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.

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

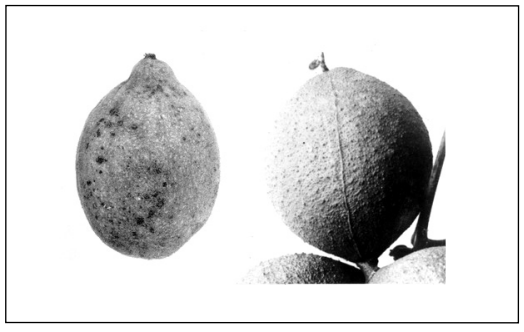


Figure 2—*Juglans*, walnut: nuts (with their husks removed) of *J. cinerea*, butternut (**top left**); *J. hindsii;* Hinds walnut (**top right**); *J. californica,* California walnut (**center left**); *J. nigra;* black walnut (**center right**); *J. microarpa*, little walnut (**bottom left**).

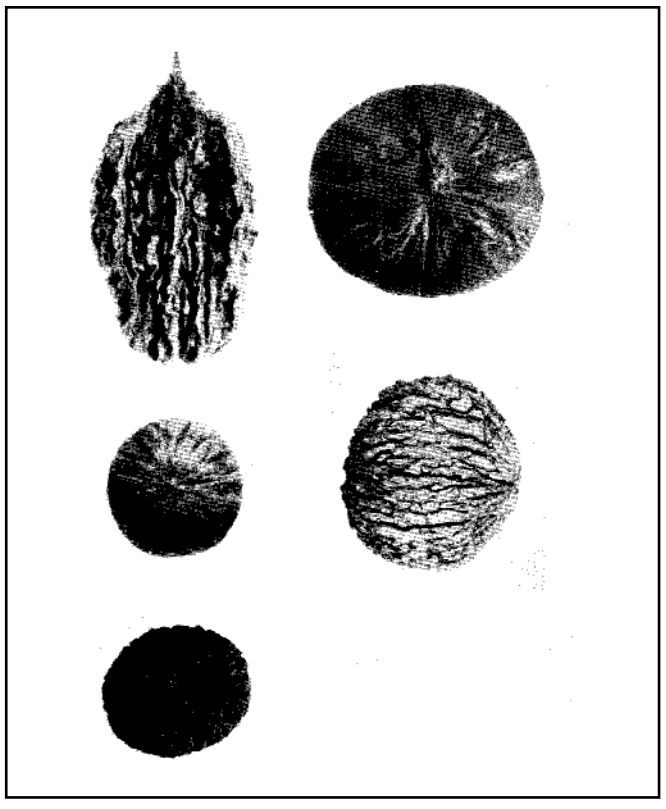
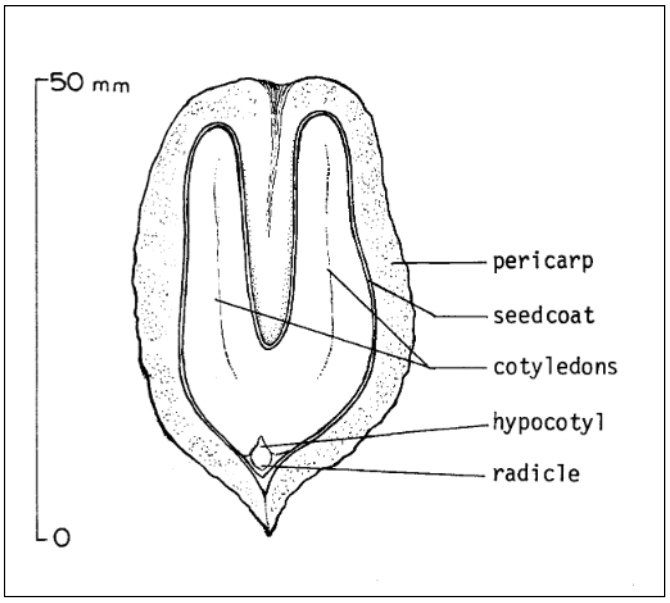


Table 2—*Juglans,* walnut: phenology of flowering and fruiting

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 % Days	Germination % Avg (%)	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	Stratification* 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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