Juglandaceae—Walnut family

Juglans L.

walnut

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Growth habit, occurrence, and use. The walnuts include about 20 species of deciduous trees or large shrubs that occur in the temperate regions of North America, northwestern South America, northeastern Europe, and eastern Asia. Six are native to the United States, and 2 exotic species are also planted in this country (table 1). The wood of most species is used to some extent, and that of many species, primarily black walnut, is highly valued for furniture, cabinet work, gunstocks, and interior trim. The nuts provide food for humans as well as for wildlife, and ground shells are used as an abrasive grit for industrial cleaning. Numerous medicinal products and dyes have been made from extracts of walnut fruits (Krochmal and Krochmal 1982). English walnut is a major nut crop in many temperate regions around the world, including the United States. Of the 6 native species, black walnut is by far the most widely planted. Butternut, little walnut, and Hinds walnut have had limited utilization. Butternut is currently being killed throughout its range in North America by *Sirococcus clavigignenti–juglandacearum* Naiv. Kostichka & Kuntz, a fungus of unknown origin (Ostry and others 1994). Research is underway to identify and propagate resistant trees.

Geographic races. There is considerable genetic variation in the walnuts that are widely distributed. Three distinct geographic races of English walnut are recognized: Turkestani, Himalayan, and Central Asian—and many horti-

Table 1—*Juglans,* walnut: nomenclature and occurrence

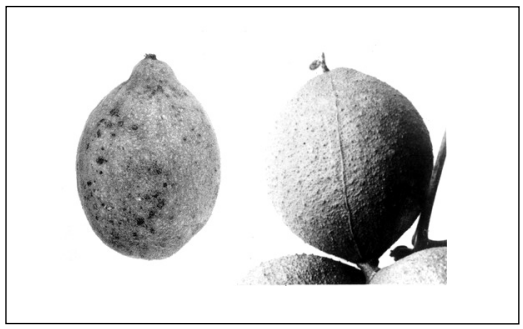
Scientific name & synonym(s)	Common name(s)	Occurrence
***J. ailantifolia* Carriere** *J. sieboldiana* maxim.	**Japanese walnut,** Siebold walnut	Japan
***J. californica* S. Wats.**	**California walnut,** southern California walnut, black walnut	Coastal S California (Santa Barbara Co. to Orange Co.) California
***J. cinerea* L.** *Wallia cinerea* (L.) Alef.	**butternut,** oilnut, white walnut	New Brunswick to S Ontario & SE Minnesota, S to Arkansas, N Mississippi, N Georgia, & W South Carolina
***J. hindsii* (Jepson) Jepson ex R.E. Sm.** *J. californica* var. *hindsii* Jepson	**Hinds walnut,** northern California walnut, Hinds black walnut	Central California (Shasta Co. through Stanislaus Co.)
***J. major* (Torr.) Heller** *J. rupestris* var. *major* Torr. *J. microcarpa* var. *major* (Torr.) L. Benson *J. elaeopyren* Dode	**Arizona walnut,** Arizona black walnut, *nogal, nogal silvestre*	Central & SW Texas to SW New Mexico, Arizona, & mtns of northern Mexico
***J. microcarpa* Berl.** *J. rupestris* Englem. ex Torr.	**little walnut,** Texas walnut, river walnut, *nogal*, Texas black walnut	W Oklahoma, W & S Texas & SE *nogalito, namboca,* New Mexico, S to NE Mexico
***J. nigra* L.** *Wallia nigra* (L.) Alef.	**black walnut,** eastern black walnut, American walnut	W Vermont, S Ontario, & New York, W to S Minnesota & SE South Dakota; S to central Texas & NW Florida
***J. regia* L.**	**English walnut,** Persian walnut, Carpathian walnut	SE Europe to Himalayas & China

Sources: Brinkman (1974), Little (1979).

cultural varieties of English and Japanese walnuts have been developed (Brinkman 1974). Black walnut has demonstrated tremendous geographic variation in growth, wood, and fruiting characteristics (Bey 1970; Bresnan and others 1994; Rink and Kung 1995; Rink and Phelps 1989; Rink and others 1994; Williams and others 1985), and selected material has performed well (Beineke 1989; Hammitt 1989). Around 400 cultivars of this species alone have been released (Rink 1988; Williams 1990). Seed collection zones have also been recommended for black walnut (Deneke and others 1980).

Flowering and fruiting. Walnuts are monoecious. The greenish male flowers are slender catkins that develop from axillary buds on the previous year's outer nodes. They range in length from 5 to 7 cm on California walnut to 10 to 20 cm on Arizona walnut (Krochmal and Krochmal 1982; Sargent 1965). The small female flowers, usually 6 to 12 mm long, occur in short terminal spikes on the current year's shoots. The flowers appear with or shortly after the leaves in the spring (table 2). The ovoid, globose, or pear-shaped fruits ripen in the first year. The fruit is a nut enclosed in an indehiscent, thick husk that develops from a floral involucre (figure 1). The diameters range from 1 to 2 cm for little walnut to 5 to 8 cm for butternut (Krochmal and Krochmal 1982; Sargent 1965). The nut (figure 2) is incompletely 2- or 4-celled and has a bony, furrowed shell (figure 3). Available data on seeding habits of 8 species are listed in table 3.

Figure 1—*Juglans*, walnut: nuts (enclosed in their husks) of *J. cinerea*, butternut (**left**) and *J. nigra*, black walnut (**right**).



Collection of fruits. Walnut fruits can be collected from the ground after natural dispersal in fall or early winter (table 2), or they may be dislodged from the trees by shak-

Figure 2—*Juglans*, walnut: nuts (with their husks removed) of *J. cinerea*, butternut (**top left**); *J. hindsii;* Hinds walnut (**top right**); *J. californica,* California walnut (**center left**); *J. nigra;* black walnut (**center right**); *J. microarpa*, little walnut (**bottom left**).

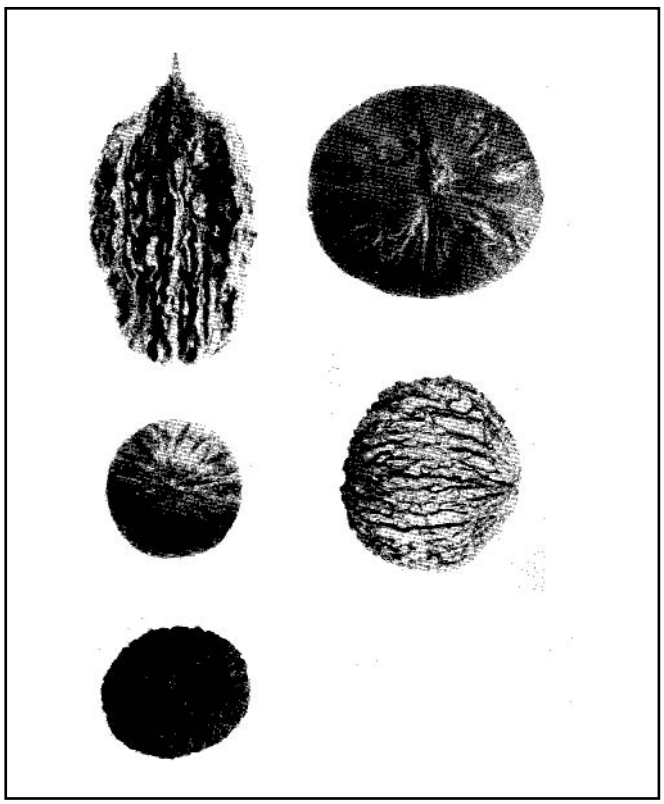
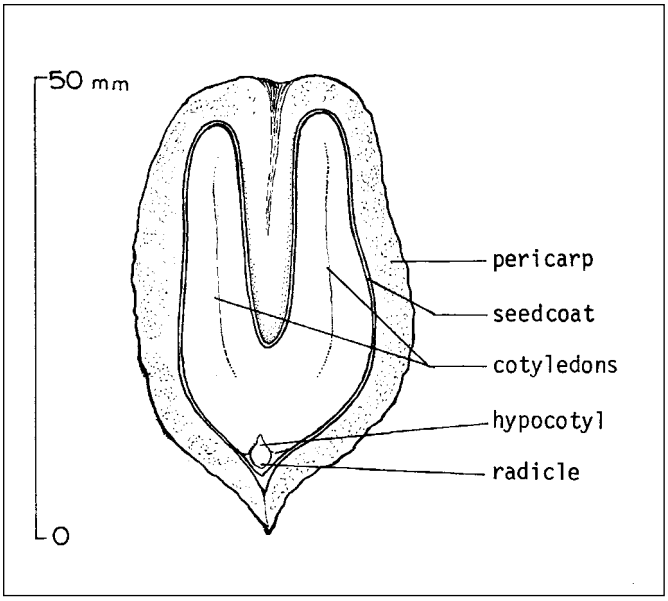


Table 2—*Juglans,* walnut: phenology of flowering and fruiting

Species	Flowering	Fruit ripening	Seed dispersal
*J. ailantifolia**	May–June	Aug–Oct	Oct
J. californica	Mar–Apr	Fall	Fall
J. cinerea	Apr–June	Sept–Oct	After leaf-fall
J. hindsii	Apr–May	Aug–Sept	Sept–Oct
J. major	Spring	Fall	Fall
J. microcarpa	Mar–Apr	Aug–Sept	Fall
J. nigra	Apr–June	Sept–Oct	After leaf-fall
J. regia	Mar–May	Sept–Nov	Fall

Sources: Brinkman (1974), Rink (1990), Vines (1960), Williams (1990), Wyman (1947).
* Dates are for Japan and Massachusetts.

Figure 3—*Juglans cinera*, butternut: longitudinal section through a seed.



ing branches or the whole tree with mechanical shakers. Collections should start promptly after the nuts are mature to prevent losses to rodents. Maturity is generally indicated by a darkening color of the fruit husk (table 3). Healthy butternut trees will yield up to .3 hl (.9 bu) each of clean nuts, and black walnut may produce 1 hl (2.9 bu) or more of fruit. Even though black walnut nut production is under strong genetic control (Jones 1993), environmental factors are very important. Nut production on pole-sized black walnuts was doubled in one trial by application of nitrogen and phosphorus at 4.5 and 2.3 kg (9.9 and 5.1 lb), respectively, per tree (Ponder 1976). Yield was 400 to 450 nuts/tree. Three hectoliters (8.4 bu) of black walnut and Hinds walnut fruits should yield about 1 hl (2.8 bu) of sound seeds (Brinkman 1974). Yield, size, and number of fruits per weight vary considerably among species (table 4).

Extraction and storage of seeds. Nuts are easy to extract when the husks are in an early stage of softening—that is, firm on the outside but slightly soft next to the nut. Black walnut nuts collected in the eastern United States are

Table 3—*Juglans*, walnut: height, seed-bearing age, seedcrops frequency, and fruit ripeness criteria

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Years between large seedcrops	Fruit ripeness criteria	
					Preripe color	Ripe color
J. ailantifolia	20	1860	10	1–3	—	—
J. californica	12	1889	5-8	—	Light green	Dark brown
J. cinerea	30	1633	20	2–3	Greenish bronze	Greenish brown
J. hindsii	24	1878	9	—	Light yellow-green	Dark brown to black
J. major	15	1894	—	—	—	—
J. microcarpa	6	1868	20	—	—	—
J. nigra	46	1686	12	2–3	Light green	Yellowish green
J. regia	27	Long cultivated	8	—	Light yellowish green	Black

Source: Brinkman (1974).

Table 4—*Juglans*, walnut: cleaned seed and other yield data

Species	Place collected	Fruit wt/ fruit vol		Seed wt/ fruit vol		Cleaned seeds/weight				Samples
						Range		Average		
		kg/hl	lb/bu	kg/h	lb/bu	/kg	/lb	/kg	/lb	
J. ailantifolia	Japan	—	—	—	—	130–175	60–80	155	70	2
J. californica	California	—	—	—	—	65–165	30–75	110	50	2
J. cinerea	—	—	—	—	—	33–88	15–40	66	30	13
J. hindsii	Shasta Co., California	47	36	16	12.5	64–175	29–80	100	45	3
J. major	Coconino Co., Arizona	—	—	—	—	170–225	77–102	200	90	10
J. microcarpa	—	—	—	—	—	170–235	78–107	203	92	2
J. nigra	—	62	48	—	—	25–220	11–100	88	40	20+
J. regia	California	—	—	—	—	66–110	30–50	88	40	10+

often spread on the ground in the shade to allow husks to dry and deteriorate. If husks are allowed to dry too much, however, they become very hard and removal is difficult. In the slightly soft stage, husks can be removed by hand or by running the fruits through a macerator or a corn sheller. For commercial quantities of nuts, mechanical hullers are available. After complete husk removal, unfilled nuts can be separated from filled nuts by water floatation. Seeds enclosed in their husks will germinate, but most nurseries find it easier to control seedling density in the beds with cleaned seeds. Husking is necessary if seeds are to be treated with a fungicide.

Walnut nuts are basically orthodox in storage behavior (that is, capable of surviving desiccation), but their high lipid contents put them in the sub-orthodox category (Bonner 1990). Nuts of most species can be stored with or without their husks and are commonly stored without. If their moisture contents are reduced to around 10 to 15%, nuts can be stored at below-freezing temperatures. Long-term storage of walnuts is not common, however, and nuts are commonly stored at higher temperatures and moisture contents. Nuts of Japanese and little walnuts and butternut were successfully stored for several years at relative humidities of 80 to 90% and temperatures of 1 to 4 °C (Brinkman 1974). Cleaned black walnuts with a moisture content of 20 to 40% were stored successfully at 3 °C for a year in plastic bags (Williams 1971b), and nuts with 50% moisture in a screen container were buried in an outdoor pit for 4 years without significant loss in germination capacity (Williams 1971a).

Table 5—*Juglans*, walnut: stratification period, germination test conditions and results

Species	Cold stratification period* (days)	Germination test conditions† Daily light period (hr)	Temp (°C) Day	Temp (°C) Night	Germination rate Days	Germination rate Amt (%)	Germination rate Days	Germination % Avg (%)	Germination % Samples	Purity (%)
J. ailantifolia‡	0	—	—	—	42	—	—	75	3	—
J. californica	156	—	—	—	30	—	—	58	3+	—
J. cinerea	90–120	8+	30	20	50–80	54	58	65	7	96
J. hindsii	156	—	30	20	30+	—	—	41	4	—
J. major	120–190	8+	30	20	49	10	28	64	5	—
J. microcarpa	190	—	30	20	30–60	68	14	46	7	94
J. nigra	90–120	8+	30	20	15–40	60	24	50	14+	87
J. regia	30–156	—	30	20	40	—	—	82	4	High

Source: Brinkman (1974).
* Stratification temperatures ranged from 1 to 5 °C.
† Test media were soil or sand.
‡ Seeds were soaked in water for 10 days before sowing.

Table 6—*Juglans*, walnut: nursery practice

Species	Stratification* Medium	Days	Sowing season	Seedlings/area /m²	Seedlings/area /ft²	Sowing depth cm	Sowing depth in	Mulch Type	Mulch Depth cm	Mulch Depth in
J. californica	Peat	150	Spring	—	—	5	2	—	—	1
J. cinerea	Sand	90–120	Spring	—	—	2.5–5	1–2	Sawdust	2.5	1
	—	—	Fall	—	—	2.5–5	1–2	None	—	—
J. hindsii†	—	—	Fall	65–68	700–732	2.5	1	Vermiculite	2.5	1
J. major	Sand or peat	90–150	Spring	—	—	5	2	—	—	—
J. microcarpa	—	—	Fall	35–65	377–700	2.5–5	1–2	Sawdust	2.5	1
J. nigra	Sand	90–100	Spring	35–65	377–700	2.5–5	1–2	—	—	—
J. regia	Sand	30+	Spring	—	—	5	2	—	—	—

Sources: Brinkman (1974), Schultz and Thompson (1990), Williams and Hanks (1976).
* Outdoors during the winter or in a cold room at 1 to 5°C.
† Seeds were soaked in water at 88 °C for 1 1/2 to 2 minutes before sowing.

Pregermination treatment. Seeds of most walnut species exhibit an embryo dormancy that can be broken by stratification at temperatures of 1 to 5 °C (table 5). For Japanese walnut, however, water soaking is adequate (Brinkman 1974). In practice, walnut seeds are either sown in the fall soon after collection or stratified over winter for spring-sowing. Large amounts are sometimes stratified in moist sand covered with at least 15 cm (6 in) of soil, sand, or mulch (Rink 1988). This process can be carried out in a hole in the ground or above ground with wooden sideboards to hold sand, nuts, soil, and mulch in place. Screening is nearly always necessary to exclude rodents, and a fungicide may be applied to prevent disease during stratification. Small lots of seeds may be stratified in plastic bags, moist peat, or sand at the same temperatures for 90 to 120 days. For Illinois sources, at least 100 days of cold stratification are required to overcome dormancy (Van Sambeek and others 1990).

Germination tests. There are no official seed testing prescriptions for walnuts. Germination of stratified nuts can be tested in flats of sand, peat, or soil (table 5). An alternating temperature regime of 20 °C for 16 hours and 30 °C for 8 hours is best; light is not necessary during testing. Nuts can also be tested in laboratory germinators on thick paper wadding, but their size often makes this impractical. Properly stratified seeds usually germinate within 4 weeks, but much variation among seedlots can be expected. Examples of test results are included in table 5. Indirect estimates of viability can also be made with radiographs, although exact predictions of viability are unlikely. If radiopaque agents are employed, cracked seedcoats and damaged tissues can be detected (Vozzo 1978). Moisture determinations can be made on walnuts by breaking open the nuts and drying the pieces for 17 hours at 103 °C (Bonner 1982). If the nuts are not broken, moisture may be trapped inside during drying, and the resulting percentage calculation will underestimate the moisture content.

Nursery practice. Research has demonstrated that a good black walnut seedling should have a top length of 38 to 50 cm (15 to 20 in), a stem diameter of 8 mm ($^1/_3$ in), and 8 to 10 permanent first-order lateral roots (Schultz and Thompson 1990). Unstratified nuts may be sown in the fall soon after collection, usually with the husks removed. It has been reported that husk removal will prevent predation by rodents (Nielson 1973), but subsequent tests have not supported this claim (Phares and others 1974). A hot-water soak of 1.5 to 2 minutes preceding fall-sowing of Hinds walnut has been helpful (Stuke 1960). To minimize alternate freezing and thawing overwinter, seedbeds should be mulched with sawdust, hay, or straw. The heavier mulches must be removed when germination begins in the spring. Stratified nuts must be used for spring-sowing; in the northeastern United States, spring-sown stratified black walnuts had more than double the germination of fall-sown unstratified seeds (DeHayes and Waite 1982). Although only 100 days of stratification may be required to overcome dormancy, additional time (up to 184 days) can increase the rate of emergence (Van Sambeek and others 1990). Some nurseries broadcast the nuts on tilled beds and press them into the soil with rollers, but a more common practice is to sow the nuts by hand in drill marks at a bed density of about 160 nuts/m^2 (15/ft^2). To produce the large seedlings that are necessary for successful outplanting of black walnut, bed densities of 35 to 65 seedlings/m^2 (3 to 6/ft^2) and root pruning in July (for the midwestern United States) to a depth of 15 cm (6 in) are recommended (Schultz and Thompson 1990). Nuts should be covered with 2.5 to 5 cm (1 to 2 in) of nursery soil (table 6); screening to exclude rodents is prudent, especially for fall-sown nuts.

Nuts of Hinds walnuts often are sown directly into growing beds, and the seedlings are then thinned to leave 20 cm (8 in) between plants in the row. A special technique is used in some nurseries: (a) unhulled nuts are air-dried to reduce moisture to about 50% and kept outdoors until January; (b) the partially dried nuts then are put into "sprout beds" containing as many as 3 layers of nuts with 2.5 cm (1 in) of sand below and 2.5 cm (1 in) of vermiculite above each layer; (c) about March 15, the beds are opened up and the sprouted nuts are hand-transferred to growing beds in rows spaced 1.5 m (5 ft) apart with the nuts 20 cm (8 in) apart in the row (Brinkman 1974). Black walnut can also be grown in containers (Van Sambeek 1988a).

Black walnut is susceptible to 2 serious root rot diseases in the nursery caused by *Phytophthora citricola* Sawada and *Cylindrocladium* spp. (Williams 1990). At one time, these diseases were controlled by chemical fumigation of seedbeds, but environmental concerns have eliminated these treatments. An alternative, but less effective, method is to treat the nuts with fungicides before sowing (Brinkman 1990). Because regulations for chemical applications change frequently, persons growing walnut seedlings should check with local state and federal extension agents for the latest information.

Vegetative propagation by cuttings is possible, but difficult (Farmer 1973). Most cultivars are budded or bench-grafted on seedling understock (Dirr and Heuser 1987; Van Sambeek 1988b). There has also been considerable research activity in embryo and tissue culture of walnuts (Long and others 1995; Van Sambeek and others 1990).

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Cupressaceae—Cypress family

Juniperus L.

juniper

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Growth habit, occurrence, and use. There are about 50 species of junipers widely distributed throughout the temperate and subtropical regions of the Northern Hemisphere and south of the Equator in Africa. Most are evergreen shrubs and small trees. Thirteen species are native to the United States (Little 1979), and 11 of these are included in this book (table 1). Eastern redcedar is the most widespread juniper in the eastern United States, and Rocky Mountain juniper and Utah juniper are very common in the West. Common juniper is one of the most widespread tree species in the Northern Hemisphere, ranging from Asia to Europe and North America.

The close-grained, aromatic, and durable wood of the larger junipers was once used for furniture, interior paneling, novelties, posts, poles, fuel, and charcoal (Dealy 1990; Hemmerly 1970; Lawson 1990; Noble 1990; Wilhite 1990). The most important current uses are for firewood, furniture, paneling, and novelty products. Juniper "berries" are used for flavoring in cooking and in gin (the word "gin" is derived from the Dutch word for juniper, *jenever)*. Junipers are also valuable for watershed and windbreak plantings, wildlife habitat and food, and ornamental use (Dealy 1990; Johnsen and Alexander 1974; Lawson 1990; Noble 1990; Wilhite 1990). Their utility as ornamental plants has led to the selection and propagation of many horticultural varieties (Dirr and Heuser 1987; Vines 1960). Some junipers are sources for natural oil products. Cedar-wood oil is extracted from the heartwood and foliage of Ashe juniper and eastern redcedar to produce fragrance in soaps, sprays, disinfectants, and cleaning agents. Rocky Mountain juniper oils have the potential for these uses also (Adams 1987). Because of the encroachment of junipers onto range and pasture lands, particularly in the West, considerable effort has been directed toward their control (Burkhardt and Tisdale 1976; Jameson 1966; Johnsen 1962; McPherson and Wright 1990).

Genetic variation and hybridization. Junipers exhibit considerable natural variation in their growth habit and appearance, and studies have established marked differences in color, crown form, growth rate, and disease resistance in eastern redcedar (Henderson and others 1979; Minckler and Ryker 1959; Seidel and Watt 1969; Tauer and others 1987; Van Deusen 1979), Rocky Mountain juniper (Tauer and others 1987), and western juniper (Matthews 1945). Where ranges of the junipers overlap, natural hybridization abounds. This condition probably explains the large number of reported varieties of North American junipers (Dealey 1990; Fassett 1945; Hall 1952; Hall and others 1961; Lawson 1990; Noble 1990; Ross and Duncan 1949; Vines 1960; Wilhite 1990).

Flowering and fruiting. The small, inconspicuous flowers are borne in the spring (table 2) on the ends of short branchlets or along the branchlets. The flowers are dioecious or occasionally monoecious in oneseed juniper and some sources of western juniper (Dealy 1990; Johnsen and Alexander 1974). Pollen cones are yellow, terminal, and about 3 to 4 mm long; ovulate cones are composed of pointed scales, 3 to 8 in number, that fuse to form a fleshy cone 6 to 8 mm long (figure 1) (Brown and Kirkman 1990). The fleshy cones are commonly called berries. Cones are usually greenish in color when immature and change to a bluish black or reddish brown as they mature in the autumn (table 2). Most are covered with a conspicuous glaucous bloom. Cones of alligator, Utah, and common junipers require 2 years to reach full maturity, but those of common juniper may require 3 years in some parts of its range (Johnsen and Alexander 1974; Vines 1960). Cones of the other junipers mature in the fall of the first year (table 2). The outer skins of the cones may be thin and resinous, as in Virginia redcedar and Rocky Mountain and oneseed junipers, or dry and leathery or mealy, as in alligator and Utah junipers (Johnsen and Alexander 1974).

Table 1—*Juniperus,* juniper: nomenclature and occurrences

Scientific name & synonym(s)	Common name(s)	Occurrence
***J. ashei* Buchh.** *J. sabinoides* (H.B.K.) Nees *J. mexicana* Spreng. *J. monticola* Martinez	**Ashe juniper,** mountain cedar, rock cedar, Mexican juniper	S Missouri, N Arkansas, NE & S Oklahoma, central & trans-Pecos Texas, & Mexico
***J. californica* Carr.**	**California juniper,** desert white-cedar	SW Oregon, N California to Baja California & Mexico
***J. communis* L.** *J. sibirica* Burgsd.	**common juniper,** dwarf juniper, prostrate juniper	Greenland, Newfoundland, & Labrador to NW Alaska, S in US from Washington, Montana, North Dakota, & Minnesota to California, Arizona, New Mexico, Georgia, & South Carolina; also in Europe & Asia
***J. deppeana* Steud.** *J. mexicana* Schlecht. & Cham. *J. pachyphlaea* Torr. *J. deppeana* var. *pachyphlaea* (Torr.) Martinez	**alligator juniper,** checkered-bark juniper, western juniper (lumber)	Trans-Pecos Texas to W New Mexico & central Arizona; S to N & central Mexico
***J. monosperma* (Engelm.) Sarg.** *J. occidentalis* var. *monosperma* Engelm. (Engelm.) Cory *J. mexicana* var. *monosperma*	**oneseed juniper,** cherrystone juniper, redberry juniper, west Texas juniper, *sabina*	Colorado, Utah, & Nevada S to SE Arizona, S New Mexico, central Texas, & Mexico
***J. occidentalis* Hook**	**western juniper,** Sierra juniper	W Montana, Idaho, & Washington to Oregon, S California & W Nevada
***J. osteosperma* (Torr.) Little** *J. californica* var. *utahensis* Engelm. *J. utahensis* (Engelm.) Lemmon	**Utah juniper,** bigberry juniper, western juniper (lumber), *sabina*	S Idaho & Nevada & SW Wyoming S to E & SE California, central Arizona, & W New Mexico
***J. pinchotii* Sudworth** *J. monosperma* var. *pinchotii* (Sudworth) Van Melle *J. texensis* Van Melle	**Pinchot juniper,** redberry juniper	Central to NW & trans-Pecos Texas, SW Oklahoma & SE New Mexico
***J. scopulorum* Sarg.** *J. scopulorum* var. *columnaris* Fassett	**Rocky Mountain juniper,** Rocky Mountain redcedar, redcedar, river juniper	NW to SE Alberta, E & S British Columbia, S to W North Dakota & Montana, Washington, E Oregon, Nevada, Colorado, South Dakota, Nebraska, to S Arizona, New Mexico, & trans-Pecos & NW Texas
***J. virginiana* L.** *J. viriginiana* var. *crebra* Fern. & Grisc.	**eastern redcedar,** red juniper, *savin*	SW Maine, W to N New York, S Quebec, Ontario, Michigan, Wisconsin, Minnesota to SW North Dakota, to W Kansas, Oklahoma, to central Texas & E to Georgia
***J. virginiana* var. *silicicola* (Small) J. Silboa** *J. silicicola* (Small) Bailey	**southern redcedar,** eastern redcedar	SE North & South Carolina & S & central Florida, W to S Mississippi & SE Texas

Sources: Johnsen and Alexander (1974), (1971, 1979).

There may be 1 to 4 brownish seeds per juniper cone (table 3). The seeds are rounded or angled, often with longitudinal pits (figure 2) and have thick, bony seedcoats (figure 3). Embedded within the fleshy, white- or cream-colored endosperm is a straight embryo with 2 to 6 cotyledons. Junipers begin bearing seeds when they are about 10 to 20 years old. Heavy seedcrops are irregular, but some seeds are produced almost every year. Large numbers of empty seeds are common in juniper crops, a likely result of poor pollination. Seeds disperse during the autumn, but some ripe cones of most species will persist on the trees through the winter. Seeds are naturally dispersed, usually by birds that eat the cones (Chavez-Ramirez and Slack 1994; Holthuijzen and others 1987; Livingston 1972).

Not much is known about the insects that infest seeds of junipers, or how much damage they do to seedcrops. Larvae of *Eurytoma juniperina* Marcovitch, a sawfly, have been found in seeds of Utah and western junipers and eastern redcedar. Larvae of *Periploca atrata* Hodges and another unnamed Cochylidae moth are known to feed on seeds of alligator and California junipers (Hedlin and others 1980).

Collection of cones. Juniper cones are usually collected in the fall by stripping them from the branches by hand directly into containers. Cones can also be collected by shaking or flailing the limbs to dislodge the cones onto netting or dropcloths on the ground. The larger fruits of alli-

Figure 1—*Juniperus,* juniper: strobili ("berries") of *J. ashei*, Ashe juniper (**top left**); *J. californica*, California juniper **(top center)**; *J. deppeana*, alligator juniper (**top right**); *J. occidentalis*, western juniper (**middle left**); *J. pinchotii*, Pinchot juniper (**middle center**); *J. scopulorum*, Rocky Mountain juniper (**middle right**); and *J. virginiana* var. *silicicola*, southern juniper (**bottom left**); *J. virginiana*, eastern redcedar (**bottom right**).

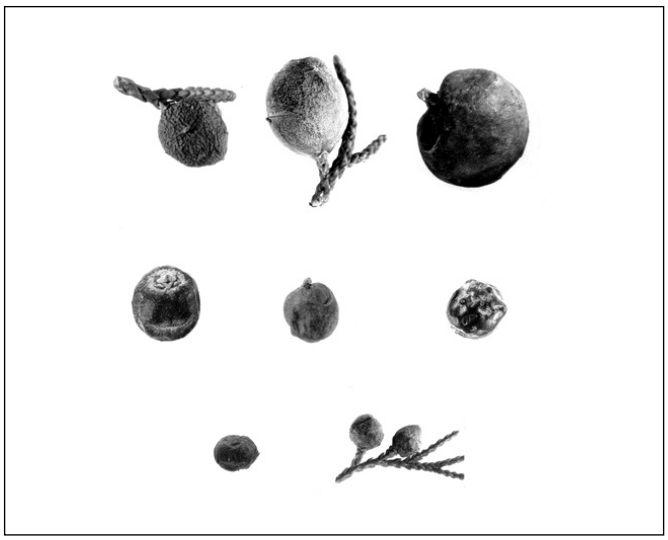
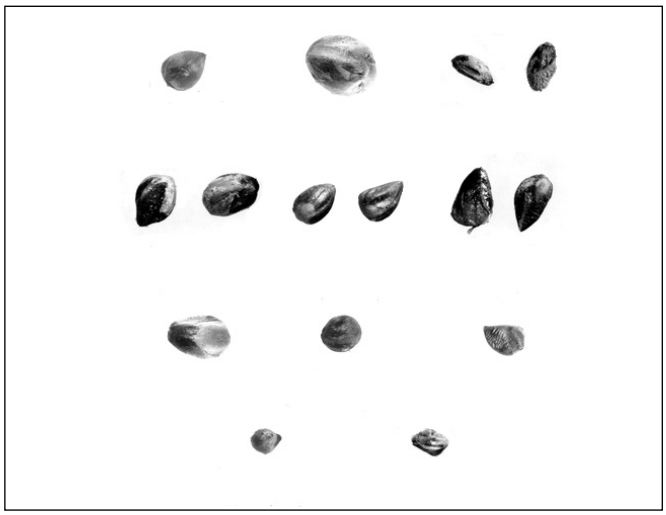


Figure 2—*Juniperus*, juniper: seeds of *J. ashei*, Ashe juniper (**top left**); *J. californica*, California juniper (**top center**); *J. communis*, common juniper (**top right**); *J. deppeana*, alligator juniper (**second row left**); *J. monosperma*, oneseed juniper (**second row middle**); *J. occidentalis*, western juniper (**second row right**); *J. osteosperma*, Utah juniper (**third row left**); *J. pinchotii*, Pinchot juniper (**third row middle**); *J. scopulorum*, Rocky Mountain juniper (**third row right**); and *J. virginiana* var. *silicicola*, southern juniper (**bottom left**); *J. virginiana*, eastern redcedar (**bottom right**).



gator and Utah junipers may be picked up from the ground after dispersal (Johnsen and Alexander 1974). Care should be taken to avoid collecting from plants with large numbers of green immature cones because they are difficult to separate from the mature ones. It is always wise to perform cutting tests on samples from each tree or group of trees to determine the percentage of filled seeds. The number of filled seeds can vary widely from tree to tree, as noted above, and collections can be adjusted to allow for this condition. Although collection can be delayed over much of the winter for some species, it is desirable to collect the fruits as soon as possible after ripening to reduce losses to wildlife. Freshly collected cones should be spread to avoid heating but should not be dried enough to make the fleshy covering tough and difficult to remove.

Table 2—*Juniperus,* juniper: phenology of flowering and fruiting

Species	Location	Flowering	Fruit ripening	Seed dispersal
J. ashei	—	Jan–Apr	Sept–Nov	Fall–winter
J. communis	—	Apr–May	Aug–Oct	Persists for 2 yrs (2nd–3rd yr)
J. deppeana	—	Feb–Mar	Aug–Oct	Persists for 2 seasons (2nd yr)
J. monosperma	Arizona	Mar–Apr	Aug–Sept	Oct–Nov (persists 1–2 yrs)
J. occidentalis	Oregon	Mid-Apr–mid-May	Mid-Sept	Persists for 2 yrs
J. osteosperma	Arizona	Mar–Apr	Sept (2nd year)	Persists for 2 yrs
J. pinchotii	Texas	Spring	Oct–Nov	Year-round
J. scopulorum	—	Mid–Apr–mid-June	Mid-Sept–mid-Dec	October (persists 2–3 yrs)
J. virginiana	Nebraska	Mid–Mar–mid-May	Sept–Nov	Feb–Mar (1st yr)
J. virginiana var. *silicicola*	South Carolina	Jan–Feb	Oct–Nov	—

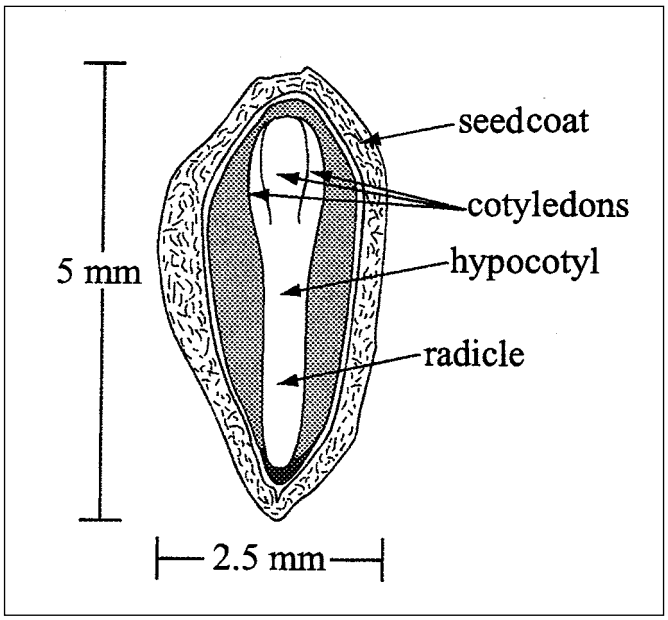
Sources: Johnsen and Alexander (1974), Rehder (1956), Vines (1960).

Table 3—*Juniperus,* juniper: height, seedcrop frequency, and fruit color

Species	Height at maturity (m)	Year first cultivated	Seeds/ cone	Years between large seedcrops	Fruit ripeness criteria	
					Preripe color	Ripe color
J. ashei	3–6	1925	1–2	—	Green	Deep blue
J. californica	1–5	—	1–2	—	Bluish w/dense bloom	Reddish brown
J. communis	1–15	1560	1–3	Irregular	Red	Bluish to black, glaucous
J. deppeana	3–20	1873	2–4	—	Green	Bluish to reddish brown, glaucous
J. monosperma	3–8	1900	1–2	2–5	Green with waxy bloom	Copper to dark blue with white waxy bloom
J. occidentalis	5–9	1840	2–3	—	Green-blue	Bluish black, glaucous
J. osteosperma	5–12	1900	1–2	2	Green glaucous	Reddish brown,
J. pinchotii	1–5	—	1	—	Green with light bloom	Copper to red to reddish brown
J. scopulorum	6–15	1936	1–2	2–5	Green with	Blue w/white waxy bloom
J. virginiana	9–30	1664	1–2	2–3	Green	Blue
J. virginiana var. *silicicola*	7	—	1–2	—	Green	Dark blue

Sources: Johnson and Alexander (1974), Sargent (1965), Vines (1960).

Figure 3—*Juniperus scopulorum*, Rocky Mountain juniper: longitudinal section through a seed.



Extraction and storage of seeds. Twigs, leaves, and other debris should be removed by winnowing, screening, or aspiration. Seeds can be easily extracted from the pulpy cones by maceration with water. Small seedlots can be cleaned with laboratory or kitchen blenders, and large lots can be cleaned in larger macerators. Full seeds should sink, and pulp and empty seeds can be floated off the top of the water (Johnsen 1959; Johnsen and Alexander 1974). For extraction of Rocky Mountain juniper and eastern redcedar seeds, a cone volume to water volume ratio of 1:2.5 is recommended. The pulp residue can then be removed from the filled seeds by adding a little liquid detergent to warm water and agitating for about 5 minutes (Van Haverbeke and Barnhart 1978). Dried fruits should be soaked in water for several hours before macerating. After the seeds have been separated from the pulp and cleaned, they can be prepared for stratification or dried for storage. Intact cones can be stored also, but this is not usually done. Seed yields and weights are listed in table 4.

Juniper seeds are orthodox in storage behavior. They should be air-dried to a moisture content of about 10% and stored at temperatures of 5 to 18 °C (Johnsen and Alexander 1974; Jones 1962; Stoeckler and Slabaugh 1965). There have been no long-term studies to compare different storage temperatures and moisture contents for juniper, but results are available from several sources. Seeds of Ashe juniper stored in a bag at about 5 °C and high humidity retained about half their original viability after 4 years, and seeds of Rocky Mountain juniper stored in sealed containers at 12 to 16 °C (both in dried cones and as cleaned seeds) showed about 30% germination after 3 $^{1}/_{2}$ years (Johnsen and Alexander 1974). The seeds of alligator, oneseed, and Utah junipers stored dry in sealed bags or jars at room temperature for 45, 21, and 9 years, respectively, yielded germination of 17, 51, and 16% (Johnsen 1959).

Pregermination treatments and germination tests. Juniper seeds germinate very slowly due to conditions of deep dormancy. Their dormancy appears to result from internal embryo dormancy, seed coat dormancy, germination inhibitors in the pulp of the cones, or a combination of all

Table 4—*Juniperus*, juniper: seed yield data

Species	Place collected	Cleaned seeds/weight				Samples
		Range		Average		
		/kg	/lb	/kg	/lb	
J. ashei	—	—	—	22,270	10,100	1
J. communis	—	56,120–120,170	25,450–54,500	80,480	36,500	8
J. deppeana	Arizona	19,840–34,400	9,000–15,600	28,270	12,820	5
J. monosperma	Arizona & New Mexico	33,650–44,100	15,260–20,000	40,350	18,300	10
J. occidentalis	Oregon	17,640–34,970	8,000–15,860	27,120	12,300	—
J. osteosperma	Arizona	7,940–15,660	3,600–7,100	10,910	4,950	15
J. pinchotii	Sonora & Texas	21,280–30,650	9,650–13,900	24,230	10,990	2
J. scopulorum	Arizona	39,360–92,830	17,850–42,100	59,760	27,100	36
J. virginiana	Great Plains	81,580–121,270	37,000–55,000	96,140	43,600	34

Sources: Johnsen and Alexander (1974), Stoeckler and Slabaugh (1965), Vines (1960).

three (Johnsen and Alexander 1974). There is wide variation among species in degree of dormancy. The least dormant may be eastern and southern redcedars, whereas Rocky Mountain juniper is among the most dormant (Rietveld 1989). There is also considerable variation among sources and crop years; some seedlots from alligator and oneseed junipers germinated without any stratification (Johnsen 1959; Meagher 1943; Riffle and Springfield 1968).

The most common treatment for overcoming dormancy is long periods of moist stratification at 3 to 5 °C. Periods of 30 to 180 days have been used for seeds of Ashe, alligator, and oneseed junipers and eastern redcedar (Barton 1951; Benson 1976; Johnsen and Alexander 1974; Taylor 1941). Early reports suggested freezing juniper seeds during stratification, but this method has generally been unsuccessful (Johnsen and Alexander 1974). Seeds of common, Utah, and Rocky Mountain junipers, eastern redcedar, and possibly western juniper often respond positively to warm stratification at room temperature (around 25 °C) or alternating temperatures of 20 °C (night) and 30 °C (day) for 45 to 240 days, followed by cold stratification for similar periods (Johnsen and Alexander 1974; Rietveld 1989; Van Haverbeke and Comer 1985). Young and others (1988), however, reported no response by western and Utah junipers to the 2-temperature pretreatment. The best treatment for eastern redcedar was to first soak the seeds for 96 hours in a 10,000 ppm solution of citric acid, followed by warm stratification for 6 weeks and cold stratification for 10 weeks (Van Haverbeke and Comer 1985). The use of citric acid was suggested by Cotrufo (1963), and although the nature of the stimulation is unknown, some seedlots respond with faster germination rates. Faster germination has also been reported for seeds of Pinchot and Rocky Mountain junipers and eastern redcedar that were soaked in concentrated sulfuric acid for periods of 35 to 120 minutes (Djavanshir and Fechner 1976; Johnsen and Alexander 1974), although stimulation for the latter 2 species occurred only when the carbonized layer was removed from the surface of the seeds (Djavanshir and Fechner 1976). Washing seeds of oneseed juniper in running water for 48 hours, followed by 30 minutes in 30% hydrogen peroxide, stimulated germination to 79% from 47% for untreated controls (Riffle and Springfield 1968). Another promising method reported for western and Utah junipers is 12 weeks of soaking in aerated water at 5 °C; germination percentages of around 50% were recorded for both species. If gibberellin (GA_3 at 0.289 mmol/liter) was added to the aerated solution, germination increased to 84% for western juniper and to 64% for Utah juniper (Young and others 1988).

Prescriptions for official germination tests have been established for 3 species: common juniper, eastern redcedar, and Rocky mountain juniper (ISTA 1993). Tetrazolium staining is the recommended method for these species, but alternative stratification directions are also suggested. Common juniper should be stratified for 90 days at 3 to 5 °C, whereas eastern redcedar and Rocky Mountain juniper seeds should receive 60 days at 20 °C, followed by 45 and 40 days, respectively, at 3 to 5 °C. Recommended germination temperatures are 20 °C for common juniper and 15 °C for eastern redcedar and Rocky Mountain juniper. Germination of Pinchot juniper is reported to be best at 18 °C (Smith and others 1975), but no data exist for the other junipers. There is obviously much to learn about stimulation of germination for the junipers, and more research is called for. Germination capacities for various pretreatments and test conditions are given in table 5. Germination is epigeal (figure 4).

Nursury practices. Juniper seeds are usually sown in the late summer or fall, but may be sown in the spring or early summer. All seeds should usually be stratified, no matter when they are sown, but untreated seeds can be used in some circumstances. Untreated fresh seeds may be sown in the fall within a week after collection and extraction if they are not dried (Meines 1965). Stratified seeds sown in the spring should be in the ground early enough to ensure complete germination before the air temperatures go higher than 21 °C. If stratification is successful, germination should begin 6 to 10 days after sowing and be completed in 4 to 5 weeks (Johnsen and Alexander 1974; Stoeckler and Slabaugh 1965).

Juniper seeds are usually drilled in rows 15 to 20 cm (6 to 8 in) apart and covered with about 6 mm ($^1/_4$ in) of firmed soil or sand (Stoeckler and Slabaugh 1965). The seeds are occasionally broadcast by hand onto the seedbed and covered with sand. The beds should be mulched with straw, sawdust, burlap, or plastic film to prevent winter drying, alternate freezing and thawing, and premature germination in the spring. The mulch normally must be held in place to prevent blowing (Stoeckler and Slabaugh 1965). The seedbeds should be kept moist, and burlap or plastic film mulches should be removed as soon as germination begins. Light shade should then be provided by slat-wire snow fence or plastic screening materials; young seedlings of eastern redcedar and Ashe, oneseed, and Rocky Mountain junipers should be shaded throughout the first growing season. Seedlings of alligator juniper (figure 4) should be shaded only during the germination period (Johnsen and Alexander 1974). Burlap may be used over snow-fence shade structures to conserve moisture and to protect against early spring freezing (Stoeckler and Slabaugh 1965). During the autumn,

Figure 4—*Juniperus deppeana*, alligator juniper: seedling development at 2, 17, 43, and 96 days after germination

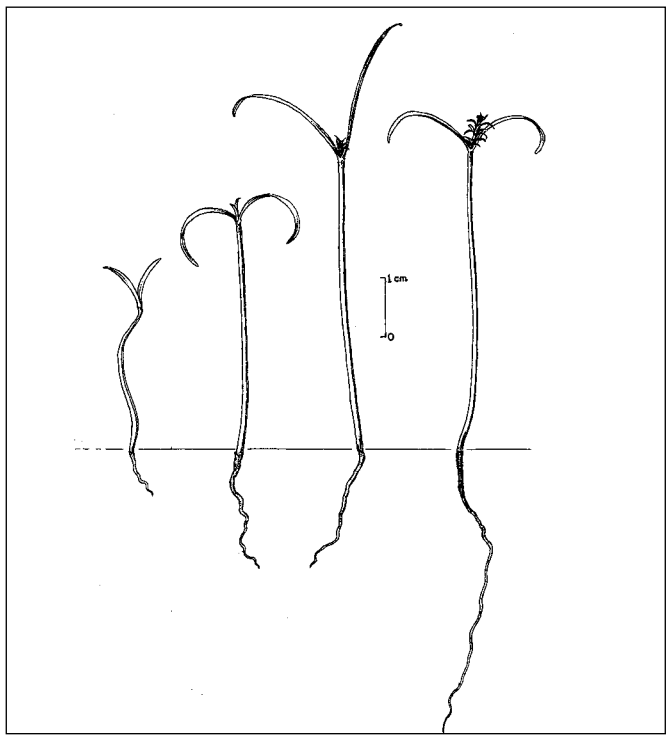


Table 5—*Juniperus,* juniper: germination test conditions and results

Species	Stratification period (days)		Germination test conditions				Germination rate		Germination percentage		Samples
	Warm*	Cold†	Daily light (hr)	Medium	Temp (°C) Day	Night	Days	%	Days	%	
J. ashei	0	120	—	Sand	86	68	60	30	10	33	1
	0	120	—	Sand	50	50	60	27	29	36	1
J. communis	60–90	90+	8	Paper, sand	86	68	20–30	—	—	7–75	10+
J. deppeana	0	0	—	Paper, sand	86	68	40	—	—	16-30	2
	0	30–60	—	Sand, peat	86	68	30–40	—	—	45	1
J. monosperma	0	0	—	Sand, peat, soil	86	68	30–70	—	—	20–75	34
J. osteosperma	120	120	—	Sand, soil	86	68	70	—	—	8–49	8
J. pinchotii‡	0	0	8	Perlite	60	60	36+	—	—	63	4
	30	60	8	Perlite	60	60	—	—	—	53	4
J. scopulorum	120	120	—	Paper, sand	86	68	20–30	5–31	8–15	22	7
J. virginiana	0	30–120	—	Paper, sand	50	77	20–30	6–74	9–24	76	16
	4§	90	0	Perlite	58	58	60	84	30	87	3
	0	45	—	Kimpak	60	60	66	70	43	78	2

Sources: Cotrufo (1963), Johnsen (1959), Johnsen and Alexander (1974), Meagher (1943), Riffle and Springfield (1968).
* 30 to 20 °C alternated diurnally.
† 5 °C.
‡ Seeds soaked in sulfuric acid 45 minutes.
§ Seeds soaked in 1% citric acid for 4 days.

the seedlings may change color due to freezing weather, reduced watering, or increased light intensity resulting from removal of the half-shades. Seedlings of eastern redcedar change from green to purple, most markedly with the 1+0 seedlings. The normal green color returns the next spring.

In the West, juniper seedlings are usually transplanted in the nursery after the first or second year. Early lifting in the spring gives the best survival. Roots must be kept moist during lifting, and the seedlings can be stored as long as a week before transplanting with little damage if kept cool and moist (Afanasiev and others 1959). Spacing in the transplant bed ranges from 15 by 2.5 cm (6 by 1 in) to 20 by 5 cm (8 by 2 in) for eastern redcedar and Rocky Mountain juniper (Johnsen and Alexander 1974; Stoeckler and Slabaugh 1965). Undercutting of third-year transplants of Rocky Mountain juniper seems to stimulate strong lateral root development (Stoeckler and Slabaugh 1965).

The most serious nursery disease that affects junipers is the cedar blight, which is caused by *Phomopsis juniperovora* Hahn (Otta and others 1980; Peterson 1973; Stoeckler and Slabaugh 1965). Good sanitation practices in the nursery and chemical control measures are needed to keep this disease in check. Once established in a nursery site, it is very difficult to eradicate (Stoeckler and Slabaugh 1965). Other diseases that cause problems for junipers are cercospora blight, caused by *Cercospora sequoiae* Ellis & Everh. var. *juniperi* Ellis & Everh. (Peterson 1977; Peterson and Wysong 1968) and cedar apple rust, caused by *Gymnosporangium juniperi-virginianae* Schwein. (Stoeckler and Slabaugh 1965). Application regulations and chemical recommendations change frequently, so local extension experts should be consulted for the current chemical control measures for these diseases in the nursery.

Other nursery pests that affect junipers are nematodes, grubs, and red spiders—*Pentamerismus erythrens* Ewing. Foliage may be damaged by winter injury and drying out, even in second-year beds and transplant beds. The plants usually recover during the spring. Small juniper seedlings are also subject to frost heaving, which can be reduced by heavy mulching or overhead sprinklers (Stoeckler and Slabaugh 1965).

Many junipers can be propagated vegetatively with cuttings (Dirr and Heuser 1987). There is evidence of wide variation in rooting ability among populations of common juniper (Houle and Babeux 1994). Rooting success as high as 82% has been reported for Rocky Mountain juniper (Edson and others 1996). Treatment of the 12-cm-long (5-in-long) cuttings with 1.6 or 3.0% indole-butyric acid (IBA) accelerated rooting by several months and increased overall succes by up to 36%. Two years after transplanting to containers, 92% of the stecklings survived.

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