Notes on the temperate species of *Juglans*

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Introduction

The walnuts have always excited interest for their combination of utility and beauty, but despite this, most species of *Juglans* remain little known in cultivation and poorly described in the literature, while specimens in many collections are incorrectly named. This paper aims to clarify the situation with regard to the 11 hardy species and their hybrids. It should be regarded as a supplement to the information provided in the works of Elwes and Henry (1906-1913: vol. II), Bean (1973) and Krüssmann (1985).

The taxonomy of *Juglans* is confused. To a considerable extent this can be attributed to Louis-Albert Dode (1875-1943), a French enthusiast who published his revisions of *Juglans* in 1906 and 1909, recognizing 44 species. Keen to find differences, he was accordingly prolific in naming new taxa. Walnuts are difficult to study in the herbarium, as the massive stems, large leaves and bulky fruits do not make good dried specimens. Furthermore, the position and vigour of the shoot makes a considerable difference to the size and appearance of the foliage, and a young shoot, perhaps with flowers, looks quite different with its pubescent, unexpanded leaves, to one collected when the foliage has matured. Dode based many of his taxa on fruit characters, but this is again a dangerous area, as although each species has certain parameters of variation, there is considerable difference in nut shape and surface texture (evident even in commercial supplies of *J. regia* nuts).

Dode, however, did establish the four sections within the genus that are recognized today: Section *Juglans* (syn. *Dioscaryon*), containing *J. regia* and *J. sigillata*; Section *Rhysocaryon*, the black walnuts of the Americas; Section *Cardiocaryon*, the Asiatic heartnuts, and Section *Trachycaryon*, containing only *J. cinerea*, the butternut of North America. These appear to be well-defined, natural groupings (although Sections *Cardiocaryon* and *Trachycaryon* are very closely related). This classification was adopted by W.E. Manning, whose work is the most useful recent contribution to walnut taxonomy (Manning 1957, 1960, 1978).

Manning recognized 21 species of walnut[1], distributed throughout temperate Eurasia (Sects. *Juglans* and *Cardiocaryon*) and temperate and tropical America from Canada to Argentina and the Caribbean Islands (Sect. *Rhysocaryon* and *J. cinerea*). Ten species are tropical or sub-tropi

cal (although they usually grow at higher altitudes), and are unlikely to be introduced to temperate gardens. One possible exception is *J. mollis* Engelm., which grows in the fog belt of the mountains of eastern Mexico at altitudes of at least 2200 m (7200') (Manning 1957) and may be tried in areas with warm wet summers and cool winters.

Manning has clarified the taxonomy and distributions of the American species, but the Asian species in Section *Cardiocaryon* are less well studied. Dode and others have named a raft of species from mainland Asia and Japan, varying in small fruit characters, which do not hold up when a series is compared. Manning clarified the position considerably, recognizing only *J. mandschurica* and *J. cathayensis* from mainland Asia, and *J. ailantifolia* from Japan. More recently, Lu Anmin, Stone and Grauke, authors of the Juglandaceae account in *Flora of China*, Vol.4 (1999) have united *J. cathayensis* with *J. mandschurica*. In this I fully concur, finding no significant difference between any plants or specimens I have seen. *J. ailantifolia* is clearly the Japanese representative of this group and is very similar indeed, it being almost impossible to find any key character on which to separate vegetative material. It is not surprising that recent DNA-based research finds that *J.mandschurica* is very close to *J. ailantifolia* (Stanford, Harden & Parks 2000), and a comfort to learn that the great breeder Luther Burbank was also unable to distinguish between young plants within this group (Burbank 1891).

Asian populations of *J. regia*, the common walnut, both in the wild and in cultivation, are also variable, and Dode segregated several species. Most authors have disregarded these, but the names recur in varying combinations in the literature and in gardens. A related species from China, *J. sigillata*, is not yet in cultivation, but is discussed here. To complicate further the identification of cultivated walnuts, the species are highly interfertile, both within and beyond sections, and the hybrids are often themselves fertile. Seedlings from trees in mixed collections should be observed with caution. They are more likely to be found in N. America, where the frequency of *J. nigra* and others as wild plants makes them more available for random miscegenation.

Identification

Most species of cultivated *Juglans* are not at all familiar and care should be taken with their identification. As is so often the case, the safest guide to an identity is the wild origin of the tree in question,

but in cultivated material this is seldom available.

The following key enables the identification of the 11 species described in this paper using only vegetative characters. While a full set of flowering and fruiting specimens are desirable herbarium reference materials, the dendrologist in an arboretum usually has only a leafy shoot to examine. Features such as different hair types may seem to be obscure, but in practice it will be found that they can be discerned with a x10 hand-lens, and used in conjunction with other non-key characters such as leaf posture and leaf scent which become familiar in due course. The Asian pair *J. mandschurica* (mainland) and *J. ailantifolia* (Japan) are the most difficult to distinguish on vegetative features alone; see the discussion below.

Hybrids are excluded from this key, so specimens not conforming to the key characters should be studied carefully in comparison with their potential parents. A few other large, pinnate-leaved trees could be confused with *Juglans*; *Ailanthus altissima* and *Cedrela sinensis* both have certain similarities with *J. nigra*, for example.

Vegetative key to cultivated *Juglans*

1. Leaflets 5-11(-15), entire or very slightly toothed, ± glabrous — **2** (Sect. *Juglans*)
1. Leaflets more than 9, often toothed, often hairy — **3**

2. Leaflets 5-9(-11), entire or almost so — *J. regia*
2. Leaflets 9-11(-15), margins sometimes indistinctly toothed — *J. sigillata*[2]

3. Leaf scar with persistent fringe of hairs on upper edge[3] — **4**
3. Leaf scar without persistent fringe of hairs on upper edge — **6**

4. Upper edge of leaf scar notched — **5**
4. Upper edge of leaf scar not notched, fringe of hairs conspicuous — *J. cinerea*

5. Leaflets ovate-elliptic, shortly acuminate, borne at right angles to rachis — *J. mandschurica*
5. Leaflets elliptic-lanceolate, acuminate, borne at *c*. 45^{o} to rachis — *J. ailantifolia*

6. Leaflets with tufts of hairs in vein axils on undersurface — **7**
6. Leaflets without tufts of hairs in vein axils on undersurface — *J. californica*

7. Leaflet blades glabrous, hairs only on major veins — *J. hindsii*
7. Leaflet blades and veins hairy, at least below, especially when young — **8**

8. Leaflets narrow, 0.8-1.1(-2.2) cm wide[4], lamina with only capitate-glandular hairs, non-glandular hairs only in vein axils below[5] — *J. microcarpa*
8. Leaflets broader, 1.5-5.5 cm wide, lamina with both glandular and non-glandular hairs throughout — **9**
9. Small tree with elegant leaves, leaflets 9-15(-19), 2-3.5 cm wide, hairs on upper surface of leaf abundant when young, persisting on major veins — *J. major*
9 Large tree with big leaves, leaflets (9-)15-19(-23), up to 5.5 cm wide, hairs few on upper surface of leaf, scattered on midrib — *J. nigra*

Walnut species: *Juglans microcarpa*, top. *J. mandshurica*, centre. The lower picture shows the leaves of *J. ailantifolia* (upper) and *J. mandshurica* (lower) for comparison

Species

Juglans ailantifolia Carr. **Japanese walnut**
Syns: *J. sieboldiana* Maxim., non Goepp., *J. cordiformis* var. *ailantifolia* (Carr.) Rehd., *J. allardiana* Dode, *J. coarctata* Dode, *J. lavallei* Dode, *J. sachalinensis* (Miyabe & Kudo) Komar., *J. mirabunda* Koidz.

Described by Bean (1973) and Krüssmann (1985) and quite widely planted. It seems safe to state that this is the Japanese representative of the variable taxon of mainland China and Manchuria, *J. mandschurica*. The morphological similarities are confirmed by DNA studies (Stanford, Harden & Parks 2000). It is almost impossible to find useful vegetative characters with which to distinguish the two taxa. A trivial, but apparently reasonably consistent distinction in trees in British arboreta is that the leaflets are inserted on the rachis at about 45°, causing them to point forwards, while in *J. mandschurica* they tend to be more nearly perpendicular. The nut morphology would appear to fit within the range of *J. mandschurica*. Without making a complete objective study it is inappropriate to combine the two taxa, but my feeling is that their distinctness cannot be maintained.
J. ailantifolia was widely planted in the United States after 1870, but Walnut Bunch disease has killed most of those in the south and it survives best in the north-eastern states and in Ontario. It is extremely hardy, having survived – 40°C in New York state (the youngest wood was killed but it soon regenerated), but is given USDA Hardiness Zone 6 rating as the early flushing of the new growth is easily damaged. Selected cultivars include 'Schubert' and 'Brock', which both have large, easily cracked nuts (McDaniel 1979).
Distribution: JAPAN: Hokkaido, Honshu, Shikoku, Kyushu;
RUSSIA: Sakhalin
Habitat: broad-leaved forest on rich moist soil
Conservation status: unknown
USDA hardiness zone: 6

Juglans ailantifolia var. ***cordiformis*** (Maxim) Rehd. **Heartnut**
Syn: *J. cordiformis* Maxim.

This is apparently a horticultural variant of *J. ailantifolia* with flattened, heart-shaped nuts with relatively thin shells. About 70% of seedlings

show this trait, which is also passed on to hybrid offspring. Selections include 'Callander', a protandrous clone with nuts of good flavour, and 'Canoka' with large nuts containing 36% kernel by weight. It is a good annual cropper, but requires a long growing season for the fruits to mature. Both were raised by J.U. Gellatly, of Westbank, British Columbia (McDaniel 1979).
USDA hardiness zone: 6

Juglans californica S. Wats. **Californian Walnut**

Originating in southern California, this species has usually been considered tender in the British Isles, but a specimen has been growing at Wakehurst Place, Sussex, since 1963 (not seen) and it would be suitable for gardens in the Mediterranean area. It has been confused with *J. hindsii* in the past, but is morphologically distinct and geographically disjunct.
J. californica is a rapidly growing tree normally reaching 10 m (to 18 m), and said to live 125-150 years (Elias 1980). The trunk often forks at the base and the resulting multiple stems can produce a rather shrubby appearance. The bark is smooth and greyish-white when young, darkening to dark brown or black as it ages and thickens, when it becomes deeply furrowed by long ridges. The branches are stout and spreading, sometimes becoming pendulous with age; the new growth is covered in dense rust-coloured hairs when young, but becomes smooth with pale lenticels. Leaf scars are rounded to triangular. Leaves are 15-25 cm long, with 9-15 (-17) leaflets; leaflets 2.5-7.5 long, 1-2 cm wide, oblong to lanceolate, usually somewhat curved and acute to acuminate at the apex, with the base tapering, rounded or unequal, margins finely toothed. The leaves are yellowish-green and glabrous, except for occasional tufts of hairs at the junctions of the main veins on the lower surface. Male flowers are borne in slender catkins 5-8 cm long, each flower having 30-40 stamens; female flowers 1-4. Fruits 1-4 cm diameter, globose; husk thin, green, becoming brown, covered with short hairs, not splitting when mature. Nuts are nearly round, but flattened at the base and slightly laterally compressed, with a few shallow grooves; shell thin, light to dark brown. Kernel sweet.
Distribution: USA: southern California
Habitat: gravelly soil along river courses
Conservation status: Vulnerable (IUCN 1998). Population dwindling (Elias 1980)

Juglans cinerea L. **Butternut**

Described by Elwes & Henry (II), Bean (1973) and population dwindling (Elias 1980) Krüssmann (1985). The butternut is better known in the literature than in European gardens, and although it has been grown here for some 350 years it is an uncommon tree. This seems likely also to become the case in its native North America, where Butternut Canker (*Sirococcus clavigignenti* b *juglandacearum*) is killing trees across its range; no regeneration occurs and the species' range is diminishing (Whittemore & Stone 1997). The Butternut Canker has been equated with Chestnut Blight and Dutch Elm disease as a scourge of the North American forest (see below, Pests and Diseases) (Schlarbaum *et al* 1999).
The name *J. cinerea* is often attached to trees in UK collections, but few are correctly named. The butternut is quite easily recognized by the straight upper margin of the leaf scar; in members of section Cardiocaryon this is emarginate, showing a distinct notch in the outline. Both have a pad of velvety hairs above the scar. This can be conspicuous or almost invisible, but is always detectable. The leaves of a true butternut are also densely pubescent, giving a slight greyish cast. The impostors are mostly members of section Cardiocaryon, or possibly hybrids between them and *J. cinerea*, but *J. nigra* has also been seen. L. Banks (*pers. comm.*) informs me that there are good mature specimens of *J. cinerea* at Tervuren in Belgium.
Cultivars have occasionally been selected in the United States, but have never become widely distributed (McDaniel 1979).

Juglans hindsii (Jepson) R.E. Smith **Northern California Walnut**
Syn: *J. californica* var. *hindsii* Jepson

In many ways this is one of the most important species of *Juglans*, having been commonly used as a stock for *J. regia*, widely planted as an ornamental, and as a parent of hybrids. There is evidence that it was appreciated for its fruits by pre-Spanish Native Americans in California, as it has been found growing around their former campsites (Wilken 1993), but the small sweet kernel is no longer considered useful. Although rare as a truly wild tree (Wilken 1993), it is said to be naturalized over much of California, having been planted for timber production as well as for its ornamental and rootstock purposes (Elias

1980). As a rootstock for *J. regia*, *J. hindsii* and its hybrid 'Paradox' (*q.v.*) provide resistance to root rot caused by *Phytophthora* and root lesion nematodes, but the necrotic 'blackline' disease at the graft union can be a problem. Nevertheless, *J. hindsii* has been extensively used as a stock for the Californian walnut orchards.

The taxonomic position of *J. hindsii* in relation to *J. californica* has frequently been questioned, with even the modern *Flora of California* (ed. Hickman 1993) treating it as a variety, but DNA studies by Stanford *et al*. (2000) show that it is a clearly distinct taxon.

A small to medium-sized tree, 15-20 (-25) m high, with straight trunk to 70 cm diameter. Bark smooth when young, becoming cracked with age, when moderately thick with narrow brown-grey plates. The branches are stout, spreading or somewhat pendulous; new growth densely red-brown pubescent, but twigs becoming smooth; leaf scars broadly triangular with rounded corners. Leaves 22-35 cm long, with 15-19 leaflets each 5.5-10 x 1.8-2.6 cm, lanceolate to broadly lanceolate, slightly curved, long acuminate at apex, tapering to rounded at base, margins sometimes with small teeth, bright green, glabrous above, paler below with tufts of hairs at the junctions of the main veins. Male catkins greenish-yellow, 7.5-13 cm, glabrous to slightly hairy, each flower with 30-40 stamens; female flowers 1-3. Fruits large, globose, 3-5 cm diameter; husk green becoming dark brown, covered in small hairs. Nut globose, flattened at base, more or less smooth or with occasional obscure longitudinal grooves, shell thick, kernel small and sweet.

Distribution: USA: central California
Habitat: rocky, well-drained sites on hill slops, sometimes near streams.
Conservation status: Rare
USDA hardiness zone: 9

Juglans major (Torrey) Heller var. ***major*** **Arizona Walnut** (*also*: Arizona Black Walnut, Nogal Silvestre)

Syns: *J. rupestris* Engelm. ex Torrey var. *major* Torrey, *J. microcarpa* var. *major* (Torrey) L.D. Benson, *J. arizonica* Dode, *J. torreyi* Dode, *J. elaeopyren* Dode

Juglans major is the name accepted by Manning and the authors of the *Flora of North America*, but European authors (e.g. Wijnands 1989) have adopted *J. elaeopyren* for this small to medium-sized tree**.** *J. major* has priority, however and is adopted here. It is said to be fast - growing,

reaching 10-18 m, but the majority of large wild trees have been harvested for timber. Elias (1980) suggests that it can reach ages of up to 400 years, but also mentions that natural regeneration from seed is infrequent. The town of Nogales in Arizona is said to be named for the stands of this walnut tree that once grew there (Elias 1980). It is not clear when true *J. major* was introduced to Europe, as this short to medium-sized tree has been much confused in gardens and by botanists with the related *J. microcarpa*. The two species are genetically quite distinct (Stanford *et al*. 2000), with disjunct distributions, but they will hybridize. They can be distinguished by the following key characters:

> *J. major*: Leaflets 9-15 (-19), usually (1.5-)2-3.5 cm wide when mature; stamens 30-40; fruits 2.5-3.5 cm diameter
> *J. microcarpa*: leaflets (15-) 17-23, usually 1.5(-1.7) cm wide or less; stamens 20-30; fruits not more than 2 cm diameter

Juglans major usually has a straight trunk, reaching a diameter of 130 cm. The bark is smooth and thin, and light grey when young, becoming dark grey to brownish-black, thick and deeply ridged, with irregular scales developing on the ridges. The branches are stout and spreading, forming an open, rounded crown; they may become pendulous with age. Branch tips are slender, with rufous hairs when young, but become reddish-brown and smooth with small lenticels, and silvery-brown later; leaf scars are large, triangular with rounded corners, suggesting a shark's tooth in outline, and are conspicuously pale. Leaves 22-32 cm long, with 9-15 (-19) shortly-stalked leaflets 4.5-10 x 1.5-4 cm, ovate to lanceolate, usually curved, long acuminate at apex, tapering to rounded or unequal at base, margins coarsely toothed. Leaves are yellowish-green, paler beneath, pubescent above when young but becoming smooth with scattered solitary hairs below, the rachis remaining pubescent with white hairs (var. *major*). Male catkins yellowish, slender, 12-20 cm long, each flower with 30-40 stamens; female flowers 1-4. Fruits solitary or sometimes 2, 2.5-3.5 cm diameter, globose to almost ovoid, with a small sharp point at apex, husk fibrous, green becoming rufous and then brown, densely hairy. Nuts globose, flattened at base, 2.5-4 cm diameter, dark brown to black, with deep, broad grooves in the thick shell; kernel large and sweet.

Arizona walnut is considered to be less hardy than *J. microcarpa*, and in cultivation should probably be given a warm sheltered site. It appears

to thrive at Kew where a tree planted in 1982 has reached 5.5 m and appears to be growing strongly without evidence that it has been crippled by frost damage in the past.

Distribution: (var. *major*): USA: central and southern New Mexico, Arizona MEXICO: Chihuahua, Sonora, Sinaloa, Durango
Habitat: streamsides and flood plains, 700-2300 m
Conservation status:??
USDA hardiness zone: 9

J. major var. ***glabrata*** According to Manning, the leaflets and rachis are essentially glabrous, and the fruit is also almost hairless. At the University of California's agricultural research stations at Davis and Riverside var. *glabrata* has been used as a rootstock for *J. regia*. Manning reports (1960) that it is sub-evergreen in California, being leafless for less than one month.
Distribution:MEXICO: Mexico, Guarrero, Jalisco, Michoacan, Durango.
J. major var. ***stellata*** The undersides of the leaflets are hairy (Manning).

Juglans mandschurica Maxim. **Manchurian Walnut** (*also*: Chinese Walnut)
Syns: *J. cathayensis* Dode, *J. collapsa* Dode, *J. draconis* Dode, *J. formosana* Hayata, *J. hopeiensis* Hu, *J. stenocarpa* Maxim.

As indicated by its synonymy, *Juglans mandschurica* is a variable tree with a vast range covering most of China and extending into adjacent Russia (Manchuria), North Korea and Taiwan. It is a robust tree that can reach 25 m, although in cultivation at least it has a tendency to branch from the base and become shrubby. This is probably because the young shoots, which break in early April, are vulnerable to frost and lose their apical growth. Tony Kirkham (*pers. comm.* 2003) recommends growing it in a tree cage while young to enable it to develop a reasonable length of clean stem before it branches. It is, however, a tree worth the effort, for the enormous leaves (90 cm or more long, especially when young) give a very exotic effect, and are supplemented by male catkins that can reach 40 cm. Clusters of nuts on pendulous stems in autumn are another attraction, although the kernel is too small to be worth the trouble of cracking the thick shell. Historically a scarce tree in Britain (More & White 2003), recent reintroductions may make it more familiar.

As indicated above, treating *J. cathayensis* as synonymous with *J. mandschurica* is slightly controversial, but on morphological evidence at least there is no reason to maintain them as separate species. The principal differences were thought to be that *J. mandschurica* had glabrescent leaves, a fruiting spike of 4-5 nuts, and a distribution north of the Huang He river, while *J. cathayensis* was found south of the Huang He, had tomentose foliage and 6-10 nuts (Lu Anmin *et al*. 1999). In China it grows in mixed forests and is said to be quite common there (Bean 1973). In Taiwan, Kirkham and Flanagan (ETOT, 1992) noted it as the dominant component in broad-leaved woodland growing on steep rocky hillsides, accompanied by *Styrax formosana*, *Carpinus kawakamii* and occasional *Pinus taiwaniana*. Lancaster (1989) records it in Sichuan growing with *Cornus controversa* and *Acer davidii* on steep hillsides. Here and also in the Changbai-Shan in eastern China he noted abundant regeneration from seed, commenting on the conspicuous sight of the large-leaved saplings in the thickets; a useful suggestion of how to grow it in gardens, where a surrounding of shrubs would help protect the terminal bud and encourage the development of a strong leader, while the long pinnate leaves would give a pleasing contrast to more mundane foliage. *J. mandschurica* was also noted to be a pioneer species in regenerating vegetation by the 1996 Sichuan expedition (SICH) of Kirkham, Flanagan, Howick and McNamara. Interestingly, in this situation it had formed trees only up to 7 m in height, but these were already fruiting, which further enhances its value as a garden tree. In all locations it seems to be tolerant of apparently poor, thin-soiled, stony ground, but it has been noted to have a particularly massive taproot from germination onwards.

Juglans mandschurica is a sometimes shrubby tree that can reach 25 m. Young specimens exhibit enthusiastic growth, capable of producing massive stems of over 2 m in one season; these bear extremely large leaves and thus form a very striking feature, but leave a rather gaunt, wide-spreading winter skeleton. Clean stems are seldom seen in the UK, with trees usually having heavy limbs from the base. The old specimen at Hergest Croft, probably bought from Veitch in about 1900 according to Lawrence Banks, is about 15 m tall, with a clean stem achieved through pruning, but the limbs spread to at least this width. On young specimens the bark is silvery, but dulls to a pale greenish-grey attractively reticulated with longitudinal anastomosing ridges; it becomes deeply furrowed with age, but remains a pale greenish-grey. Young stems glandular pubescent with russet hairs, but these are lost

as the stem ages. Leaf scars are very variable in shape and can be unequal, but are usually distinctly three pointed and on vigorous young shoots can look like dinosaur footprints; in some accessions at Kew from CAFA collections (as *J. cathayensis*) the stems are prominently ridged from the lower angle of the leaf scar, while in others this ridging is much less prominent but detectable to the touch. Leaves are 40-90 cm (or longer on vigorous shoots when young), with (7-) 9-19 leaflets; leaflets 6-17 x 2-7.5 cm, laterally sessile, the terminal leaflet petiolulate, elliptic to ovate-elliptic or long elliptic-lanceolate, tomentose or slightly pubescent below, with midvein pubescent, base subcordate, usually unequal, apex acuminate, margins serrate to serrulate. Young leaves are tinged with bronze and covered in pubescence, yellowish-green when expanded. Male catkins 9-40 cm, slender, yellowish-green, flowers with 12-40 stamens; female flowers numerous. Fruits in pendulous clusters of 5-10 (-13), ovoid, 3-7.5 x 3-5 cm; husk green, densely glandular-pubescent. Nut oval-oblong, 3-4 cm long, usually with a sharp tip and a variable number ((4-) 6-8) of strong ridges separated by deep fissures in a thick shell. Kernel sweet, but very difficult to extract.

Distribution: CHINA: Anhui, Fujian, Gansu, Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Liaoning, Shaanxi, Shanxi, Sichuan, Yunnan, Zhejiang; TAIWAN; NORTH KOREA; RUSSIA.
Habitat: mixed forest, often on steep rocky slopes
Conservation status: unthreatened
USDA hardiness zone: 5

Juglans microcarpa Berlandier var. ***microcarpa*** **Texas Walnut** (*also*: Little Walnut, Texas Black Walnut, Dwarf Walnut, Nogal, Nogalillo, Nogalito)
Syn: *J. rupestris* Engelm., *J. nana* Engelm.

The Texas Walnut has been cultivated in Europe since 1868 (Henry, in Elwes & Henry II) but has never become widely known. This is regrettable as it forms an attractive small tree, with finer, more graceful foliage than any other *Juglans* species. Growing in full sun in the wild, it produces a particularly strong taproot when young, before putting on much growth above ground (Elias 1980), enabling it to withstand summer droughts. This drought resistance has caused it to be used for shelterbelt plantings in the SW United States, although the largest wild trees have mostly been removed for timber (Elias 1980). In central

Texas and south-central Oklahoma intermediates between *J. nigra* and *J. microcarpa* are known, suggesting hybridization (Whittemore & Stone 1997).

A small tree, occasionally reaching 15 m, but usually much less, often multi-trunked or even shrubby in the wild. Bark smooth and grey when young, darkening to deeper grey or dark brown with age, and becoming thicker with deep furrows with flat-topped ridges. The branches are stout and spreading, with new growth being usually pubescent with russet hairs that later fade to grey on brown to grey-brown twigs with abundant lenticels; leaf scars are large, heart-shaped with rounded corners, with a fringe of pale hairs along the upper edge. Leaves are 20-40 cm long, with 11-25 subsessile leaflets each 9-24 x 1-1.5 (-2.7) cm, lanceolate to narrowly lanceolate, often somewhat curved, with a long-acuminate apex and a rounded, tapering or unequal base, margins usually toothed. The yellow-green leaves are glabrous above, but usually sparsely hairy below; they are aromatic when crushed. Male catkins are slender, 5-10 cm long, with an almost hairless rachis, each flower with 20-30 stamens; female flowers 1-4. Fruits are globose, solitary or in clusters of 2-3, 2-3.5 cm in diameter; husk dark green, becoming brown, with rufous hairs when young but glabrous at maturity. Nuts are no more than 20 mm in diameter, round but slightly flattened at the base, with deep longitudinal, sometimes forked, grooves in the thick shell; the kernel is small and although oily, tastes sweet.

J. microcarpa seems to be a reliable tree in southern England, and should be planted more frequently. A tree dated 1906 at Kew is approximately 15 m tall, but has a markedly curved trunk due to its avoidance of competition from its neighbours.

Distribution: USA: SW Kansas, W Oklahoma, Texas to Arizona. MEXICO: NW Nuevo Leon, Coahuila, NE Chihuahua.

Habitat: limestone outcrops and drainage lines, especially gravelly stream bottoms.

Conservation status: not threatened

USDA hardiness zone: 6-7

J. microcarpa var. ***stewartii*** (Johnston) Manning

Differs in having more (17-21 (-32)) and broader leaflets than *J. microcarpa*, 1.1-1.9 cm wide, long-acuminate, usually with an oblique base. The fruits are also larger, 1.8 - 2.5 cm diameter.

Distribution: MEXICO: Coahuila, Chihuahua (and possibly in Texas).

Juglans nigra L. **Black Walnut**

This magnificent forest tree has been well described in the literature and has inspired several monographs (Chenoweth 1995, Thompson 1976). Information is also available on numerous websites. It should be noted that *J. nigra* is strongly allelopathic, causing the problem known as 'walnut wilt' so it should be sited with care (a list of tolerant species is available at http://plantclinic. cornell. edu/ FactSheets/ WALNUTW.HTM); by-products such as sawdust are toxic to domestic livestock. The black walnut is one of the most attractive trees in cultivation, and should be planted more frequently where fine trees are required in the landscape; it is too big for small gardens.

Some 400 selections of *J. nigra* for its fruits have been made, but their performance has been found to be strongly influenced by local conditions. Funk (1979) considered that there was 'no consistently better' clone than 'Thomas', originating in Pennsylvania in 1881, but even 'Thomas' varies in performance and is not suitable for the Midwest (it is available from European nurseries). Another recommended fruiting cultivar is 'Vandersloot', which bears a large nut that cracks easily and is resistant to anthracnose leaf spot. For ornamental planting *J. nigra* 'Laciniata' is recommended for its finely dissected foliage, which apparently has no effect on its vigour (Grafted Walnut Trees nursery website: www.graftedwalnuts.co.uk 2003). The 19th century cultivar 'Alburyensis' has narrower leaflets than normal and in this resembles some specimens of *J. nigra* from Oklahoma and Texas, where introgression with *J. microcarpa* may have occurred (see above). It also differs in bearing its fruit in clusters and in having a more pendulous habit (Bean 1973).

Juglans sigillata Dode **Iron Walnut**

A member of Section *Juglans*, this species seems to be sufficiently distinct from *J. regia* to be worthy of specific rank, but is apparently still unknown in western collections despite being grown for its nuts in Yunnan (Lu Anmin *et al*. 1999). The nuts are very hard, hence the Chinese name Iron Walnut, and deeply impressed with pits and depressions that resemble the indentations of a seal in wax and suggested the name *sigillata* (sealed) to Dode.

J. sigillata forms a tree to 25 m. Leaves 15-50 cm long, with 9-11(-15) leaflets, each 6-18 x 3-8 cm, ovate-lanceolate or elliptic-lanceolate,

sessile or subsessile, with base oblique and apex acuminate, margins sometimes indistinctly finely toothed. Dode says that the leaflets are a beautiful luminous green above, paler below, and pubescent. Male catkins 13.5-18 cm, flowers with 24-27 stamens. Fruits are solitary or in clusters of up to 3, ovoid-globose or subglobose, 3.4-6 x 3-5 cm, husk hairy when young, glabrescent later, irregularly dehiscent. Nuts with thick shell, smooth but with two or more strong ridges and deep indentations.

Distribution: INDIA: Sikkim; BHUTAN; CHINA: Guizhou, Sichuan, SE Xizang, Yunnan.
Habitat: forested slopes and valleys, 1300-3300 m.
Conservation status: unknown.
USDA hardiness zone: unknown.

Juglans regia L. **Walnut** (*also*: English Walnut, Persian Walnut)

J. regia will remain the most commonly planted walnut, and despite being such a superficially familiar plant the full extent of its variation has not been adequately covered in dendrological works (although there is coverage of older European cultivars and forms in Elwes & Henry (II), Bean (1973) and Krüssmann (1985)). *J. regia* is almost certainly a relict species from the Tertiary forests of Europe and Asia (Mitchell 1996, B. Juniper *pers. comm.* 2003); Barrie Juniper believes its current wild stronghold is southern Kyrghyzstan. Occurring from eastern Europe to China and perhaps even Japan as a wild, naturalised or semi-domesticated tree, the range of variation in the *J. regia* group is considerable and natural variation has probably been supplemented in parts of the range by selection for certain fruit characteristics in semi-domesticated trees. Into this situation Dode plunged with enthusiasm, recognizing six full species allied to *J. regia* in Asia. Dealing with the trees of the Punjab, the forester R.N. Parker (1924) found he had three of these 'species' in his territory, and summarised the situation very aptly: "differences between these so-called species are based on indefinite and variable characters, and as far as I have seen are not accompanied by differences in the trees as they grow." Nevertheless, he did concede that there was some geographical basis to the variation, and it is this variation that has attracted the attention of collectors in recent years who have brought back material under 'Dodian' nomenclature.

A tree labelled *J. regia* var. *kamaonia* HOMC 1907, prominently planted on the lawn close to the main gate at RBG Kew, is a good example.
Dode recognized the following species:
J. duclouxiana Dode (*J. regia* var. *tenera* C. de Candolle: this would be the correct name if recognised as distinct): cultivated, Himalaya to China, with thin shelled nuts and longer, more pointed leaflets than *J. regia*. Parker (1924) related this to the kaghazi walnut of central Asia, valued for its thin, easily cracked shell. Kaghazi nuts were introduced to California in the 1870s, and gave rise to the important cultivar 'Eureka' (Forde 1979).
J. kamaonia (C. de Candolle) Dode (*J. regia* var. *kamaonia* (C. de Candolle) Dode): wild in west central Himalaya, cultivated from Turkestan possibly to Japan. Variable in nut size and shape, leaves very pubescent. The specimens at Kew under this name, planted in 1996 as seedlings grown from HOMC 1907 collected in Himachal Pradesh, India, have very robust new growth and attractive silvery-grey bark. The leaves are large and somewhat pendulous, with narrowly ovate leaflets, the terminal leaflet being particularly large. The parent tree was noted as being 20 m tall with a spread of 15 m, standing amongst cultivated land at about 2540 m "overlooking a large plot of *Cannabis sativa*" (Howick & McNamara fieldnotes, 1993). Parker (1924) noted that large trees had mostly been felled for timber and that the survivors were often lopped for fodder and therefore produced little fruit.
J. fallax Dode: Iran to China, with very hard round nuts, leaves large, fewer leaf pairs (2-4 instead of 3-5).
J. orientis Dode (*J. regia* var. *orientis* (Dode) Kitam.): Japan, globose nuts, leaf pairs 2-4, pubescent, with toothed margins (only when young, according to Ohwi (1984)).
J. sinensis (C. de Candolle) Dode (*J. regia* var. *sinensis* C. de Candolle, *J. regia* subsp. *sinensis* (C. de Candolle) H. Ohle): northern China, nuts obovate, leaves large. Dode (1906) comments that "*sinensis*" merits cultivation for its beautiful foliage and curious nuts. Rehder later considered it to be a hybrid between *J. regia* and *J. mandschurica,* as *J.* x *sinensis*, a decision that has been followed by later authors (Kindel 1984, Krüssmann 1985).
J. sigillata Dode: eastern Himalaya, western China. This is clearly a distinct taxon and is maintained as such by the *Flora of China* (see entry above).
In addition, Soviet and other botanists have named new taxa (e.g. *J.*

regia subsp. *turcomanica* Popov (which is the same as *J. duclouxiana* Dode, according to Kindel (1984)) or recombined names: *J. regia* subsp. *fallax* (Dode) Popov includes both *J. fallax* and *J. duclouxiana*. Kitamura has created *J. regia* var. *orientis* (Dode) Kitamura. All of these taxa have been listed in recent publications (e.g. Bean 1973, Krüssmann 1985, Huxley *et al*. 1992) under one name or another, and may be found in collections as such. Until the *J. regia* group has received modern taxonomic study it seems unwise to be dogmatic about taxonomic status, but the horticultural Group concept may be the most applicable form of taxonomic treatment, specially for the more dubiously wild entities.

Cultivars of *J. regia*

Unless for association or a collection of wild species, it makes little sense to plant a random walnut seedling if nuts are wanted. Great steps have been made recently to identify the most suitable cultivars for garden and orchard use in different parts of the world, and these are usually available commercially. Of particular importance is the date of leaf emergence, and the necessity (or not) for a pollinator.

Van t'Westeinde (1971) divided the cultivars of *J. regia* into four groups; Carpathian, French, German and Eureka. The Eureka Group is descended from the thin-shelled Asian kaghazi walnut and is very frost - sensitive, being suitable only for California or Australia. French walnuts are the sort usually cultivated commercially, especially the cultivar 'Franquette', important in California and Australia. It is late-leafing and has good flavour and shape, but comparatively low yields. Of the German group, 'Hansen' (selected in Ohio) is considered the best in North America, being very winter hardy and forming a small tree that bears at a young age (3-4 years after transplanting). It is curious for bearing clusters of up to 13 nuts, which ripen early and although only of medium size have a thin shell and up to 60% kernel by weight (Grimo 1979; www.graftedwalnuts.co.uk 2003). The most interesting group are the Carpathian walnuts. These derive from introductions made to Canada during the 1930s by Rev. Paul C. Crath, a Ukrainian emigrant who realised that if walnuts could grow in the Ukraine they could also grow in Canada. Numerous seedlings were planted all over Canada and the northern United States, proving hardy to –30°C. From these, good selections have been made and in the Dutch trials reported on by van t'Westeinde Carpathian walnuts performed very well.

From these trials the two outstanding cultivars are 'Buccaneer' and 'Broadview'. 'Buccaneer', which originated in The Netherlands, was

judged best, being healthy, late to leaf, self-pollinating while also being a good pollinator for other clones and giving well-flavoured fruit. 'Broadview', however is considered to be the best walnut of all for normal garden purposes, coming into fruit at a very young age (3-4 years after planting) and reliably bearing heavy crops, even when isolated from other walnuts (although 'Buccaneer' is recommended as a pollinator for it). There is even a suggestion of frost resistance by the young growth and flowers (Dunn 2001). In the UK the leaves emerge in early May, about a week earlier than those of 'Buccaneer' (www.graftedwalnuts.co.uk 2003). For those who want a good-looking, fruiting tree 'Buccaneer' should be chosen, as 'Broadview' is a weaker grower and makes a low, bushy tree, but if space permits both should be grown. 'Broadview' originated in British Columbia in the 1920s, grown from a nut sent from Odessa. Other good walnut clones are available in North America and Europe and may be more appropriate for specific conditions; specialist nurseries should be able to advise.

Hybrids

Walnuts are promiscuous outbreeders and hybrids occur wherever two species meet (see Table 1). Other combinations have probably not occurred due to the rarity of the species in arboreta, but may occur in favourable circumstances. Many of these crosses are rare or unknown in Europe, but should be investigated as potential foliage trees.

TABLE 1. Recorded hybrids in temperate *Juglans*

No direction of parentage is implied

	ailantifolia	***cinerea***	***hindsii***	***mandschurica***	***microcarpa***	***nigra***
ailantifolia		*J.x bixbyi*		yes		'Leslie Burt'
ailantifolia* var. *cordiformis		"butterjap" or "buartnut"				
cinerea				yes	yes	yes
hindsii						'Royal'
major					yes	
nigra					yes	
regia	*J.x notha*	*J.x quadrangulata*	'Paradox'	*J.* x *sinensis*		*J.* x *intermedia*

Juglans* x *bixbyi Rehd**.** (*J. cinerea* x *J. ailantifolia)*
Funk (1979) describes this hybrid as a vigorous sprawling tree that is almost impossible to prune to achieve a decent shape, always remaining bushy with thick branches. There are about seven pairs of leaflets, which are large, oblong and shortly acuminate; they are pubescent below, but lack distinct axillary hair tufts. Funk notes that it fruits well after only 3-4 years. The nuts show a high degree of fertility (McDaniel 1979). The cross is best known when *J. ailantifolia* var. *cordiformis* is one parent, the resultant offspring being known as 'butterjaps' or 'buartnuts'. Several cultivars have been named, of which 'Fioka' is an annual cropper, giving nuts that are 24% kernel with a butternut flavour. 'Helen' is regarded as 'a fair cropper, but a bad cracker' (McDaniel 1979) – hard shells are a problem with many of these hybrids.

Juglans* x *intermedia Carr. (*J. regia* x *J. nigra*)
The earliest known walnut hybrid (the first specimen being planted in the Vilmorin garden at Verrieres les Buisson in 1816 (Bean 1973)), occurring regularly where the parents meet and varying slightly. The F_1 generation has limited fertility, but the F_2 may be fully fertile (Henry, in Elwes & Henry II). It is well described by Elwes & Henry, Bean and Krüssmann. Its leaves are genuinely intermediate, having 9-11 leaflets that favour *J. regia* in colour and texture, but the pointed shape and minute marginal teeth suggest *J. nigra*. They are glabrous with the exception of tiny tufts of hairs in vein axils below. Earlier accounts discuss the two clones that were distributed by nurserymen, 'Pyriformis' and 'Vilmoreana'; a most magnificent tree of the latter may be seen at Hergest Croft. According to Lawrence Banks it never fruits.

***Juglans nigra* x *J. ailantifolia* 'Leslie Burt'**
A very vigorous hybrid, resistant to anthracnose leaf spot, but susceptible to butternut curculio (weevil) (Funk 1979). Trees of this parentage could be expected to have magnificent foliage, but seem to be unknown in the United Kingdom.

***Juglans nigra* x *J. hindsii* 'Royal'**
A hybrid raised in California about 1888 by Luther Burbank, and first described in his 1898 catalogue. He noted that it was vigorous and probably suitable for timber, giving huge, deeply-furrowed nuts. It

has apparently not lived up to expectations, as it is not discussed by more recent authors. A specimen approximately 12 m tall grows at Kew, however, close to the wall near the Lion Gate, and is clearly intermediate between the parents. The bark is dark brown and longitudinally furrowed. The attractive, dark green leaves are up to 45 cm long with 21-23 leaflets. The rachis is pubescent throughout with both glandular and eglandular hairs. Leaflets are lanceolate, with sharply toothed margins, dark green in colour with minute hairs on the midrib above and very sparse eglandular pubescence on the midrib and main veins below.

Juglans x ***notha*** Rehd. (*J. ailantifolia* x *J. regia*)
Described by Krüssmann (1985). According to McDaniel the F_1 generation of this little-known tree is not fully fertile. A young tree at Kew closely resembles *J. regia* except that the leaves are slightly larger than normal.

Juglans x ***quadrangulata*** (Carr.) Rehd. (*J. cinerea* x *J. regia*) (*J.* x *alata* Carr.)
Described by Krüssmann (1985), probably most abundant in North America. The young wood is downy. Leaflets usually nine, resembling *J. regia* but slightly toothed, and pubescent below.

***Juglans regia* x *J. hindsii* 'Paradox'**
A hybrid raised in California by Luther Burbank, being described and illustrated in his 1898 catalogue. It has been widely used as stocks for grafted *J. regia* in the Californian walnut orchards. Burbank offered seedlings from his original clone and noted that these showed a lot of variation, so it is probable that the name is attached to a range of rather dissimilar trees. The British nursery Grafted Walnut Trees, however, offers F_1 stock that it claims to be infertile.

J.* x *sinensis (D.C) Rehd. (*J. mandschurica* x *J. regia*)
Described by Krüssmann and see discussion under *J. regia* above. A specimen at Kew has large leaves, up to 39 cm long, with four pairs of ovate leaflets, of which the third pair is largest at 12 x 6.5 cm. They are glabrous except for small axillary hair tufts and a few hairs on the main veins below.

Cultivation Notes
Propagation

Seed is the most usual means of propagating *Juglans* species, but grafting is essential for selected clones. Softwood cuttings taken in early summer can be rooted in heat and high humidity, but the success rate is not high. Walnut seeds retain their viability for several years if stored correctly (Bonner 1990), but in most cases they will be sown immediately. Stratification at 1-5ºC for three to four months is required to break embryo dormancy; this may be achieved artificially in a refrigerator, with the nuts packed in plastic bags containing moist sand or peat, or by sowing in autumn and allowing natural stratification through the winter (Brinkman 1974).

Nuts should be sown singly in 'long tom' pots, just covering the nut; larger quantities may be sown direct in sandy nursery soil. Particular care must be taken to prevent predation by rodents, while poor drainage may cause *Phytophthora* root rots. As a long and vigorous tap root is produced soon after germination the pots should not be in direct contact with soil or other substrate, but placed on a bench or other support to enable free air circulation that will encourage air pruning of the root system. When the shoot is growing freely it may be advisable to pot up once or twice to prevent the plants becoming pot bound, but plants should be placed in a nursery bed as soon as possible. It is advisable, however, to wait until all danger of frost has passed before planting out, to avoid damage to the growing point.

Planting in the permanent site should take place as early as possible, probably in the second autumn of the seedling's life. A long unbranched trunk is desirable and this necessitates protection from spring frosts; a tree cage is a sensible precaution. In plantations of *J. nigra* in the United States *Elaeagnus umbellata* has been recommended as a nurse crop, with the additional advantage of having a nitrogen-fixing symbiont (Funk 1979), and this system could be adopted in arboreta with other shrubs. (The well-known allelopathic effects of juglone should be considered wherever walnuts are planted, however, as this compound can have a severely stunting effect on neighbouring plants.) Some species of *Juglans*, such as *J. mandschurica*, are very reluctant to form a clean stem and branch low down, creating potential weak points (T. Kirkham, *pers. comm*. 2003).

Walnuts are heavy feeders and a high nitrate fertilizer is indicated. For *J. regia* orchards Grimo (1979) recommends an annual application of

NPK 20:10:10 of 150 g per 2.5 cm of diameter for trees between 2.5 and 15 cm diameter, and 340 g per additional 2.5 cm increment thereafter, up to 10-14 kg per tree.

The *Nutshell guide to growing walnuts*, subtitled *Everything you need to know in a nutshell* by Clive Simms, published in 2003 by Orchard House Books (www.orchardhousebooks.com), does what it claims and is charmingly written and illustrated. The extensive section on repelling squirrels will be appreciated by anyone frustrated by a vanishing crop!

Pests and Diseases

Walnut blight is a bacterial disease caused by the organism *Xanthomonas campestris* pv. *juglandis*. First symptoms are small black dots on the leaflets, enlarging to cause withered patches and eventually leaf drop. Young shoots and catkins are also vulnerable, especially if flowering coincides with wet weather. Infected shoots should be cut back to below the point of infection and good hygiene practised. It can be a serious disease, but is not common in the UK. Selection of late-leafing cultivars of *J. regia* will help minimise the risk. Repeated applications of Bordeaux mixture during the early growing season are said to give some control (www.graftedwalnuts.co.uk, Simms 2003).

Walnut leaf blotch or walnut anthracnose (*Gnomonia leptostyla*/*Massonia juglandis*, or *Mycosphaerella* sp.) presents as small brown-black spots on the leaves that develop into larger patches of dull yellow withered tissue. It is most frequent on young growth, and is particularly prevalent in wet weather. It can cause heavy leaf drop and loss of fruits; repeated defoliation will cause tree death. Infected fallen leaves should be raked up and burnt, and an application of Bordeaux mixture made. Some cultivars of *J. regia* are resistant and should be sought out for planting in cool wet countries such as the UK. *J. nigra* is particularly susceptible, and others can be attacked (Berry 1981). Berry's detailed account of the disease is also available at http:www.na,fs.fed.us/spfo/pubs/fidls/walnut_anthr/wa_anthr.htm.

Walnut bunch appears to be caused by mycoplasma-like organisms, and a brooming effect on the shoots is the main visible symptom. It seems to be particularly problematic on *J. ailantifolia* in the hot and humid areas of the southern and eastern United States (McDaniel 1979).

As mentioned above, butternut canker (*Sirococcus clavigignenti* b *juglandacearum*) is a major problem on *J. cinerea* in North America. Probably an introduced pathogen, it was first noted in 1967: by 1995

the disease had killed almost 80% of all butternut trees in the south-eastern USA. The symptoms are perennial stem cankers killing the cambium below the bark, usually located on the main stem, at the base of the tree and on the roots; the lesions eventually coalesce and effectively girdle the trunk, killing the tree (Ostry *et al*. 1996). Spores are carried by wind and rain, and possibly also by squirrels. No treatment is known, but there is some evidence that some individuals are resistant to the disease. Butternut canker has been recorded in *J. regia*, but this species is apparently resistant to it.

Blackline is a form of the Cherry Leaf Roll virus affecting grafted walnuts on alternative stocks; *J. regia* stocks are not affected. It causes necrosis at the union, with further symptoms of weak growth, yellowing leaves and premature leaf drop. It is spread by the use of infected tissue as scions or stocks, but also by pollen and in seeds.

In N.America, the walnut caterpillar (*Datana integerrima*) can occur in epidemic numbers, causing defoliation of host trees. See http://www.na.fs.fed.us/spfo/pubs/fidls/Walnutcat/walnutfidl.htm.

Squirrels are perhaps the most annoying pest of walnuts, causing enormous or almost total loss of crops, and may also damage young shoots. An ingenious method of foiling their attempts on individual trees, using metal plates attached to the trunk, is described by Simms (2003). Others prefer a shotgun.

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Notes

1 The count remains at 21 if *J. cathayensis* is incorporated in *J. mandschurica* and *J. sigillata* is recognized as distinct.
2 Not in cultivation.
3 This 'fringe' of hairs is a variable feature. In *J. cinerea* it can be a distinct pad of russet hair, but also just a thin 'moustache', in others it is usually a narrow line of velvety short hairs and this can wear down after a year or so to merely an indication of its former presence. However, its presence can usu ally be detected and it will not be imagined in Sect. Rhysocaryon.
4 May be slightly broader in cultivation, but always appearing narrow and willow-like.
5 This distinction is clear through a x10 lens; glandular hairs may be sparse. Axillary tufts may be absent, especially in upper leaflets, but willowy leaf-shape distinguishes from *J. californica*.