** *A. incana* var. *occidentalis* (Dippel) Hitch. *A. incana* var. *virescens* S. Wats. *A. occidentalis* Dippel *A. rugosa* var. *occidentalis* (Dippel) Hitch. *A. tenuifolia* Nutt.	**thinleaf alder,** mountain alder	Yukon & Alaska S to W Montana & Oregon, in Sierra Nevada to central California, & E to Arizona & New Mexico
***A. maritima* (Marsh.) Muhl. ex Nutt.** *A. maritima* ssp. *metoporina* (Furlow) E. Murr. *A. metoporina* Furlow *Betula-alnus maritima* Marsh.	**seaside alder,** brook alder	Widely disjunct populations in Delaware, Maryland, & Oklahoma
***A. nepatensis* D. Don** *A. boshia* Buch.-Hamilt. ex D. Don *Clethropsis nepalensis* (D. Don) Spach.	**Nepal alder,** utis, maibao	Native of India & Burma; planted in Hawaii
***A. oblongifolia* Torr.**	**Arizona alder,** New Mexican alder, aliso (Mexico)	Scattered populations in high mtns of Arizona, New Mexico, & Mexico
***A. rhombifolia* Nutt.** *A. rhombifolia* var. *bernardina* Munz & Johnson	**white alder,** Sierra alder, California alder	Interior of S British Columbia, Washington, Oregon, & Idaho; Sierra Nevada & coast ranges in California & N Baja California
***A. rubra* Bong.** *A. oregona* Nutt.	**red alder,** Oregon alder, western alder, Pacific Coast	Pacific Coast region from SE Alaska to S California

A. oregona var. *pinnatisecta* Starker	alder	
***A. serrulata* (Ait.) Willd.** *A. incana* var. *serrulata* (Ait.) Boivin *A. novebroacensis* Britt. *A. rubra* (Marsh.) Tuckerman *A. rugosa* (Du Roi) Spreng. var. *serrulata* (Ait.) Winkler *A. serrulata* var. *subelliptica* Fern. *Betula serrulata* (Ait.)	**hazel alder,** smooth alder, black alder	SW Nova Scotia & central Maine W to Missouri & S to E Texas & Florida
***A. viridis* (Vill.) Lam. & DC.** *A. ovata* (Schr.) Lodd. *Alnobetula* (Ehrh.) K. Koch *Betula viridis* Vill.	**Sitka alder**	S Arctic subarctic, and N mountainous regions of North America & Asia
***A. viridis* ssp. *crispa* (Ait.) Turrill** *A. crispa* (Ait.) Pursh *A. crispa* var. *elongata* Raup. *A. crispa* var. *harricanensiis* Lepage *A. crispa* var. *mollis* (Fern.) Fern. *A. crispa* var. *stragula* Fern. *A. mollis* Fern. *A. viridis* var. *crispa* (Michx.) House *A. alnobetula* var. *crispa* (Michx.) Winkler *Betula crispa* (Ait.)	**American green alder,** green alder, mountain alder	Labrador to Alberta, S to Minnesota & New England
A. viridis* ssp. *fruticosa* (Rupr.) Nyman *A. fruticosa* Rupr. *A. viridis* var. *fruticosa* (Rupr.) Reg.	Siberian alder	Alaska S to British Columbia & Alberta, disjunct populations in Washington, Oregon, & N California
***A. viridis* ssp. *sinuata* (Regel) A. Löve & D. Löve** *A. crispa* ssp. *sinuata* (Reg.) Hultén *A. sinuata* (Reg.) Rydb. *A. sitchensis* (Reg.) Sarg. *A. viridis* var. *sinuata* Reg.	**Sitka alder,** mountain alder, wavyleaf alder	Yukon & Alaska S to N California & W Montana; also in E Asia

Source: Schopmeyer (1974), FNAEC 1997).
* In western North America, Siberian alder *(A. viridis* ssp. *fruticosa*) has long been mistaken for American green alder (*A. v.* ssp. *crispa*), which is closely resembles, or for Sitka alder (*A. v.* ssp. *sinuata*) (FNASEC 1997).

Table 2C*Alnus,* alder: phenology of flowering and fruiting*

Species	Location	Flowering dates*	Fruit ripening dates	Seed dispersal dates
A. glutinosa	E US	MarBMay	Sept	Sept or OctBearly spring
	S US & England	(can start Jan)	C	C
		C	FebBApril	C
A. incana	Europe	MarBMay	SeptBNov	SeptBDec
A. i. ssp. *rugosa*	Canada, US	Mar-May	C	C
A. i. ssp. *tenuifolia*	Idaho, Montana, Oregon	MarBApr	AugBSept	C
A. nepalensis	Hawaii	C	OctBFeb	OctBApr
A. rhombifolia	Oregon	Mar	Late SeptBearly Oct	C
A. rubra	Washington, Oregon	Late winterB early spring	AugBOct	SeptBDec
A. serrulata	C	FebBMay	Late SeptBearly Oct	C
A. viridis ssp. *crispa*	E US, Alaska	Spring	Late AugBmid-Oct	Soon after ripening
		AprBJune	Mid SeptBearly Oct	SeptBearly spring
A. viridis ssp. *sinuata*	Alaska, W Canada, NW US	AprBJune	SeptBDec	C

Sources: Densmore (1979), Fernald (1950), Funk (1990), Harrington (1990), Hitchcock and others (1964), Lewis (1985), McDermott (1953), McGee (1988), McVean (1955), Schopmeyer (1974), White (1981).

* Flowering occurs during the period when leaves unfold.

Table 3C*Alnus,* alder: growth habit, height, seed-bearing age, and seed crop frequency

Species	Growth habit	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Interval between large seed crops (yrs)
A. glutinosa	Tree	to 35	1866	6B7	C
A. incana	Tree	to 20	C	under 25	1B4
A. i. ssp. *rugosa*	Tree or shrub	to 8	C	C	C
A. i. ssp. *tenuifolia*	Tree or shrub	1B9	1880	C	C
A. nepalensis (Hawaii)	Tree	15B30	1916	10	C
A. rhombifolia	Tree	20B25	1885	C	C
A. rubra	Tree	12B27	1884	3B4	3B5
A. serrulata	Tree or shrub	to 8	1769	C	C
A. viridis ssp. *crispa*	Shrub	to 3	1782	C	C
A. v. ssp. *sinuata*	Tree or shrub	to 12	1903	C	C

Sources: Carlson and Bryan (1959), Fernald (1950), Funk (1990), Harrington (1990), Sargent (1965), Schopmeyer (1974).

Table 4C*Alnus,* alder: yield data and soundness

		Seed wt/ vol of strobiles		Cleaned seed/ wt of strobiles		Cleaned seed/ vol of strobiles		Cleaned seeds (thousands)/wt of strobiles					
								Range		Average			
cies		kg/hl	lb/bu	kg/100 kg	lb/100 bu	kg/hl	lb/bu	/kg	/lb	/kg	/lb	Samples	(%)
											A. glutinosa		
ennsylvania		C	C	C	C	1.5	1.2	565B882	257B401	706	321	7	C
urope	C	C	C	C	C	C	635B1,406	289B639	774	352	86	39	
ncana													
urope	21B30	16B23	8B10	8B10	C	C	961B1,980	437B900	1,470	668	123	51	
ncana													
p. *rugosa*	C	C	C	C	4.8	3.7	C	C	660	299	C	30-60	
p. *tenuifolia*													
(fresh)*	14	11	7	7	1.3	1.0	C	C	C	C	C	C	
(air dry)*	8	6	13	13	1.0	0.8	C	C	1,485	673	1	C	
hombifolia													
resh)*	23	18	5	5	1.3	1.0	C	C	C	C	C	C	
ir dry)*	9	7	13	13	1.3	1.3	1,349B1,511		613B687	1,430	650	2	71
ubra	9	7	1.4B15	1.4B15	0.1B1.4	0. 1B1.1	1,843B2,700		350B1,400	1,712	776	5	70
viridis													
p. *crispa*	C	C	C	C	C	C	1,530B4,101		694B1,860	2,816	1,277	2	42B93
p. *sinuata*		C	C	C	C	C	C	C	C	2,200	998	1	70

rces: Hibbs and Ager (1989), Liscinsky (1965), Mirov and Kraebel (1939), Schopmeyer (1974), Niemic and others (1995), USDA data on file at Olympia Forestry Sciences Laboratory.

Yield data were determined on clusters of strobiles including stems.

Table 5C*Alnus,* alder: stratification periods, germination test conditions, and results

Species	Cold stratification period*(days)	Germination test conditions: Temp. (°C) Day	Night	Duration (days)	Germination rate: Amount (%)	Period (days)	Germination (%)	Samples	Soundness (%)
A. glutinosa (Pennsylvania)	0	30	21	28	C	C	52	7	C
A. glutinosa (Finland)									
fresh seed	0	25	25	21	21	5	28	1	43
dried seed	0	25	25	21	9	5	13	1	43
dried seed	180	25	25	21	27	5	35	1	43
dried seed	180+3H	25	25	21	35	5	46	1	43
A. incana (Europe)	0	21	21	30	C	C	45	100	C
A. incana (Finland)									
fresh seed	0	25	25	21	21	5	29	1	45
dried seed	0	25	25	21	12	5	16	1	45
dried seed	180	25	25	21	25	5	34	1	45
dried seed	180+3H	25	25	21	38	5	49	1	45
A. i. ssp. *tenuifolia*									
fresh seed	0	30	20	26	4	13	4	1	6
A. rhombifolia									
fresh seed	0	30	20	30	59	14	59	1	65
A. rubra 0	24	16	7	56	7	56	4	C	
dried seed	0-60I	30'	20	28	18	7	71	6	C
fresh seed	01	30	20	28	21	7	75	6	87
fresh seed	14	30	20	28	42	7	72	6	87
fresh seed	28	30	20	28	49	7	72	6	87
fresh seed	01	15	5	56	0	21	16	6	87
fresh seed	14	15	5	56	17	21	63	6	87
fresh seed	28	15	5	56	54	21	80	6	87
A. serrulata	??I	27	23	10	27	2	36	1	C
A. viridis ssp. *crispa*	60	30	20	30B40	28	12	28	3	30B40
A. viridis ssp. *sinuata*	14	30	20	21	5	7	14	1	C

Sources: ISTA (1993), McDermott (1953), Radwan and DeBell (1981), Schalin (1967), Schopmeyer (1974), Tanaka and others (1991), data on file at Olympia Forestry Sciences Laboratory.

Note: Day/night, 8 hrs/16 hrs; 5 °C = 41 °F, 15 °C = 59 °F, 16 °C = 61 °F, 20 °C = 68 °F, 21 °C = 70 °F, 23 °C = 73 °F, 24 °C = 75 °F, 25 °C = 77 °F, 27 °C = 81 °F, 30 °C = 86 °F.

* Stratification, when used, was in a moist medium at 1 to 5 °C.

H 180 days at 5 °C, plus 3 days at – 20 °C,

I No difference 0, 30, or 60 day stratification, 24-hour water soak.

' Light period was 10 hour/ day at this temperature.

I Seeds were stratified for an unspecified period.