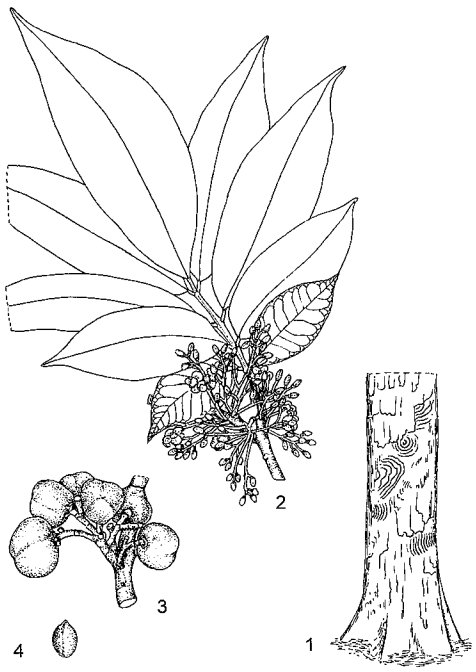
9400–12,900 N/mm², compression parallel to grain 47–60 N/mm², shear 10–15 N/mm², cleavage 11–24 N/mm, Janka side hardness 4000 N and Janka end hardness 5420 N.
The wood is usually fairly easy to saw and work, with moderate blunting effects on cutting edges because the wood contains some silica (up to 1.0%). It can be finished to a smooth surface, but there may be a slight tendency to pick up in planing quarter-sawn material and gum may appear at the surfaces. The wood holds nails and screws well, but may split upon nailing. It glues satisfactorily except when gum is present; the use of a filler is recommended for staining and polishing. The bending properties are usually satisfactory. Good-quality veneer can be produced by both rotary cutting and slicing. The wood is moderately durable and only occasionally attacked by termites and pinhole borers, but it is slightly more susceptible to attacks by powder-post beetles. The heartwood is strongly resistant to impregnation, the sapwood permeable to moderately resistant. The wood dust may cause irritation to the skin.
Some preliminary pulping tests gave satisfactory results for paper production. The wood fibres are about 1.4 mm long, with a diameter of 21 µm, a lumen width of 13 µm and a cell wall thickness of 4 µm. The wood contains 54% cellulose, 40% α-cellulose, 30% lignin and 13% pentosans. The solubility in ether is 0.6%, in alcohol-benzene 0.7%, in hot water 1.9% and in 1% NaOH 11.2%.
The bark contains essential oil, which consists exclusively of sesquiterpenes, with as major constituents β-caryophyllene (45%) and globulol (11%). Limonoids, including dregeanin, have been isolated from the bark.

Adulterations and substitutes The wood of *Guarea thompsonii* Sprague & Hutch. is sometimes mixed with that of *Guarea cedrata*, but is in general slightly heavier and darker. The wood resembles that of *Khaya* spp., and is close to that of *Entandrophragma* spp. It is also difficult to distinguish from that of *Beilschmiedia* spp. ('kanda').

Description Evergreen, dioecious, large tree up to 45(–55) m tall; bole branchless for up to 26(–41) m, usually straight and cylindrical, sometimes fluted, up to 150(–200) cm in diameter, sometimes with spreading, blunt buttresses up to 3 m high; bark surface greyish to yellowish brown and smooth but exfoliating in small circular scales leaving concentric rings of markings (mussel shell pattern), inner bark



Guarea cedrata – 1, base of bole; 2, flowering twig; 3, infructescence; 4, seed.
Redrawn and adapted by Iskak Syamsudin

pinkish or reddish pale brown, fibrous, with cedar-like smell; crown rounded, dense; twigs densely yellowish-brown hairy but glabrescent. Leaves arranged spirally, paripinnately or imparipinnately compound with (3–)4–6(–7) pairs of leaflets; stipules absent; petiole 2–5 cm long, broadly winged and deeply grooved, rachis 2–18 cm long; petiolules up to 1.5(–2) cm long; leaflets opposite or nearly so, oblong-ovate to narrowly oblong-elliptical, (4–)8–28(–32) cm × 2–9(–10.5) cm, cuneate or sometimes rounded and slightly asymmetrical at base, usually acuminate at apex, margins entire to wavy, thickly papery or thinly leathery, nearly glabrous, pinnately veined with 10–22 pairs of lateral veins, smallest veins finely reticulate and markedly raised on the lower surface. Inflorescence an axillary panicle up to 7 cm long, densely hairy. Flowers unisexual, male and female flowers very similar in appearance, regular, 4–5-merous, pale yellow, fragrant; pedicel 1–3 mm long; calyx cup-shaped, 1–2 mm long, with short lobes; petals free, narrowly elliptical, 4–7(–9) mm × 3–4 mm, reflexed; stamens fused into an urn-shaped tube 4.5–6 mm long, with 8–10(–12) included an-

thers near apex, alternating with rounded lobes; ovary superior, globose to conical, c. 2 mm in diameter, (3–)4(–5)-celled, style 2–3 mm long, thick, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit a nearly globose capsule 3–5.5 cm in diameter, yellowish to orange-red, densely short-hairy, dehiscent by 3–5 valves, (2–)3–5-seeded. Seeds kidney-shaped to rounded-triangular, 2–4 cm × 1.5–2 cm, with fleshy orange seed coat. Seedling with hypogeal germination, cotyledons remaining enclosed in the seedcoat; epicotyl 8–12 cm long; first 2 leaves opposite, usually 3-foliolate.

Other botanical information *Guarea* comprises about 8 species in tropical Africa and about 35 in tropical America. It belongs to subfamily *Melioideae* tribe *Guareeae* and seems most closely related to *Turraeanthus*, which differs in its petals that are fused with the staminal tube.

Guarea mayombensis Pellegr. (synonym: *Leplaea mayombensis* (Pellegr.) Staner) from Cameroon. Gabon, Congo, DR Congo and eastern Uganda, is a medium-sized tree up to 25 m tall. It differs from other *Guarea* spp. in its large, indehiscent or tardily dehiscent fruit, often only breaking up after falling. It resembles *Guarea cedrata* in its leaves, but has larger flowers. Its wood is similar and undoubtedly used for the same purposes. *Guarea mayombensis* is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, selective felling, and poor regeneration due to the absence of seed dispersal agents.

Anatomy Wood-anatomical description (IAWA hardwood codes):

Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 65: septate fibres present; (66: non-septate fibres present); 69: fibres thin- to thick-walled; (70: fibres very thick-walled). Axial parenchyma: (80: axial parenchyma aliform); (82: axial parenchyma winged-aliform); 83: axial parenchyma confluent; (85: axial parenchyma bands more than three cells wide); (86: axial parenchyma in narrow bands or lines up to three cells wide); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 115: 4–12 rays per mm. Mineral inclusions: (136: prismatic crystals present); (137: prismatic crystals in upright and/or square ray cells); (142: prismatic crystals in chambered axial parenchyma cells); 159: silica bodies present; 160: silica bodies in ray cells.

(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development Initial growth of seedlings is slow, less than 30 cm after 1 year. Seedlings showed best growth at 10% of full sunlight. If they are exposed to more sunlight after 1 year, growth may speed up, reaching annual growth rates of up to 1 m in height in plots managed by the tropical shelterwood system. In Guinea trees planted in the understorey showed a mortality of about 50% and reached a mean height of 2.5–3.0 m at 6 years of age, for those planted in forest paths the mortality was 25–30% but the height only 1.2 m, and all seedlings planted in full sun died within 2 years. It is recommended to start thinning the upper storey of the forest 4 years after planting so that the saplings receive progressively more light. Planted trees in Ghana reached a height of up to 15 m and 19 cm in bole diameter in 14 years. Under natural conditions in Côte d'Ivoire an average annual diameter increment of 2.9 mm was recorded, and in Ghana it was 3.2–5.5 mm. In Nigeria it has been estimated that it takes more than 170 years for *Guarea cedrata* trees to reach 100 cm in bole diameter.

Flushes of new leaves are strikingly pinkish red. Ripe fruits often develop at the beginning of the dry season. In Côte d'Ivoire trees are recorded as fruiting twice a year, in June–July and in October–December. Birds such as hornbills, monkeys, duikers and porcupines eat the fleshy seedcoat and may disperse the seeds. A study in the Dja reserve in Cameroon showed that hornbills are very important for seed dispersal of *Guarea cedrata*.

Ecology *Guarea cedrata* occurs in lowland evergreen rainforest, usually primary forest, in regions with more than 1600 mm annual rainfall. In Ghana it is most common in moist semi-deciduous forest and drier localities in the moist evergreen forest zone, especially in un-

disturbed forest. It attains its highest density in regions with 2000 mm annual rainfall. In Uganda it occurs in lowland rainforest, up to 1100 m altitude. *Guarea cedrata* is classified as a shade-bearer. Seedlings are most common in the shade, although they are occasionally found in full sunlight. They are often even common in deep shade, where they can survive for a long time. All sizes of seedlings and saplings are less abundant in forest affected by recent logging, in comparison with undisturbed, not too dense forest. However, for further development, some opening of the forest canopy seems essential. *Guarea cedrata* prefers well-drained soils and tolerates infertile soils.

Propagation and planting *Guarea cedrata* has comparatively large seeds, with a 1000-seed weight of 1–3.5 kg. Fresh seeds have a fairly high water content, about 27%. They have a short viability, but can be stored in sealed containers for at least 2 weeks. It is recommended to add ash to reduce damage by insects. Germination is irregular and often rather slow, taking 20–45(–65) days. Soaking in cold water for 12 hours before sowing has been recommended to speed up germination. Seed beds in the nursery should be shaded. Seedlings are drought sensitive.

Management In general, larger trees of *Guarea cedrata* occur in low densities in the forest. In Liberia densities of less than 1 to 16 boles of over 60 cm in diameter per km^2 have been recorded. For some regions in Côte d'Ivoire 1 exploitable tree per 12–16 ha has been recorded, and the average wood volume for forest in Côte d'Ivoire has been estimated at 0.3 m^3/ha. In southern Cameroon the average density of boles of *Guarea* spp. over 60 cm in diameter is 0.03–0.14 per ha, with a wood volume of 0.16–1.22 m^3/ha. In the Central African Republic the average wood volume has been recorded at 0.26–0.34 m^3/ha. In Gabon *Guarea cedrata* is rare; the average wood volume of *Guarea* trees has been estimated at 0.13 m^3/ha. In Congo wood volumes of up to 0.30 m^3/ha have been reported. In Uganda larger trees of *Guarea cedrata* are uncommon; in many regions they have even become very rare. *Guarea cedrata* is rarely planted, but several village nurseries in western Cameroon offer seedlings.

Diseases and pests In Ghana it has been reported that fruits are commonly infested by *Menemachus* beetles.

Harvesting The minimum bole diameter for harvesting of *Guarea cedrata* is 60 cm in Côte d'Ivoire and DR Congo, 70 cm in the Central African Republic, and 80 cm in Cameroon and Liberia.

Yield A tree with a bole diameter of 60 cm yields on average 4.1 m^3 of timber, and a tree with 100 cm diameter 11.6 m^3.

Handling after harvest Freshly harvested boles often float in water and can be transported by river.

Genetic resources *Guarea cedrata* is quite widespread, but occurs usually in low densities and is usually restricted to undisturbed forest. It is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling. In general, the levels of exploitation are moderate, but *Guarea cedrata* sometimes suffers from its similarity to other commercial species such as *Entandrophragma angolense* (Welw.) C.DC.

Prospects More research is needed on appropriate management systems in natural forest to ensure a sustainable exploitation of *Guarea cedrata*. However, its rather slow growth and poor regeneration in logged-over forest are serious drawbacks for larger-scale commercial exploitation, necessitating long rotation cycles. The establishment of plantations seems unprofitable, although some planted *Guarea cedrata* trees showed fair growth rates, indicating potential for selection and breeding.

Major references Bolza & Keating, 1972; Burkill, 1997; CTFT, 1978a; Katende, Birnie & Tengnäs, 1995; Phongphaew, 2003; Siepel, Poorter & Hawthorne, 2004; Styles & White, 1991; Takahashi, 1978; Voorhoeve, 1979; Wilks & Issembé, 2000.

Other references ATIBT, 1986; Aubréville, 1959a; CIRAD Forestry Department, 2003; CTFT, 1951; CTFT, 1961c; de Koning, 1983; de la Mensbruge, 1966; de Saint-Aubin, 1963; Farmer, 1972; Hawthorne, 1995; Hawthorne & Jongkind, 2006; InsideWood, undated; Istas, Raekelboom & Heremans, 1959; Keay, 1989; Kyereh, Swaine & Thompson, 1999; Menut et al., 1995; Neuwinger, 2000; Normand & Paquis, 1976; Raponda-Walker & Sillans, 1961; Tailfer, 1989; Vivien & Faure, 1985.

Sources of illustration Voorhoeve, 1979; Wilks & Issembé, 2000.

Authors R.B. Jiofack Tafokou

GUAREA THOMPSONII Sprague & Hutch.

Protologue Bull. Misc. Inform. Kew 1906: 245 (1906).

Family Meliaceae

Chromosome number $2n = 72$

Vernacular names Dark bosse, sweet cedar, black guarea (En). Bossé foncé, guarea noir (Fr).

Origin and geographic distribution *Guarea thompsonii* occurs from Liberia to Gabon and DR Congo.

Uses The wood is valued for house building, flooring, joinery, interior trim, panelling, doors, ship building, vehicle bodies, furniture, cabinet work, veneer and plywood. It is suitable for toys, novelties, boxes, crates, carving and turnery. Traditionally, the wood is used for dugout canoes.

The bark is used in traditional medicine. In Côte d'Ivoire bark decoctions are applied as an enema to treat kidney pain, bleeding after childbirth, rheumatism and leprosy. A bark maceration is taken as a strong purgative.

Production and international trade The wood of *Guarea thompsonii*, *Guarea cedrata* (A.Chev.) Pellegr. and *Guarea laurentii* De Wild. is all traded as 'bosse'. Congo exported 11,000 m³ of *Guarea* logs in 2003, at an average price of US$ 174/m³, 15,000 m³ in 2004, at an average price of US$ 177/m³, and 25,000 m³ in 2005, at an average price of US$ 172/m³. Exports of *Guarea* sawnwood from Congo were 4000 m³ in 2004, at an average price of US$ 333/m³, and 9000 m³ in 2005, at an average price of US$ 304/m³. Small amounts of veneer were exported from Congo in 2003 and 2004, at an average price of US$ 331/m³ and 363 US$/m³, respectively. Cameroon exported 12,250 m³ and 11,700 m³ of *Guarea* logs in 1997 and 1998, respectively, and exports of sawn 'bosse' were 4150 m³ in 2003, 3300 m³ in 2004, and 3000 m³ in 2006. The Central African Republic exported 3,200 m³ of logs in 1999, and 2300 m³ in 2006. Ghana exported 2450 m³ of *Guarea* logs in 1994, at an average price of US$ 221/m³, and 3710 m³ of sawn wood, at an average price of US$ 424/m³. *Guarea* has some importance as export timber in Gabon, with in 2001–2005 an annual export volume of about 5000 m³ of logs for all *Guarea* species together. The share of *Guarea thompsonii* in these statistics is obscure.

Guarea thompsonii – wild

Properties The heartwood is pinkish brown when freshly cut, darkening to reddish brown upon exposure. It is usually distinctly demarcated from the paler sapwood. The grain is usually straight, sometimes interlocked, texture fine. The wood has a slight cedar-like smell when fresh. It may have some gummy exudate.

The wood is medium-weight, with a density of 620–740 kg/m³ at 12% moisture content. It generally air dries fairly easily with little degrade, but has some tendency to checking during kiln drying. The rates of shrinkage are moderately high, from green to oven dry 5.2–5.5% radial and 6.5–7.0% tangential. Once dry, the wood is fairly stable in service.

At 12% moisture content, the modulus of rupture is 101–171 N/mm², modulus of elasticity 10,800–14,500 N/mm², compression parallel to grain 58–69 N/mm², shear 12–14 N/mm², cleavage 15–18 N/mm, Janka side hardness 4890 N and Janka end hardness 6090 N.

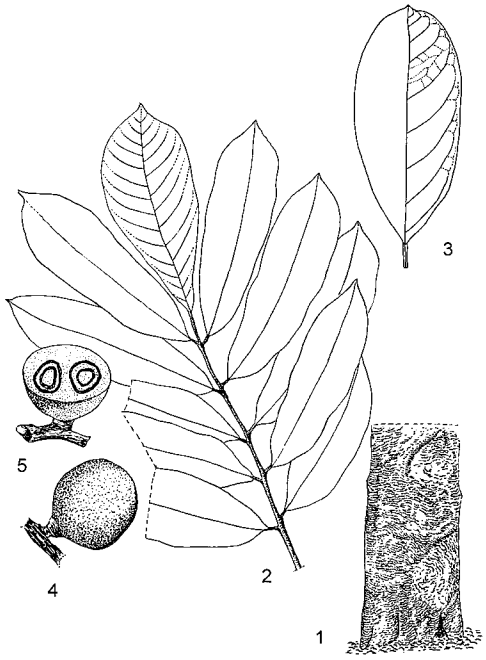
The wood is usually fairly easy to saw and work; it contains less silica than the wood of *Guarea cedrata*, but is slightly more dense. It can be finished to a smooth surface, but there may be a slight tendency to pick up during planing of quarter-sawn material and some gum may appear at the surfaces. A cutting angle of 20° is recommended when interlocked grain is present. The wood holds nails and screws well, but may split upon nailing and pre-boring is recommended. It glues satisfactorily and takes paints, varnishes and stains well, but filling is recommended. The bending properties are usually moderate. Good-quality veneer can be produced by slicing. The wood dust may cause irritation to the skin and mucous membranes.

The wood is moderately durable and only occasionally attacked by termites and pinhole borers, but it is slightly more susceptible to at-

tacks of powder-post beetles. The heartwood is strongly resistant to impregnation, the sapwood permeable to moderately resistant.

Adulterations and substitutes The wood of *Guarea cedrata* (A.Chev.) Pellegr. is sometimes mixed with that of *Guarea thompsonii*, but is usually slightly lighter in weight and colour. The wood resembles that of *Khaya* spp., and is also close to that of *Entandrophragma* spp.

Description Evergreen, dioecious, medium-sized to fairly large tree up to 35(–55) m tall; bole branchless for up to 20 m, usually straight, often fluted, up to 150 cm in diameter, sometimes with short, blunt buttresses at base; bark surface greyish to brown, smooth to warty but exfoliating in rectangular scales leaving concentric rings of markings (mussel shell pattern), inner bark yellowish, granular, with or without cedar-like smell, exuding latex; crown rounded, dense; twigs short-hairy but glabrescent. Leaves arranged spirally, paripinnately or imparipinnately compound with (3–)4–8 pairs of leaflets; stipules absent; petiole 6–14 cm long, slightly winged at margins and slightly grooved, rachis 8–30 cm long; petiolules 5–7 mm long, but in terminal leaflet up to 3.5 cm; leaflets opposite or nearly so, oblong-elliptical to obovate-elliptical, 12–34 cm × 4–11 cm, cuneate and slightly asymmetrical at base, obtuse or shortly acuminate at apex, margins entire to wavy, thickly papery or thinly leathery, glabrous, pinnately veined with 9–16 pairs of lateral veins, smallest veins not conspicuous. Inflorescence an axillary panicle or raceme up to 30 cm long, sparsely hairy or glabrous. Flowers unisexual, male and female flowers very similar in appearance, regular, 4–5-merous, pale yellow, fragrant; pedicel 2–5 mm long; calyx cup-shaped, 1–2 mm long, entire or with very short lobes; petals free, elliptical-oblong to obovate-elliptical, 8–15 mm × 3–6 mm; stamens fused into an urn-shaped tube 8–10 mm long, with 8–10 included anthers near apex, alternating with rounded lobes; ovary superior, globose to flask-shaped, 6–7 mm long, 4-celled, style c. 4 mm long, thick, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit a nearly globose capsule 3–4 cm in diameter, reddish purple, glabrous, rough, dehiscing by 3–4 valves, 1–2(–4)-seeded. Seeds kidney-shaped to rounded-triangular, c. 3 cm × 1.5 cm, with fleshy reddish orange seed coat. Seedling with hypogeal germination, cotyledons remaining enclosed in the seed coat; epicotyl 6–10 cm long; first 2 leaves opposite, simple.



Guarea thompsonii – 1, base of bole; 2, leaf; 3, leaflet; 4, fruit; 5, fruit in cross section. Redrawn and adapted by Iskak Syamsudin

Other botanical information *Guarea* comprises about 8 species in tropical Africa and about 35 in tropical America. It belongs to subfamily *Melioideae* tribe *Guareeae* and seems most closely related to *Turraeanthus*, which differs in its petals that are fused with the staminal tube.

Guarea laurentii De Wild. from the Central African Republic, Gabon, Congo and DR Congo closely resembles *Guarea thompsonii*. Both these species have latex in the bark and obscure fine venation on the lower surface of leaves, in which they differ from *Guarea cedrata*. *Guarea laurentii* differs from *Guarea thompsonii* in its slightly smaller flowers and thinner walled fruit. Its wood is reportedly most similar to that of *Guarea cedrata*, used for the same purposes and mixed in trade. The bark is used as purgative in traditional medicine.

Several *Guarea* spp. in tropical Africa are understorey shrubs or small trees, of which wood is only available in small dimensions. One of these is *Guarea glomerulata* Harms, occurring from south-eastern Nigeria to Gabon and DR

Congo; its reddish brown wood is occasionally used for small objects.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; (43: mean tangential diameter of vessel lumina ≥ 200 μm); (46: ≤ 5 vessels per square millimetre); 47: 5–20 vessels per square millimetre; (58: gums and other deposits in heartwood vessels). Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 65: septate fibres present; (66: non-septate fibres present); 69: fibres thin- to thick-walled. Axial parenchyma: 83: axial parenchyma confluent; 85: axial parenchyma bands more than three cells wide; 86: axial parenchyma in narrow bands or lines up to three cells wide; 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 106: body ray cells procumbent with one row of upright and/or square marginal cells; (107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells); 115: 4–12 rays per mm. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells; (159: silica bodies present); (160: silica bodies in ray cells).
(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development Initial growth of seedlings is slow. When they are exposed to more sunlight after one year, growth may speed up. However, planted trees in Nigeria reached on average only 10 m in height and 20 cm in diameter after 25 years, and it has been estimated that it takes about 200 years for *Guarea thompsonii* trees to reach 100 cm in bole diameter. Fruits mature about 6 months after flowering. In Côte d'Ivoire fruiting is in August and in December. Birds such as hornbills, monkeys, duiker and porcupines eat the fleshy seed coat and may disperse the seeds.

Ecology *Guarea thompsonii* occurs in lowland evergreen rainforest, usually primary forest. In Ghana it is most common in moist evergreen forest, especially in undisturbed forest, but it occurs also in moister types of semi-deciduous forest. It reaches its highest density in flat but well-drained sites. *Guarea thompsonii* is classified as a shade-bearer. In the forest, seedlings are most common in the shade, although generally less common than those of *Guarea cedrata*. For proper development of seedlings, some opening of the forest canopy seems essential.

Propagation and planting *Guarea thompsonii* has comparatively large seeds, with a 1000-seed weight of about 2 kg. They have short viability. Germination is rather slow, taking 20–35 days in Côte d'Ivoire. Seedlings are drought sensitive.

Management In general, larger trees of *Guarea thompsonii* occur in low densities in the forest. In Côte d'Ivoire *Guarea thompsonii* seems to be less common than *Guarea cedrata*. However, it is locally common in Ghana. In southern Cameroon the average density of boles of *Guarea* spp. over 60 cm in diameter is 0.03–0.14 per ha, with a wood volume of 0.16–1.22 m^3/ha. In the Central African Republic the average wood volume has been recorded at 0.26–0.34 m^3/ha. In Gabon *Guarea thompsonii* is slightly less uncommon than *Guarea cedrata*; the average wood volume of *Guarea* trees has been estimated at 0.13 m^3/ha. In Congo wood volumes of up to 0.30 m^3/ha have been reported.

Harvesting The minimum bole diameter for harvesting of *Guarea thompsonii* is 60 cm in Côte d'Ivoire and DR Congo, 70 cm in the Central African Republic, and 80 cm in Cameroon and Liberia.

Yield In DR Congo a tree with a bole diameter of 79 cm yielded 5.3 m^3 of timber, and a tree 100 cm in diameter yielded 8.8 m^3, which is less than for *Guarea cedrata* due to a shorter bole.

Handling after harvest The density of the wood is often around 1000 kg/m^3 before drying, which means that freshly harvested boles may sink in water; this limits the possibilities of transport by river.

Genetic resources *Guarea thompsonii* is quite widespread, but usually occurs in low densities and is usually restricted to undisturbed forest. It is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling. In general, the levels of exploitation are moderate.

Prospects More research is needed on appropriate management systems in natural forest to ensure a sustainable exploitation of *Guarea thompsonii*. However, its slow growth rate is a serious drawback for larger-scale

commercial exploitation, necessitating very long rotation cycles. The establishment of plantations seems unprofitable. Biosystematic research is needed to clarify whether the recorded differences between *Guarea thompsonii* and *Guarea laurentii* justify their distinction on species level. The wood properties and wood anatomy of the two species should also be considered in this research because these reportedly differ between the species.

Major references Bolza & Keating, 1972; Burkill, 1997; CTFT, 1961c; CTFT, 1978a; de Koning, 1983; Farmer, 1972; Keay, 1989; Takahashi, 1978; Tailfer, 1989.

Other references ATIBT, 1986; Aubréville, 1959a; CIRAD Forestry Department, 2003; CTFT, 1951; de la Mensbruge, 1966; de Saint-Aubin, 1963; Fouarge, Sacré & Mottet, 1950; Hawthorne, 1995; Hawthorne & Jongkind, 2006; InsideWood, undated; Keay, 1958b; Neuwinger, 2000; Normand, 1955; Normand & Paquis, 1976; Staner & Gilbert, 1958; Vivien & Faure, 1985; Voorhoeve, 1979; Wilks & Issembé, 2000; World Conservation Monitoring Centre, 1998b.

Sources of illustration Aubréville, 1959a; Tailfer, 1989; Vivien & Faure, 1985.

Authors R.H.M.J. Lemmens

HAPLORMOSIA MONOPHYLLA (Harms) Harms

Protologue Engl. & Drude, Veg. Erde 9, III, 1: 533 (1915).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

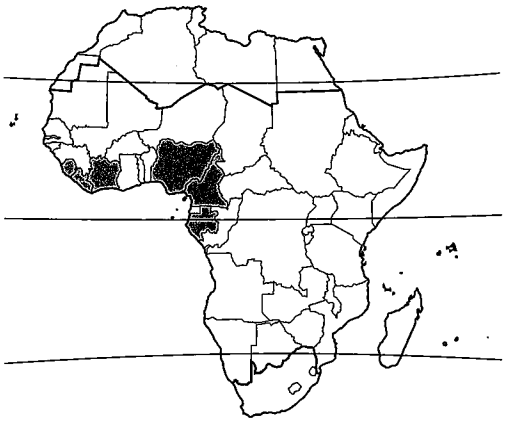
Chromosome number $n = 10$

Vernacular names Black gum (En). Chêne d'Afrique (Fr).

Origin and geographic distribution *Haplormosia monophylla* occurs from Sierra Leone to Côte d'Ivoire, and from southern Nigeria to Cameroon and Gabon.

Uses The wood (trade name: idewa) is used for furniture, cabinet work, flooring, interior trim, poles in house building, wharf piles, canoes and sliced veneer. In Liberia it is one of the favourite woods for carving. It is also suitable for heavy construction, mine props, ship building, vehicle bodies, handles, ladders, sporting goods, agricultural implements, railway sleepers and turnery. It is used for charcoal production.

Production and international trade The timber is traded on the international market in small amounts under the name 'idewa', but statistics are not available. In trade it is probably often mixed with 'afrormosia', i.e. the wood of *Pericopsis* spp.



Haplormosia monophylla – wild

Properties The heartwood is yellowish brown to chocolate brown and distinctly demarcated from the narrow, yellowish white sapwood. The grain is straight, sometimes interlocked, texture fine to moderately fine. The wood surfaces show a figure of fine brown and black bands. Polished wood surfaces are slightly lustrous.

The wood is heavy, with a density of (780–)800–950(–1020) kg/m^3 at 12% moisture content. It should be air dried slowly and with great care because of the high risk of distortion. In Liberia boards 2.5 cm thick air dry to 20% moisture content in about 3 months. The rates of shrinkage are moderate, from green to oven dry 3.0–3.4% radial and 6.7–7.3% tangential.

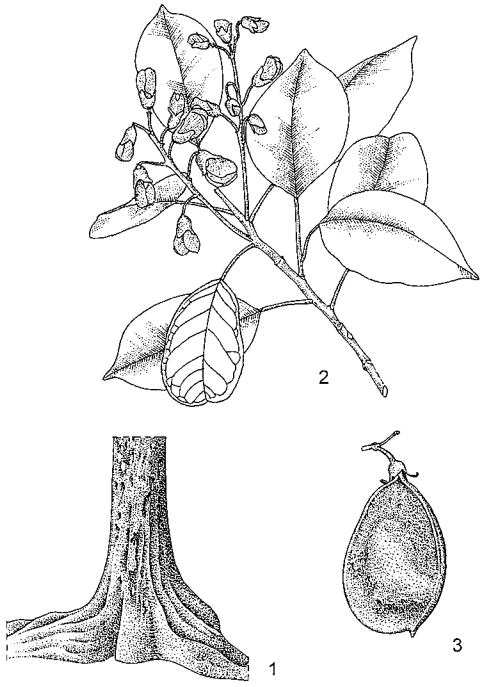
At 12% moisture content, the modulus of rupture is 141–186 N/mm^2, modulus of elasticity 13,600–17,200 N/mm^2, compression parallel to grain 70 N/mm^2, shear 11 N/mm^2, cleavage 21 N/mm and Chalais-Meudon side hardness 8.0.

Sawing and working of the wood is rather difficult; the blunting effect is fairly high and stellite-tipped saw teeth and tungsten-carbide-tipped cutting tools are recommended. The wood has a smooth finish and usually planes well, but sometimes with a slight picking up due to the presence of interlocked grain. It holds nails and screws well, but pre-boring is necessary. Gluing does not cause problems. The wood produces decorative sliced veneer. It is very durable, being resistant to termite, *Lyctus* and marine borer attacks. The wood is

resistant to impregnation by preservatives. Many phenolic compounds have been isolated from the heartwood. The root, stem bark and leaf blade have a high alkaloid content, the stem bark contains saponins, and the root bark contains tannins. The seed contains quinolizidine alkaloids of the sparteine/lupanine class.

Adulterations and substitutes The wood resembles that of *Pericopsis elata* (Harms) Meeuwen which is used for similar purposes, but *Haplormosia monophylla* wood is slightly heavier and more difficult to work and dry.

Description Small to medium-sized tree up to 20(–30) m tall; bole branchless for up to 15 m, fairly straight, often low-branching, fluted or angular, up to 80(–100) cm in diameter, with short and thick buttresses at base often extending in thick surface roots; bark surface smooth to slightly furrowed and thin-scaly, greyish brown, inner bark fibrous, yellow-orange, with conspicuous ripple marks; crown compact, much-branched with ascending branches; young shoots sparsely short-hairy, soon glabrous. Leaves alternate, simple and entire; stipules minute, triangular; petiole 1.5–4 cm long, jointed at base and top, with 2 small stipels just below the top; blade elliptical to obovate, 4.5–15(–20) cm × 3.5–6.5(–9) cm, base obtuse to slightly cuneate, apex obtuse to shortly acuminate, leathery, glabrous, glossy, pinnately veined with 5–9 pairs of lateral veins. Inflorescence an axillary few-flowered raceme up to 12 cm long, nearly glabrous; bracts ovate, up to 1.5 mm long. Flowers bisexual, papilionaceous; pedicel 8–12 mm long; calyx cup-shaped, tube c. 3 mm long, lobes 3–5 mm long, upper 2 fused, glabrous outside, woolly hairy inside; corolla purplish blue, with transversely elliptical standard 12–15 mm × 15–20 mm, wings and keel 12–15 mm long; stamens 10, free, 10–13 mm long; ovary superior, 3–4 mm long, shortly stiped, flattened, 1-celled, style curved, c. 7 mm long. Fruit an elliptical-obovate, flattened pod 5–8 cm × 4–5 cm, with c. 5 mm long stipe at base and short point at apex, thickly leathery, glabrous, dehiscent, 1-seeded. Seed oblong, 4–5 cm × 2–3 cm, completely enveloped by an aril. Seedling with epigeal germination; hypocotyl 1.5–2 cm long, densely hairy, epicotyl c. 7 cm long, sparsely hairy; cotyledons thick and fleshy; first c. 10 leaves scale-like.



Haplormosia monophylla – 1, base of bole; 2, flowering twig; 3, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Haplormosia* comprises a single species. It seems related to *Ormosia* from tropical America, Asia and Australia and *Pericopsis* from tropical Africa and Asia.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23: shape of alternate pits polygonal; 26: intervessel pits medium (7–10 μm); 27: intervessel pits large (≥ 10 μm); 29: vestured pits; 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 70: fibres very thick-walled. Axial parenchyma: 80: axial parenchyma aliform; 82: axial parenchyma winged-aliform; 83: axial parenchyma confluent; (84: axial parenchyma unilateral paratracheal); 85: axial parenchyma bands more than three cells wide; 91: two cells per

parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 104: all ray cells procumbent; 115: 4–12 rays per mm; 116: ≥ 12 rays per mm. Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells.
(P. Ng'andwe, H. Beeckman & P.E. Gasson)

Growth and development In Liberia and Côte d'Ivoire the tree is briefly deciduous in November–December and it flowers in April. New leaves are brilliant red. Fruits mature in about 6 months. No information on nodulation is available.

Ecology *Haplormosia monophylla* characteristically occurs along river banks and in swampy valleys in lowland evergreen forest, where it locally grows in groups. However, larger-sized trees are often found isolated in the forest at some distance from water courses.

Propagation and planting Natural regeneration may be abundant on sandy river banks, but it is apparently rare in more closed forest.

Harvesting The trees are difficult to fell with traditional tools because of the hard wood.

Handling after harvest The logs do not float in water and consequently cannot be transported by river.

Genetic resources *Haplormosia monophylla* is fairly widespread in West and Central Africa, but in most regions it is uncommon and it is selectively felled for its timber. It is expected that overexploitation and habitat degradation will result in serious population decline in the near future, and therefore *Haplormosia monophylla* has been included in the IUCN Red list as vulnerable.

Prospects Although *Haplormosia monophylla* provides a good-quality timber, its prospects as a commercial timber are poor because the supplies are very limited. This is mainly due to the scattered occurrence, especially of larger-sized trees. Information is lacking on growth rates and propagation.

Major references ATIBT, 1986; Aubréville, 1959c; Bolza & Keating, 1972; Burkill, 1995; de Saint-Aubin, 1963; Dudek, Förster & Klissenbauer, 1981; Raponda-Walker & Sillans, 1961; Takahashi, 1978; Voorhoeve, 1979.

Other references Bouquet & Debray, 1974; Hepper, 1958; InsideWood, undated; Keay, 1989; Kinghorn et al., 1988; Kryn & Fobes, 1959; Lewis et al., 2005; Normand, 1950; Normand & Paquis, 1976; Sallenave, 1971.

Sources of illustration Voorhoeve, 1979.
Authors R.H.M.J. Lemmens

HERITIERA DENSIFLORA (Pellegr.) Kosterm.

Protologue Penerb. Madj. Ilmu Peng. Indon. 1: 71 (1959).

Family Sterculiaceae (APG: Malvaceae)

Synonyms *Tarrietia utilis* (Sprague) Sprague var. *densiflora* Pellegr. (1941), *Tarrietia densiflora* (Pellegr.) Aubrév. & Normand (1958).

Vernacular names Ogoué (Fr).

Origin and geographic distribution *Heritiera densiflora* is endemic to the north-western part of Gabon.

Uses The wood is recommended for joinery, carpentry, moulding and sliced veneer, and is also useful for exterior and marine applications.

Production and international trade In the period 1966–1970 Gabon exported about 3000 m³ of round logs of *Heritiera densiflora* annually. The export increased to on average 8000 m³/year in the period 1999–2003. *Heritiera densiflora* is traded in mixed consignments of medium-weight hardwood, and is often sold on the timber market mixed with *Heritiera utilis* (Sprague) Sprague (niangon) from West Africa.

Properties The heartwood is pinkish brown to reddish brown or coppery brown and clearly demarcated from the whitish sapwood. The grain is slightly interlocked, texture moderately coarse. The wood is oily to the touch. The density is 630–840 kg/m³ at 12% moisture content. The wood of *Heritiera densiflora* dries more slowly than that of *Heritiera utilis*, often with a tendency to twist. The shrinkage rates are moderate to high: from green to oven dry 3.6–6.6% radial and 7.8–12.7% tangential. At 12% moisture content, the modulus of rupture is 126–188 N/mm², modulus of elasticity 10,700–14,000 N/mm², compression parallel to grain 44–72 N/mm², shear 7–9 N/mm², cleavage 13–24 N/mm and Chalais-Meudon side hardness 3.2–6.0.

Botany Medium-sized to fairly large tree up to 30 m tall; bole up to 60(–100) cm in diameter, with large buttresses; bark pale grey to brown, fissured; young twigs brown pubescent. Leaves alternate, simple or digitately lobed; stipules 0.5–1 cm long, early caducous; petiole 3–45 cm long; blade 10–45 cm × 5–30 cm in outline, elliptical when simple or with 2–7 lobes, obtuse at base, acuminate at apex, densely but not contiguously scaly hairy below,

pinnately veined with 10–20 pairs of lateral veins. Inflorescence an axillary, narrow panicle up to 11 cm long, reddish brown pubescent; bracts 0.5–1 cm long, caducous. Flowers unisexual, regular, 4–5-merous, whitish, c. 0.5 cm long; pedicel slender, 0.5–1 cm long; calyx campanulate with lobes about as long as tube, stellately hairy; petals absent; disk annular; male flowers with stamens fused into a column; female flowers with 3–5 carpels united loosely. Fruit consisting of 1–5 woody nuts c. 3 cm × 2 cm with a large wing c. 7.5 cm × 3 cm.

Heritiera comprises about 35 species, the majority of which occur in tropical Asia and 3 species in Africa. *Heritiera densiflora* is closely related to *Heritiera utilis* (Sprague) Sprague (niangon) from West Africa. The two species should be carefully compared as they are very similar with most of the recorded differences obscure, e.g. density of indumentum and length of inflorescences. Both species often have simple leaves, but *Heritiera densiflora* may also have digitately lobed leaves (with lobes distinctly fused at base) and *Heritiera utilis* may have digitately compound leaves (with leaflets completely free).

Ecology *Heritiera densiflora* occurs in lowland rainforest, often in swampy localities and on sandy-loamy soils.

Genetic resources and breeding *Heritiera densiflora* has a very limited distribution area and is probably uncommon there, which makes it easily liable to genetic erosion.

Prospects Although *Heritiera densiflora* is exploited for its timber, which is traded on the international market, very little is known about it. Research is needed to prove that it is truly distinct from *Heritiera utilis* in botanical characteristics or wood properties.

Major references de Saint-Aubin, 1963; Eyma, Méausoone & Martin, 2004; Hallé, 1961.

Other references Raponda-Walker & Sillans, 1961; Savard & Caumartin, 1970; Takahashi, 1978.

Authors R.H.M.J. Lemmens

HERITIERA LITTORALIS Aiton

Protologue Hort. kew. 3: 546 (1789).

Family Sterculiaceae (APG: Malvaceae)

Chromosome number $2n = 38$

Synonyms *Heritiera minor* (Gaertn.) Lam. (1797).

Vernacular names Looking-glass tree (En). Bois de table (Fr). Luabo (Po). Msikundazi, mkokoshi, mgongongo (Sw).

Origin and geographic distribution *Heritiera littoralis* occurs along the coast of eastern Africa from Kenya through Tanzania to Mozambique, in the Indian Ocean islands, tropical Asia, tropical Australia, Hawaii and New Caledonia. It does not occur wild in Réunion and Mauritius, but has been introduced there.

Uses In eastern Africa the tree boles are used to make masts of boats, for shipbuilding and furniture. In tropical Asia the wood is more commonly used, particularly for rice pounders and other domestic articles, but sometimes also for piling, bridges and shipbuilding. It is recommended for steamed bentwork and when strength and durability are required. The wood is excellent firewood, having a high energy value. It is suitable for the production of wrapping, writing and printing paper. The bark has been used for tanning, and is occasionally still used for toughening fishing nets. In Kenya a root decoction is used to treat mouth infection and toothache. In tropical Asia a seed extract is used to treat diarrhoea and dysentery. The seed is occasionally eaten and has been used as a cola substitute. In the Philippines the roots are used as fish poison.

Production and international trade The wood of *Heritiera littoralis* is of little commercial value, but has been of some importance in the Philippines.

Properties The wood of *Heritiera littoralis* is heavy, hard and strong. The heartwood is reddish brown or dark brown, often with a chocolate or purple tinge. The density is 830–1040 kg/m^3 at 15% moisture content. The grain is interlocked, texture fine and even. The wood often smells like leather.

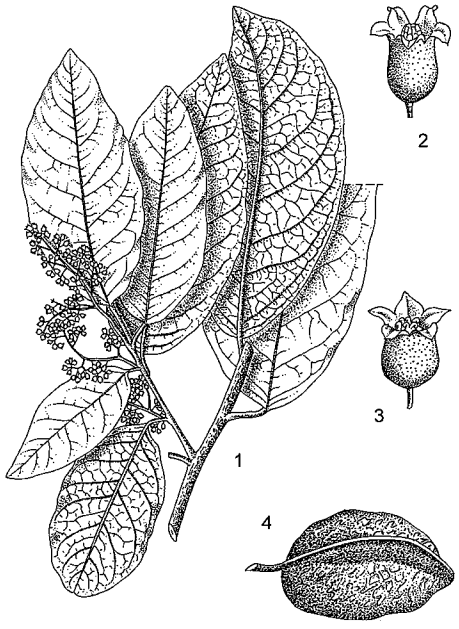
At 12% moisture content wood of New Guinean origin had a modulus of rupture of 132 N/mm^2, modulus of elasticity 18,000 N/mm^2, compression parallel to grain 72 N/mm^2, shear 14 N/mm^2, cleavage 62 N/mm radial and Janka side hardness 7600 N.

The shrinkage rates are fairly high, from green to 15% moisture content about 2% radial and 4.5% tangential. The timber is difficult to season, being subject to considerable end splitting and surface checking. It rapidly blunts edged tools due to the presence of silica, but turns fairly well and takes a good finish. The wood is moderately durable when exposed to the weather or in contact with the ground; a life of 3 years in contact with the ground under tropical conditions is probably as much as can be expected. In durability tests in Tanzania, fungi

showed a particularly high affinity for *Heritiera littoralis* wood. The wood is not susceptible to powder-post beetles, and is reported to be resistant to marine borers, but not always to termites. It is probably difficult to impregnate with preservative because gum-like deposits are present.

The bark contains 12–15% tannin on dry weight basis. The poisonous activity of the roots to fish is due to the presence of sesquiterpenoids such as heritonin and vallapin. The latter compound also showed activity against boll weevils. In tests in Japan, an ethanol extract of *Heritiera littoralis* branches showed strong DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity. The seed oil is characterized by high contents of the cyclopropenoic acids malvalic acid (54%) and sterculic acid (12.5%).

Botany Evergreen, monoecious, small to medium-sized tree up to 25 m tall, but usually smaller; bole up to 60 cm in diameter, often twisted and stunted, with thin, wavy and ribbon-like buttresses, often extending far out; bark fissured, greyish. Leaves arranged spirally, simple; stipules subulate, up to 1 cm long, caducous; petiole 1–2 cm long, swollen at both ends; blade oblong-elliptical to ovate-elliptical, 9–30 cm × 4–15 cm, rounded or slightly cordate at base, acute or obtuse at apex, margin entire or slightly wavy, leathery, silvery scaly below, pinnately veined. Inflorescence an axillary panicle up to 18 cm long, much-branched, scaly hairy. Flowers unisexual, regular, (4–)5-merous, small; pedicel up to 5 mm long; calyx cup-shaped, c. 5 mm long, with short lobes, hairy; petals absent; male flowers with stamens fused into a column; female flowers with (4–)5 carpels united loosely, usually only 1 carpel developing into fruit. Fruit an ellipsoid to oblong-ovoid nut 6–8 cm × 3–6 cm, with a distinct, raised keel on one side, woody, glossy brown, 1-seeded. Seed oblong-ellipsoid, flattened, c. 3 cm long, brown. Seedling with hypogeal germination; first nodes with pairs of stipules only; first leaves comparatively narrow.



Heritiera littoralis – 1, flowering twig; 2, male flower; 3, female flower; 4, fruit.
Source: PROSEA

Heritiera comprises about 35 species, the majority of which occur in tropical Asia and with *Heritiera littoralis* as the most widespread species. In Africa two other species occur, although these are often considered to belong to a separate genus *Tarrietia*. A distinct subspecies of *Heritiera littoralis* has been described from Madagascar: subsp. *ralima* Arènes, differing in its almost globose fruits on thicker stalks.

The fruits float in water, with the ridge upwards, and the seeds germinate readily in muddy substrates. When washed up on a beach, the flattened base of the fruit weakens, allowing moisture to penetrate. The fruit is split by the extruding thick, hard radicle, which develops into a primary root penetrating deeply into the soil. The primary root branches soon, and subsequently the plumule extrudes. The growth of the branches is rhythmic and the shoots are distinctly articulate.

Ecology *Heritiera littoralis* occurs on the landward side of mangroves, where fresh water mixes with sea water or predominates. It seems intolerant of high salinity. It is sometimes also found on rocky shores, and more often on the banks of tidal rivers.

Management Moth larvae and beetles (*Curculionidae* and *Scolytidae*) may damage seeds of *Heritiera littoralis*. High percentages of seeds may show evidence of borers, and research in Australia showed that very few seeds contain an intact embryo. Seeds are eaten by large crabs, monkeys and wild pigs. Moreover, crabs may damage seedlings.

Genetic resources and breeding *Heritiera littoralis* is extremely widespread and as such not threatened. However, it depends on a habi-

tat type, i.e. mangrove vegetation, that is under much pressure, and in many regions it has become endangered, e.g. in India. Along the coasts of eastern Africa and the Indian Ocean islands it occurs only locally abundantly (e.g. the Tana River delta has the only significant stand in Kenya and in Madagascar *Heritiera littoralis* occurs scattered and has only been recorded as abundant in the Betsiboka River delta).

Prospects It is not expected that the value of *Heritiera littoralis* as a timber tree will increase because the bole is often of too small size and poor shape. Moreover, it occurs in too small quantities to allow cutting on a larger scale.

Major references Arènes, 1959; Lemmens et al., 1993; Tomlinson, 1986; Wild, 1961.

Other references Beentje, 1994; Coates Palgrave, 1983; Das, Mukherjee & Das, 2001; Dharani, 2002; Friedmann, 1987; Gaydou et al., 1993; Geissler et al., 2002; Miles et al., 1991; Miles et al., 1989; Watt & Breyer-Brandwijk, 1962.

Sources of illustration Lemmens et al., 1993.

Authors R.H.M.J. Lemmens

HERITIERA UTILIS (Sprague) Sprague

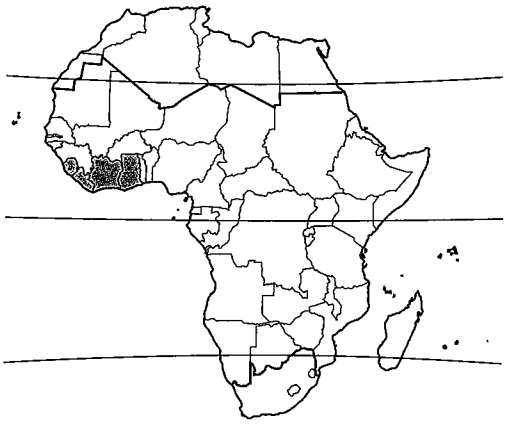
Protologue Bull. Misc. Inf.: 348 (1909).
Family Sterculiaceae (APG: Malvaceae)
Chromosome number $2n = 32$
Synonyms *Tarrietia utilis* (Sprague) Sprague (1916).

Vernacular names Niangon, nyankom, red cedar, cola cedar, whismore (En). Niangon (Fr).

Origin and geographic distribution Niangon is restricted to the West African forest zone, where it occurs from Sierra Leone to Ghana. However, it has been found in some localities in the savanna zone, in remnants of evergreen rain forest, e.g. at the foot of the Loma mountains in Sierra Leone and in riparian forest in the savanna zone in Côte d'Ivoire.

Uses The wood is widely used for exterior and interior joinery, panelling, flooring, moulding, carpentry, furniture, cabinet work, stairs (inside), shipbuilding (planks, deck), and sliced veneer for interior and exterior faces of plywood. Locally, it is popular for making canoes, oars and planks for house building. It has been used for shingles.

The bark has been used for tanning leather. In Côte d'Ivoire the wood is considered to have



Heritiera utilis – wild

antidysenteric properties. The bark also has medicinal applications, a decoction being applied to skin affections caused by leprosy and taken internally as an aphrodisiac. The seeds are reportedly edible; the seed oil is used as an aphrodisiac, whereas ground seeds are applied to abscesses.

Production and international trade Niangon timber has been exported in large quantities for decades, mainly from Côte d'Ivoire. In 1984 exports from Côte d'Ivoire reached a peak of 145,000 m^3, thereafter declining dramatically to 3600 m^3 in 1989, and increasing again to 30,000 m^3 in 1991. By then, however, the logs exported from Côte d'Ivoire originated mainly from forests in Liberia. In 1995 Côte d'Ivoire exported 41,000 m^3 of logs at an average price of US$ 311/m^3, Ghana 5000 m^3 of sawn timber at an average price of US$ 653/m^3, and Liberia 4000 m^3 of logs at an average price of US$ 250/m^3. The timber is mainly exported to countries of the European Union. In 2004 the average free-on-board price of round logs ranged between US$ 250 and US$ 275 per m^3. The volumes exploited constitute 1–2% of the total commercial log production in West Africa.

Properties The heartwood is pale pink to red-brown, usually distinctly demarcated from the whitish sapwood, which is 3–7.5 cm thick. The grain is interlocked, texture moderately coarse. The wood is oily to the touch, and there is a distinct silver grain.

The wood is moderately heavy. The density is (510–)625–700(–750) kg/m^3 at 12% moisture content. The shrinkage rates are moderately high: from green to 12% moisture content

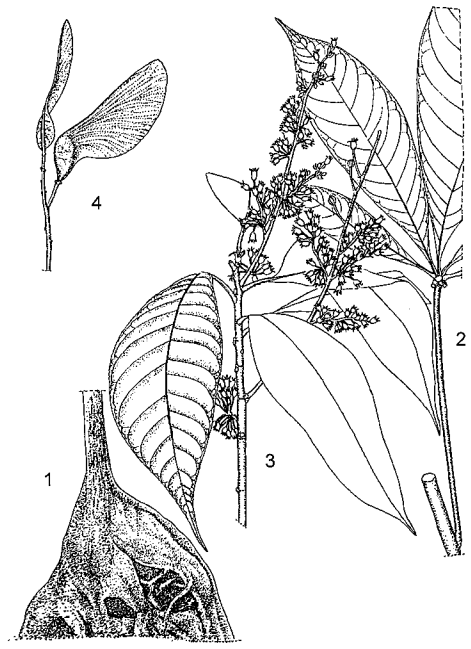
about 2.5% radial and 4.5% tangential, and from green to oven dry 2.9–5.0% radial and 5.9–10.1% tangential. The timber dries fairly easy and fairly rapidly, but often with a tendency to twist and occasional end surface checking. Once dry, it is moderately stable in service.

At 12% moisture content, the modulus of rupture is 74–171 N/mm², modulus of elasticity 9120–14,400 N/mm², compression parallel to grain 38–62 N/mm², shear 4–13 N/mm², cleavage 12–22 N/mm, Janka side hardness 3740–4890 N and Janka end hardness 3740–5330 N. The wood blunts edged tools moderately rapidly due to the presence of interlocked grain, and there is a risk of tearing in machining and of clogging due to the presence of resin. Stellite-tipped sawteeth are recommended. A cutting angle of 15° is recommended when planing to prevent tearing. Peeling is difficult due to irregular logs. Filling is recommended to obtain a good finish. The nailing and screwing properties are good, although splitting may occur. Gluing does not cause problems. The bending properties are moderate, staining and polishing satisfactory.

The heartwood is moderately durable. It is moderately resistant to fungi and termites, but resistant to dry-wood borers; the sapwood is liable to powder-post beetle attack. The heartwood is extremely resistant to preservative treatment. The wood may cause dermatitis, although it is generally considered non-toxic and non-allergenic.

Adulterations and substitutes The woods of *Heritiera densiflora* (Pellegr.) Kosterm. from Gabon and *Heritiera javanica* (Blume) Kosterm. from tropical Asia have similar properties to those of *Heritiera utilis* wood, although they are usually slightly higher in density. Niangon timber is also traded as a substitute for African mahogany (*Entandrophragma* and *Khaya* spp.).

Description Medium-sized to large tree up to 35(–45) m tall; bole cylindrical but often crooked, branchless for up to 20(–30) m, up to 150(–300) cm in diameter, with high, thin and arched buttresses or with stilt-like buttresses (especially well developed in swamp forest); bark pale brown, thin, smooth; crown compact and rounded, with golden to bronze colour when viewed from below. Leaves alternate, simple or digitately compound; stipules c. 0.5 cm long, early caducous; petiole 1–25 cm long; blade 5–30 cm × 2–10 cm in outline, elliptical when simple or with 5–7 leaflets, cuneate at base, acuminate at apex, densely and contiguously bronze scaly hairy below, pinnately veined with 8–18 pairs of lateral veins. Inflorescence an axillary, narrow panicle up to 20 cm long, reddish brown pubescent; bracts c. 1 cm long, caducous. Flowers unisexual, regular, 4–5-merous, whitish or cream-coloured, c. 0.5 cm long; pedicel slender, 0.5–1 cm long; calyx campanulate with lobes about as long as tube, stellately hairy; petals absent; disk annular, orange; male flowers with stamens fused into a column; female flowers with 4–6 carpels united loosely. Fruit consisting of 1–6 woody nuts c. 2.5 cm × 1.5 cm with a large wing c. 8 cm × 3 cm. Seedling with epigeal germination; hypocotyl 10–15 cm long, scaly especially towards apex, epicotyl 2–3 cm long; cotyledons leafy, obovate, 6–7 cm long, 3-veined from the base.



Heritiera utilis – 1, base of bole; 2, part of digitately compound leaf; 3, flowering twig; 4, fruits.
Redrawn and adapted by Iskak Syamsudin

Other botanical information *Heritiera* comprises about 35 species, the majority of which occur in tropical Asia and 3 species in Africa. *Heritiera utilis* is closely related to *Heritiera densiflora* (Pellegr.) Kosterm. from Gabon. The two species should be carefully compared as they are very similar and most of the recorded differences are obscure, e.g. density of

indumentum and length of inflorescences. Both species often have simple leaves, but *Heritiera utilis* may have digitately compound leaves (with leaflets completely free) and *Heritiera densiflora* may have digitately lobed leaves (with lobes distinctly fused at base).

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 25: intervessel pits small (4–7 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; (36: helical thickenings in vessel elements present); (37: helical thickenings throughout body of vessel element); 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 63: fibre pits common in both radial and tangential walls; 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 76: axial parenchyma diffuse; 77: axial parenchyma diffuse-in-aggregates; 79: axial parenchyma vasicentric; 86: axial parenchyma in narrow bands or lines up to three cells wide; (89: axial parenchyma in marginal or in seemingly marginal bands); (90: fusiform parenchyma cells); 91: two cells per parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; (102: ray height > 1 mm); (103: rays of two distinct sizes); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 110: sheath cells present; 114: ≤ 4 rays per mm; 115: 4–12 rays per mm. Storied structure: 120: axial parenchyma and/or vessel elements storied; 121: fibres storied; 122: rays and/or axial elements irregularly storied. Mineral inclusions: (136: prismatic crystals present); (137: prismatic crystals in upright and/or square ray cells); (140: prismatic crystals in chambered upright and/or square ray cells); (142: prismatic crystals in chambered axial parenchyma cells); (154: more than one crystal of about the same size per cell or chamber).
(P. Ng'andwe, H. Beeckman & P.E. Gasson)

Growth and development Seedlings develop a taproot with numerous lateral roots. Seedling leaves are simple until about the tenth leaf, when seedlings are 25–30 cm tall, and subsequently they start developing compound leaves with 3 leaflets until about 50 cm tall. From then on 5-foliolate leaves are formed until the seedling is about 1 m tall and 15 months old, when 7-foliolate leaves may appear. The leaves increase in size until the seedling is 4–5 years old, with leaflets up to 60 cm × 20 cm; after that leaf size decreases. The sapling grows without branching until 5–6 years old and 5–7 m tall. At the same age the stilt-like buttresses may start to develop. Simple leaves develop near the surface of the crown of larger trees. Natural pruning is quite good, but the bole is nevertheless often slightly sinuous, especially in swamp forest.
Niangon is a light demander, but seedlings and saplings can tolerate shade for years and start to grow immediately once the canopy is opened. In Ghana seedling growth rates of 27–65 cm in natural forest and 22.5–90 cm in the nursery have been recorded for the first year. Plantation trees in Sierra Leone showed an average annual diameter growth of 1.7 cm over the first 15 years, and they reached a height of 20 m after 15 years. In plantations without shade trees in Côte d'Ivoire, the average growth is up to 1 m/year during the first 4–5 years, but then accelerates to 2 m/year until 10 years old. In a 62-year-old plantation in Côte d'Ivoire, mean annual bole diameter increment was 1 cm for the largest trees (20% of all trees), but in natural forest it is about 0.4 cm. In plantations the timber can be harvested after 50–60 years, when the boles have attained an average diameter of 50 cm. Trees are evergreen, and new leaves appear twice a year during the rainy seasons, more or less simultaneously in all trees. They flower in October–November and fruit from January to March, which is towards the end of the dry season. Trees start setting fruit when 15–17 years old. The fruits may be dispersed by wind, but they are not very light and do not travel far.

Ecology Niangon occurs in evergreen forest, moist semi-deciduous forest and gallery forest, also in secondary forest, rarely higher than 500 m altitude. It is often found along watercourses and in swamps, being very drought-sensitive. However, trees with best-shaped boles occur on well-drained localities. Niangon occurs in regions with an annual rainfall of 1500–2500 mm. It seems to prefer loamy soils to sandy soils. It has a tendency to patchy occurrence;

locally it is very common, elsewhere it occurs only scattered. Niangon reaches the middle and upper strata of the forest, but is not an emergent tree. In Liberia an average density of 2 trees over 40 cm in bole diameter and 0.5 trees over 60 cm in diameter has been recorded per ha. In Côte d'Ivoire an average of 5 exploitable trees per ha was recorded at the end of the 1950s, but stands have been largely depleted since.

Propagation and planting Niangon is propagated by seed. One kilogramme contains about 1250 seeds. The seeds are recalcitrant and have no dormancy. Germination starts after (2–)3–4 days. Fresh seeds have high germination rates, up to over 80% within 2 weeks. The seed is put into the soil with the wing protruding. Saplings were usually planted in the field when 18–30 months old and 1–1.5 m tall, but nowadays are often already planted out when 8–9 months old and 30–50 cm tall. Potted seedlings, bare-rooted seedlings or striplings are used as planting material. Pruning of lateral roots about one month before transplanting promotes the formation of a dense system of short lateral roots, enhancing the chance of successful establishment in the field. Spacing varies from 3 m × 3 m to 5 m × 5 m, depending on the cropping system (pure plantation, taungya system or agroforestry system). Natural regeneration in the forest may be abundant, especially where the canopy has been disturbed but not entirely removed. In years with few fruits, wildlings are sometimes transplanted to the nursery.

Management Niangon timber is generally produced in natural forest managed under a selective logging system, where logs are removed based on minimum diameter and in a cyclical manner, with or without silvicultural treatment. The minimum diameter varies between countries, ranging from 50 cm in Côte d'Ivoire to 70 cm in Ghana at 1.3 m above ground level or 30 cm above the buttresses. The length of the cutting cycle also varies, ranging from 15 years to 60 years. In Ghana the felling intensity per km^2 is based on the ratio between the number of stems above 70 cm diameter and the number of stems in the 50–69 cm diameter class after a 100% inventory. When the ratio is 1:1, 70% of the stock above 70 cm diameter can be harvested, but generally 50–70% is harvested.

Several planting systems have been tried in Côte d'Ivoire. The first plantations covering about 100 ha were established in 1930. Striplings of 1.5 m tall were planted at 2 m × 2 m in forest in which the undergrowth had been cleared and smaller trees girdled. Subsequently girdling of the canopy trees was practised until 5 years after planting, and thinning was done regularly, resulting in 400–550 niangon trees per ha, with straight and clean boles and an average annual diameter growth of 0.5 cm. This is a labour-intensive method. From 1931 to 1948 about 2700 ha of natural forest was enriched by line planting of niangon. Lines 2 m wide were cut at 10–25 m intervals, trees were poisoned, niangon striplings planted at a spacing of 5 m, weeding was done during the first 5 years as was regular thinning, resulting in about 380 niangon trees per ha. This method is less labour-intensive, but was abandoned because of difficulties with weeding and poisoning. Niangon was sometimes planted in a mixture with other valuable timber species, notably *Khaya ivorensis* A.Chev. Later the taungya system was used to plant about 400 ha of niangon trees, and since 1986 about 180 ha of plantations have been successfully established using seedlings of 30–50 cm tall, planted in full sunlight. In 1950 niangon originating from Côte d'Ivoire was introduced in forest near Kribi, Cameroon.

Diseases and pests Numerous insects may attack niangon, but damage is usually of minor importance. Nursery stock may be attacked by galling insects and top-shoot coleopterous and lepidopterous borers. It has been observed that larvae of the lepidopterous *Anaphe venata* eat the leaves in natural forest, as is the case with several other coleopterous and lepidopterous insects.

Harvesting Timber harvesting is done year-round, but mostly during the dry season. Harvesting involves felling of trees and cross cutting the logs. The logs are skidded to a central log yard using crawlers or wheeled tractors fixed with winches.

Yield Based on forestry practice in Ghana, sustainable harvest of niangon ranges from 5 to 80 stems per km^2, depending on forest type and density of the species. The average merchantable bole volume per tree is 6–7 m^3. The mean annual timber production in niangon plantations in Côte d'Ivoire is 8–14 m^3/ha.

Handling after harvest Logs are debarked soon after felling to prevent attack from powder-post beetles, which lay their eggs under the bark and of which the larvae may attack the sapwood. Spraying with insecticides may also be practised. Fungicides may be applied to

avoid discoloration by stain or decaying fungi. The logs are transported from the log yards to processing mills or log markets using articulated hauling rigs. They are sorted into end use categories, i.e. sawn wood, veneer or export logs, and stacked in piles or put in log ponds. The timber is either exported as round logs if there is no ban on log exports, or processed in local mills into sawn wood, veneer or plywood before export. The products are exported according to specifications demanded by the customer and packaged according to standard shipping rules and regulations.

Genetic resources *Heritiera utilis* is classified on the IUCN red list as vulnerable, being considered at high risk of extinction in the wild in the medium-term future as a result of serious reduction of populations in recent years. In Ghana it is rated as a 'red star species', indicating that current rates of exploitation represent a significant danger of genetic erosion.

Prospects Being an excellent timber but also a red list species, sustainable production of niangon from natural resources will require intensive management. Niangon is a good candidate for plantation establishment and reforestation in the humid evergreen forest zone of West Africa. Although there is already a good deal of experience with plantations in Côte d'Ivoire, more research is needed, especially concerning silvicultural treatments of natural forest, provenance trials and optimal methods of propagation.

Major references Burkill, 2000; Chudnoff, 1980; CIRAD Forestry Department, 2003; Dupuy & Chézeaux, 1994; Holmgren et al., 2004; Richter & Dallwitz, 2000; Voorhoeve, 1979.

Other references Abbiw, 1990; Aubréville, 1959a; Brunck, 1994; InsideWood, undated; Takahashi, 1978.

Sources of illustration Voorhoeve, 1979.

Authors K.A. Adam

HIBISCUS LASIOCOCCUS Baill.

Protologue Bull. Mens. Soc. Linn. Paris 1: 511 (1885).

Family Malvaceae

Synonyms *Hibiscus domatiocarpus* Hochr. (1925).

Origin and geographic distribution *Hibiscus lasiococcus* is endemic to eastern Madagascar.

Uses The wood, known as 'alampona', is locally used for furniture and logs are made into dug-out canoes. The wood is considered suitable for light construction, light carpentry, interior trim, ship and boat building, furniture, cabinet work, shuttering, boxes, crates, carvings, toys, novelties, model building, food containers, veneer, plywood, blockboard core and particle board. The durable bast fibre is woven into 'lamba' cloth and made into cordage. It is suitable for fishing nets.

Hibiscus lasiococcus – wild and planted

Properties The heartwood is beige to pale brown, sometimes yellow; it is sharply demarcated from the up to 5 cm wide, whitish sapwood. The grain is usually straight, texture medium. The wood is sometimes streaked or veined, and it has a pepper-like odour when freshly cut.

The wood is lightweight, with a density of (240–)380–450 kg/m³ at 12% moisture content. It air dries rapidly without deformation or checking. The rates of shrinkage from green to oven dry are moderate: (2.2–)3.2–3.9% radial and (4.1–)6.0–6.9% tangential. The wood is moderately stable in service.

The wood is flexible, tough and soft. At 12% moisture content, the modulus of rupture is 85–97 N/mm², modulus of elasticity 6600–9400 N/mm², compression parallel to grain 32–40 N/mm², shear 6–7 N/mm², cleavage 8–15 N/mm and Chalais-Meudon side hardness 1.2–1.6.

Working properties are good with all tools and the wood saws easily. It planes to a surface with a nice lustre. It peels well, but slicing is advisable because of the brittle or hollow centre of the log. The wood glues, nails and screws well, with good holding power.

The durability is low. A single test indicated resistance to termites, but this needs confirma-

tion. The resistance to attacks by other insects and by fungi is very poor. The sapwood is susceptible to *Lyctus* borers. Both heartwood and sapwood are permeable to preservatives.

Description Small to medium-sized tree up to 20(–25) m tall; bole up to 60(–120) cm in diameter; branchlets brown hairy. Leaves alternate, simple and entire; stipules small, deciduous; petiole shorter than blade, brown hairy; blade broadly ovate-circular, more or less 3-angular, 7–12.5 cm × 7–13.5 cm, rounded to slightly cordate at base, leathery, almost glabrous above, hairy below, palmately 7-veined. Flowers solitary in leaf axils, bisexual, regular, 5-merous, large; involucre of 9 bracts c. 1.5 cm long, connected to calyx for c. 1 cm, reddish hairy; calyx short-lobed, c. 2 cm × 2.5 cm, reddish hairy outside, densely silky inside, persistent; petals obovate, up to 6 cm long, densely hairy outside, yellowish; stamens numerous, united into a column up to 7 cm long fused to the base of the petals, anthers c. 2.5 mm long; ovary superior, 5-celled, style with 5 branches, stigmas head-shaped, large. Fruit a globose to obovoid capsule c. 3 cm in diameter, hairy, 5-celled, many-seeded. Seeds with many long hairs.

Hibiscus lasiococcus – 1, flowering twig; 2, fruit; 3, seed.
Redrawn and adapted by R.H.M.J. Lemmens

Other botanical information *Hibiscus* comprises 200–300 species, mainly in the tropics and subtropics; many of them grown as ornamentals. The estimated number of species varies because opinions differ about inclusion in the genus of several related groups of species. In Madagascar about 45 species can be found.
The wood of *Hibiscus boryanus* DC. ('foulsapate marron', 'mahot bâtard'), a rare shrub or small tree up to 8 m tall with a bole up to 20 cm in diameter, endemic to Réunion and Mauritius, was formerly used in construction. A tea from the leaves was taken against cough and the leaves were used in a bath against kidney pain.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: (4: wood semi-ring-porous); 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 25: intervessel pits small (4–7 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 68: fibres very thin-walled; 69: fibres thin- to thick-walled. Axial parenchyma: 76: axial parenchyma diffuse; 77: axial parenchyma diffuse-in-aggregates; 78: axial parenchyma scanty paratracheal; (89: axial parenchyma in marginal or in seemingly marginal bands); 90: fusiform parenchyma cells; 91: two cells per parenchyma strand; (92: four (3–4) cells per parenchyma strand). Rays: (97: ray width 1–3 cells); (98: larger rays commonly 4- to 10-seriate); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 110: sheath cells present; 115: 4–12 rays per mm. Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells.
(P. Mugabi, A.A. Oteng-Amoako, P. Baas & P. Détienne)

Growth and development Fast growth has been observed in plantations, with 2-year-old plants reaching a height of 4–5 m, 10-year-old plants a height of 10–12 m and a bole diameter

of 12–15 cm, and 14-year-old trees a height of 16–18 m and a bole diameter of 18–25 cm. Flowering is in August–October, fruiting in November.

Ecology *Hibiscus lasiococcus* occurs scattered in forest in eastern Madagascar, up to 1000 m altitude.

Management Little information is available on appropriate planting and management techniques. In Madagascar at least 13 ha were planted at the beginning of the 1960s, at a spacing of 3 m × 3 m after clear cutting of the natural vegetation. Early growth was homogenous and fast, the form of the boles was good and natural pruning very satisfactory. In 1951–1955 some enrichment plantings were carried out successfully in forest paths. The centre of large boles is often hollow or providing wood of low quality.

Genetic resources *Hibiscus lasiococcus* is confined to eastern Madagascar, where it only occurs scattered, so there may be some risk of genetic erosion.

Prospects The wood of *Hibiscus lasiococcus* is not much used, because of its softness and the scattered occurrence of the tree. The species deserves more research on plantation techniques, because it grows fast and the wood has good physical properties.

Major references Bolza & Keating, 1972; Guéneau, Bedel & Thiel, 1970–1975; Guéneau & Guéneau, 1969; Sallenave, 1964; Sallenave, 1971.

Other references Aubert, Rafidinarivo & Razafiarison, 1996; Boiteau, Boiteau & Allorge-Boiteau, 1999; Cailliez & Guéneau, 1972; Gachet, 1965; Guéneau, 1963; Guéneau, 1971; Hochreutiner, 1955; InsideWood, undated; Marais & Friedmann, 1987; Schatz, 2001; Vololomboahangy, 2004.

Sources of illustration Hochreutiner, 1955.

Authors M. Brink

HILDEGARDIA ERYTHROSIPHON (Baill.) Kosterm.

Protologue Bull. Jard. Bot. Etat 24(4): 338 (1954).

Family Sterculiaceae (APG: Malvaceae)

Vernacular names Vinoa, vonoa (Fr).

Origin and geographic distribution *Hildegardia erythrosiphon* is native to western Madagascar, where it occurs scattered over a large area.

Uses The wood of *Hildegardia erythrosiphon* is sometimes used in traditional boat building. It could be useful for heat and sound insulation, for scale modelling and as core for slatted panels.

Properties The heartwood of *Hildegardia erythrosiphon* is whitish and not distinct from the 3–4 cm wide sapwood. The grain is straight, texture coarse. The wood is soft and very light, with a density of 170–340 kg/m^3 at 12% moisture content. The wood dries rapidly, with slight risk of distortion; shrinkage rates are low. The wood is stable when dried and easy to saw. It is not durable, but easy to treat with preservatives.

Botany Small to medium-sized tree up to 20 m tall; bole up to 150 cm in diameter, swollen; outer bark rather smooth, blackish or greyish, more or less striate, inner bark 2–3 cm thick, fibrous; crown globose; branches cylindrical, short, horizontal. Leaves alternate, simple, entire or 3–5-lobed; petiole up to 25 cm long, glabrous; blade orbicular in outline, 5–26 cm × 4.5–25 cm, base cordate, apex obtuse to acuminate, margin revolute, lower surface densely covered with whitish stellate hairs, upper surface glabrous, basal veins 7–9. Inflorescence a raceme grouped in pseudo-umbels at the end of leafless branches. Flowers bisexual or male, regular; pedicel glabrous, jointed; calyx persistent, red, 5-lobed with 5–8 mm long lobes; petals absent; stamens 10–20 on top of a long, slender androgynophore, anthers sessile; ovary superior, consisting of 5 free carpels on top of androgynophore. Fruit consisting of 1–5 samaras inserted on the top of the androgynophore; samaras 5–11 cm × 1.5–4 cm, stiped, with a large, veined membranous wing, 1-seeded. *Hildegardia erythrosiphon* flowers before the leaves appear.

Hildegardia comprises 11 species, 3 each from mainland Africa and Madagascar, and 1 each from India, Indonesia, the Philippines, Australia and Cuba. *Hildegardia erythrosiphon* is variable and has been subdivided into several subspecies and varieties.

Ecology *Hildegardia erythrosiphon* occurs in dry forest and thickets up to 600 m altitude, on calcareous, gneissic or sandy soils.

Genetic resources and breeding Although the distribution area of *Hildegardia erythrosiphon* in Madagascar is rather large, it may be endangered by overgrazing and habitat destruction. It is not, however, included in the IUCN red list of threatened species.

Prospects The properties of the wood of *Hildegardia erythrosiphon* (low weight, softness,

low durability) limit its usefulness to very specific uses. It may be a good substitute for balsa wood (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) especially for insulation purposes and modelling. With good promotion, demand for the wood may increase.

Major references Arènes, 1959; Guéneau, Bedel & Thiel, 1970–1975.

Other references Cheek & Leach, 1994; Kostermans, 1954; Kostermans, 1960; Parant, Chichignoud & Rakotovao, 1985; Schatz, 2001.

Authors M. Brink

HYPODAPHNIS ZENKERI (Engl.) Stapf

Protologue Dyer, Fl. trop. Afr. 6(1): 185 (1909).

Family Lauraceae

Origin and geographic distribution *Hypodaphnis zenkeri* is distributed in southern Nigeria, Cameroon and Gabon.

Uses The heartwood is of good quality. In Cameroon the bark is used as a spice in traditional sauces; it is locally sold on markets under the name 'écorce rouge'.

Properties The heartwood is grey to dark chestnut brown, the sapwood is white or pale yellow. The air-dried wood has a density of less than 650 kg/m^3. The wood is easy to work. Bark obtained from the market contained 10% moisture; per 100 g dry matter it contained: protein 2.7 g, fat 3.4 g, carbohydrate 33 g, fibre 42 g, Ca 790 mg, Mg 814 mg, P 29 mg, Fe 0.4 mg and Zn 2 mg.

Botany Small tree up to 15(–20) m tall; bole often twisted, up to 60 cm in diameter; bark surface dark grey or blackish brown, usually smooth, but sometimes rough and scaly, inner bark pale cream coloured, fibrous; crown bushy, dark green; branches reddish hairy when young, becoming glabrous when older. Leaves alternate, simple and entire; stipules absent; petiole up to 5 cm long; blade elliptical to obovate, 12–30 cm × 6–15 cm, base shortly cuneate, apex acuminate, papery, upper surface slightly shiny, green, lower surface dull, paler green, pinnately veined with 4–6 pairs of lateral veins. Inflorescence an axillary, umbel-like panicle 3–8 cm long, reddish hairy, many-flowered; bracts caducous. Flowers bisexual, regular, yellowish, orange-yellow or brown, reddish hairy; perianth cup-shaped, c. 4 mm long, with 6 lobes; stamens in 3 whorls, with basal glands, staminodes absent; ovary inferior. Fruit an ovoid drupe up to 6 cm × 5 cm, 1-seeded. Seed 3–3.5 cm long.

In Nigeria *Hypodaphnis zenkeri* flowers from February–July, and fruits from May–November; in Gabon flowering is from March–April and fruiting in August. *Hypodaphnis zenkeri* trees have vesicular-arbuscular mycorrhizae.

Hypodaphnis comprises a single species. Within the *Lauraceae*, it is characterized by its inferior ovary.

Ecology *Hypodaphnis zenkeri* occurs in the lower storey of lowland rainforest. In the Lopé reserve (Gabon) it occurs as isolated individuals, locally becoming quite common.

Genetic resources and breeding It is unclear to what extent *Hypodaphnis zenkeri* is threatened by genetic erosion.

Prospects *Hypodaphnis zenkeri* provides a good-quality timber, but detailed information on its wood properties is lacking, as is information on its actual use.

Major references Burkill, 1995; Fouilloy, 1974; Keay, 1989; Normand & Paquis, 1976; Tchiégang & Mbougueng, 2005.

Other references Fouilloy, 1965; Keay, 1954b; Newbery et al., 1988; Raponda-Walker & Sillans, 1961; White & Abernethy, 1997.

Authors M. Brink

JUNIPERUS BERMUDIANA L.

Protologue Sp. pl. 2: 1039 (1753).

Family Cupressaceae

Vernacular names Bermuda cedar, Bermuda red cedar (En). Cedro das Bermudas (Po).

Origin and geographic distribution *Juniperus bermudiana* originates from Bermuda and is occasionally grown elsewhere, e.g. in the Mascarene islands. It is fairly often planted in Réunion and Mauritius, somewhat less often in Rodrigues; it has sometimes become naturalized. *Juniperus bermudiana* is also recorded as being sold in nurseries in Harare (Zimbabwe).

Uses The wood of *Juniperus bermudiana* is used in carpentry in the Mascarene islands. In Bermuda it was formerly much used for ship and house building, joinery and cabinet work, but large trees have become scarce, and the wood is now mainly used for making furniture and souvenirs, and as firewood.

In the Mascarene islands *Juniperus bermudiana* is planted as an ornamental. A decoction of the leafy branches is taken to treat cough; the leafy branches are also applied in steam baths for inhalation against respiratory diseases.

Properties The wood is generally knotty, due to the branching habit of the tree and lack of pruning. It has an attractive colour and a sweet scent. The grain is often irregular due to the knots, making it unsuitable for pencil-making. An ethanol extract of the twigs and leaves of *Juniperus bermudiana* has shown antitumour activity due to the presence of the lignan deoxypodophyllotoxin.

Botany Evergreen, dioecious, small tree up to 12(–15) m tall; bole up to 60 cm in diameter; outer bark thin, exfoliating in strips, red-brown becoming grey-brown; crown pyramidal in young trees, spreading or flat-topped in older ones; branches spreading or ascending. Leaves on ultimate branchlets decussately opposite, on some leading branches in alternating whorls of 3, scale-like, on ultimate branchlets ovate-rhombic to rhombic-lanceolate, 1.5–2.5 mm × 1–1.5 mm, apex obtuse to acute, margin entire, green. Male cone terminal on ultimate branchlets, oblong-cylindrical, more or less quadrangular, 4–6 mm × 2–3 mm, yellowish green when young, yellowish brown to pale brown when mature; scales 12–16, decussately opposite, peltate, each bearing 4–6 flattened pollen sacs. Female cone terminal on erect ultimate branchlets, mature one irregularly globose or pear-shaped to almost kidney-shaped, 4–6 mm × 5–8 mm, pulpy, resinous, pruinose-blue or dark purplish blue, 1–2(–3)-seeded; scales 6, decussately opposite, fused. Seeds ovoid-globose, 2–3 mm long, more or less keeled, lustrous brown.

Juniperus comprises about 50 species and is very widespread in subtropical and temperate regions of the Northern Hemisphere, with some species in tropical mountains.

Ecology In Bermuda *Juniperus bermudiana* occurs near sea-level, on sandy soils and limestone rocks.

Management Germination takes 3–6 months; growth during the first 10 years is slow. In Mauritius *Juniperus bermudiana* is attacked by the aphid *Cinara cupressi*, which damages the terminal growing points, thus retarding new growth, causing desiccation of stems, and progressive die-back. The aphids are easily transported on planting stock, and can multiply rapidly.

Genetic resources and breeding In Bermuda the once extensive and dominating stands have been decimated by overexploitation, introduction of exotic species and epidemics of accidentally introduced scale insects. *Juniperus bermudiana* is classified as critically endangered in the 2006 IUCN Red list of threatened species.

Prospects Little is known on the wood properties of *Juniperus bermudiana*, but its quality seems not as high as that of the well-known East African cedar (*Juniperus procera* Hochst. ex Endl.), which is widely used in East and southern Africa. Therefore, and in view of its limited distribution, its importance as a source of timber in tropical Africa is unlikely to increase.

Major references Farjon, 2005; Groves, 1955; Gurib-Fakim, Guého & Bissoondoyal, 1996; Marais, 1997a; Walker, 1998.

Other references Alleck & Seewooruthun, 2001/2002; Conifer Specialist Group, 1998a; Mullin, 2000; Tammami, Torrance & Cole, 1977.

Authors M. Brink

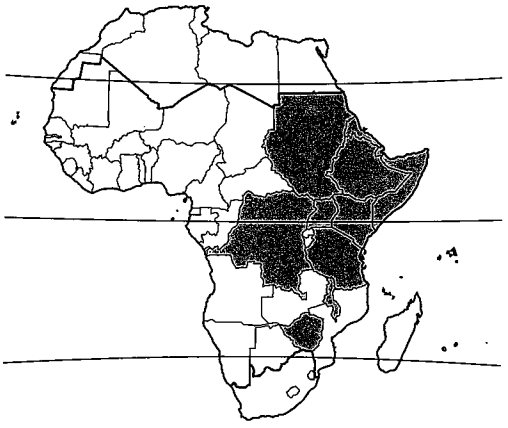
JUNIPERUS PROCERA Hochst. ex Endl.

Protologue Syn. conif.: 26 (1847).

Family Cupressaceae

Vernacular names African pencil cedar, East African cedar, East African juniper, pencil cedar (En). Genévrier d'Afrique, genévrier d'Abyssinie (Fr). Mwangati (Sw).

Origin and geographic distribution *Juniperus procera* occurs wild from Sudan, Eritrea and Ethiopia southwards through East Africa and eastern DR Congo to Malawi and Zimbabwe; it also occurs wild in Saudi Arabia and Yemen. It is grown in plantations in its native range and elsewhere, including South Africa, France, the United Kingdom, the United States, India and Australia.



Juniperus procera – wild

Uses The wood of *Juniperus procera* (trade name: African pencil cedar) is widely used for building (both construction and lining), joinery, flooring (strip and parquet), furniture and all sorts of outdoor work such as roofing shingles, fence posts, water flumes and transmission poles. In Kenya the wood is also used for making fire sticks, beehives and salt-troughs. *Juniperus procera* wood was exported to Europe and North America for the manufacture of pencils and penholders, while small quantities were used for wardrobe linings. It is also suitable for ship and boat building, agricultural implements, musical instruments, carving, vats, toys and novelties, turnery, draining boards and food containers. It can be used for making veneer and plywood, hardboard and particle board, and as pulpwood. The wood is used as firewood and to make charcoal.

The bark is used for roof shingles and for covering beehives. Essential oil distilled mainly from the sawdust ('cedar wood oil', 'cedar oil') is used in the cosmetic industry in soaps and perfumes. Since *Juniperus procera* can grow in extreme conditions, it is replanted in deforested areas for soil conservation or improvement and for erosion control, e.g. in Eritrea, Ethiopia and Kenya. It is also a useful shade tree, and is frequently planted as an ornamental tree and in windbreaks.

In traditional African medicine, an infusion of ground young twigs is taken against intestinal worms. People with rheumatism are treated by exposure to the smoke of burnt twigs and seed cones. The smoke is also inhaled as an expectorant. Ground dried leaves are applied on wounds of humans and animals. A hot bath to which the leaves are added is used in the treatment of fever. The resin is used as a stimulant and applied to ulcers. Bark macerations are drunk and applied as a vaginal wash as birth-control agents. A decoction of the seed cones is used as a sudorific and emmenagogue. In veterinary medicine, chopped and finely ground leaves mixed with water are used as a drench for horses and mules with stomach disorders, whereas a decoction of dry young branches is a medicine against itch of camels.

Juniperus procera has ceremonial and religious significance, as in some parts of Ethiopia, where it is used especially in September during the traditional orthodox ceremony of Meskel.

Production and international trade There was formerly considerable overseas trade in African pencil cedar: in 1910, for instance, 31,000 logs were exported from East Africa to Germany. Later the wood of *Juniperus procera* was exported to Europe and North America in the form of slats for the production of pencils and other articles, but these exports have ceased. Cedar wood oil has also been exported.

Properties The heartwood is pale red, yellow-brown or purple-red when freshly cut, turning reddish brown on exposure; it is well demarcated from the cream-coloured or white sapwood, which is up to 2.5 cm wide in mature trees. The grain is usually straight, texture fine and even. The wood is very fragrant, with a characteristic and persistent aromatic cedar smell. Ingrown bark, spiral grain and compression wood are common defects. The wood is liable to bleach in the sun and is sometimes streaked with zones of darker and lighter colour which produce an attractive figure.

The wood is medium-weight, with a density of 510–670 kg/m^3 at 12% moisture content. It seasons well when dried with care, but larger pieces are liable to end-splitting and surface-checking, and the wood should not be allowed to dry rapidly in the initial stages. Kiln drying is preferable. The rates of shrinkage from green to 12% moisture content are 2.0% radial and 3.0% tangential, and from green to oven dry 3.3% radial and 5.0% tangential. Once seasoned, the wood is very stable; thus movement in service is small. At 12% moisture content, the modulus of rupture is 86 N/mm^2, modulus of elasticity 8925 N/mm^2, compression parallel to grain 38 N/mm^2, shear 10.3 N/mm^2 and Janka side hardness 1910 N.

The wood is easy to work with hand and machine tools, although it is rather brittle and fissile, tending to break and chip on drilling and mortising. It can split on nailing and screwing, and pre-boring is necessary. The wood glues, stains and polishes well.

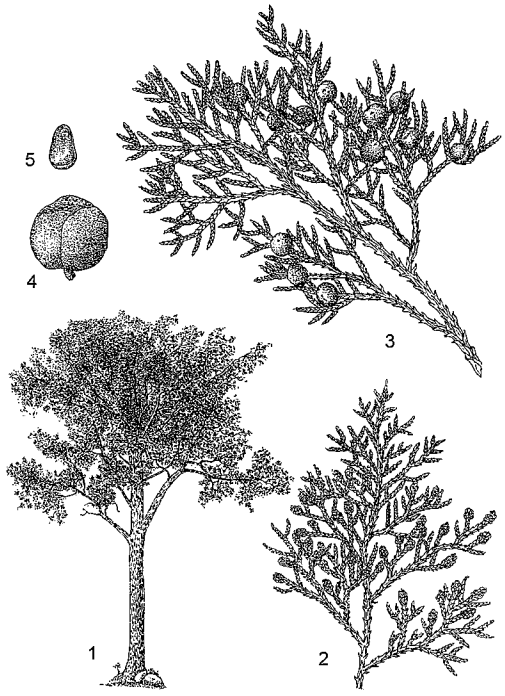
The durability is high, also in the ground. The heartwood is resistant to fungi, termites and most borers except *Oemida gahani*. The sapwood is not susceptible to attack by *Lyctus* beetles. The heartwood is impermeable to preservatives, and only thin material can be sufficiently impregnated; the sapwood, however, is permeable.

The wood burns evenly when fresh, but fast, and the charcoal does not last long. The wood contains 0.5–3% essential oil, with as most important component cedrol (23–79%). Cedrol is known to have antitermite effects. Essential oil from the leaves has shown antioxidant activity. The leaves and bark contain diterpenes with antibacterial activity. The butanol frac-

tion of an ethanol extract of the bark has shown anti-implantation activity in rats. The bark contains about 3.5% tannin.

Adulterations and substitutes The properties of the wood of African pencil cedar are quite similar to those of 'podo' (*Afrocarpus* and *Podocarpus* spp.).

Description Large, evergreen, usually dioecious tree up to 40(–50) m tall; bole branchless for up to 20 m, straight, tapered, up to 200(–300) cm in diameter, often fluted; outer bark fissured, exfoliating in long narrow papery strips, pale brown weathering grey-brown; crown pyramidal in young trees, wide-spreading and flat-topped in older ones; branches spreading or ascending. Leaves decussately opposite, simple, scale-like, on ultimate branchlets triangular-rhombic, 0.5–1 mm × c. 0.5 mm, acute, on older branches lanceolate-acute and up to 6 mm long, margin entire, yellowish green to pale green. Male cone terminal on short branchlets, solitary, globose to ovoid, 2–5 mm × 1.5–3 mm, yellowish or green when young, orange-brown when mature; scales 10–12(–14), decussately opposite, peltate, each bearing (1–)2–3(–4) pollen sacs. Female cone terminal on short erect branchlets, mature one berry-like, globose, 3–7(–8.5) mm in diameter, brown, blue or purplish black, usually glaucous or pruinose, (1–)2–3(–6)-seeded; scales 4(–6), decussately opposite, fused. Seeds angular-ovoid, one side more or less flattened, 3.5–5.5 mm × 2–4 mm, yellowish brown.



Juniperus procera – 1, tree habit; 2, branchlet with male cones; 3, branchlet with female cones; 4, seed cone; 5, seed.
Redrawn and adapted by Iskak Syamsudin

Other botanical information *Juniperus* comprises about 50 species and is very widespread in subtropical and temperate regions of the Northern Hemisphere, with some species in tropical mountains. *Juniperus procera* is the largest tree in the genus. *Juniperus procera* is closely related to *Juniperus excelsa* Bieb., distributed in Europe and temperate Asia. The 2 species have sometimes been treated as conspecific, but this view is not widely accepted.

Anatomy Wood-anatomical description (IAWA softwood codes):
Growth rings: (40: growth ring boundaries distinct); (41: growth ring boundaries indistinct or absent); 43: transition from earlywood to latewood gradual. Tracheids: 44: tracheid pitting in radial walls (predominantly) uniseriate (earlywood only); 54: latewood tracheids thin-walled (double wall thickness less than radial lumen diameter); 56: torus present (pits in earlywood tracheids only). Axial parenchyma: 72: axial parenchyma present; 78: transverse end walls beaded or nodular. Ray composition: 80: ray tracheids absent or very rare; 85: end walls of ray parenchyma cells smooth (unpitted); 87: horizontal walls of ray parenchyma cells smooth (unpitted). Cross-field pitting: 93: cross-field pits cupressoid; 98: 1–3 pits per cross-field (earlywood only). Ray size: 102: average ray height very low (≤ 4 cells); 103: average ray height medium (5–15 cells); 107: ray width exclusively uniseriate.
(P. Baas & I. Heinz)

Growth and development Growth of *Juniperus procera* is slow. In Ethiopia 10–15-year-old plantation trees were 6–9 m tall, with a bole diameter of 8–16 cm, whereas 30–40-year-old plantation trees were 17–21 m tall, with a bole diameter of 16–29 cm. In a 200-year-old stand, the trees were 37.5 m tall, with a bole diameter of 107 cm. In the Usambara mountains in Tanzania (altitude 1450 m, average annual temperature 18°C, average annual rainfall 1070 mm) 61-year-old *Juniperus procera* trees in a density of 182 trees/ha had an average height of 32.5 m and an average bole diameter of 47 cm. The standing volume was 247 m^3 per ha. A naturally regenerated 15-

year-old stand in Kenya, result of an earlier fire, had an average tree height of 14.7 m and an average bole diameter of 23 cm; 35 years later the trees in this stand (density 262 stems/ha) had an average height of 23.5 m and an average bole diameter of 39 cm. In a 41-year-old plantation in Burundi, trees had an average height of 24 m and an average bole diameter of 29.5 cm (range 19–50 cm).

Juniperus procera has irregular flowering and fruiting periods, only flowering once every several years. It is wind pollinated and seeds are dispersed by birds. *Juniperus procera* is assumed to be deep-rooting, like other *Juniperus* spp., but the characteristics of its root system are poorly known.

Ecology *Juniperus procera* is a highland species and prefers cold high ridges. It is commonly found between 1800 m and 2800 m altitude, but occurs in a broader range of 1000–3500 m, with an average annual temperature range from 5°C to 20°C. Average annual rainfall in the forest belt with much *Juniperus procera* is 1000–1400 mm, but the tree can grow in a wide range of rainfall zones (300–2000 mm/year). Individual trees can survive in hot and dry conditions, once established, but in areas with low rainfall, the trees are generally of poor form and small size. Where rainfall exceeds 1400 mm/year, the forests dominated by *Juniperus procera* are gradually replaced by moister types of evergreen forest in which *Juniperus procera* becomes increasingly rare. *Juniperus procera* prefers rocky soils, with a light to medium texture and free drainage.

Juniperus procera is a characteristic tree of the undifferentiated and dry Afromontane forest types, but can also occur in forests transitional between dry Afromontane forest and semi-evergreen bushland and thicket. The understorey of *Juniperus procera* forest is usually a dense, evergreen mix of shrubs and herbaceous plants. The trees are sometimes covered with mosses and lichens. Climbers are common (the large liana *Toddalia asiatica* (L.) Lam. is very frequent) and epiphytic figs are occasionally found. *Juniperus procera* is a prolific seed-bearer and the seeds, though sometimes damaged by seed-boring insects, are usually fertile. However, no regeneration is observed in mature juniper forests as young seedlings are very light demanding and absolutely intolerant of any decomposing organic matter covering the ground. Therefore the seeds can only germinate freely in open, grassed areas or among shrubs, such as in glades or forest edges, with adequate light and mineral soils. Consequently, *Juniperus procera* forests can only develop in two principal ways: either saplings are found growing under the shelter of bushes at forest edges, or natural regeneration occurs after a fire or in large clearings of other origin, giving rise to usually very dense, even-aged stands of trees with long, branch-free boles. Due to these strict requirements, artificial regeneration appears to be the easiest and fastest way to maintain *Juniperus procera* forests.

Propagation and planting *Juniperus procera* is easily propagated by seed. The 1000-seed weight is 20–30 g. Seeds can be obtained by collecting seed cones from the tree, spreading them on a floor to dry, crushing them with mortar and pestle, and separating the seeds by sieving and winnowing. The seed stores well. The optimum temperature for germination is around 20°C; germination is better in light than in the dark. The germination rate in nurseries is usually 40% after 6 weeks, but considerable variation has been found in seed and germination characteristics of *Juniperus procera*. Germination can be enhanced by pretreatment with hot water, concentrated sulphuric acid or scorching. Seedlings are ready to be planted out when 1–2 years old and 15–25 cm tall. Relatively dense spacing is required, preferably 1.2–2 m × 1.2–2 m, to promote self-pruning in the extremely branchy thicket-stage. Wildlings are also used for planting. Under conditions in which *Juniperus procera* readily regenerates, stand establishment by direct sowing may even be applicable.

Vegetative propagation of *Juniperus procera* is possible: stecklings (rooted cuttings) with well-developed root systems easily establish and grow well. In experiments, rooting was best in cuttings from young plants (5 months old), but somewhat older plants (10–15 months) yield more cuttings. Rooting in cuttings from mature trees is poor.

Management In plantations, weeding should be done during the rainy season at least once a year during the early growth stages. Pruning is an important management operation which can significantly increase the timber production of a stand, although the presence of wounds in which the heartwood is exposed increases the risk of damage by the wood-rot fungus *Fomes juniperinus*. Pruning should start 3–6 years after planting. Early selective thinning, starting in the 5th year, is also recommended to enhance crown development and diameter growth. Litter fallen from the tree

makes the soil acidic, so *Juniperus procera* should not be intercropped with crops.

Diseases and pests *Juniperus procera* is subject to serious attacks by the wood-rot fungus *Fomes juniperinus*. The fungus creates cavities of various sizes, and in the case of serious infestation a large tree may be reduced to a mere shell. Mature trees or trees growing in humid locations almost always contain at least some heart rot. The fungus cannot survive in dead trees. Measures to reduce damage by *Fomes juniperinus* include strict protection from fire and other injury, maintenance of dense stands to favour natural pruning while trees are still young (before heartwood formation), periodical thinning of all stems with broken branches or wounds in which the heartwood is exposed, and removal of stems already attacked by the fungus. The tree is also affected by *Rhynchosphaeria cupressi*, causing stem and branch canker.

Juniperus procera is damaged by the cypress aphid (*Cinara cupressi*), but not as severely as *Cupressus lusitanica* Mill.

Harvesting The production of suitable logs for the sawn wood and veneer market may be possible with a rotation period of 70–100 years.

Yield The growth of plantations ranges from 3.5 to 13 m^3/ha/year, averaging 7.5 m^3/ha/year, considerably less than that of some exotic species on the same sites, e.g. 50 m^3/ha/year for *Eucalyptus globulus* Labill.

Genetic resources In spite of its wide distribution, *Juniperus procera* is mentioned in the 2006 IUCN Red list of threatened species, although in the lower risk category. Overexploitation, changing land use patterns, browsing (particularly by buffalo and elephants) and the increasing populations of fast-growing exotic species are contributing to the decline of *Juniperus procera*. Populations in Ethiopia and Kenya are of wide extent, but outlying populations in Zimbabwe, DR Congo and Malawi are extremely small and threatened. The single wild *Juniperus procera* tree specimen known in Zimbabwe is protected.

Prospects *Juniperus procera* has favourable attributes for employment as a plantation species: it is able to adapt to extreme climatic conditions and it produces high-quality timber. However, its slow growth, coupled with fluting of the bole and poor survival in the field due to attacks by heart rot, has discouraged cultivation in its native range. Replanting to convert poor sites into woodland is carried out in deforested areas, e.g. in Eritrea, Ethiopia and Kenya. However, this practice is limited, mainly because it does not provide direct income to the countries concerned. In general it is likely that in plantation forestry continued preference will be given to species that grow faster than *Juniperus procera*.

Major references Chalk, Burtt Davy & Desch, 1932; Couralet et al., 2005; Eggeling & Dale, 1951; Farjon, 2005; Friis, 1992; Jansen, 1981; Maundu & Tengnäs, 2005; Pohjonen & Pukkala, 1992; Teketay, 1997; World Agroforestry Centre, undated.

Other references Akeng'a & Chhabra, 1997; Berhe & Negash, 1998; Bolza & Keating, 1972; Borota, 1979; Bryce, 1967; Dale & Greenway, 1961; Desta, 1994; Farjon, 1992; Gilbert & Bellefontaine, 1973; Heinz, 2004; Kigomo, 1985a; Kinyanjui, Gitu & Kamau, 2000; Kokwaro, 1993; Kollert & Teshome, 1997; Mamo et al., 2006; Mossa, el-Feraly & Muhammad, 2004; Negash, 2002; Neuwinger, 2000; Takahashi, 1978; Teketay & Granstrom, 1997; Wimbush, 1957.

Sources of illustration Farjon, 2005.

Authors C. Couralet & H. Bakamwesiga

KHAYA ANTHOTHECA (Welw.) C.DC.

Protologue Monogr. phan. 1: 721 (1878).

Family Meliaceae

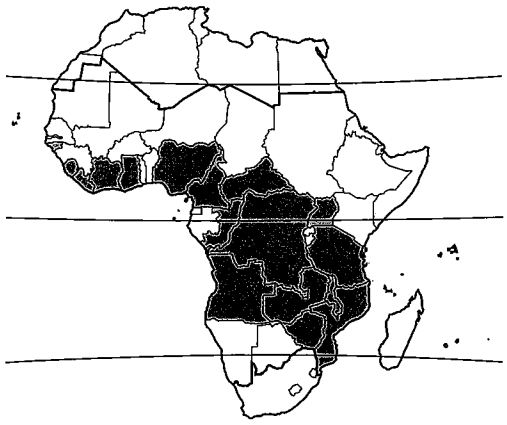
Chromosome number $2n = 50$

Synonyms *Khaya nyasica* Stapf ex Baker f. (1911).

Vernacular names Smooth-barked mahogany, white mahogany, red mahogany, Uganda mahogany (En). Acajou blanc, acajou à peau lisse (Fr). Acaju branco, acaju de casca lisa, kibaba de Mussengue (Po). Mkangazi, mwovu, nyalulasi, linjo (Sw).

Origin and geographic distribution *Khaya anthotheca* is widespread, from Guinea Bissau east to Uganda and Tanzania, and south to Angola, Zambia, Zimbabwe and Mozambique. It is fairly widely grown in plantations within its natural area of distribution, but also in South Africa, tropical Asia and tropical America.

Uses The wood (trade names: African mahogany, acajou d'Afrique) is highly valued for furniture, cabinet work, decorative boxes and cases and veneer, and is also commonly used for window frames, panelling, doors and staircases. It is suitable for light flooring, ship building, vehicle bodies, sporting goods, musical instruments, toys, novelties, carving, ply-



Khaya anthotheca – wild

wood and pulpwood. Traditionally, the wood is used for dugout canoes. It is also used as fuelwood and for charcoal production.

The bitter-tasting bark is widely used in traditional medicine. It is taken to treat cough, whereas bark decoctions or infusions are taken to treat fever, colds, pneumonia, abdominal pain, vomiting and gonorrhoea, and applied externally to wounds, sores and ulcers. Pulverized bark is taken as aphrodisiac and to treat male impotence. In Tanzania root decoctions are drunk to treat anaemia, dysentery and rectal prolapse. In Tanzania the bark has been used by the Shambaa people for reddish brown dyeing. In DR Congo the leaves are said to be used for making an arrow-poison.

Khaya anthotheca is fairly commonly planted as an ornamental shade tree and roadside tree. It is occasionally planted as a shade tree in agroforestry systems.

Production and international trade Congo exported 2000 m³ of sawn *Khaya anthotheca* wood in 2003, at an average price of US$ 213/m³, 2000 m³ in 2004, at an average price of US$ 333/m³, and 4000 m³ in 2005, at an average price of US$ 305/m³. Small volumes of veneer were exported from Congo in 2003 and 2004, at an average price of US$ 359/m³ and US$ 352/m³, respectively. *Khaya anthotheca* wood is exported from West African countries (e.g. Ghana) in mixed consignments with other *Khaya* spp., particularly *Khaya ivorensis* A.Chev. Under the latter name, 11,000 m³ of sawn wood was exported from Ghana in 2003, at an average price of US$ 714/m³, 14,000 m³ in 2004, at an average price of US$ 527/m³, and 17,000 m³ in 2005, at an average price of US$ 755/m³. The export of *Khaya* veneer from Ghana was 4000 m³ in 2003, at an average price of US$ 443/m³, 6000 m³ in 2004, at an average price of US$ 1677/m³, and 5000 m³ in 2005, at an average price of US$ 1938/m³. The proportion of *Khaya anthotheca* in these amounts is obscure. Côte d'Ivoire exported 41,000 m³ of sawn *Khaya* wood in 2003, at an average price of US$ 397/m³, and 34,000 m³ in 2005, at an average price of US$ 439/m³. Cameroon exported 11,000 m³ of sawn *Khaya* wood in 2003, and 8600 m³ in 2004 and 2006. In Uganda, Malawi, Zambia and Mozambique *Khaya anthotheca* is one of the most important timber species, but production statistics from these countries are not available. In recent years, the United States market has dominated the international trade in *Khaya* timber, especially as a substitute for American mahogany (from *Swietenia*) of which the availability has declined considerably.

Properties The heartwood is pinkish brown to deep red and more or less distinctly demarcated from the pale brown, up to 6 cm wide sapwood. The grain is straight or interlocked, texture rather coarse. The wood has an attractive figure with irregular ripple marks.

The wood is medium-weight, with a density of 490–660 kg/m³ at 12% moisture content. It generally air dries easily with little degrade, but the presence of tension wood may cause serious distortion. The rates of shrinkage are moderate, from green to oven dry 2.7–4.1% radial and 5.8–6.4% tangential. Once dry, it is fairly stable in service.

At 12% moisture content, the modulus of rupture is 50–110 N/mm², modulus of elasticity 7800–10,300 N/mm², compression parallel to grain 24–53 N/mm², shear 8–14 N/mm², cleavage 11–12 N/mm radial and 13–16 N/mm tangential, Janka side hardness 3250–5120 N and Janka end hardness 3600–6360 N.

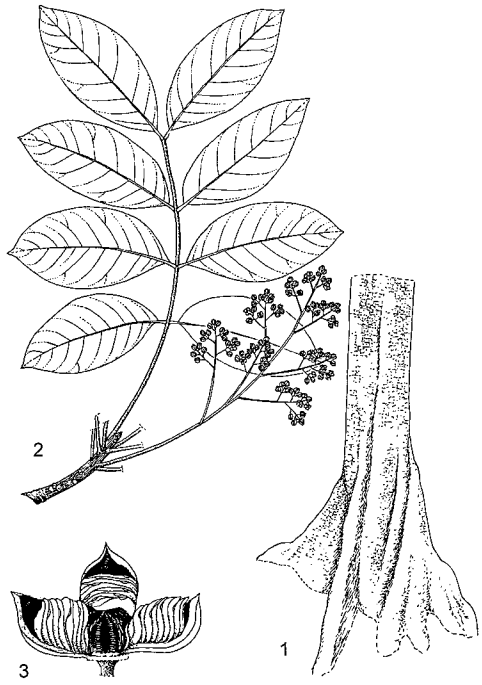
The wood is usually fairly easy to saw and work, although the presence of interlocked grain may cause some difficulties; saws should be kept sharp to prevent a woolly finish and a cutting angle of 20° is recommended. The wood can be finished to a smooth surface, but the use of a filler is required before staining and varnishing. The wood holds nails and screws well, but may split upon nailing, and glues satisfactorily. The bending properties are usually poor. The wood peels and slices well, producing an excellent quality of veneer. It turns fairly well. The wood is moderately durable but can be susceptible to termite and pinhole borer at-

tacks. The heartwood is strongly resistant to impregnation, the sapwood moderately resistant. The wood dust may cause irritation to the skin.

The use of the bark as an anti-anaemic agent has been confirmed in preliminary tests. The tests also showed the presence of iron (16 mg/100 g), copper (0.7 mg/100g) and ascorbic acid. In Cameroon the bark showed anthelmintic activity in calves. Crude seed extracts showed high toxicity in tests with tadpoles. The stem, bark and seeds contain limonoids.

Adulterations and substitutes The wood of *Khaya ivorensis* is very similar to that of *Khaya anthotheca*. The wood of both species and that of *Khaya grandifoliola* C.DC. is exported in mixed consignments from West Africa as 'African mahogany' or 'acajou d'Afrique'. The wood of makore (*Tieghemella*) is similar, but more durable.

Description Evergreen or deciduous, monoecious, large to very large tree up to 60(–65) m tall; bole branchless for up to 30 m, usually straight and cylindrical, up to 120(–500) cm in diameter, with large buttresses up to 4(–6) m high, sometimes extending into prominent surface roots; bark surface grey and smooth but exfoliating in small circular scales leaving a pock-marked, mottled grey and yellowish brown surface, inner bark pink to reddish; crown massive, rounded; twigs glabrous. Leaves arranged spirally but clustered near ends of branches, paripinnately compound with 2–5(–7) pairs of leaflets; stipules absent; petiole 3.5–7 cm long, rachis 2–20 cm long; petiolules 0.5–1.5 cm long; leaflets opposite, ovate-oblong to elliptical, 5–20 cm × 2–10 cm, cuneate to obtuse and slightly asymmetrical at base, obtuse to shortly acuminate at apex, margins entire, leathery, glabrous, pinnately veined with 6–10 pairs of lateral veins. Inflorescence an axillary panicle up to 30(–40) cm long. Flowers unisexual, male and female flowers very similar in appearance, regular, 4–5-merous, whitish, sweet-scented; pedicel 1.5–3 mm long; calyx lobed almost to the base, with rounded lobes 1–1.5 mm long; petals free, elliptical, 4–6 mm × 2–4 mm, somewhat hooded; stamens fused into an urn-shaped tube 3–5 mm long, with 8–10 included anthers near apex, alternating with rounded lobes; disk cushion-shaped; ovary superior, globose to conical, 1–2 mm in diameter, 4–5-celled, style up to 1 mm long, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit an erect, nearly globose, woody capsule 4–8(–10) cm in diameter, greyish brown, dehiscent by 4–5 valves, many-seeded. Seeds disk-shaped or quadrangular, strongly flattened, 1–2.5 cm × 1.5–3.5(–5) cm, narrowly winged all around the margin, brown. Seedling with hypogeal germination, cotyledons remaining enclosed in the seed coat; epicotyl 5–8 cm long; first 2 leaves opposite, simple.



Khaya anthotheca – 1, base of bole; 2, flowering twig; 3, dehisced fruit with one valve removed. Redrawn and adapted by Iskak Syamsudin

Other botanical information *Khaya* comprises 4 species in mainland Africa and 1 or 2 endemic to the Comoros and Madagascar. It belongs to subfamily *Swietenoideae* and seems most closely related to *Carapa* and *Swietenia*. *Khaya* species strongly resemble each other in flowers and fruits, and differences are most prominent in their leaflets. *Khaya grandifoliola* C.DC. is very close to *Khaya anthotheca* and may even be conspecific. *Khaya nyasica* Stapf ex Baker f. is often still kept separate from *Khaya anthotheca*, but can better be considered synonymous.

Khaya madagascariensis Jum. & H.Perrier occurs in the Comoros and northern and eastern Madagascar. The reddish brown wood is highly valued for joinery, implements, carving and traditional canoes. It has been used for

supporting columns of traditional palaces in Antananarivo. The bark is used in traditional medicine to treat fever, and it is applied externally to treat wounds and haemorrhages. *Khaya madagascariensis* grows fairly rapidly and is progressively planted in timber plantations. However, natural populations are under high pressure because of habitat destruction and selective felling, and *Khaya madagascariensis* is included in the IUCN Red list as endangered.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; (43: mean tangential diameter of vessel lumina ≥ 200 μm); (45: vessels of two distinct diameter classes, wood not ring-porous); 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 65: septate fibres present; 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 78: axial parenchyma scanty paratracheal; 79: axial parenchyma vasicentric; 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; (103: rays of two distinct sizes); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 131: intercellular canals of traumatic origin. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells.
(N.P. Mollel, P. Détienne & E.A. Wheeler)

Growth and development Young trees have a slender stem and a small crown. Extensive lateral growth starts when the upper canopy of the forest has been reached. In Ghana the average height of seedlings was 2.5 m and average stem diameter 4–4.5 cm after 2.5 years. In Côte d'Ivoire *Khaya anthotheca* trees planted in the open in the semi-deciduous forest zone reached an average height of 12 m and an average bole diameter of 18 cm after 10 years. However, trees planted in the evergreen forest zone were only 6 m tall and 9 cm in diameter after 8 years. In Malawi planted *Khaya anthotheca* trees reached a height of 8 m and a diameter of 9 cm after 7 years. Trees may already develop fruits when they have a bole diameter of 18 cm, but abundant fruiting usually starts at diameters above 70 cm. This means that the removal of trees of diameter classes below 70 cm from the forest may result in lack of natural regeneration. Fruits are usually produced in the dry season, from January to March in Côte d'Ivoire and Guinea. Dispersal of the seeds is by wind. The maximum dispersal distance is over 50 m, but about 75% of all seeds are dispersed within 30 m of the parent tree.

Ecology *Khaya anthotheca* occurs in semi-deciduous forest, in both wetter and drier types, and in the transitional zone between dry semi-deciduous forest and savanna, in areas with 1200–1800 mm annual rainfall and a dry season of 2–4 months. In moist semi-deciduous forest it may occur together with *Khaya ivorensis*. *Khaya anthotheca* often occurs scattered on slopes along watercourses. In East and southern Africa it is found in rainforest and riparian forest up to 1500 m altitude. In plantations it requires fertile deep soils and plenty of water. It is susceptible to fire.
Seeds can germinate in full sun as well as in the shade, but natural regeneration may be very sparse in the forest. In DR Congo it was found that seedling survival and height growth were higher in gaps than in the forest understorey, with 59% and 37% survival, respectively, and most seedlings in the forest understorey being stunted. It was also observed that secondary forest resulting on abandoned shifting-agricultural land offers favourable conditions for the regeneration of *Khaya anthotheca*.

Propagation and planting *Khaya anthotheca* is propagated by seed. The 1000-seed weight is 180–280 g. The seeds are often already attacked by insects while they are still on the tree, and undamaged seeds should therefore be selected before sowing or storage. The seeds can be stored for up to 1 year in a cool and dry place; adding ash to reduce insect damage is recommended. Fungi can cause serious losses of stored seed, with seeds stored at −18°C and 5°C showing higher occurrence of fungi and lower germination rates than seeds stored at 15°C. The seeds are best sown in seed beds in the nursery, they should be covered with only a thin layer of soil, or left partially

uncovered. Germination takes 8–35 days. The germination rate of fresh healthy seed is up to 85%, but decreases rapidly under natural circumstances. When seedlings are grown in small containers, they can be planted out when they reach 30 cm and have fully developed compound leaves. Seedlings can also be left in the nursery until they are 1–2 m tall, after which the root system is slightly pruned and leaves stripped off before planting into the field as striplings. In experiments in Indonesia, vegetative propagation by means of cuttings was successful, with a rooting success rate of 75% when growth hormone was applied.
In Côte d'Ivoire *Khaya anthotheca* has been planted in degraded or secondary forests at a distance of 7–25 m between lines and 3–7 m within the line. Pure plantations have also been established with trees planted at 3 m × 3 m.

Management In general, *Khaya anthotheca* occurs scattered and in low densities in the forest, e.g. in southern Cameroon the density is on average 0.02 boles of over 60 cm in diameter per ha and 0.15 m^3 of wood per ha, but locally in Liberia densities of 0.3–0.9 boles of over 60 cm in diameter per ha have been recorded. In Côte d'Ivoire 2–5 trees over 10 cm in diameter have been counted per ha. Enrichment planting in natural forest is locally applied in Côte d'Ivoire and Uganda. In Uganda the survival rates were often low, often less than 50%, due to poor silvicultural management. In Côte d'Ivoire *Khaya anthotheca* trees have been planted under the shade of 2-year-old *Leucaena leucocephala* (Lam.) de Wit, which suppresses weeds and fixes nitrogen into the soil. Regular thinning of the shade trees in the first years is needed for good growth of the *Khaya anthotheca* trees. The first thinning of a plantation of 1000 stems/ha is done when trees have reached 15 m in height and 15 cm in bole diameter, to a density of 400–500 stems/ha. The second thinning can be done when trees are 20 m tall and 20 cm in diameter to 200–250 stems/ha, the third at 25 m tall and 25 cm diameter to 125–150 stems/ha and the fourth at 30 cm diameter to 75–100 stems/ha. In Indonesia *Khaya anthotheca* has been used successfully in the taungya system, with economic benefits through the associated crops (rice, maize, peanuts) after the second year of tree planting. Realistic rotation cycles in natural forest are probably in the range of 60–80 years.

Diseases and pests Plantations of *Khaya anthotheca* may suffer seriously from *Hypsipyla robusta* shoot borers that kill the main stem of young trees, causing excessive branching and contributing to mortality. Silvicultural techniques, such as overhead shading of saplings, mixed planting and removal of lateral shoots, can reduce damage by shoot borers. Seeds are commonly attacked by seed-boring beetles and eaten by small rodents.

Harvesting The minimum bole diameter for harvesting of *Khaya anthotheca* trees in natural forest is 60 cm in Côte d'Ivoire, 80 cm in Cameroon, Central African Republic and DR Congo, and 110 cm in Ghana. The boles are occasionally so large that they cannot be sawn with normal equipment. The high buttresses at the base of the bole often necessitate the construction of a platform before felling can take place, or the removal of the buttresses before felling to recover more timber.

Yield For plantations at an age of 30 years, the annual production is 2–4 m^3/ha.

Handling after harvest Logs are susceptible to attack by longhorn beetles and should be processed not too long after felling. They may also have brittle heart, and care is needed in felling and sawing operations. The boles float in water and thus can be transported by river.

Genetic resources *Khaya anthotheca* is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling. It has been proposed for inclusion in CITES appendix I or II, but it has not been listed due to insufficient information on regeneration, extent of plantations and sustainability under current management regimes. Provenance trials in Ghana showed a high heritability for height growth, with the growth of the highest-ranking progenies being twice that of the lowest-ranking one. This may be partly due to some genetic resistance against *Hypsipyla robusta* attack.

Prospects Natural regeneration of *Khaya anthotheca* after logging is seriously hindered by the low density of adult trees in most forests, the fruit production being largely limited to larger sized trees and the comparatively poor dispersal ability of the seeds. It has been suggested that additional sowing at favourable sites would enhance sufficient regeneration after logging. It has also been suggested that the inclusion of shifting cultivation such as a taungya-like system into management systems may offer possibilities for sustainable management of *Khaya anthotheca*. However, more research is needed on appropriate management systems in natural forest to ensure sustainable

exploitation of *Khaya anthotheca*. Its fair growth rate makes more extensive establishment of plantations an option, but *Hypsipyla attack* is a serious drawback. The combined effects of selection of provenances with genetic resistance and appropriate silvicultural practices could have a substantial positive impact on the damage caused by *Hypsipyla robusta* stem borers.

Major references Bolza & Keating, 1972; Burkill, 1997; Dupuy & M'Bla Koua, 1993; Katende, Birnie & Tengnäs, 1995; Makana & Thomas, 2004; Ofori, Opuni-Frimpong & Cobbinah, 2007; Phongphaew, 2003; Styles & White, 1991; Takahashi, 1978; Voorhoeve, 1979.

Other references ATIBT, 1986; Chilufya & Tengnäs, 1996; CIRAD Forestry Department, 2003; Coates Palgrave, 1983; de la Mensbruge, 1966; Farmer, 1972; Hawthorne, 1995; Hawthorne & Jongkind, 2006; InsideWood, undated; Kanor, 1991; Keay, 1989; Makana, 2004; Mittal, Mathur & Thomsen, 2003; Neuwinger, 2000; Plumptre, 1995; Siepel, Poorter & Hawthorne, 2004; Terashima & Ichikawa, 2003; van Wyk & Gericke, 2000; Vivien & Faure, 1985; Williamson, 1955; Wiselius, 1998a.

Sources of illustration Styles & White, 1991; Vivien & Faure, 1985.

Authors A. Maroyi

KHAYA GRANDIFOLIOLA C.DC.

Protologue Bull. Soc. Bot. France 54, mém. 8: 10 (1907).

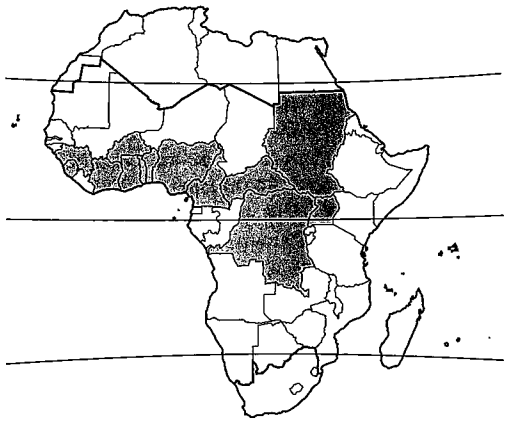
Family Meliaceae

Chromosome number $2n = 50$

Vernacular names Broad-leaved mahogany, big-leaved mahogany, dry-zone mahogany, Benin mahogany (En). Acajou à grandes feuilles, acajou du Bénin (Fr). Mogno de Benim (Po).

Origin and geographic distribution *Khaya grandifoliola* occurs from Guinea east to Sudan and Uganda. It is occasionally grown in plantations within its natural area of distribution, e.g. in Côte d'Ivoire and Ghana, and trial plantations have been established in Indonesia.

Uses The wood (trade names: African mahogany, acajou d'Afrique) is valued for carpentry, joinery, furniture, cabinet work and decorative veneer. It is suitable for light construction, light flooring, interior trim, ship building, musical instruments, toys, novelties, carving, turnery and pulpwood. Traditionally, the wood



Khaya grandifoliola – wild

is used for furniture, household implements and dug-out canoes. It is also used as fuelwood and for charcoal production.

The bitter-tasting bark is used in traditional medicine. It is widely used against fever caused by malaria. Bark decoctions are taken to treat stomach complaints including gastric ulcers, pain after childbirth, and skin diseases. In Sudan a bark infusion is used to treat diarrhoea caused by intestinal parasites. A decoction of the root bark is drunk to treat gonorrhoea and pulverized root bark is applied externally to skin diseases. In Uganda the bark is used as a fish poison, and in DR Congo the bark is used for washing cloth. *Khaya grandifoliola* is planted as a roadside tree and ornamental shade tree. In Uganda it is valued for stabilization of river banks.

Production and international trade The first *Khaya* logs were shipped to the British timber market around 1833 from Côte d'Ivoire, and export from Ghana started in 1888. Until the 1950s *Khaya* timber formed up to 70% of the total export from Ghana, with an annual volume of approximately 100,000 m^3, but since then its export has steadily declined. *Khaya grandifoliola* wood is exported from West African countries (e.g. Ghana) in mixed consignments with other *Khaya* spp., particularly *Khaya anthotheca* (Welw.) C.DC. and *Khaya ivorensis* A.Chev. Ghana exported 11,000 m^3 of sawn *Khaya* wood in 2003, at an average price of US$ 714/m^3, 14,000 m^3 in 2004, at an average price of US$ 527/m^3, and 17,000 m^3 in 2005, at an average price of US$ 755/m^3. The export of *Khaya* veneer from Ghana was 4000 m^3 in 2003, at an average price of US$ 443/m^3,

6000 m³ in 2004, at an average price of US$ 1677/m³, and 5000 m³ in 2005, at an average price of US$ 1938/m³. The proportion of *Khaya grandifoliola* in these amounts is obscure, but is probably much smaller than for the other species. Côte d'Ivoire exported 41,000 m³ of sawn *Khaya* wood in 2003, at an average price of US$ 397/m³, and 34,000 m³ in 2005, at an average price of US$ 439/m³. Cameroon exported 11,000 m³ of sawn *Khaya* wood in 2003, and 8600 m³ in 2004 and 2006. In recent years, the United States market has dominated the international trade in *Khaya* timber, especially as a substitute for American mahogany (from *Swietenia*) of which the availability has declined considerably.

Properties The heartwood is pinkish brown, darkening to reddish brown upon exposure. It is usually distinctly demarcated from the pale brown to pinkish brown, up to 5 cm wide sapwood, at least in dried wood. The grain is usually interlocked, sometimes straight, texture rather coarse. Wood from savanna trees is reported to be darker than that of forest trees.

The wood is heavier than that of *Khaya anthotheca* and *Khaya ivorensis*. It is medium-weight to moderately heavy, with a density of (560–)640–730(–770) kg/m³ at 12% moisture content. It generally air dries rather slowly, but with little degrade. The rates of shrinkage are moderate. Once dry, the wood is stable in service.

At 12% moisture content, the modulus of rupture is 92–119 N/mm², modulus of elasticity 10,600–11,400 N/mm², compression parallel to grain 53–74 N/mm², shear 15–17 N/mm², cleavage 14 N/mm radial and 18 N/mm tangential, and Janka side hardness 6090 N.

The wood is fairly easy to saw and work, with moderate blunting effect on cutting edges. It can be finished to a smooth surface and takes an excellent polish. The wood holds nails and screws well, but it has some tendency to split. It has good gluing properties. The peeling properties are poor because of the higher density in comparison with *Khaya anthotheca* and *Khaya ivorensis* and the interlocked grain, but slicing gives decorative veneer. The wood is moderately durable, being resistant to termites but susceptible to *Lyctus*. The heartwood is strongly resistant to impregnation, the sapwood moderately resistant.

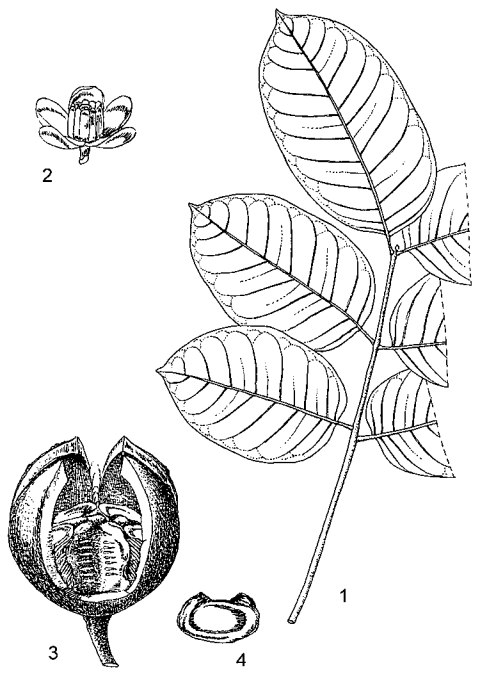
Bark extracts exhibited antimalarial activity in mice infected with *Plasmodium berghei*. Several limonoids isolated from bark and seeds showed distinct in-vitro antimalarial activity against chloroquine-resistant strains of *Plasmodium falciparum*, particularly gedunin, 7-deacetylkhivorin, methylangolensate and 6-acetylswietenolide. The most active limonoid, gedunin, exhibited an additive effect when combined with chloroquine. In tests with rats, bark extracts showed hypoglycaemic, hypoproteinaemic and hypocholesterolaemic effects, and also showed good results for the treatment of gastric ulcers. They had positive effects on the production of red blood cells.

Bark extracts showed nematicidal activity against *Pratylenchus brachyurus*, a nematode injurious to many crops worldwide. They inhibited egg-hatch in sugarcane cyst nematode (*Heterodera sacchari*). Bark and seed extracts showed toxic effects on *Aedes aegypti* mosquitoes. Seed extracts resulted in high mortality in the cotton stainer (*Dysdercus* sp.). The mexicanolide-type limonoids isolated from the seeds showed antifeedant activity against larvae of the Mexican bean beetle (*Epilachna varivestis*), a notorious pest of beans and other leguminous crops. Bark and seed extracts, as well as the limonoids khivorin isolated from the bark and fissinolide isolated from the seed, have molluscicidal properties.

The gum from the bark is extremely resistant to hydrolysis and highly acidic (pH 3.0–4.0). It contains the sugars rhamnose, arabinose and galactose, as well as glucuronic acid and galacturonic acid. Research showed that the gum can serve as a useful formulating agent in the pharmaceutical industry. It showed good properties for sustained-release tablets for up to 5 hours, whereas a combination with hydroxypropylmethylcellulose could be used to provide a release for longer periods. The gum was effective as a coating to extend the storage life of cassava roots, and it could also be used as ice cream stabilizer.

Adulterations and substitutes The wood of *Khaya grandifoliola* resembles true mahogany (from *Swietenia* spp.) more closely than the woods of *Khaya anthotheca* and *Khaya ivorensis* do. However, it is usually exported from West Africa in mixed consignments with these species as 'African mahogany' or 'acajou d'Afrique'. The wood of makore (*Tieghemella*) is similar, but more durable.

Description Usually deciduous, monoecious, medium-sized to large tree up to 40 m tall; bole branchless for up to 23 m, often twisted or leaning near the top, up to 120(–200) cm in diameter, usually with buttresses up to 3 m high; bark surface greyish brown, rough, exfo-



Khaya grandifoliola – 1, leaf; 2, flower; 3, dehisced fruit with one valve removed; 4, seed. Redrawn and adapted by Iskak Syamsudin

liating in small circular scales and becoming pitted, inner bark dark pink to reddish, with white streaks, exuding a clear gum; crown large, rounded; twigs glabrous. Leaves arranged spirally but clustered near ends of branches, paripinnately compound with 3–5 pairs of leaflets; stipules absent; petiole and rachis together up to 50 cm long; petiolules 0.5–1 cm long; leaflets opposite or nearly so, elliptical to ovate-elliptical or oblong-elliptical, (10–)12–20(–30) cm × 5–10 cm, cuneate to obtuse or rounded and slightly asymmetrical at base, shortly but distinctly acuminate at apex, often with twisted acumen, margins entire or wavy, thickly papery to thinly leathery, glabrous, pinnately veined with 9–15 pairs of lateral veins. Inflorescence an axillary panicle up to 40 cm long. Flowers unisexual, male and female flowers very similar in appearance, regular, usually 5-merous, whitish, sweet-scented; pedicel 1–2 mm long; calyx lobed almost to the base, with rounded lobes c. 1.5 mm long; petals free, elliptical, c. 5 mm × 2 mm, somewhat hooded; stamens fused into an urn-shaped tube c. 5 mm long, with usually 10 included anthers near apex, alternating with rounded lobes; disk cushion-shaped; ovary superior, globose to conical, 1–2 mm in diameter, usually 5-celled, style up to 1 mm long, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit an erect, nearly globose, woody capsule 6–9 cm in diameter, greyish brown, dehiscent by 5 valves, many-seeded. Seeds disk-shaped or quadrangular, strongly flattened, c. 2 cm × 3.5 cm, narrowly winged all around the margin, brown. Seedling with hypogeal germination, cotyledons remaining enclosed in the seed coat; epicotyl c. 6 cm long; first 2 leaves opposite, simple.

Other botanical information *Khaya* comprises 4 species in mainland Africa and 1 or 2 endemic to the Comoros and Madagascar. It belongs to subfamily *Swietenoideae* and seems most closely related to *Carapa* and *Swietenia*. *Khaya* species strongly resemble each other in flowers and fruits, and differences are most prominent in their leaflets. *Khaya grandifoliola* is very close to *Khaya anthotheca* (Welw.) C.DC. and may even be conspecific. The latter differs in its usually smaller and thicker leaflets, and thinner fruit walls. Hybrids between the two species have been recorded.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; (43: mean tangential diameter of vessel lumina ≥ 200 μm); (46: ≤ 5 vessels per square millimetre); 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; (65: septate fibres present); 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 78: axial parenchyma scanty paratracheal; 79: axial parenchyma vasicentric; (89: axial parenchyma in marginal or in seemingly marginal bands); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; (103: rays of two distinct sizes); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of

upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 131: intercellular canals of traumatic origin. Mineral inclusions: (136: prismatic crystals present); (137: prismatic crystals in upright and/or square ray cells); (138: prismatic crystals in procumbent ray cells).
(N.P. Mollel, P. Détienne & E.A. Wheeler)

Growth and development In Nigeria saplings reached an average height of 4.2 m and bole diameter of 7 cm 4 years after planting. In Côte d'Ivoire *Khaya grandifoliola* trees planted in the open in the semi-deciduous forest zone reached an average height of 13.5 m and an average bole diameter of 17 cm after 10 years. However, trees planted in the evergreen forest zone only reached 9 m in height and 11.5 cm in diameter after 8 years. In Nigeria an average height of 21 m after 20 years was recorded. However, in natural forest in Nigeria the average bole diameter for trees 100 years old was estimated at only 60–70 cm.
Trees are usually deciduous in the dry season; young leaves are strikingly reddish and often occur together with flowers. The flowers are pollinated by insects such as bees and moths. In Côte d'Ivoire fruiting is in January–March. Dispersal of the seeds is by wind, but most seeds fall close to the parent tree.
The presence of endotrophic mycorrhizal fungi in nurseries is important; inoculation with *Endogone* spores markedly improved the growth of seedlings.

Ecology *Khaya grandifoliola* occurs in semi-deciduous forest, especially in drier types and in savanna, but in the latter case usually along watercourses, in areas with 1200–1800 mm annual rainfall and a dry season of 3–5 months. It occurs up to 1400 m altitude. Sometimes it can be found in rocky and hilly parts of moist semi-deciduous forest, where *Khaya anthotheca* also occurs. In Sudan and Uganda it occurs in lowland forest, particularly in gallery forest. It prefers moist but well-drained soils, and is locally common on alluvial soils in valleys.
Seeds can germinate in full sun as well as in the shade, but natural regeneration may be very sparse in the forest. In Nigeria it was found that although seedlings could become established in closed forest, they showed very poor growth and rarely survived for long. In Sudan *Khaya grandifoliola* reportedly does not regenerate under a closed forest canopy. Natural regeneration can be abundant in savanna which is close to the forest and protected from fire. In gallery forest in Nigeria regeneration was most abundant in the boundary zone with the savanna. In Nigeria it has been noted that more seeds and seedlings are produced in years with abundant rainfall.

Propagation and planting *Khaya grandifoliola* is propagated by seed. The 1000-seed weight is 200–300 g. The seeds are often already attacked by insects while they are still on the tree, and undamaged seeds should therefore be selected before sowing. The seeds can be stored in a cool place; in a test in Benin the germination rate was still 76% after 4 months. It is recommended to add ash during storage to reduce insect attacks. The seeds are very liable to desiccation. It is not necessary to treat seeds before sowing. They can best be sown in seed beds in the nursery or in pots. Upon sowing seeds should be covered with only a thin layer of soil, or left partially uncovered. Fresh healthy seeds have a high germination rate, about 90%, but this decreases rapidly to nearly zero after 2 months under natural circumstances. Germination takes 10–35 days. It has been recommended to provide light shade to young seedlings until they are 1–2 months old, but in Nigeria it was found that seedlings grew best with full light, watering at least every second day and weekly supplementation with NK solution. Seedlings can be left in the nursery for about one year until they are 0.5–1 m tall, after which the root system is pruned to a length of about 30 cm and most leaves stripped off before planting into the field. Stumps can also be planted out, leaving 2–3 cm of stem and 25–30 cm of root. In Uganda seedlings of 2.5 m tall with a stem diameter of 5–8 cm at the base have been used for planting into the field. Normal spacing is 2–4 m × 2–4 m. Wildlings are sometimes collected for planting.

Management Enrichment planting in natural forest has been applied in Uganda, but failed possibly due to poor silvicultural management operations. In young plantations weeding is necessary; the young trees are susceptible to suppression by weeds, and also to fire. In Côte d'Ivoire *Khaya grandifoliola* trees have been planted under the shade of 2-year-old *Leucaena leucocephala* (Lam.) de Wit, which suppresses weeds and fixes nitrogen into the soil. Regular thinning of the shade trees in the first years is needed for good growth of the *Khaya grandifoliola* trees. The first thinning of a plantation of 1000 stems/ha is done when trees have reached 15 m in height and 15 cm in bole diameter, to a density of 400–500

stems/ha. The second thinning can be done when trees are 20 m tall and 20 cm in diameter to 200–250 stems/ha, the third at 25 m tall and 25 cm diameter to 125–150 stems/ha and the fourth at 30 cm diameter to 75–100 stems/ha. In tropical Africa *Khaya grandifoliola* has been planted successfully in mixed plantations, e.g. with *Milicia excelsa* (Welw.) C.C.Berg, *Triplochiton scleroxylon* K.Schum., *Gmelina arborea* Roxb. and *Margaritaria discoidea* (Baill.) Webster.

Realistic rotation cycles in natural forest are probably in the range of 80–100 years, but in plantations a rotation of 40–60 years is feasible.

Diseases and pests In plantations *Khaya grandifoliola* may suffer seriously from *Hypsipyla robusta* shoot borers that kill the main stem of young trees, causing excessive branching and contributing to mortality. Silvicultural techniques such as overhead shading of saplings, mixed planting and removal of lateral shoots can reduce damage by shoot borers. Seeds are commonly attacked by seed-boring beetles and eaten by small rodents.

Harvesting The minimum bole diameter for harvesting of *Khaya grandifoliola* trees in natural forest is 60 cm in Côte d'Ivoire, 80 cm in Cameroon, Central African Republic and DR Congo, and 110 cm in Ghana.

Handling after harvest Logs are susceptible to attack by longhorn beetles and should be processed not too long after felling. The sapwood is often removed soon after felling to prevent attacks by ambrosia beetles. The boles float in water and thus can be transported by river.

Genetic resources *Khaya grandifoliola* is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling. Like other *Khaya* spp., populations have been depleted in many regions through centuries of commercial exploitation.

Prospects More research is needed on appropriate management systems in natural forest to ensure a sustainable exploitation of *Khaya grandifoliola*. Its fair growth rate makes more extensive establishment of plantations an option, but *Hypsipyla* attack is a serious drawback. The combined effects of selection of provenances with genetic resistance and appropriate silvicultural practices could have a substantial positive impact on the damage caused by *Hypsipyla robusta* stem borers. Research priority should be given to range-wide selection of genotypes which are resistant to stem-borer attack, fast growing and have acceptable wood quality. The establishment of appropriate methods of vegetative propagation including tissue culture is urgently needed.

The bark demonstrated several interesting pharmacological activities, especially against malaria and gastric ulcers. This deserves more research attention for possible development into new drugs. The insecticidal, molluscicidal and nematicidal activities of bark and seeds are also noteworthy. The gum has potential as compression coating for drugs targeting the colon, and as a stabilizing and protective agent.

Major references Bolza & Keating, 1972; Burkill, 1997; CTFT, 1959a; Dupuy & M'Bla Koua, 1993; Farmer, 1972; Katende, Birnie & Tengnäs, 1995; Opuni-Frimpong, 2006; Siepel, Poorter & Hawthorne, 2004; Styles & White, 1991; Takahashi, 1978.

Other references Anim-Yeboah, 1995; ATIBT, 1986; Bickii et al., 2000; CAB International, 2005; Caniato & Puricelli, 2003; CIRAD Forestry Department, 2003; CTFT, 1979; de la Mensbruge, 1966; Djodjouwin, 1990; Hawthorne, 1995; Hawthorne & Jongkind, 2006; InsideWood, undated; Keay, 1989; Neuwinger, 2000; Njikam & Njikam, 2006; Odeku & Fell, 2004; Phongphaew, 2003; Sommerlatte & Sommerlatte, 1990; Terashima & Ichikawa, 2003; Vivien & Faure, 1985; Wiselius, 1998a.

Sources of illustration Hawthorne & Jongkind, 2006; Keay, 1958b.

Authors E. Opuni-Frimpong

KHAYA IVORENSIS A.Chev.

Protologue Veg. Ut. Afr. Trop. Franç. 5: 207 (1909).

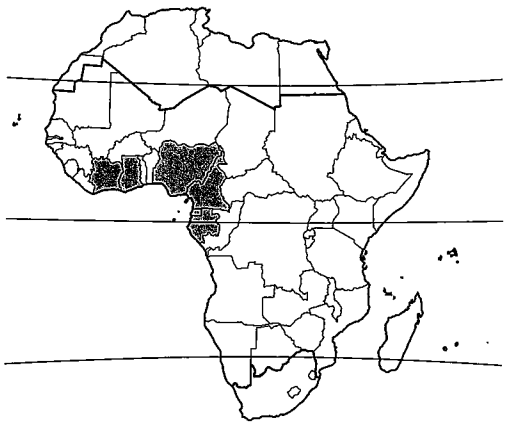
Family Meliaceae

Chromosome number $2n = 50$

Vernacular names Red mahogany, Lagos mahogany (En). Acajou rouge, acajou du Gabon, acajou Bassam, acajou à peau rugueuse (Fr). Acaju de Bassan (Po).

Origin and geographic distribution *Khaya ivorensis* is distributed from Côte d'Ivoire east to Cameroon and south to Cabinda (Angola); it possibly also occurs in Guinea, Liberia, the Central African Republic and Congo. It is fairly widely grown in plantations within its natural area of distribution, but also in tropical Asia and tropical America.

Uses The wood (trade names: African mahogany, acajou d'Afrique) is highly valued for



Khaya ivorensis – wild

furniture, cabinet work, decorative boxes and cases, and veneer, and is also commonly used for window frames, panelling, doors and staircases. It is suitable for light construction, light flooring, ship building, vehicle bodies, handles, ladders, sporting goods, musical instruments, toys, novelties, precision equipment, carving, turnery and pulpwood. The wood is in demand for making backs or sides of acoustic guitars as it is considered to have good acoustical characteristics. Traditionally, the wood is used for dugout canoes. It is also used as fuelwood and for charcoal production.

The bitter-tasting bark is widely used in traditional medicine. Bark decoctions are taken to treat cough, fever and anaemia, and are applied externally to wounds, sores, ulcers and tumours, and as an anodyne to treat rheumatic pains and lumbago. Root pulp is applied as an enema to treat dysentery. Ground young shoots and leaves are applied externally as an anodyne. The seeds are used in soap production. In Nigeria *Khaya ivorensis* trees are locally retained in cocoa plantations to serve as shade trees and ultimately for timber production.

Production and international trade *Khaya ivorensis* wood is exported from West African countries in mixed consignments with other *Khaya* spp., particularly *Khaya anthotheca* (Welw.) C.DC. Côte d'Ivoire has long been the main exporter of *Khaya* wood: as early as in 1925 it exported around 10,000 m^3 per year, and during in 1965–1974 it exported more than 1.5 million m^3 *Khaya* logs and about 115,000 m^3 of sawn wood, more than all other African countries together. Exports from Côte d'Ivoire have decreased since then, but 41,000 m^3 of sawn *Khaya* wood was exported in 2004, at an average price of US$ 397/m^3, and 34,000 m^3 in 2005, at an average price of US$ 439/m^3. Ghana exported 11,000 m^3 of sawn *Khaya* wood in 2003, at an average price of US$ 714/m^3, 14,000 m^3 in 2004, at an average price of US$ 527/m^3, and 17,000 m^3 in 2005, at an average price of US$ 755/m^3. The export of *Khaya* veneer from Ghana was 4000 m^3 in 2003, at an average price of US$ 443/m^3, 6000 m^3 in 2004, at an average price of US$ 1677/m^3, and 5000 m^3 in 2005, at an average price of US$ 1938/m^3. The proportion of *Khaya ivorensis* in these amounts is obscure. Cameroon exported 11,000 m^3 of sawn *Khaya* wood in 2003, and 8600 m^3 in 2004 and 2006. Exports of logs from Gabon amounted to 21,300 m^3 in 2000, 18,700 m^3 in 2001, 14,300 m^3 in 2002, 17,800 m^3 in 2003, and 18,600 m^3 in 2004. In recent years, the United States market has dominated the international trade in *Khaya* timber, especially as a substitute for American mahogany (from *Swietenia*), the availability of which has declined considerably.

Properties The heartwood is pale pinkish brown to pale red, darkening to deep brown with a golden lustre upon exposure. It is more or less distinctly demarcated from the creamy white, up to 5 cm wide sapwood. The grain is straight or interlocked, texture rather coarse.

The wood is medium-weight, with a density of (420–)460–570 kg/m^3 at 12% moisture content. It generally air dries and kiln dries easily with little degrade, but some warping may occur due to the presence of interlocked grain. The rates of shrinkage are moderate, from green to oven dry 2.2–4.1(–5.0)% radial and 5.0–6.9(–8.4)% tangential. Once dry, the wood is fairly stable in service.

At 12% moisture content, the modulus of rupture is 71–126 N/mm^2, modulus of elasticity 8700–10,800 N/mm^2, compression parallel to grain 37–48 N/mm^2, compression perpendicular to grain 4–8 N/mm^2, shear 8–12 N/mm^2, cleavage 10–17 N/mm, Janka side hardness 3210–3700 N and Janka end hardness 4810 N.

The wood is usually fairly easy to saw and work, although the presence of interlocked grain may cause some difficulties. Saws should therefore be kept sharp to prevent a woolly finish and a cutting angle of 15–20° is recommended. The wood can be finished to a smooth surface, but the use of a filler is required in staining and varnishing. The wood holds nails and screws well and glues satisfactorily. The bending properties are poor. The wood peels

and slices well, producing an excellent quality of veneer. It turns fairly well. The wood dust may cause irritation to the skin.

The wood is moderately durable and can be susceptible to termite and pinhole borer attacks. The heartwood is strongly resistant to impregnation, the sapwood moderately resistant. The wood is suitable for paper production, and even peeler cores, often regarded as waste, are suitable for pulp production.

Limonoids have been isolated from the bark and seeds. Some of these showed significant antifeedant activity in insects, and some antifungal and antibacterial activities. Bark extracts showed weak antitrypanosomal and antiplasmodial activities in tests with mice. Tests in rats showed that the bark has dose-dependent anti-inflammatory activity and that it is toxic only at high doses. The bark showed anticonvulsant activity in mice. The seeds contain 17–27% oil, with palmitic acid, oleic acid and linoleic acid as the dominant fatty acids. Another analysis indicated an oil content of about 48% at 7% moisture content, and a fatty acid composition of: palmitic acid 7%, stearic acid 32%, oleic acid 15% and linoleic acid 45%. The oil can be used as an additive in liquid soaps, and may act as an antibacterial and antifungal agent because of the presence of limonoids such as methylangolensate. In Nigeria the bark was found to contain 27% extractable tannins. Smoke from the wood showed good results in tests of smoking fish, protecting the fish effectively against fungi.

Adulterations and substitutes The wood of *Khaya anthotheca* is very similar to that of *Khaya ivorensis*. The wood of both species and that of *Khaya grandifoliola* C.DC. is exported from West Africa in mixed consignments as 'African mahogany' or 'acajou d'Afrique'. The wood of makore (*Tieghemella*) is similar, but more durable.

Description Evergreen or deciduous, monoecious, large to very large tree up to 60 m tall; bole branchless for up to 30 m, usually straight and cylindrical, up to 160(–210) cm in diameter, with large buttresses up to 2(–4) m high, sometimes extending into prominent surface roots; bark surface brown and slightly rough, exfoliating in small circular scales leaving a pock-marked, mottled greyish brown and orange brown surface, inner bark pink to reddish; crown massive, rounded; twigs glabrous. Leaves arranged spirally but clustered near ends of branches, paripinnately compound with (3–)4–7 pairs of leaflets; stipules absent; petiole 1–4 cm long, rachis 6–20 cm long; petiolules 0.5–1 cm long; leaflets opposite, oblong to oblong-elliptical, 5–14 cm × 2–6 cm, cuneate to obtuse and slightly asymmetrical at base, distinctly acuminate at apex, margins entire, leathery, glabrous, pinnately veined with 5–10 pairs of lateral veins. Inflorescence an axillary panicle up to 20 cm long. Flowers unisexual, male and female flowers very similar in appearance, regular, (4–)5-merous, whitish, sweet-scented; pedicel 1–3 mm long; calyx lobed almost to the base, with rounded lobes c. 1 mm long; petals free, elliptical, c. 4 mm × 2 mm, somewhat hooded; stamens fused into an urn-shaped tube c. 5 mm long, with (8–)10 included anthers near apex, alternating with rounded lobes; disk cushion-shaped; ovary superior, globose to conical, 1–2 mm in diameter, 5-celled, style up to 1 mm long, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit an erect, nearly globose, woody capsule 5–7 cm in diameter, greyish brown, dehiscent by 5 valves, many-seeded. Seeds disk-shaped or quadrangular, strongly flattened, 2–2.5 cm × 2.5–3.5 cm, narrowly winged

Khaya ivorensis – 1, base of bole; 2, leaf and inflorescence; 3, dehisced fruit; 4, seed. Redrawn and adapted by Iskak Syamsudin

all around the margin, brown. Seedling with hypogeal germination, cotyledons remaining enclosed in the seed coat; epicotyl 5–10 cm long; first 2 leaves opposite, simple.

Other botanical information *Khaya* comprises 4 species in mainland Africa and 1 or 2 endemic to the Comoros and Madagascar. It belongs to subfamily *Swietenoideae* and seems most closely related to *Carapa* and *Swietenia*. *Khaya* species strongly resemble each other in flowers and fruits, and differences are most prominent in their leaflets. There appears to be a more or less gradual transition in species according to ecological gradients, from the moist evergreen forest zone through semi-deciduous forest to the savanna zone. Studies on anatomical, chemical and physical properties of the wood confirmed the close relationship of *Khaya* species, with main differences in fibre lumen/wall ratio, percentage multiseriate rays and wood density, which could also be explained, at least partly, by ecological conditions. *Khaya anthotheca* (Welw.) C.DC. is very close to *Khaya ivorensis*, but differs, apart from its ecological requirements, in its more ovate-elliptical, short-acuminate leaflets and light-coloured, more smooth bark.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; (43: mean tangential diameter of vessel lumina ≥ 200 μm); 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; (65: septate fibres present); 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 78: axial parenchyma scanty paratracheal; 79: axial parenchyma vasicentric; (89: axial parenchyma in marginal or in seemingly marginal bands); 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; (103: rays of two distinct sizes); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 131: intercellular canals of traumatic origin. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells; (140: prismatic crystals in chambered upright and/or square ray cells). (N.P. Mollel, P. Détienne & E.A. Wheeler)

Growth and development In nurseries in Côte d'Ivoire 1-year-old *Khaya ivorensis* seedlings were 90–100 cm tall, 2-year-old saplings 2.5–3 m, 4-year-old saplings 4–6 m, and 6-year-old saplings were 12–15 m tall and 10–18 cm in diameter. Trees planted in the open in the evergreen forest zone reached an average height of 12 m and an average bole diameter of 15 cm after 8 years. In mixed plantations the average bole diameter was 39 cm at 27 years after planting, with dominant trees being 28 m tall and 47 cm in diameter. At 34 years after planting dominant trees were 76 cm in diameter, but the bole was branchless for only 12 m. In Nigeria the average height of saplings was 4.5 m after 4 years, with an average stem diameter of 8 cm. In 26-year-old plantations in Malaysia, a mean annual increment of 1.8 cm in diameter and 1 m in height was achieved. In a 40-year-old plantation in Malaysia, trees had an average height of 23.5 m and average bole diameter of 29.5 cm, with dominant trees 30 m and 47 cm, respectively. Young trees have a slender stem and a small crown. Extensive lateral growth starts when the upper canopy of the forest has been reached. The tree develops according to Rauh's architectural tree model, characterized by a monopodial trunk which grows rhythmically and so develops tiers of branches. The monoaxial state may persist to a height of 10 m.
Trees are sometimes leafless for a short period at the beginning of the dry season. In moist evergreen forest *Khaya ivorensis* can be found flowering and fruiting throughout the year and bearing flowers and fruits at the same time; usually flowering is seasonal, in West Africa being most abundant in June–October. Fruits mature in about 6 months. In Côte d'Ivoire there are generally 2 fruiting periods: February–April and July–August; in Ghana the main fruiting period is February–May. Trees of 30 years old may produce fruits and seeds abundantly. Mass production of seeds is reported to occur every 3–4 years. Dispersal of the seeds is by wind, but most seeds fall close to the parent tree.

Ecology *Khaya ivorensis* is most abundant in evergreen forest, but can also be found in

moist semi-deciduous forest, in areas with 1600–2500 mm annual rainfall and a dry season of 2–3 months, up to 700 m altitude. In moist semi-deciduous forest it may occur together with *Khaya anthotheca*. *Khaya ivorensis* often occurs along watercourses. It prefers alluvial soils which are moist but well-drained, but it can also be found on slopes on lateritic soils. Seeds can germinate in full sun as well as in the shade, but natural regeneration is apparently sparse in large gaps. Seedlings can survive in dense shade, but for good growth opening of the forest canopy is needed. Regeneration of *Khaya ivorensis* is not promoted by large disturbances in the forest, but it benefits from small gaps.

Propagation and planting *Khaya ivorensis* is propagated by seed. The 1000-seed weight is 130–310 g. The seeds are often already attacked by insects while they are still on the tree, and undamaged seeds should therefore be selected before sowing. The optimal temperature and moisture content for storage of seeds were found to be 3°C and 6%, respectively. The seeds are best sown in seed beds in the nursery. Germination is rather slow, taking 11–40 days. The germination rate of fresh healthy seed is high, nearly 100%, but it decreases rapidly and after 3 months viability of the seeds is only 5%. In the nursery, light shade is advantageous for seedlings up to 2 years old; this reduces attacks by *Hypsipyla* shoot borers and the development of leaf galls. The application of 0.5 g of inorganic fertilizer to seedlings has been recommended, promoting height and collar diameter growth. Seedlings are planted out when 60–90 cm tall, usually as stumps or striplings.

In experiments vegetative propagation by means of cuttings from seedlings less than 2 years old was successful with the application of auxin (IBA) at a concentration of 200 µg per cutting. Cuttings from basal nodes rooted better than those from apical nodes, longer (4 cm long) cuttings better than shorter (2 cm long) ones, whereas trimming the leaf area to 10 cm^2 also promoted rooting.

In Côte d'Ivoire the first plantation of *Khaya ivorensis* was established in 1927, at a density of 2500 seedlings/ha, but after 30 years only 72 trees/ha had an annual diameter growth of over 1 cm. Later it was planted in lines as enrichment of degraded forests, mixed with other species, at a distance of 7–25 m between lines and 3–7 m within the line, and some trees showed an annual diameter growth of over 2.5 cm after 14 years. Between 1969 and 1995 about 1730 ha of pure plantations have been established with trees planted at a spacing of 3 m × 3 m. More recently it has been planted successfully in 3 rows to mark the boundary of forestry reserves.

Management *Khaya ivorensis* occurs scattered or in small groups in the forest, usually in low densities. In southern Cameroon on average 0.02–0.08 boles of over 60 cm diameter per ha and 0.17–0.64 m^3 of wood per ha have been recorded, and in Gabon an average of 0.27 m^3 of wood per ha. In Côte d'Ivoire an average density of less than 1 exploitable tree per 10 ha has been recorded, but locally 1 exploitable tree per 2 ha has been found.

Enrichment planting in natural forest is locally applied in Côte d'Ivoire. In Gabon 4-month-old seedlings have been planted after clear-cutting of the forest, and in other sites after removal of the forest undergrowth and thinning of the upper canopy. After 6 years, the seedlings showed 92% survival in the clear-cut localities and nearly 100% in localities where the forest was cleared from undergrowth and the canopy thinned. Average heights were 10.7 m and 11.7 m, respectively, and average bole diameters 12.9 cm and 9.3 cm. After 11 years average heights were 16.1 m and 17.1 m, respectively, and average bole diameters 43.1 cm and 36.5 cm.

In Côte d'Ivoire *Khaya ivorensis* trees have been planted under the shade of 2-year-old *Leucaena leucocephala* (Lam.) de Wit, which suppresses weeds and fixes nitrogen into the soil. Regular thinning of the shade trees in the first years is needed for good growth of the *Khaya ivorensis* trees. The first thinning of *Khaya ivorensis* trees in a plantation of 1000 stems/ha is done when trees have reached 15 m in height and 15 cm in bole diameter, to a density of 400–500 stems/ha. The second thinning can be done when trees are 20 m tall and 20 cm in diameter to 200–250 stems/ha, the third one at 25 m tall and 25 cm diameter to 125–150 stems/ha and the fourth one at 30 cm diameter to 75–100 stems/ha. In tropical Africa *Khaya ivorensis* has been planted successfully in mixed plantations, e.g. with *Heritiera utilis* (Sprague) Sprague, *Terminalia ivorensis* A.Chev., *Tieghemella heckelii* (A.Chev.) Roberty and *Triplochiton scleroxylon* K.Schum. In mixed plantations with *Khaya ivorensis* in Malaysia, a final density of 80 trees/ha and a rotation of 30 years is recommended. Realistic rotation cycles in natural forest are probably in the

range of 60–80 years.

Diseases and pests In plantations *Khaya ivorensis* may suffer seriously from *Hypsipyla robusta* shoot borers that kill the main stem of young trees, causing excessive branching and contributing to mortality. Silvicultural techniques such as overhead shading of saplings, mixed planting and removal of lateral shoots can reduce damage by shoot borers. In Nigeria in the 1960s, for instance, shoot borers were found to attack 90–100% of *Khaya ivorensis* trees in pure stands, 0–30% in stands mixed with other *Meliaceae*, 0–50% in stands mixed with non-*Meliaceae* and 0% when planted in lines in natural forest. In Brazil *Khaya ivorensis* is used for reforestation because of its resistance to *Hypsipyla grandella*, the major pest of Brazilian mahogany. However, since 1999 a high incidence of leaf spot caused by the fungus *Thanatephorus cucumeris* (teleomorph of *Rhizoctonia solani*) has been observed, causing numerous lesions on leaves of larger trees and 100% leaf fall in seedlings.

Seeds are commonly attacked by seed-boring beetles and eaten by small rodents. Attacks of living trees by wood borers (*Apate* spp.) have been observed. The bark of saplings is sometimes eaten by porcupines and squirrels, which can kill the plants. In nurseries in Côte d'Ivoire seedlings are frequently attacked by psyllids (*Phacosema* spp.), bugs and scale insects, after which they are infested by secondary fungal pathogens, resulting in a smut blackening the leaves.

Harvesting The minimum bole diameter for exploitation is 60 cm in Côte d'Ivoire and Gabon, 80 cm in Cameroon and 110 cm in Ghana. The boles of *Khaya ivorensis* trees are occasionally so large that they cannot be sawn with normal equipment. The high buttresses at the base of the bole often necessitate the construction of a platform before felling can take place, or the removal of the buttresses before felling to recover more timber.

Yield A natural forest tree with a bole diameter of 80 cm yields on average 6.6 m^3 of timber, a tree 120 cm in diameter 15.5 m^3, and a tree 160 cm in diameter 17.9 m^3.

For plantations at an age of 30 years in tropical Africa, the annual wood production is 2–4 m^3/ha. On good soil in Côte d'Ivoire a 31-year-old stand with 70 trees/ha (on average 37–40 m tall and 57 cm in diameter) produced 8 m^3/ha/year. In 26–28-year-old plantations in Malaysia, mean annual increments of 7.4–7.7 m^3/ha have been recorded.

Handling after harvest Logs may have a spongy or brittle heart, and care is needed in felling and sawing operations. They are susceptible to attack by longhorn beetles and should be processed not too long after felling. The sapwood is often removed soon after felling to prevent attacks by ambrosia beetles. The boles float in water and thus can be transported by river.

Genetic resources *Khaya ivorensis* is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling. It has been proposed for inclusion in CITES appendix I or II, but it has not been listed due to insufficient information on regeneration, extent of plantations and sustainability under current management regimes.

Breeding Provenance trials in Ghana showed a fairly high heritability for height growth, with the growth of the highest-ranking progenies being nearly twice that of the lowest-ranking ones. This may be partly due to some genetic resistance against *Hypsipyla robusta* attack. Provenance trials have also been planted in Côte d'Ivoire.

Prospects Natural regeneration of *Khaya ivorensis* after logging is often poor due to the often low density of mature trees in the forest and low regeneration rates in heavily disturbed forest. It has been suggested that the addition of seeds at favourable sites is a realistic option to obtain sufficient regeneration after logging. More research is needed on appropriate management systems in natural forest to ensure a sustainable exploitation. Management under the tropical shelterwood system seems most appropriate.

Khaya ivorensis is considered one of the most important timber species for plantations, combining fast growth and good timber quality. More extensive establishment of plantations of *Khaya ivorensis* is certainly desirable in tropical Africa, but *Hypsipyla* attack is a serious drawback. The combined effects of selection of provenances with genetic resistance and appropriate silvicultural practices could have a substantial positive impact on the damage caused by *Hypsipyla robusta* stem borers. The integration of *Khaya ivorensis* in agroforestry systems, as is already the case in cocoa based systems in Nigeria, can be considered economically and technically feasible and an ecologically sound strategy.

Extensive biosystematic studies on *Khaya* are recommended, covering the whole range of the

genus and also considering the ecological requirements.

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Sources of illustration Aubréville, 1959a; Wilks & Issembé, 2000.

Authors R.H.M.J. Lemmens

KHAYA SENEGALENSIS (Desr.) A.Juss.

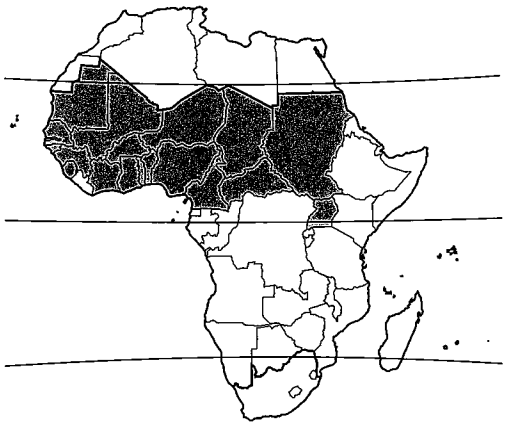
Protologue Mém. Mus. natl. Hist. nat., Paris 19: 250 (1830).

Family Meliaceae

Chromosome number $2n = 50$

Vernacular names Dry-zone mahogany, Senegal mahogany, Gambia mahogany (En). Acajou du Sénégal, acajou caïlcédrat (Fr). Acaju do Senegal, bisselon, mogno de Africa (Po).

Origin and geographic distribution *Khaya senegalensis* occurs from Mauritania and Senegal east to northern Uganda. It is commonly planted within its natural area of distribution, mainly as ornamental and roadside tree, and also outside this area, e.g. in Cape Verde, Tanzania, Malawi, Madagascar, Réunion, Egypt, South Africa, India, Indonesia, Vietnam, Australia and tropical America. In drier zones in Sri Lanka it has become a priority species for timber plantation establishment since mid 1990s, with more than 500 ha of plantation established by 2004 and 200 ha/year of new plantations planned for the future.



Khaya senegalensis – wild

Uses The wood is valued for carpentry, joinery, furniture, cabinet work, ship building and decorative veneer. It is suitable for construction, flooring, interior trim, vehicle bodies, toys, novelties, railway sleepers, turnery and pulpwood. Traditionally, the wood is used for dugout canoes, household implements such as mortars and spoons, and drums. It is also used as fuelwood and for charcoal production.

The bitter-tasting bark is highly valued in traditional medicine. Bark decoctions or macerations are widely taken against fever caused by malaria, and against stomach complaints, diarrhoea, dysentery and anaemia, as anodyne in cases of rheumatism and headache, and as tonic, emmenagogue and anthelmintic. They are also used as purgative, antidote and abortifacient, and to treat syphilis, leprosy, chickenpox and angina. The bark is applied externally as disinfectant in cases of inflammations and to treat skin diseases, rash, scabies, wounds, ulcers, boils, haemorrhoids, swellings and toothache. The bark is commonly used in veterinary medicine, as anthelmintic, tonic and appetizer, and to treat trypanosomiasis, liver flukes, diarrhoea and ulcers. In Uganda it is used as fish poison. In Cameroon the bark is in demand as an additive in local beer brewing. Leaves are also used in traditional medicine, to treat skin complaints, wounds, jaundice, oedema, headache and depression, and as purgative. Roots are applied against jaundice, stomach-ache, oedema and amenorrhoea. The roots and/or bark are an ingredient of complex arrow poisons of which *Strophanthus* roots or seeds are the main ingredients. Flowers are used in medicines against stomach complaints and syphilis. Seed oil is rubbed in to treat rheumatism and influenza, and it is taken to treat syphilis. Young twigs and roots are used as chewing sticks and toothbrushes.

In Ghana the bark has been used for dyeing cloth brownish. The foliage is a common source of fodder, but it has a low fodder quality and is

mainly used towards the end of the dry season when better-quality forage is not available, or in mixtures with better fodders. The seed oil is used in cosmetics and for cooking. The wood ash is added to stored grain to prevent insect attack. *Khaya senegalensis* is commonly planted as a roadside tree and ornamental shade tree, and sometimes for soil stabilization. It has been planted successfully in Burkina Faso in a taungya system with groundnut as intercrop. In many regions it is considered a magic tree used in rituals.

Production and international trade Logs of *Khaya senegalensis* have been exported from West Africa already since the first half of the 19th century, e.g. from Gambia. *Khaya senegalensis* has been heavily exploited for its timber since then. Nowadays, the wood is mainly used locally, and statistics on production and trade are not available. In several countries in the African savanna area *Khaya senegalensis* wood is very important, e.g. in Burkina Faso and Mali, where it may contribute up to 80% of all logs entering local sawmills. Probably the wood of *Khaya senegalensis* is occasionally mixed with the wood of other *Khaya* spp. and traded on the international timber market. The bark is in high demand for medicinal purposes and can be found on many local markets. Seeds are harvested from natural stands and traded worldwide, e.g. 400–600 kg of seed is distributed per year from the Centre National de Semences Forestières (CNSF) in Burkina Faso, of which more than 80% is exported.

Properties The heartwood is pinkish brown, darkening to reddish brown with a purplish tinge upon exposure. It is usually distinctly demarcated from the paler, up to 8 cm wide sapwood, at least in dried wood. The grain is usually interlocked, sometimes straight, texture moderately coarse.

The wood is moderately heavy, with a density of (620–)710–810(–900) kg/m³ at 12% moisture content. It generally air dries rather slowly, but with little degrade; the presence of tension wood may cause splitting and warping. The rates of shrinkage are moderate, from green to oven dry 4.0–5.9% radial and 4.3–7.2% tangential. Once dry, the wood is fairly stable in service.

At 12% moisture content, the modulus of rupture is 82–122 N/mm², modulus of elasticity (7200–)9800–11,650 N/mm², compression parallel to grain 45–54(–72) N/mm², cleavage 15–28 N/mm and Chalais-Meudon side hardness 3.5–5.9(–7.2).

The wood is fairly easy to saw and work, with moderate blunting effect on cutting edges. However, surfaces tend to become woolly and cutting edges should be kept sharp. A reduced cutting angle is recommended when machining quarter-cut boards. The wood holds nails and screws well. It has good gluing properties. It takes polishes and paints well, but the use of a filler is necessary. The peeling properties are poor because of the higher density in comparison with *Khaya anthotheca* and *Khaya ivorensis* and the interlocked grain, but slicing gives decorative veneer. The heartwood is moderately durable to durable, being resistant to termites but moderately susceptible to fungi. The sapwood is susceptible to *Lyctus*. The heartwood is strongly resistant to impregnation, the sapwood moderately resistant. The gross energy value of the wood is about 19,990 kJ/kg.

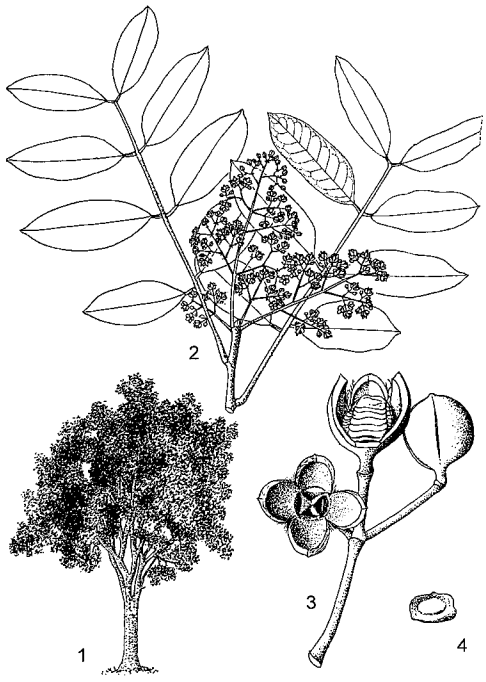
Bark extracts showed in-vitro antiviral activity. They also showed in-vitro antibacterial properties against strains of *Enterococcus faecalis* and *Streptococcus* sp. They exhibited significant leishmanicidal activity. The bark showed anticonvulsant effect in mice, and weak antimalarial activity in mice inoculated with *Plasmodium berghei*. Bark extracts exhibited pronounced antiplasmodial activity against *Plasmodium falciparum* strains, with IC_{50} values less than 5 µg/ml. Some limonoids isolated from the bark showed in-vitro antimalarial activity against strains of *Plasmodium falciparum*, e.g. fissinolide, which also has molluscicidal properties. The anthelmintic effects of the bark have been confirmed in in-vitro tests as well as in in-vivo tests in sheep. In tests with rats, the bark showed anti-inflammatory activity after local application. Aqueous extracts of the bark and leaves exhibited strong antisickling activity. The main active constituent was identified as a rearranged limonoid, of which the activity was much higher than that of pentoxifylline used as standard in managing sickle cell disease. In addition, it did not alter significantly the corpuscular indices. Bark extracts displayed anti-proliferative, anti-inflammatory and pro-apoptotic effects on human colorectal cancer cell lines. The limonoid 3α,7α-dideacetylkhivorin isolated from the bark showed significant growth-inhibitory activity against several cancer cell lines. The extracts showed larvicidal effect against the mosquito *Culex annulirostris*, comparable to azadirachtin, a well-known insecticide of plant origin. Some limonoids iso-

lated from the bark showed significant antifeedant and growth-inhibitory activities against the cotton leafworm *Spodoptera littoralis*; khayanolide B showed strongest activity. Polyphenols from the bark have high antioxidant activity. Leaves contain in general about 5 g of digestible protein and 620 kJ net energy per 100 g dry matter, signifying poor fodder quality. Leaves (moisture content 67.2%) from the Sudanian zone of West Africa were found to contain 8.2% crude protein and 3.7% digestible protein, on a dry matter basis. Leaf extracts are highly toxic to rice weevil (*Sitophilus oryzae*) and may have potential as protectant in stored grain.

The seeds have an oil content of up to 67% and are rich in oleic acid. However, seed oil contents of only 17–27% have also been recorded. Seeds from Senegal contained 58.5% oil, with as principal fatty acids: oleic acid (70.3%), linoleic acid (10.8%), palmitic acid (8.3%) and stearic acid (8.3%).

Adulterations and substitutes The wood of *Khaya senegalensis* resembles true mahogany (from *Swietenia* spp.) more closely than the wood of *Khaya anthotheca* and *Khaya ivorensis* do, but it is heavier and harder. It most closely resembles the wood of *Khaya grandifoliola* C.DC. The wood of makore (*Tieghemella*) is similar, but more durable.

Description More or less evergreen, monoecious, medium-sized tree up to 30(–35) m tall; bole branchless for up to 10(–16) m but often much shorter and crooked, up to 100(–250) cm in diameter, buttresses short or absent; bark surface grey to dark grey or greyish brown, initially smooth but becoming scaly with thin, rounded scales, inner bark dark pink to reddish, exuding a reddish gum; crown rounded, dense; twigs glabrous. Leaves arranged spirally but clustered near ends of branches, paripinnately compound with (2–)3–5(–6) pairs of leaflets; stipules absent; petiole and rachis together up to 25 cm long; petiolules 3–4 mm long; leaflets opposite or nearly so, elliptical to oblong, 5–12 cm × 2.5–5 cm, cuneate and slightly asymmetrical at base, obtuse or very shortly acuminate at apex, margins entire, thinly leathery, glabrous, pinnately veined with 8–10 pairs of lateral veins. Inflorescence an axillary or seemingly terminal panicle up to 20 cm long. Flowers unisexual, male and female flowers very similar in appearance, regular, usually 4-merous, whitish, sweet-scented; pedicel 1–2 mm long; calyx lobed almost to the base, with rounded lobes c. 1.5 mm long; petals free, elliptical, c. 4 mm × 2 mm, somewhat hooded; stamens fused into an urn-shaped tube c. 5 mm long, with usually 8 included anthers near apex, alternating with rounded lobes; disk cushion-shaped; ovary superior, globose to conical, 1–2 mm in diameter, 4-celled, style up to 1 mm long, stigma disk-shaped; male flowers with rudimentary ovary, female flowers with smaller, non-dehiscing anthers. Fruit an erect, nearly globose, woody capsule 4–6 cm in diameter, pale grey to greyish brown, dehiscent by 4 valves, many-seeded. Seeds disk-shaped or quadrangular, strongly flattened, c. 2 cm × 2.5 cm, narrowly winged all around the margin, brown. Seedling with hypogeal germination, cotyledons remaining enclosed in the seed coat; epicotyl 5–6 cm long; first 2 leaves opposite, simple.



Khaya senegalensis – 1, tree habit; 2, flowering twig; 3, fruits; 4, seed.
Redrawn and adapted by Iskak Syamsudin

Other botanical information *Khaya* comprises 4 species in mainland Africa and 1 or 2 endemic to the Comoros and Madagascar. It belongs to subfamily *Swietenoideae* and seems most closely related to *Carapa* and *Swietenia*. *Khaya* species strongly resemble each other in flowers and fruits, and differences are most prominent in their leaflets. *Khaya senegalensis*

is close to *Khaya anthotheca* (Welw.) C.DC. and *Khaya grandifoliola* C.DC., but is usually smaller in all parts.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 24: intervessel pits minute (≤ 4 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; (65: septate fibres present); 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 78: axial parenchyma scanty paratracheal; 79: axial parenchyma vasicentric; (89: axial parenchyma in marginal or in seemingly marginal bands); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 131: intercellular canals of traumatic origin. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells.
(N.P. Mollel, P. Détienne & E.A. Wheeler)

Growth and development Seedlings develop a taproot in deeper soils. They may reach a height of 10 cm after 3 months, with roots about 25 cm long. Under natural conditions, initial growth is slow, seedlings being 12–25 cm tall after 2 years. Early growth may be much faster, but *Khaya senegalensis* is often attacked by *Hypsipyla* shoot borers and it is browsed by cattle and other herbivores, resulting in slow growth and poor form of the stem. Under favourable and unshaded conditions, with the topsoil loosened, seedlings reached 0.5–1.2 m in height after 2 years, in Nigeria even 2 m with a stem diameter of 4.7 cm after 2 years. In very favourable conditions in Senegal even higher growth rates have been recorded. In Côte d'Ivoire *Khaya senegalensis* trees planted in the open in the semi-deciduous forest zone reached an average height of 9 m and an average bole diameter of 16.5 cm after 10 years. In the savanna of northern Côte d'Ivoire trees reached a mean height of 5.5 m at 7.5 years after planting, and sprouts reached 4.8 m after 4.5 years. In southern Burkina Faso, on deep soils on river banks, *Khaya senegalensis* has a diameter up to 50 cm after 25 years. In Benin the average bole diameters in plantations of about 48 years old varied between 30.5 cm and 52 cm. In planted trees in Australia, exceptional annual growth rates of 3 m in height and 4 cm in bole diameter have been recorded.
Trees usually gradually lose their leaves in the dry season, the fallen leaves often immediately being replaced by new ones. Flowering occurs at the end of the dry season or beginning of the rainy season. The flowers are pollinated by insects such as bees and moths. Fruits mature 3–5 months after flowering. Trees can start producing seeds after 20–25 years. Dispersal of the seeds is by wind, but most seeds fall close to the parent tree, normally up to 100 m.

Ecology *Khaya senegalensis* occurs in savanna woodland, often in moist localities and along watercourses, in areas with 650–1300(–1800) mm annual rainfall and a dry season of 4–7 months. It occurs up to 1500(–1800) m altitude. In riparian forest it can sometimes be found together with *Khaya grandifoliola*. It prefers deep and well-drained alluvial soils and termite mounds, but can also be found on shallow, rocky soils, where it usually remains much smaller. It tolerates flooding in the rainy season.

Propagation and planting Natural regeneration can be abundant in savanna areas on good soils without too much competition from herbs, and when protected from fire. In the first years, seedlings tolerate light shade.
The 1000-seed weight is 140–330 g. The seeds are often attacked by insects while they are still on the tree, and undamaged seeds should therefore be selected before sowing. Soaking for 24 hours in water reportedly improves germination, but is not necessary. The seeds can best be sown in seed beds in the nursery or in pots. Fresh healthy seeds have a high germination rate, 90–100%, and they may retain their viability for 6(–8) months. However, when they are exposed to high relative humidity, they may lose their viability within 3 months. When stored at 0–10 °C and a seed moisture content of 5%, seeds retain their high germination rate for at least 4 years. However, other tests showed that storage at 4°C resulted in loss of

viability between 12 and 18 months, whereas storage at −20°C, 15°C and 20°C all showed good results. It is recommended to add ash during storage to reduce insect attacks.

Upon sowing seeds should be covered with only a thin layer of soil, or left partially uncovered. Germination takes 10–18 days. It has been recommended to provide light shade to young seedlings until they are 1–2 months old. In Mali and Côte d'Ivoire seedlings are planted out when they are 3–4 months old and 25–30 cm tall. Seedlings can also be left in the nursery for about one year until they are 0.5–1 m tall, after which the root system is pruned to about 30 cm long and most leaves stripped off before planting out into the field. Stumps with 2–3 cm of stem and 25–30 cm of root can also be planted out. In Senegal 50% of the stumps planted out into the field survived after 5 years, but for good survival rates regular watering after planting is needed. To reduce damage by grazing, seedlings may be planted out when over 1.5 m tall. Normal spacing is 4–5 m × 4–5 m. Wildlings are sometimes collected for planting. Trees also reproduce by root suckers. Grafting and layering is possible, but propagation using cuttings is much more difficult.

In northern Côte d'Ivoire pure plantations were unsatisfactory because of numerous attacks of by *Hypsipyla* shoot borers from as early as the 2nd year after plantation onwards. Planting of small plots with 5–9 *Khaya senegalensis* transplants 1 m apart from each other within a plantation of teak trees planted at the same time significantly reduced borer attacks and allowed good initial growth of both species. Planting *Khaya senegalensis* at wide spacing under light cover in a thinned natural forest or plantation also reduced attacks.

Management In general, *Khaya senegalensis* occurs scattered under natural conditions, often as single individuals. Enrichment planting in woodland has been applied successfully in Vietnam. Plantations in northern Togo established in 1918 showed 70 years later an average tree height of only 12 m and an average bole diameter of 32 cm; possibly they failed due to poor silvicultural management. In Benin the first plantations were established in 1935, but also here they usually failed, not only because of poor management, but probably also because of illegal logging of the largest individuals.

The application of a complete fertilizer at a rate of 200 g/tree at the time of planting is recommended. In young plantations weeding is necessary, as young trees are susceptible to suppression by weeds. Young trees are also susceptible to fire, but older trees are quite fire resistant. In Côte d'Ivoire *Khaya senegalensis* has been planted under the shade of 2-year-old *Leucaena leucocephala* (Lam.) de Wit, which suppresses weeds and fixes nitrogen into the soil. Regular thinning of the shade trees in the first years is needed for good growth of the *Khaya senegalensis* trees. The latter reached an average height of 4.9 m after 5 years, which was more than trees planted nearby in the open, with an average height of 4.0 m. In tropical Africa *Khaya senegalensis* has been planted successfully in mixed plantations with *Azadirachta indica* A.Juss., *Senna siamea* (Lam.) Irwin & Barneby and *Dalbergia sissoo* Roxb. ex DC., in Benin also in a mixture with teak (*Tectona grandis* L.f.).

Realistic rotation cycles under natural conditions are probably in the range of 80–100 years, but in plantations a rotation of 40–60 years is feasible.

Khaya senegalensis trees planted along streets often grow faster than in those in forest plantations, but pruning is necessary to obtain a nice bole.

Diseases and pests In plantations *Khaya senegalensis* suffers seriously from *Hypsipyla robusta* shoot borers that kill the main stem of young trees, causing excessive branching and contributing to mortality. Silvicultural techniques such as overhead shading of saplings, mixed planting and removal of lateral shoots can reduce damage by shoot borers. Products based on methidathion have proved effective in plantations of up to 2 years old, but the costs are very high. In Burkina Faso roadside trees have been attacked by leaf-eating caterpillars, e.g. of *Bourgognea microcera*. Seeds are commonly attacked by seed-boring beetles and eaten by small rodents, whereas young plants can be heavily browsed by cattle, antelopes and other herbivores.

Harvesting The logs are quite difficult to fell using traditional equipment because of the dense and fairly hard wood. Firewood is normally collected from fallen branches, as crosscutting and splitting of larger dimensions of wood is difficult. Bark is collected whenever needed, and in many regions many larger trees show signs of debarking. In some regions the crowns are heavily affected by harvesting the branches for fodder.

Yield In experimental plantations in Burkina Faso the annual production has been esti-

mated at 3.7 m³/ha. In dry forests in northern Côte d'Ivoire a tree 51 cm in diameter yields on average 1.4 m³ of timber, and a tree 67 cm in diameter 2.6 m³.

Genetic resources *Khaya senegalensis* is included in the IUCN Red list as a vulnerable species because of habitat loss and degradation, and selective felling for its timber. Like other *Khaya* spp., populations have been depleted in many regions through centuries of commercial exploitation. The large-scale harvesting of the bark for medicinal purposes and of branches for fodder constitutes another threat to *Khaya senegalensis* populations. It has been reported for some regions in Benin that Fulani people harvest the full crown of more than 70% of the trees, and that additionally the bark is commonly collected as malaria medicine. The harvesters prefer larger trees, and heavily exploited populations showed significantly lower densities of seedlings and saplings than populations under less pressure.
In-situ conservation stands for seed production have been identified and managed in partnership with local people by the Centre National de Semences Forestières (CNSF) in Burkina Faso. The most comprehensive provenance trial reported so far has been established in the early 1970s near Darwin, Australia, with provenances from 9 African countries.

Prospects The actual overexploitation of *Khaya senegalensis* for timber, fodder and medicine is a serious threat for many of its populations. Therefore, sustainable methods of harvesting should be established and implemented as soon as possible. However, much research is still needed to realize this, whereas the environmental conditions and traditional land use are complications that should be considered. The fair growth rate under appropriate conditions makes extensive establishment of plantations an option, but *Hypsipyla* attack is a serious drawback. The combined effects of selection of provenances with genetic resistance and appropriate silvicultural practices could have a substantial positive impact on the damage caused by *Hypsipyla robusta* stem borers. Research priority should be given to range-wide selection of genotypes which are resistant to stem-borer attack, are fast growing and have acceptable wood quality. The establishment of appropriate methods of vegetative propagation including tissue culture is urgently needed.
The bark demonstrated several interesting pharmacological activities, such as antimalarial, anti-inflammatory and anticancer effects. This deserves more research attention for possible development into new drugs. The insecticidal and anthelmintic activities of the bark are also noteworthy.

Major references Arbonnier, 2004; Arnold, 2004; Bolza & Keating, 1972; Burkill, 1997; CAB International, 2005; CTFT, 1959a; CTFT, 1988b; Katende, Birnie & Tengnäs, 1995; Sokpon & Ouinsavi, 2004; World Agroforestry Centre, undated.

Other references Androulakis et al., 2006; Caniato & Puricelli, 2003; CIRAD Forestry Department, 2003; Danthu, Gaye & Sarr, 1999; Djodjouwin, 1990; Donkor, 1997; Dupuy & M'Bla Koua, 1993; Fall et al., 1999; InsideWood, undated; Lauber & Bellefontaine, 1989; Miralles, 1983; Neuwinger, 1996; Neuwinger, 2000; Neya, 2006; Nikles, Reilly & Robertson, 2004; Styles & White, 1991; Takahashi, 1978; Thiel et al., 1993; von Maydell, 1986; Wiselius, 1998; Zhang et al., 2007.

Sources of illustration Aubréville, 1950; CTFT, 1988b.

Authors A. Nikiema & D. Pasternak

KIRKIA ACUMINATA Oliv.

Protologue Fl. trop. Afr. 1: 311 (1868).

Family Simaroubaceae (APG: Kirkiaceae)

Vernacular names White syringa, white kirkia, bastard marula (En).

Origin and geographic distribution *Kirkia acuminata* is distributed in DR Congo and throughout southern Africa; possibly in Tanzania as well. It also occurs in South Africa.

Uses The wood of *Kirkia acuminata* is used for poles and planks, household utensils (bowls, spoons), carts, musical instruments, tourist items, veneer and plywood. In South Africa the wood is made into furniture and floor blocks. The wood is also considered suitable for light construction, flooring, vehicle bodies, cabinet work, interior trim, agricultural implements, boxes and crates, core stock, matches, toys and novelties, turnery, hardboard and particle board, and as pulpwood. In Malawi the wood is made into charcoal.
Kirkia acuminata is often planted as a live fence. The bark fibre is made into cloth. The seeds and leaves are browsed by livestock. The swollen roots are used as a source of water in times of drought. In Zimbabwe an infusion of the bark is taken against vomiting and abdominal pain. An infusion of the root is taken to treat cough. The fruit sap is applied on

wounds and as an antidote on snake bites. Pulverized roots are a remedy for toothache.

Properties The heartwood is pale brown or green-brown, with an attractive dark brown veining; the sapwood is yellow-white or pale grey and up to 7.5 cm wide. The grain is usually straight, locally interlocked, the texture is fine. The density of the wood is 580–720 kg/m^3 at 12% moisture content. It is soft to moderately hard. Thin boards dry easily, but thick boards are difficult to season; splitting and surface checking may occur.

The wood saws easily, but rapidly blunts tools, due to the presence of silica crystals; frequent sharpening of cutting edges is necessary. The wood planes easily and turns fairly well. It polishes readily, glues satisfactorily and slices and peels well.

The durability of the heartwood is moderate, and the sapwood is susceptible to *Lyctus* borers. The heartwood is resistant to impregnation and the sapwood moderately resistant.

The seeds have an in-vitro dry matter digestibility of 39%. Per 100 g dry matter they contain: crude protein 11.0 g, neutral detergent fibre 61.0 g, acid detergent fibre 50.5 g, tannins 3.1 g, Ca 840 mg, Mg 430 mg and P 290 mg. Per 100 g dry matter the leaves contain: crude protein 8.1 g and neutral detergent fibre 11.8 g.

Botany Semi-deciduous, monoecious medium-sized tree up to 20(–23) m tall; bole up to 90 cm in diameter; bark pale grey to grey, smooth, becoming fissured with age, with salmon-pink lenticels; crown large, rounded, spreading; branches marked with leaf scars. Leaves arranged spirally, clustered at ends of branches, up to 45 cm long, imparipinnately compound with (3–)6–12(–20) pairs of leaflets, viscid when young; stipules absent; petiole 3–10 cm long; petiolules up to 2 mm long; leaflets opposite, narrowly ovate to lanceolate, 2–9(–11) cm × 1–2.5(–3) cm, base slightly oblique, apex acuminate, margin finely notched, glabrous or hairy, pinnately veined. Inflorescence an axillary thyrse up to 30 cm long, many-flowered; peduncle up to 20 cm long; bracts up to 2.5 cm long. Flowers functionally unisexual, regular, 4-merous; pedicel up to 6 mm long, jointed near base, whitish hairy; sepals almost completely free, ovate, 1–2.5 mm × 1–2.5 mm, glabrous or pubescent; petals free, lanceolate, 3–6 mm × 1–1.5 mm, glabrous or pubescent outside, greenish white to cream; stamens free, alternate with petals, in female flowers reduced and sterile; ovary superior, 4-locular, reduced in male flowers. Fruit oblong-ellipsoid, 4-sided, 8–25 mm × 5–11 mm, woody, pubescent to glabrous, separating into 1-seeded mericarps, each attached by a strip of tissue to top of central carpophore. Seeds almost as large as mericarp, rounded at one end and pointed at the other, 3-angled.

In southern Africa *Kirkia acuminata* forms new leaves in September–October, flowers in October–December and fruits from January onwards.

Kirkia comprises 5 species, distributed in tropical Africa from Ethiopia and Somalia to northern South Africa.

Ecology *Kirkia acuminata* is drought resistant and prefers hot and dry areas; it is susceptible to frost. It occurs up to 1600 m altitude in a range of habitats: bushland, woodland, savanna and rocky hillslopes. It prefers well-drained, basic soils, but may be found on various soil types, from alluvial flats and sandy or loamy soils near rivers to sandy and dry soils and rocky slopes.

Management *Kirkia acuminata* is easily propagated using seed or stem parts, and it is fast-growing.

Genetic resources and breeding As *Kirkia acuminata* is widely distributed and occurs in a wide range of habitats, it is unlikely to be threatened by genetic erosion. It is, however, protected in South Africa.

Prospects The softness of the wood and the relatively wide sapwood restrict the usability of the wood of *Kirkia acuminata*, but the attractive figure of the wood makes it suitable for decorative purposes, e.g. for panelling and veneer. *Kirkia acuminata* has potential as an ornamental and shade tree.

Major references Bolza & Keating, 1972; Coates Palgrave, 1983; Immelman, 1986; Scott, 1950; Stannard, 1981.

Other references Aganga & Mosase, 2001; Braedt & Standa-Gunda, 2000; Gelfand et al., 1985; Gilbert, 1958b; Grundy et al., 1993; Msekandiana, 2001; Pardy, 1952; Sibanda & Ndlovu, 1992; Stannard, 2000; Wild, Phipps & Paiva, 1969.

Authors M. Brink

LECOMTEDOXA KLAINEANA (Pierre ex Engl.) Dubard

Protologue Ann. Inst. Bot.-Géol. Colon. Marseille sér. 3, 3: 32 (1915).

Family Sapotaceae

Origin and geographic distribution *Lecom-*

Lecomtedoxa klaineana – wild

tedoxa klaineana occurs in southern Cameroon, Equatorial Guinea and Gabon.

Uses The wood (trade name: ogoumo) is used for carpentry. It is suitable for heavy construction, heavy flooring, ship and boat building, vehicle bodies, furniture, sliced veneer, interior trim, joinery, railway sleepers, poles, mine props and toys and novelties. In Gabon the latex has been administered as a tonic to women after childbirth.

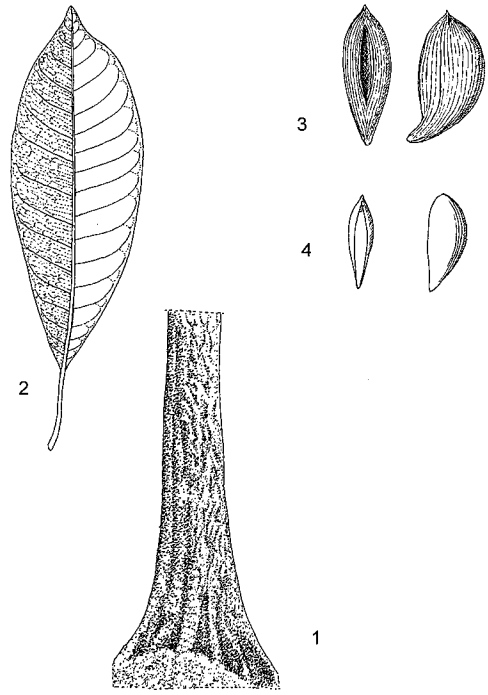
Properties The heartwood is reddish brown, distinctly demarcated from the whitish sapwood. The grain is fairly straight, texture fine. The wood is heavy, with a density of 900–1040 kg/m^3 at 12% moisture content. It dries slowly and needs to be dried with care. The shrinkage rates are high, from green to oven dry 5.9–7.8% radial and 9.0–11.8% tangential.

At 12% moisture content, the modulus of rupture is 180–232 N/mm^2, modulus of elasticity 13,600–20,300 N/mm^2, compression parallel to grain 75–91 N/mm^2, shear 8.9–18.9 N/mm^2, cleavage 26–39 N/mm and Chalais-Meudon side hardness 4.8–17.9.

The wood saws slowly, and has a moderate blunting effect on saws and other tools, although silica is absent. The latex may gum up sawteeth and tool edges. The wood planes fairly easily with a smooth finish and takes a good polish. It tends to split on nailing and preboring is needed. The gluing properties are satisfactory. The wood can be used for sliced veneer, but rotary peeling is difficult. It is durable and resistant to fungi, dry-wood borers and termites. It is resistant to impregnation with preservatives.

Adulterations and substitutes The wood is similar to several other heavy *Sapotaceae* woods, e.g. those of *Autranella congolensis* (De Wild.) A.Chev. and *Baillonella toxisperma* Pierre, which both occur in the same region as *Lecomtedoxa klaineana*.

Description Medium-sized to large tree up to 40 m tall; bole straight and cylindrical, branchless for up to 25 m, up to 120 cm in diameter, often with broad and steep buttresses; outer bark reddish brown, scaly, inner bark pinkish brown, containing white latex; crown hemispherical; young branches glabrous. Leaves arranged spirally, clustered at the ends of branchlets, simple and entire; stipules absent; petiole c. 2 cm long; blade elliptical to slightly obovate, 8–15 cm × 2.5–5.5 cm, cuneate at base, rounded to shortly acuminate at apex, leathery, glabrous, pinnately veined with 10–15 pairs of lateral veins and with small veins parallel to lateral veins. Flowers in fascicles in leaf axils, bisexual, regular, 5-merous, c. 5 mm long, pedicellate; sepals free, ovate; corolla with short tube and 5 lobes divided to near the base into 3 segments, white; stamens inserted at top of corolla tube, opposite each corolla lobe, alternating with lanceolate staminodes



Lecomtedoxa klaineana – 1, base of bole; 2, leaf; 3, fruits; 4, seeds.
Redrawn and adapted by Iskak Syamsudin

with a long point at apex; ovary superior, hairy, 5-celled, style long and slender. Fruit a boat-shaped capsule c. 5 cm × 2.5 cm in diameter, with leathery wall, dehiscent, 1-seeded. Seed slightly obliquely ellipsoid, flattened, c. 3 cm × 2 cm, yellowish brown, shiny, with a scar over almost the full length.

Other botanical information *Lecomtedoxa* comprises 5 species and is restricted to a small part of Central Africa, with most species in Gabon. It is poorly known, but seems most closely related to *Neolemonniera*, which is similar in flower and fruit structure, but differs by its leaf striations and presence of stipules. *Lecomtedoxa nogo* (A.Chev.) Aubrév. (of which the illegitimate name *Lecomtedoxa heitziana* (A.Chev.) Aubrév. is possibly a synonym) differs from *Lecomtedoxa klaineana* in its larger leaves with small veins transverse to lateral veins. Its wood is probably used in the same way as that of *Lecomtedoxa klaineana*. Its seeds provide a cooking oil used in Gabon, although fresh seeds are reportedly toxic. *Lecomtedoxa nogo* is classified as vulnerable in the 2006 IUCN Red list of threatened species, due to its restricted distribution, which is limited to western Gabon.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 7: vessels in diagonal and/or radial pattern; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); (24: intervessel pits minute (≤ 4 μm)); 25: intervessel pits small (4–7 μm); 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 32: vessel-ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade); (33: vessel-ray pits of two distinct sizes or types in the same ray cell); 42: mean tangential diameter of vessel lumina 100–200 μm; 47: 5–20 vessels per square millimetre; 56: tyloses common. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 70: fibres very thick-walled. Axial parenchyma: (76: axial parenchyma diffuse); (77: axial parenchyma diffuse-in-aggregates); 86: axial parenchyma in narrow bands or lines up to three cells wide; (87: axial parenchyma reticulate); 93: eight (5–8) cells per parenchyma strand; 94: over eight cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 108: body ray cells procumbent with over 4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells.
(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development The fruits of *Lecomtedoxa klaineana* ripen in October–December. They are eaten by monkeys, which may serve as seed dispersers.

Ecology *Lecomtedoxa klaineana* occurs in primary rainforest.

Handling after harvest The freshly cut logs are too heavy to float in water and cannot be transported by river.

Genetic resources *Lecomtedoxa klaineana* has a limited area of distribution. Although it may be locally dominant, it is in general uncommon. This makes it liable to genetic erosion and attention is needed to sufficiently protect this species.

Prospects *Lecomtedoxa klaineana* has few prospects as a commercial timber tree. It is an uncommon species of limited distribution, and focus should be on its protection instead of commercialization.

Major references Aubréville, 1961; Bolza & Keating, 1972; de Saint-Aubin, 1963; Normand & Paquis, 1976; Raponda-Walker & Sillans, 1961; Takahashi, 1978.

Other references Aubréville, 1964; InsideWood, undated; Pennington, 1991; Tailfer, 1989; Usongo & Amubode, 2001; Wilks & Issembé, 2000; World Conservation Monitoring Centre, 1998c.

Sources of illustration Aubréville, 1961; de Saint-Aubin, 1963.

Authors R.H.M.J. Lemmens

LEPIDOTRICHILIA VOLKENSII (Gürke) J.-F.Leroy

Protologue Fl. Zamb. 2(1): 305 (1963).

Family Meliaceae

Synonyms *Trichilia volkensii* Gürke (1894).

Origin and geographic distribution *Lepidotrichilia volkensii* occurs in mountainous areas in eastern DR Congo, Rwanda, Burundi, Sudan, Ethiopia, Kenya, Uganda, Tanzania, Malawi and Zambia.

Uses In Ethiopia the wood is used for local construction and as fuelwood. In Tanzania it has the same uses, and is additionally used for spoons and tool handles, and for charcoal pro-

duction. The fruit is edible and eaten raw in Ethiopia, where the bark is used in fermentation processes.

Properties The heartwood is whitish and hard, with a fine texture. The sesquiterpenoid voleneol has been isolated from *Lepidotrichilia volkensii*.

Botany Evergreen shrub or small to medium-sized tree up to 20(–25) m tall; bole often fluted; bark surface smooth, greyish; inner bark pink to red, sometimes with white lines, scented; crown spreading, strongly branched; young branches densely short-hairy. Leaves alternate, imparipinnately compound with (5–)7–11 leaflets; stipules absent; petiole 2.5–8 cm long, rachis 5–20 cm long; petiolules 2–10 mm long; leaflets opposite or alternate, elliptical to ovate, oblong or lanceolate, 5–20 cm × 2–7.5 cm, cuneate to obtuse and often asymmetrical at base, acute to acuminate at apex, short-hairy below with stellate hairs and minute glandular dots, pinnately veined. Inflorescence an axillary contracted panicle up to 25 cm long, short-hairy with yellowish brown, stellate hairs. Flowers bisexual, regular, 5-merous, creamy white, fragrant; pedicel 1–2.5 mm long; calyx cup-shaped, c. 2 mm long, with minute teeth; petals free, oblong-lanceolate, 4–5 mm long; stamens 3–4 mm long, fused in lower half into a tube, slightly hairy inside; ovary superior, nearly globose, glabrous, 2–4-celled, style 1–2 mm long, stigma head-shaped, surmounted by 2–4 erect stigmatic lobes. Fruit a depressed-globose berry 7–15 mm in diameter, shallowly grooved, densely covered with stellate hairs, (1–)2–3-seeded. Seeds 2–3 mm long, glossy dark brown or black.
Lepidotrichilia comprises 4 species, 3 of which are endemic to Madagascar.

Ecology *Lepidotrichilia volkensii* is restricted to montane forest at (1050–)1500–2400(–3300) m altitude, where it often occurs in the understorey of moist forest types in association with *Podocarpus*, *Hagenia* and *Schefflera*, but sometimes also in secondary evergreen bushland. The mean annual rainfall range is 1500–2000 mm.

Management *Lepidotrichilia volkensii* can be propagated by seed or by planting out wildlings. Treatment of the seed is not needed, but seeds can only be stored for short periods before they lose their viability.

Genetic resources and breeding Although *Lepidotrichilia volkensii* is an Afromontane endemic, there are no indications that it suffers from genetic erosion; it is fairly widespread and locally common.

Prospects Because *Lepidotrichilia volkensii* usually has a small bole size and only occurs in mountainous areas, it is very unlikely that the future importance of its wood will exceed its actual limited usage.

Major references Bekele-Tesemma, 2007; Friis, 1992; Lovett et al., 2006; Styles & White, 1991.

Other references Beentje, 1994; Eggeling & Dale, 1951; Mulholland, Parel & Coombes, 2000; Staner & Gilbert, 1958; Styles & White, 1989; Troupin, 1982; von Breitenbach, 1963; White & Styles, 1963.

Authors R.H.M.J. Lemmens

LETESTUA DURISSIMA (A.Chev.) Lecomte

Protologue Notul. Syst. (Paris) 4: 5 (1920).
Family Sapotaceae
Synonyms *Letestua floribunda* Lecomte (1920).

Origin and geographic distribution *Letestua durissima* is distributed in Central Africa (Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, DR Congo).

Uses The wood of *Letestua durissima*, known in the trade as 'congotali' is considered suitable for heavy construction and flooring, mine props, ship and boat building, vehicle bodies, sporting goods, agricultural implements, musical instruments, precision equipment, joinery, sleepers, poles and piles, toys and novelties, and pattern making. The extent of its use in tropical Africa is unknown.
A bark decoction is a component of a traditional medicine against leprosy.

Production and international trade In 2003 the export of *Letestua durissima* sawnwood from DR Congo was 3000 m³ at an average price of US$ 102 per m³. Export from Cameroon is prohibited.

Properties The heartwood is fairly dark red-brown, turning chestnut brown with age; it is distinctly demarcated from the 5–9 cm wide pale brown sapwood. The grain is usually straight, but sometimes interlocked; the texture is fine to medium.
The wood is very heavy, with a density of 1035–1130 kg/m³ at 12% moisture content. Shrinkage rates are high: 5.9–7.8% radial and 9.0–11.8% tangential from green to oven dry. Drying is slow, with high risks of distortion and checking. The dried wood is fairly stable. The low saturation point makes the wood suit-

able for use in humid conditions, e.g. mine work. The wood is very hard, strong, resilient and stiff. At 12% moisture content, the modulus of rupture is 180–265 N/mm², modulus of elasticity 13,630–26,700 N/mm², compression parallel to grain 75–92 N/mm² and shear 9–19 N/mm².

The wood is slow and difficult to saw due to the high silica content, which leads to severe blunting, and an irritating dust is produced. The wood should be sawn as fresh as possible and stellite-tipped sawteeth are recommended. Planing is relatively easy and gives a smooth surface. Pre-boring for nailing and screwing is recommended to avoid splitting, but the wood holds nails well. It glues well, when done carefully.

The durability of the wood is high. It is rarely attacked by termites, but must be treated to prevent marine borer attack. The sapwood is not susceptible to *Lyctus* borers. The wood is resistant to preservative treatment.

Botany Large tree up to 50 m tall; bole branchless for up to 40 m, straight, cylindrical, up to 240 cm in diameter, base fluted or with steep buttresses; outer bark grey with rectangular scales, inner bark fibrous, pink, exuding a white latex; branches thick, covered with scars from fallen leaves, young branches glabrous, terminal buds glandular. Leaves arranged spirally, clustered at the ends of branches, simple and entire; stipules absent; petiole 3–4 cm long, grooved near blade; blade obovate-oblong, 16–24 cm × 5–10 cm, cuneate at base, rounded at apex, leathery, upper surface shiny, pinnately veined with 12–17 pairs of lateral veins. Flowers in fascicles in the leaf axils, bisexual, regular; pedicel c. 2 cm long, glabrous; sepals in 2 whorls of (2–)3, hairy outside, glabrous inside; corolla with a short tube and 12–18 lobes c. 3.5 mm long, each lobe with 2 large lateral appendages, white, glabrous; stamens opposite each corolla lobe; ovary superior, 16–18-celled. Fruit an ovoid-elongate fleshy berry 5–8 cm long, indehiscent, 1-seeded. Seed ellipsoid, compressed, c. 3.5 cm × 1 cm × 1 cm, tapering at both ends, with linear scar c. 3 cm long, seed coat woody, shiny brown. Seedling with epigeal germination.

In Gabon *Letestua durissima* flowers in December. In Congo the fruits ripen in October–November.

Letestua comprises a single species.

Ecology *Letestua durissima* occurs scattered in primary rainforest.

Management Germination is about 100% in 7–30 days when fresh seeds are used.

Genetic resources and breeding It is unclear to what extent *Letestua durissima* is threatened by genetic erosion. Although it is not included in the IUCN red list of threatened species, caution is warranted for a species of primary rainforest with limited distribution.

Prospects Because of its strength and durability, the wood of *Letestua durissima* is particularly suitable for heavy construction purposes, but sustainable production methods seem difficult to develop because of its probable slow growth and ecological requirements.

Major references ATIBT, 1986; Aubréville, 1961; Bolza & Keating, 1972; Pennington, 1991; Takahashi, 1978.

Other references CIRAD Forestry Department, 2003; de Saint-Aubin, 1963; Fouarge & Gérard, 1964; ITTO, 2006; Normand & Paquis, 1976; Pangou & Ilengo-Boumba, 1984; Raponda-Walker & Sillans, 1961; Wilks & Issembé, 2000.

Authors M. Brink

LOVOA TRICHILIOIDES Harms

Protologue Bot. Jahrb. Syst. 23: 165 (1896).

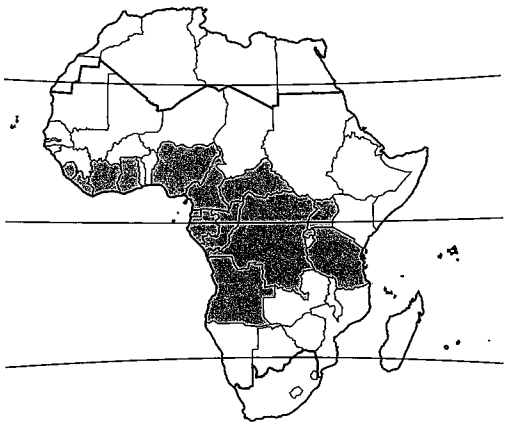
Family Meliaceae

Chromosome number $2n = 50$

Synonyms *Lovoa brownii* Sprague (1906), *Lovoa klaineana* Pierre ex Sprague (1906).

Vernacular names African walnut, tigerwood, Congowood, brown mahogany (En). Noyer d'Afrique, noyer du Gabon (Fr).

Origin and geographic distribution *Lovoa trichilioides* is widespread, from Sierra Leone east to western Uganda, and south to north-



Lovoa trichilioides – wild

western Tanzania and northern Angola.

Uses The wood (trade name: dibetou) is highly valued for furniture, cabinet work, flooring, carpentry, joinery, interior trim, stairways, panelling and decorative veneer and plywood. It is locally used for house construction, vehicle bodies, implements and handles, and to make canoes. It is suitable for ship building, sporting goods, toys, novelties, railway sleepers, carving, boxes, crates, turnery and pulpwood. It is also used as firewood and for charcoal production.

In Congo pulped bark is rubbed on the chest to treat pulmonary troubles. The bark is also used against dental caries. The tree is occasionally planted as a roadside tree. It is promoted in Uganda for tree planting programmes; it is locally planted as a shade tree in agroforestry programmes, for crops such as coffee and banana. The flowers are a source of nectar for honey bees.

Production and international trade Around 1970 Côte d'Ivoire was the most important exporter of dibetou logs with annual export volumes of about 80,000 m³ between 1968 and 1974. Cameroon exported 13,100 m³ and 10,400 m³ of sawn wood in 2003 and 2004, respectively, and 9900 m³ in 2006. In Gabon the export of dibetou logs was 10,400 m³ in 1991, decreasing to an annual average of 5100 m³ in 2000–2004. The sawn wood export from Gabon was 1000 m³ in 2001, at an average price of US$ 239/m³. Congo exported 2100 m³ of logs in 2004, and 4100 m³ in 2006. Ghana exported small amounts of African walnut plywood: in 2003, 2004 and 2005, at an average price of US$ 398/m³, US$ 352/m³ and US$ 383/m³, respectively.

Properties The heartwood is yellowish brown to greyish brown, often with golden and blackish markings, and distinctly demarcated from the pale brown to pale grey, 3–7 cm wide sapwood. The grain is usually interlocked, texture moderately fine to fine. The wood is lustrous and has an attractive appearance, with a ribbon-like aspect on quarter-sawn surfaces. It has a cedar-like scent.

The wood is medium-weight, with a density of 450–610(–680) kg/m³ at 12% moisture content. With some caution, it air dries and kiln dries well, with only slight risk of distortion and checking. The rates of shrinkage are medium, from green to oven dry 2.8–5.3% radial and 5.6–8.8% tangential. Once dry, the wood is stable in service.

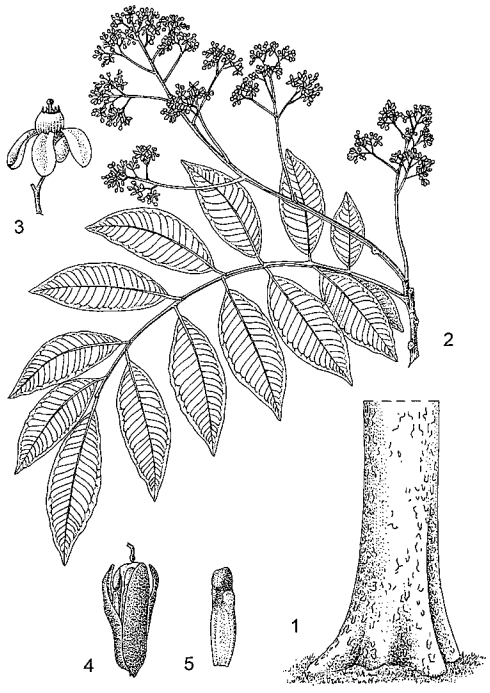
At 12% moisture content, the modulus of rupture is 70–119 N/mm², modulus of elasticity 7300–11,600(–14,900) N/mm², compression parallel to grain 39–59 N/mm², shear 6–10 N/mm², cleavage 10–18 N/mm, Janka side hardness 4180–4220 N and Janka end hardness 5000–5030 N.

The wood is easy to saw and work; ordinary equipment can be used. There is some tendency of picking up of grain when the wood is quarter-sawn, and planing may be difficult because of the presence of interlocked grain, resulting in tearing. A cutting angle of 15–20° is recommended. Tools should be kept sharp. The nailing and screwing properties are good, although there may be some tendency to splitting. The wood finishes well, but for a fine polish the use of a filler is recommended. The gluing, painting and varnishing properties are satisfactory, the steam bending properties moderate.

The wood is rather susceptible to fungal, termite and dry-wood borer attacks, and very susceptible to attack by marine borers. In a test in Ghana in which the wood was exposed to the termite *Coptotermes formosanus*, active feeding of the termite on the wood was noted. The heartwood is resistant to impregnation by preservatives. The sawdust may be irritant.

In the seed oil, dienoic unsaturated acids predominate.

Description Evergreen large tree up to 45 m tall; bole branchless for up to 25(–30) m, usually straight and cylindrical, sometimes sinuous, up to 120(–200) cm in diameter, slightly thickened at base or with short buttresses; bark surface greyish brown to blackish brown, smooth to scaly, with many lenticels, inner bark pinkish red with whitish streaks, fibrous, with strong sweet smell; crown dense, dark green; twigs glabrous. Leaves alternate, paripinnately or imparipinnately compound with (5–)10–15 leaflets, glabrous; stipules absent; petiole 3–9 cm long, channelled and slightly winged, rachis 4–20(–30) cm long; petiolules 2–10 mm long; leaflets opposite to alternate, elliptical to oblong-lanceolate, 5–25 cm × 2–10 cm, cuneate to rounded at base, obtuse to acuminate at apex, leathery, pinnately veined with closely spaced lateral veins. Inflorescence an axillary or terminal panicle up to 40 cm long, glabrous. Flowers functionally unisexual, regular, 4-merous; pedicel 1.5–3 mm long, jointed; calyx lobed almost to the base, 1–2 mm long; petals free, elliptical, 4–6.5 mm long, white, tinged greenish or reddish; male flowers with stamens fused into a cup-shaped tube with 8 anthers at margin, ovary not functional; female



Lovoa trichilioides – 1, base of bole; 2, flowering twig; 3, flower; 4, fruit; 5, seed.
Redrawn and adapted by Achmad Satiri Nurhaman

flowers with superior, globose ovary, 4-celled, gradually passing into the style, stigma head-shaped, stamens not functional. Fruit a pendulous, tetragonal capsule 4–7 cm × 1–1.5 cm, black, dehiscing with 4 valves, many-seeded with seeds attached to the top of the central column. Seeds 4–6 cm long including the large apical wing. Seedling with epigeal germination, but cotyledons often remaining within the testa; hypocotyl 3–4 cm long, epicotyl 2–3 cm long; first 2 leaves opposite, with 2 pairs of leaflets.

Other botanical information *Lovoa* comprises 2 species, both confined to tropical Africa. It belongs to the tribe *Swietenieae* and is related to *Entandrophragma*, *Khaya* and *Pseudocedrela*.

Lovoa swynnertonii Baker f. occurs in eastern DR Congo, Kenya, Uganda, Tanzania, Zimbabwe and Mozambique, in rainforest up to 1500 m altitude. It differs from *Lovoa trichilioides* by its asymmetrical leaflets and hairy inflorescences, but is otherwise similar. Its wood has been used for similar purposes as that of *Lovoa trichilioides*. *Lovoa swynnertonii* has been subject to heavy exploitation in many regions and is rare almost everywhere in its distribution area; it is listed as endangered in the IUCN Red list.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); (25: intervessel pits small (4–7 μm)); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; (65: septate fibres present); 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: (76: axial parenchyma diffuse); 78: axial parenchyma scanty paratracheal; 79: axial parenchyma vasicentric; (80: axial parenchyma aliform); (81: axial parenchyma lozenge-aliform); 83: axial parenchyma confluent; (84: axial parenchyma unilateral paratracheal); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; 104: all ray cells procumbent; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 114: ≤ 4 rays per mm; 115: 4–12 rays per mm. Secretory elements and cambial variants: 131: intercellular canals of traumatic origin. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells.
(H. Beeckman & P. Détienne)

Growth and development Natural regeneration is often abundant, although the seed suffers heavy predation. Seedlings of about 20 cm tall may be abundant even in full shade, where they may survive for several years, but saplings only grow where gaps develop in the forest canopy. Early growth is generally slow, with planted seedlings reaching 100 cm height in 2 years and 150 cm in 3 years. In exceptional cases trees reach a height of 2.5 m after 1 year. After the first years, growth becomes faster, and there are records of young trees attaining 9 m in height after 7 years. In plantations in Uganda an average bole diameter of 25 cm was reached after 25 years, whereas in

Nigeria and Cameroon a mean annual diameter increment of 1.0–1.8 cm was recorded. In experiments in Gabon, 11-year-old trees planted in light shadow were 20 m tall and 16.5 cm in diameter, whereas growth of trees planted in full sun was slower. In natural forest the mean annual diameter increment is about 5 mm.

In West Africa trees flower in the dry season and fruits are ripe in February–April. However, seeds are not produced each year; in Liberia and Nigeria good seed years reportedly occur every 3–4 years. The seeds are dispersed by wind, turning like a propeller while falling. The presence of vesicular-arbuscular mycorrhizal fungi of the genus *Glomus* in the soil close to *Lovoa trichilioides* trees has been demonstrated.

Ecology *Lovoa trichilioides* occurs scattered in evergreen forest and semi-deciduous forest, up to 1200 m altitude. It prefers moist but free draining localities on alluvial soils and more than 2000 mm annual rainfall. In Ghana it is strongly associated with acid soils. In Uganda it is common in mixed rainforest along Lake Victoria, but can also be found in gallery forest and thickets.

Propagation and planting For planting, seeds are collected from the forest floor, although many seeds may already be attacked by insects. The 1000-seed weight is 100–230 g. The seed including the wing is usually covered for up to three-quarters with soil. Seeds have a short viability, with up to 90% germination for fresh seed, but only about 30% germination after 2 months. Seeds start germinating after 8–16 days. They should be stored in sealed containers and ash should be added because they are very susceptible to insect attack. Wildlings are sometimes used for planting; they should be watered abundantly. A successful method of propagation by stem cuttings has been developed in Cameroon. Long, thin cuttings with large leaf areas (50–200 cm^2) made from apical nodes of multi-stemmed stockplants rooted best, with a rooting rate of up to 60%. Stem cuttings rooted best in coarse gravel. The application of auxins had no clear effect on rooting.

For transplanting in the forest, seedlings in bags should be about 50 cm tall. Stumps or striplings 150–180 cm long can also be used. For planting in the field it is recommended to plant under moderate shade and to avoid full sun. It has been reported that trees developed very successfully when planted in groups or lines in thinned natural forest. In an experiment in Gabon, 100% of planted seedlings survived 1 year after planting, both in sites that had been clear-cut and in sites where the forest canopy was opened up and the undergrowth removed. After 6 years, survival was 94% in the undergrowth of opened-up forest, with trees having a mean height of 11.6 m and a mean bole diameter of 11.2 cm, and only 76% in clear-cut sites, with trees having a mean height of 8.9 m and a mean bole diameter of 7.0 cm. Initial weeding is important and climbers have to be removed. It is difficult, however, to progressively remove the shade without hurting the saplings.

Management In the forest, large trees of *Lovoa trichilioides* generally occur scattered. In southern Cameroon densities of trees with a bole diameter larger than 60 cm vary between 3 boles and 25 boles per 100 ha, and the average bole volume varies between 0.15 m^3 and 2.3 m^3 per ha. In Côte d'Ivoire, the Central African Republic, Gabon and Congo the densities are generally low, with less than 1 bole of more than 60 cm diameter per 10 ha, but in south-eastern Gabon up to 1 bole per 2 ha may occur. In Liberia the average number of exploitable trees is 12 per 100 ha, locally up to 25.

In Cameroon approximately 6400 ha have been planted with *Lovoa trichilioides*. Plantations have also been established in Côte d'Ivoire, Nigeria and Uganda. Pruning prevents early branching and is advantageous for timber production. In Nigeria it is recommended that pure stands of *Lovoa trichilioides* be thinned to about 300 trees per ha by the 15th year, and to 100 trees per ha by the 30th year, to enable the trees to attain a diameter of about 90 cm in 60–70 years.

Diseases and pests Large-scale destruction of seedlings by shoot borers has been recorded. In Cameroon longhorn beetles, borers, scale insects and defoliator insects are the main pests observed in young plantations, and collar decay also occurs. Antelopes and rodents eat the bark of seedlings and young trees. Fruits and seeds are subject to heavy predation by insects such as *Catopyla dysorphnaea*.

Harvesting In natural forest the minimum diameter for felling is 60 cm in Côte d'Ivoire and DR Congo, 70 cm in Liberia, Ghana and Gabon, and 80 cm in Cameroon and Central African Republic. Some caution is needed during felling operations because logs may have heart shakes and brittle heart.

Yield Trees with a bole diameter of 60, 100, 140 and 180 cm yield about 3.0, 10.9, 22.7 and 38.4 m^3 of timber, respectively. In Cameroon the annual average yield has been recorded as only 1.8 m^3/ha, but this was attributed to planting in unfavourable localities.

Handling after harvest When logs are left in the forest for some time, treatment with preservatives is recommended. Logs float in water and can be transported by river.

Genetic resources *Lovoa trichilioides* is included in the IUCN Red list of threatened species as vulnerable, mainly because exploitation rates are high.

Prospects *Lovoa trichilioides* wood is in high demand on the international market, which resulted in much pressure on natural populations. It has become vulnerable, and the establishment of methods of sustainable forest management for this species are needed. It can be expected that rotation cycles of about 50 years are needed for sustainable harvest. *Lovoa trichilioides* is recommended for forest enrichment planting.

Major references Bolza & Keating, 1972; Burkill, 1997; CAB International, 2005; CTFT, 1978b; Farmer, 1972; Katende, Birnie & Tengnäs, 1995; Nkouankou, 1989; Takahashi, 1978; Voorhoeve, 1979; World Agroforestry Centre, undated.

Other references African Regional Workshop, 1998e; ATIBT, 1986; Berti et al., 1982; Bouquet, 1969; Christy et al., 2003; CIRAD Forestry Department, 2003; de Saint-Aubin, 1963; Gérard et al., 1998; Hawthorne, 1995; Hawthorne & Jongkind, 2006; InsideWood, undated; Koumba Zaou et al., 1998; Latham, 2005; Louppe et al., 1999; Raponda-Walker & Sillans, 1961; Siepel, Poorter & Hawthorne, 2004; Staner & Gilbert, 1958; Styles & White, 1991; Tchoundjeu, 1990; Tchoundjeu & Leakey, 2001; Vivien & Faure, 1985.

Sources of illustration Styles & White, 1991; Wilks & Issembé, 2000.

Authors Nyunaï Nyemb

MAMMEA AFRICANA Sabine

Protologue Trans. Hort. Soc. London 5: 457 (1824).

Family Clusiaceae (Guttiferae)

Chromosome number $2n = 36$

Synonyms *Ochrocarpos africanus* (Sabine) Oliv. (1868).

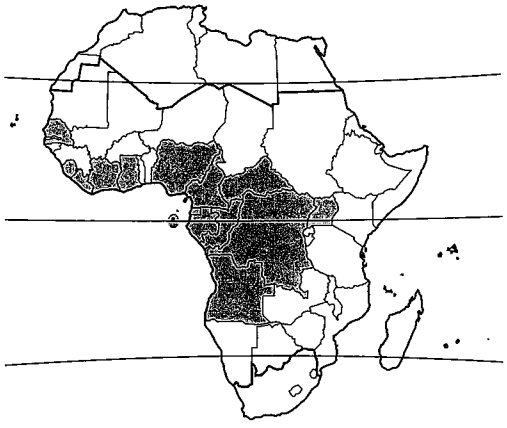
Vernacular names African mammee apple, African apple, African apricot, bastard mahogany, mammee apple (En). Abricotier d'Afrique, mammea (Fr).

Origin and geographic distribution *Mammea africana* occurs from Senegal east to western Uganda, and south to DR Congo and northern Angola.

Uses The wood of *Mammea africana*, often traded as 'oboto' or 'djimbo', is valued for construction, flooring, joinery, carpentry, interior trim, panelling, ship building, vehicle bodies, staircases, doors, window frames and furniture. It is suitable for railway sleepers, turnery and veneer. The boles are traditionally used for dug-out canoes.

The fruit is edible, but only when it is quite ripe. The white-yellow pulp is sweet but fibrous. However, the fruits of some trees remain sour. Rotting fruit pulp is attractive to large forest snails, which can be collected in large numbers under the trees for human consumption. The seeds are edible, and they contain oil that is locally used for cooking. The resin has been used in DR Congo to repair earthenware.

Several plant parts are used in traditional medicine. Bark decoctions or macerations are taken as anthelmintic, to treat stomach complaints, gonorrhoea, ovarian troubles, coughs and anaemia, and to ease childbirth. They are applied externally to treat wounds, sores, ulcers, scabies, skin diseases, itch, rheumatism, uterine and vaginal inflammations, and fever. Lotions made from the roots or fruit are applied to skin diseases and sores. The resin is applied to burns and scabies. In Liberia and Nigeria the bark is used as fish poison in small streams; its potency is limited. Burnt bark has



Mammea africana – wild

been used in soap manufacture and to produce salt.

Production and international trade The amounts of *Mammea africana* timber in trade are small. Statistics are not available, except for Cameroon, where the recorded production of logs was 81 m^3 in 2000 and 65 m^3 in 2001.

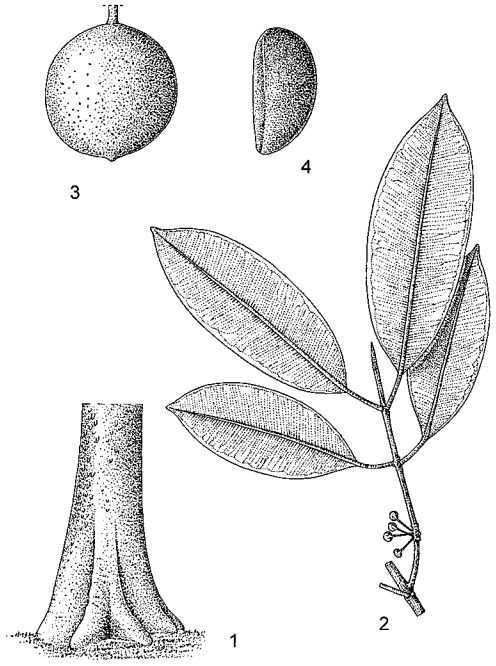
Properties The heartwood is pinkish brown to reddish brown when freshly cut, darkening to dark reddish brown or purplish brown upon exposure, and is distinctly demarcated from the pinkish brown to pale brown, up to 6 cm wide sapwood. The grain is usually interlocked, texture medium to rather coarse. Quartersawn surfaces are mottled with ribbon like figures and abundant silver grain, tangential surfaces have flowered figures. The wood is resinous and dark oily spots are often present on tangential surfaces.

The wood is moderately heavy, with a density of 650–860 kg/m^3 at 12% moisture content. It air dries slowly, and careful drying is needed because it is liable to checking and distortion. The rates of shrinkage are high, from green to oven dry 6.0–7.1% radial and 8.7–11.6% tangential. Once dry, the wood is moderately stable in service.

At 12% moisture content, the modulus of rupture is 81–201 N/mm^2, modulus of elasticity 10,300–14,600 N/mm^2, compression parallel to grain 45–77 N/mm^2, compression perpendicular to grain 10 N/mm^2, shear 9–13 N/mm^2, cleavage 15–29 N/mm, Janka side hardness 6400 N and Janka end hardness 8630 N.

The wood saws cleanly but slowly and works well; the silica content is low (0.005–0.015%). It finishes smoothly with a nice polish. The wood holds nails and screws well, but pre-boring is needed to avoid splitting. The gluing properties are satisfactory, but painting and varnishing may give poor results due to the presence of resin. The presence of resin makes peeling difficult. The wood is fairly durable, being quite resistant to fungi and to powder-post beetle and pinhole borer attacks, but moderately susceptible to termite attack. It has also shown some resistance to marine borers. The heartwood is very resistant to impregnation by preservatives. Several xanthones have been identified in the heartwood and stem bark. The seeds contain about 10% of oil, in which several unusual fatty acids occur: ricinoleic acid (20%), vernolic acid (12%), malvalic acid (6%) and sterculic acid (4%). Other, more common, fatty acids present in the oil are palmitic acid (28%), stearic acid (27.5%), myristic acid (1.5%), lauric acid (1%), and traces of oleic acid and linoleic acid. Several coumarins and the sterol friedelone have been isolated from the seeds. Coumarins have also been isolated from the bark; these showed noteworthy cytotoxicity against the human 9-KB cell line and significant antibacterial activity against *Staphylococcus aureus*. A bark extract showed vasodilator effect, in which the coumarins might also be involved. In tests with rats, the extract showed slight toxicity at doses of 30–90 mg/kg.

Description Evergreen, medium-sized to large tree up to 45 m tall; bole straight and cylindrical or slightly angular, branchless for up to 27 m, up to 125 cm in diameter, with large root swellings or steep buttresses up to 3.5 m high at base; bark surface scaly, brown, often with yellowish impressions, inner bark fibrous, reddish, becoming brownish upon exposure, slowly exuding a yellowish resin; crown small, dense, with short spreading branches; twigs slightly flattened, greyish, glabrous. Leaves opposite, simple and entire; stipules absent; petiole 0.5–2.5 cm long, stout, grooved above; blade narrowly elliptical to oblong-elliptical, 9–35 cm × 3–13 cm, obtuse to cu-



Mammea africana – 1, base of bole; 2, twig with flower buds; 3, fruit; 4, fruit stone.
Redrawn and adapted by Achmad Satiri Nurhaman

neate at base, short-acuminate at apex, leathery, glabrous, pinnately veined with numerous fine lateral veins, densely glandular dotted. Flowers in leaf axils, bisexual or male, regular; bisexual flowers solitary, with pedicel 2–3(–4) cm long, calyx entire in bud, dividing into 2(–3) nearly orbicular segments 1–1.5 cm long, reddish pink, petals 4(–6), free, elliptical to obovate, 1.5–3 cm long, white or yellowish, stamens many, fused at base, 0.5–1 cm long, ovary superior, ovoid, 2-celled, sometimes 4-celled, style short, thick, stigma disk-shaped, slightly 2-lobed; male flowers in fascicles, similar to bisexual flowers but smaller, with shorter pedicel and rudimentary ovary. Fruit a large, globose to pear-shaped drupe 7–18 cm long, pale yellow to orange, with numerous small, brown warts; stones 1–4, ovoid, 4–6 cm long, brown, wall very hard and woody, each stone 1-seeded. Seed flattened, c. 3 cm long, seed coat thin. Seedling with hypogeal germination; epicotyl 15–30 cm long, with 3–5 pairs of opposite blackish scales; cotyledons remaining enclosed in the stone.

Other botanical information *Mammea* comprises approximately 50 species, with about 20 species in Madagascar, and 30 in tropical Asia to New Caledonia. Mainland Africa harbours two species, *Mammea africana* and *Mammea usambarensis* Verdc., the latter endemic to mountain forest in north-eastern Tanzania, where it is mainly valued for its edible fruits. *Mammea usambarensis* is close to *Mammea africana*, but differs in the thin wall of the fruit stone. Tropical America is home to another species, *Mammea americana* L., which is cultivated in tropical Africa as a fruit tree. Australia has one species. *Mammea* is close to *Garcinia*, which differs in its terminal buds enclosed by the petioles (buds not enclosed by petioles but by scales in *Mammea*), in lacking glandular dots on the leaves and in its 4–5 free sepals.

The wood of *Mammea odorata* (Raf.) Kosterm. from tropical Asia and islands in the Pacific Ocean is locally exploited in its native region. *Mammea odorata* has been recorded from Zanzibar (Tanzania), where it has probably been planted.

Anatomy Wood-anatomical description (IAWA hardwood codes):

Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; (7: vessels in diagonal and/or radial pattern); 9: vessels exclusively solitary (90% or more); 13: simple perforation plates; 22: intervessel pits alternate; 25: intervessel pits small (4–7 μm); 26: intervessel pits medium (7–10 μm); 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 42: mean tangential diameter of vessel lumina 100–200 μm; 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre; 56: tyloses common. Tracheids and fibres: 60: vascular/vasicentric tracheids present; 62: fibres with distinctly bordered pits; 63: fibre pits common in both radial and tangential walls; 66: non-septate fibres present; 69: fibres thin- to thick-walled; 70: fibres very thick-walled. Axial parenchyma: 76: axial parenchyma diffuse; 77: axial parenchyma diffuse-in-aggregates; 78: axial parenchyma scanty paratracheal; (91: two cells per parenchyma strand); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand; (94: over eight cells per parenchyma strand). Rays: 97: ray width 1–3 cells; (100: rays with multiseriate portion(s) as wide as uniseriate portions); 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 108: body ray cells procumbent with over 4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 130: radial canals. Mineral inclusions: (136: prismatic crystals present); (142: prismatic crystals in chambered axial parenchyma cells); (154: more than one crystal of about the same size per cell or chamber).

(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development *Mammea africana* grows slowly; the annual growth of saplings is about 30–50 cm. In Nigeria trees have been reported to reach 15 m tall with a bole diameter of almost 30 cm 24 years after planting.

Flushes of young leaves are coppery red or deep red. Trees may start flowering at an age of 10 years, but initially without developing fruits. Flowering is irregular. The flowers are morphologically either bisexual or male, the two types occurring on different trees, but pollen research showed that the apparently bisexual flowers are functionally female, having pollen without apertures. This means that *Mammea africana* is functionally dioecious. In Côte d'Ivoire flowering takes place in August–December, sometimes up to April, and fruiting from August to March. Mass fruiting occurs every 2–3 years. The fruits ripen 10–12 months after flowering. They are eaten by ele-

phants, which disperse the fruit stones. Mammals such as porcupines and antelopes feed on the seeds.

Ecology *Mammea africana* occurs in evergreen and moist semi-deciduous forest, up to 1000 m altitude. It prefers relatively fertile and moist soils, clayey as well as sandy. It is often found on seasonally inundated alluvial soils where it may form small stands. However, *Mammea africana* usually occurs scattered in the forest. In Ghana it has been associated with base-poor soils.

Propagation and planting *Mammea africana* is propagated by the fruit stones. One kg contains about 25 stones. Germination is irregular; it begins after 3–4 weeks and may take up to 8 months. Seed treatment is not necessary, but germination is promoted by carefully filing a hole in the wall of the stone or soaking the seeds in water for 24 hours. The germination rate is often high: up to 90% for fresh seeds, about 70% for seeds sown 2–6 weeks after being harvested and about 35% for seeds sown 10 weeks after being harvested. Seed beds should be shaded. Striplings of 1.5–2 years old can be planted out, but seeds are also sown directly into the field. A spacing of 8 m has been recommended. Natural regeneration may be abundant under the mother tree.

Management In most regions within the distribution area, *Mammea africana* trees occur in low densities and scattered. In forests in southern Cameroon on average 1 tree with a bole diameter above 60 cm can be found per 30 ha. Organic mulching as well as manure application around the base of planted trees promotes growth. Young trees grow well in the shade, but when they have reached a bole diameter of 15 cm the shade can be removed gradually.

Diseases and pests In natural forest in Côte d'Ivoire it has been recorded that seedlings are heavily attacked by insects.

Harvesting The minimum felling diameter is 60 cm in Liberia, Cameroon and the Central African Republic, and 70 cm in Ghana.

Yield A tree with a bole diameter of 60 cm yields 2.7–2.8 m^3 of logs, a tree 70 cm in diameter 3.6–4.0 m^3, and a tree 100 cm in diameter 7.6–9.7 m^3.

Genetic resources *Mammea africana* is widespread, but it usually occurs in low densities in the forest. It is also planted, although not on a large scale. It does not seem to be threatened at present, and the level of exploitation for its timber seems to be low. The major threat is the ongoing destruction of the evergreen and moist semi-deciduous forest types for which it is characteristic. Some trees produce fruits which are sweet when ripe, whereas the fruits of other trees remain sour and unpalatable. This makes selection of genotypes with superior characteristics for fruit production recommendable.

Prospects The prospects for *Mammea africana* as a timber tree of higher commercial importance seem to be limited because the high rates of shrinkage of the wood, scattered occurrence and low growth rate are serious drawbacks. It may have better prospects as a fruit tree and might be useful for planting in agroforestry systems, in which timber production might also play a modest role. However, much research is still needed on means of vegetative propagation in combination with selection of superior fruit types.

Major references Bamps, Robson & Verdcourt, 1978; Bolza & Keating, 1972; Burkill, 1994; Danforth & Noren, 1997; Hawthorne, 1995; Phongphaew, 2003; Siepel, Poorter & Hawthorne, 2004; Takahashi, 1978; Voorhoeve, 1979; World Agroforestry Centre, undated.

Other references Antia et al., 2006; Borges et al., 2008; CIRAD Forestry Department, 2003; CTFT, 1949; de Koning, 1983; de la Mensbruge, 1966; de Saint-Aubin, 1963; Dongmo et al., 2007; Dunthorn, 2004; Fouarge, Gérard & Sacré, 1953; Hawthorne & Jongkind, 2006; Hosamani & Ganjihal, 2003; InsideWood, undated; Keay, 1989; Kryn & Fobes, 1959; Neuwinger, 2000; Normand, 1955; Normand & Paquis, 1976; Ouahoua et al., 2004; Raponda-Walker & Sillans, 1961; Vivien & Faure, 1985.

Sources of illustration Bamps, 1970; Wilks & Issembé, 2000.

Authors R.H.M.J. Lemmens

MANSONIA ALTISSIMA (A.Chev.) A.Chev.

Protologue Bull. Soc. Bot. France 58, Mém. 8: 138 (1912).

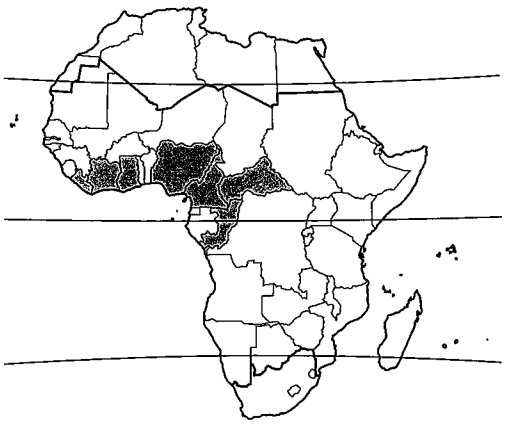
Family Sterculiaceae (APG: Malvaceae)

Chromosome number $2n = 48$

Vernacular names Mansonia, African black walnut, African walnut (En). Bété, mansonia (Fr).

Origin and geographic distribution *Mansonia altissima* occurs from Guinea and Côte d'Ivoire east to the Central African Republic and northern Congo.

Uses The wood (trade names: mansonia, bété,



Mansonia altissima – wild

African black walnut, pruno) is used for general and high-class joinery, cabinet work, furniture, turnery, decorative veneer and handicrafts. It is also used in construction for doors and windows, in railway coaches and shop fittings, and for boxes and crates. Well-coloured wood resembles American black walnut and is commonly used as a substitute, e.g. for gun stocks and grips, musical instruments and loudspeaker enclosures.

Wood waste can be used as a substrate for the edible fungus *Pleurotus tuber-regium*. Preliminary observations indicate that the fermented substrate has some value as cattle feed.

The bark is very poisonous and in parts of south-western Côte d'Ivoire it is the main component of a very effective arrow-poison, also used in spear traps for large game. In other parts of its range the bark is a component of arrow poisons too. In Nigeria and Ghana products from the bark have been used in the treatment of leprosy. A bark extract is drunk or an infusion of the root is applied as enema as an aphrodisiac. A root decoction is given as enema against leprosy. A decoction of the twig bark is applied as a bath against yaws, scabies and syphilis.

Production and international trade The wood of *Mansonia altissima* was first exported from Nigeria in the 1930s as a substitute for walnut; at that time the sustainable annual yield was estimated to 4800 m³ per year. Between 1959 and 1970, however, Nigeria exported 15,500 m³ of logs and 800 m³ of sawn wood per year. Côte d'Ivoire exported about 131,400 m³ of logs and 2700 m³ of sawn wood per year in 1967–1972. In 1994 Côte d'Ivoire exported 314 m³ of veneer. Ghana exported 2700 m³ of logs in 1998 and only 300 m³ of logs in 2000 and in 2001. In 2004 Ghana exported 1000 m³ of plywood at an average price of US$ 367/m³. Cameroon exported 1900 m³ of sawn wood in 2003. Europe and the United States are the main importers.

Properties The heartwood is yellowish brown to dark grey-brown or even dark brown, often with purple, reddish or greyish green streaks, often in alternating light and dark bands. It fades on exposure to a somewhat dull brown. It is distinctly demarcated from the 2–4(–6) cm wide, white to pinkish sapwood. The grain is usually straight, texture fine. The wood is moderately lustrous.

The wood is of medium weight with a density at 12% moisture content of 590–720 kg/m³. It dries fairly rapidly with little distortion or degrade. In Congo it takes about 15 weeks to air dry boards 5.5–6 cm thick from 75% to 23% moisture content. Shrinkage from green to oven dry is (2.6–)4.1–5.7(–7.0)% radial and (5.2–)7.1–9.7% tangential. Movement in service is medium.

At 12% moisture content the modulus of rupture is (61–)114–177(–183) N/mm², modulus of elasticity 9320–12,800 N/mm², compression parallel to grain 43–68(–96) N/mm², shear 6–15 N/mm², cleavage 9–23 N/mm, Janka side hardness 5690–7470 N and Janka end hardness 5740–7470 N.

The wood is easy to work with hand and machine tools with little or only moderate blunting effect on cutting edges and no charring. The surface can be worked to a good finish. The wood holds nails and screws fairly well, but iron tends to corrode in contact with the wood. Gluing properties are good. The wood takes stain and polish well. The wood peels well, but requires softening beforehand; veneer is rather fragile. Steam-bending is easy unless knots are present.

The heartwood is very durable, being resistant to fungi, borers and termites; in logs the sapwood is susceptible to pinhole borer and longhorn beetle attacks. The heartwood is extremely resistant to impregnation with preservatives, sapwood is permeable.

In processing the wood causes high levels of dust, and it may cause serious health problems to workers. The dust may cause dermatitis, nose-bleeding, throat irritation, asthma and eczema, the reactions becoming stronger on repeated exposure. Heart troubles have also been reported. Pigs given the sawdust as litter

developed severe contact dermatitis and piglets even died. The toxins in the wood, even in the form of thin veneer, are resistant to oxidation and are heat-stable; they remain effective for many years.

An ethanolic extract of the wood showed hepatotoxic and haematotoxic effects when administered orally to rats. Ethanol and chloroform extracts of the bark have shown a very strong toxicity against several mammals. Extracts of the bark also inhibit the growth of *Mycobacterium tuberculosis*. Because of its antibacterial properties, addition of small amounts of bark to the diets of chicken, as a substitute of commercial antibiotics, improved feed conversion rates.

The bark contains the highly toxic compound mansonine, related to cardenolides from *Digitalis* and ouabain from *Strophanthus*. Its aglycon was identified as strophantidin. In addition some 30 toxic glycosides have been identified.

From the wood similar glycosides, an azulene derivative, and a range of quinones, called mansonones A–I and L, have been isolated. Mansonone A is the main causal agent of the allergic reaction to the sawdust. The seeds too contain a large number of cardenolide glycosides, including glycosides of strophanthidin and nigrescigenin. The glycosides strophothevoside and strophalloside are about as toxic to mammals as ouabain.

Description Evergreen medium-sized to fairly large tree up to 45 m tall; bole branchless for up to 30 m, up to 100(–150) cm in diameter, generally straight, cylindrical, sometimes with narrow buttresses; bark surface fissured lengthwise, clear brown, inner bark yellowish; crown small, ovoid, dense, with branches almost horizontal, later drooping; branchlets hairy or glabrous. Leaves alternate, simple; stipules present, early falling; petiole 2–5 cm long, hairy; blade obovate to orbicular, 15–30 cm × 8–15 cm, cordate at base, rounded and sometimes short-acuminate at apex, margin slightly wavy or toothed, papery, densely hairy below, with 6–7 basal veins and 4–5 pairs of lateral veins. Inflorescence a large, stalked, terminal cyme 12–15 cm long, densely short-hairy, many-flowered. Flowers bisexual, fragrant; pedicel c. 7 mm long; calyx c. 1 cm long, split unilaterally, folded back, stellate hairy; petals 5, obovate, c. 12 mm × 6 mm, glabrous, white, twisted in bud; androgynophore well-developed, c. 18 mm long; stamens 10 in a single circle, nearly sessile; staminodes 5, scale-like; ovary superior, consisting of 5 free carpels, velvety hairy, each carpel with a thread-like, flexuous style with minute stigma. Fruit consisting of 1–2(–3) ovoid nuts c. 0.5 cm in diameter, surface reticulate, with a large papery wing 5–6 cm × c. 2 cm. Seedling with epigeal germination.

Mansonia altissima – 1, flowering twig; 2, fruit. Redrawn and adapted by Iskak Syamsudin

Other botanical information *Mansonia* comprises 4 or 5 species, 2 in Africa, 1 in India and 1 in Myanmar and Thailand. In *Mansonia altissima* 2 varieties are recognized: var. *altissima* occurring from Liberia to Nigeria, and var. *kamerunica* Jacq.-Fél. which occurs from Nigeria east to the Central African Republic. The latter is characterized by glabrous branchlets. *Mansonia nymphaeifolia* Mildbr., which is endemic to Cameroon, is doubtfully different from *Mansonia altissima* var. *kamerunica*. *Mansonia diatomanthera* Brenan is a large tree known only from 2 or 3 locations in Tanzania. The use of its wood has not been recorded, but a bark infusion is used as a bath to treat scabies. *Mansonia diatomanthera* is critically endangered.

Anatomy Wood-anatomical description (IAWA hardwood codes):

Growth rings: (1: growth ring boundaries dis-

tinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal); 24: intervessel pits minute (≤ 4 µm; 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 41: mean tangential diameter of vessel lumina 50–100 µm; 42: mean tangential diameter of vessel lumina 100–200 µm; 47: 5–20 vessels per square millimetre; (48: 20–40 vessels per square millimetre). Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 76: axial parenchyma diffuse; 77: axial parenchyma diffuse-in-aggregates; 78: axial parenchyma scanty paratracheal; (91: two cells per parenchyma strand); 92: four (3–4) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 115: 4–12 rays per mm. Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied; 121: fibres storied. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells; (138: prismatic crystals in procumbent ray cells); (140: prismatic crystals in chambered upright and/or square ray cells); (141: prismatic crystals in non-chambered axial parenchyma cells).
(P. Ng'andwe, H. Beeckman & P.E. Gasson)

Growth and development Seedlings attained a height of 1–2 m in 4 years and 6 m in 4 years in logged areas. In Kumasi (Ghana) trees attained a bole diameter of 6.5–16 cm and a height of 8–15 m in 10 years. For plantations in Cameroon faster growth has been recorded, with trees growing 2 m in height per year after 2 years decreasing to 1.3 m per year after 10 years. In Côte d'Ivoire mean annual bole diameter growth of *Mansonia altissima* trees for all diameter classes was 2.5–7 mm. Mean growth for the diameter class 30–50 cm was 5.1 mm per year. An average tree would reach a bole diameter of 50 cm in 90 years.
In Ghana flowering occurs from May to October with a peak in June and fruits ripen in July–April. The fruits are dispersed by wind at the end of the dry season.

Ecology *Mansonia altissima* is characteristic of the dense semi-deciduous forest in areas with about 1600 mm annual rainfall and a pronounced dry season. In Côte d'Ivoire the southern limit of its distribution area largely corresponds with the transition of semi-deciduous forest to evergreen forest; to the north its distribution extends to patches of dense forest in the savanna. Seedlings are most common on fertile soils on drier sites; they are fairly drought resistant. Seedlings planted in the wet forest zone died within a few years. In Ghana *Mansonia altissima* is most common in the semi-deciduous forest of the north-western part of the country, where it occurs mainly in exposed conditions. In southern Ghana seedlings up to 1 m tall are most common in disturbed forest, while smaller seedlings are more common in undisturbed forest. Adult trees are more common in logged or burnt forest than in undisturbed forest.

Propagation and planting The 1000-seed weight is about 330 g. Germination starts after about 10 days and may take one week, but a dormancy period of several months has also been observed. Dormancy caused little loss of seed viability. Germination occurs under both light and dark conditions, but is strongly depressed in large gaps in the forest. During the first 2 years after germination slight shade stimulates growth and the formation of healthy leaves. Leaves are held vertically in exposed conditions, more horizontally in the shade. After 2 years *Mansonia altissima* requires full sunlight and it has been classified as a non-pioneer light demander.

Management *Mansonia altissima* has been tried in plantations and in enrichment plantings, but no results are known. In Cameroon 420 ha have been planted, and in Côte d'Ivoire 78 ha. It is occasionally retained or grown in agroforestry systems.

Diseases and pests *Ambrosia* beetles attack the bole of the standing tree. Caterpillars of the moth *Godasa sidae* may cause complete defoliation in plantations. Wood-boring caterpillars of *Eulophonotus* spp. may cause damage to the sapwood. Larvae of the polyphagous grasshopper *Zonocerus variegatus* may seriously attack the foliage of especially older trees. In plantations they may become serious pests.

Harvesting The minimum felling diameter is 40 cm in the Central African Republic, 50 cm in Côte d'Ivoire, 60 cm in Liberia and Cameroun, and 70 cm in Ghana.

Yield A tree 40 cm in diameter yields about 1.8 m^3 of timber, trees 50, 60 and 70 cm in diameter yield 2.8 m^3, 4.1 m^3 and 5.6 m^3, respectively.

Handling after harvest Freshly cut logs are usually too heavy to be transported by river.

Genetic resources *Mansonia altissima* is protected by law in Côte d'Ivoire. In Ghana it has been ranked as a pink star species, which means that it is considered common and moderately exploited. In 1984 FAO recommended its in-situ conservation.

Prospects The wood of *Mansonia altissima* is likely to remain valuable for furniture and decoration, for which there is a stable market and growing demand. Because reliable statistics on production are lacking, it is not possible to estimate the amounts of *Mansonia altissima* timber that can be extracted sustainably. Because of its high value, it is recommended to test and include *Mansonia altissima* in plantation and enrichment programmes or in agroforestry systems.

Major references ATIBT, 1986; Aubréville, 1959a; Bolza & Keating, 1972; CIRAD Forestry Department, 2003; Détienne, 1975; Durand, 1978; Durrieu de Madron, 2003; Guina, 1990; Hawthorne, 1995; Takahashi, 1978.

Other references Akinagbe, Gailing & Finkeldey, 2007; Allgeier, Weiss & Reichstein, 1967; Ayodele, Akpaja & Anyiador, 2007; CTFT, 1960; Estlander et al., 2001; Fernandez-Villamil et al., 1990; Foahom, 1990; Foahom & Du Merle, 1993; Foli et al., 2003; Galeffi et al., 1969; Grison, 1971; Gyimah & Nakao, 2007; IARC, 1981; InsideWood, undated; Jonathan et al., 2008; Ogbamgba & Wekhe, 2006; Oke & Odebiyi, 2007; Oliver-Bever, 1982; Tanaka, Yasue & Imamura, 1966; UNEP-WCMC, 2006; Veenendaal et al., 1996.

Sources of illustration Aubréville, 1959a; Voorhoeve, 1979.

Authors F. Ohene-Coffie

MILICIA EXCELSA (Welw.) C.C.Berg

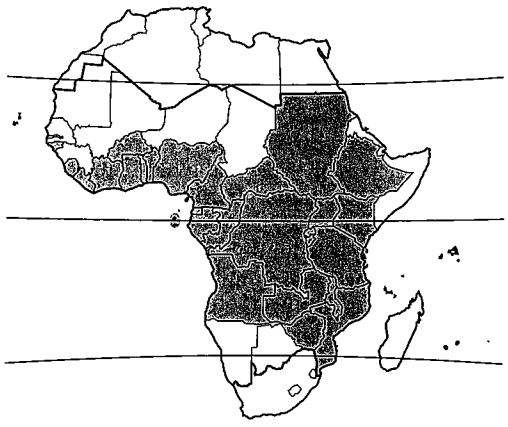
Protologue Bull. Jard. Bot. Belg. 52: 227 (1982).

Family Moraceae

Synonyms *Maclura excelsa* (Welw.) Bureau (1873), *Chlorophora excelsa* (Welw.) Benth. (1880).

Vernacular names Iroko, rock elm, African teak, African oak (En). Iroko, chêne d'Afrique, teck d'Afrique, teck kambala (Fr). Câmbala, amoreira, moreira, teca africana, tumbiro, magundo (Po). Mvule (Sw).

Origin and geographic distribution *Milicia excelsa* is distributed from Guinea Bissau eastward to Ethiopia and southward to Angola, Zimbabwe and Mozambique. It has been introduced into India and the United States.



Milicia excelsa – wild

Uses The wood of *Milicia excelsa* and the closely related *Milicia regia* (A.Chev.) C.C.Berg are not distinguished in the timber trade, and are traded under the trade name 'iroko', or 'odum' in Ghana. Other frequently used trade names for *Milicia excelsa* are 'kambala' and 'mvule'. Iroko is a highly valued commercial timber in Africa, for which demand is large. It is used for construction work, shipbuilding and marine carpentry, sleepers, sluice gates, framework, trucks, draining boards, outdoor and indoor joinery, stairs, doors, frames, garden furniture, cabinet work, panelling, flooring and profile boards for decorative and structural uses. It is also used for carving, domestic utensils, musical instruments and toys. As it is resistant to acids and bases, it is used for tanks and barrels for food and chemical products and for laboratory benches. It is used as sliced veneer but only rarely as rotary veneer. The wood is also used as firewood and for making charcoal.

The ripe fruits and cooked young leaves of *Milicia excelsa* are edible. The fruit juice is used for flavouring in India. Mature leaves have been used as sandpaper. The bark is used for dyeing leather and cloth and for roofs of houses. Formerly the bark of young trees was used for making loincloths. The tree is used for soil conservation and mulch production, and as an ornamental and shade tree. In Nigeria it is planted to mark boundaries between farms or villages. It has also been planted to attract

edible caterpillars. The wood is being tested as a substrate for the cultivation of the mushroom *Lentinus subnudus*, popular e.g. in Nigeria.

Milicia excelsa is widely used in African traditional medicine. A root decoction is taken to treat female sterility. A decoction of the root and stem bark is taken as an aphrodisiac. Preparations from the bark are taken to treat cough, asthma, heart trouble, lumbago, spleen pain, stomach pain, abdominal pain, oedema, ascites, dysmenorrhoea, gonorrhoea, general fatigue, rheumatism, sprains, and as a galactagogue, aphrodisiac, tonic and purgative. Bark preparations are externally applied to treat scabies, wounds, loss of hair, fever, venereal diseases and sprains. They are applied as an enema to cure piles, diarrhoea and dysentery. The latex is applied on burns, wounds, sores and against eczema and other skin problems. It is also taken against stomach problems, hypertension and as a galactagogue, and it is used for treatment of tumours and obstructions of the throat. Leaves are eaten to treat insanity; a leaf maceration is drunk as a galactagogue. A decoction of the leaves is taken for treatment of gallstones. Leaf preparations are externally applied to treat snakebites and fever and as eye drops to treat filariasis.

Milicia excelsa is often considered a sacred tree and is frequently protected near houses and in cultivated fields. In Benin the foliage is used as a fetish, and in Nigeria the tree has a special place in the folklore and traditions of the people.

Production and international trade *Milicia excelsa* and *Milicia regia* are both traded as iroko and the share of *Milicia excelsa* in that commerce is unknown. Iroko is a major timber in international trade; during the 1960s Côte d'Ivoire exported about 55,000 m^3 of iroko logs and 6000 m^3 of iroko sawnwood per year, and Ghana 28,000 m^3 of sawnwood. In 1973 Côte d'Ivoire exported as much as 136,500 m^3 of logs and 16,000 m^3 of sawnwood. In 1994 Cameroon exported 65,000 m^3 of logs and 12,000 m^3 of sawnwood, Congo 10,000 m^3 of logs, and Ghana at least 47,000 m^3 of sawnwood. In the season 1998–99, an estimated 133,400 m^3 of iroko timber was cut in Cameroon. From 1998 to 2003 Gabon exported about 28,500 m^3 of logs per year. Exportation of iroko logs is now forbidden in Côte d'Ivoire, Ghana and Cameroon, but export of sawnwood is allowed.

In 2003 Cameroon exported 33,000 m^3 of iroko sawnwood (US$ 948/m^3), Congo 28,000 m^3 of iroko logs (US$ 221/m^3) and 1000 m^3 of iroko veneer (US$ 343/m^3), the Central African Republic 2000 m^3 of logs (US$ 412/m^3) and 5000 m^3 of sawnwood (US$ 465/m^3), Ghana 8000 m^3 of sawnwood (US$ 754/m^3) and Togo 1000 m^3 of sawnwood (US$ 260/m^3).

In the past Tanzania and Uganda were major suppliers of iroko, and small volumes are still exported from East Africa.

Properties The heartwood is pale yellow to yellow, darkening on exposure to yellowish or greenish brown or sometimes to chocolate brown; it is clearly demarcated from the 5–7.5 cm wide yellowish white sapwood. The grain is interlocked, texture medium to coarse, figure mottled. The wood is somewhat greasy and is odourless. Logs from closed forest are usually straight and cylindrical, but savanna trees are often damaged by fire and their wood is affected by eccentric growth, ingrown bark or calcium carbonate plugs.

The wood has a density of 550–750 kg/m^3 at 12% moisture content. Shrinkage rates from green to oven dry are 1.7–4.1(–5.6)% radial and 2.4–6.3(–9.8)% tangential. The wood dries well in open air and kilns, with little degrade. Boards of 4.2 cm thick can be kiln dried from 60% to 15% moisture content in 8 days at a drying temperature of 50–80°C, and a corresponding relative humidity of 85% to 40%. Once the wood is dry, movement in service is small.

At 12% moisture content, the modulus of rupture is 75–156 N/mm^2, modulus of elasticity 8300–13,300 N/mm^2, compression parallel to grain 42–65 N/mm^2, shear 5.4–14.1 N/mm^2, cleavage 10.3–20.9 N/mm, Janka side hardness 4400–5610 N, and Janka end hardness 5360–6640 N.

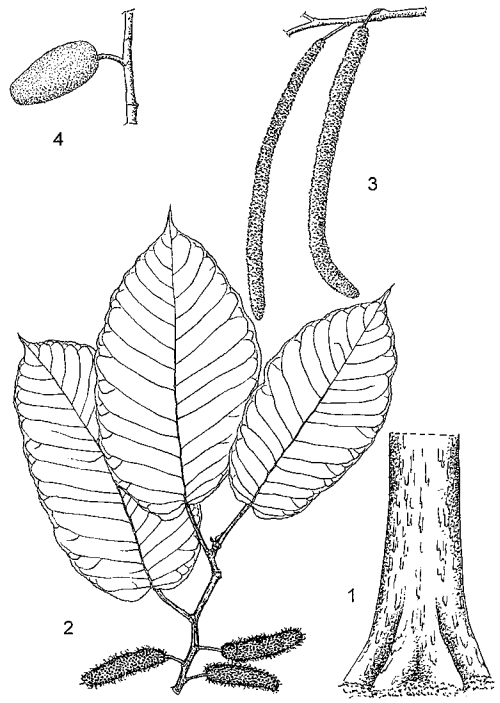
Working properties for hand and machine tools are generally good but variable; the interlocked grain may hamper sawing and planing. The wood is rather abrasive due to the presence of hard deposits ('iroko stones', mainly consisting of calcium carbonate), which can blunt cutting edges. Tearing in planing can be avoided by using cutting angles of 15° or less. The wood has good nailing, screwing, mortising and gluing properties and turns easily. It finishes well, but filler is needed. The wood contains the stilbene derivative chlorophorin, which prevents oil-based paints from drying, and which corrodes metal in contact with it. Steam-bending properties of the wood are moderate.

Although the heartwood is generally considered very durable, reports on its resistance to marine borers and termites vary. It is resistant

to fungal attack. The sapwood is liable to attack by *Lyctus* beetles. The heartwood is impermeable to preservatives, but sapwood is permeable.

The wood and sawdust may cause dermatitis, irritation to nose and throat, and asthmatic reactions, due to the presence of chlorophorin. Chlorophorin has shown inhibitory effects on melanin biosynthesis; its more stable derivative hexahydrochlorophorin may have potential for use in skin-whitening agents and for treating disturbances in pigmentation. Two phenolic compounds (chlorophorin and iroko) have shown in-vitro anti-amoebic activity. A methanol extract of the stem bark has shown in-vivo anti-inflammatory properties in mice and rats.

Adulterations and substitutes The wood properties of iroko are similar to those of teak (*Tectona grandis* L.f.). The wood of *Guibourtia arnoldiana* (De Wild. & T.Durand) J.Léonard (trade name: mutenye) has uses similar to iroko and teak. As iroko is locally overexploited, it is recommended that for some specific uses it is replaced by species such as *Piptadeniastrum africanum* (Hook.f.) Brenan (trade name: dabema), *Lophira alata* Banks ex P.Gaertn. (trade name: azobé), *Nauclea diderrichii* (De Wild. & T.Durand) Merr. (trade name: bilinga) or *Afzelia* spp. (trade name: doussié). Logs of *Morus mesozygia* Stapf ex A.Chev. (trade name: difou) have sometimes been sold mixed with iroko logs.



Milicia excelsa – 1, base of bole; 2, twig with female inflorescences; 3, male inflorescences; 4, infructescence.
Redrawn and adapted by Iskak Syamsudin

Description Large, dioecious tree up to 50 m tall; bole straight, cylindrical, branchless for up to 25(–30) m, up to 2.5(–3) m in diameter, buttresses absent or small; surface roots often long and prominent, red-brown with yellow lenticels; outer bark grey to dark brown or black, lenticelled, becoming scaly, inner bark thick, fibrous, cream-coloured speckled with orange-brown spots, exuding a white or yellowish latex; crown spreading; branches obliquely ascending. Leaves distichously alternate, simple; stipules free, slightly clasping the stem, up to 5 cm long, caducous; petiole 1–6 cm long; blade oblong to elliptical, 6–20(–33) cm × 3.5–10(–15) cm, base cordate to obtuse, often very unequal, apex acuminate, margin almost entire to wavy but toothed in juvenile specimens, papery to leathery, above glabrous or slightly hairy on the main veins, below densely short-hairy between the finest veins, pinnately veined with 10–22 pairs of lateral veins. Inflorescence a catkin, usually solitary in leaf axils or on leafless nodes at the base of twigs, white hairy, flowers numerous in longitudinal rows alternating with rows of bracts; male inflorescence 8–20(–32) cm × 0.5–1 cm, hanging, peduncle 0.5–2.5 cm long; female inflorescence 2–4 cm × 0.5–2 cm, peduncle 0.5–2 cm long. Flowers unisexual, 4-merous, sessile; male flowers c. 1.5 mm long, white, tepals 4, basally fused, stamens 4 and inflexed in bud, rudimentary pistil present; female flowers 2–3 mm long, with 4 basally fused tepals, greenish, ovary superior, c. 1 mm long, 1-celled, stigmas 2, one 3–7 mm long, the other up to 1 mm long. Fruit an ellipsoid, compressed achene 2.5–3 mm long, arranged in infructescences up to 5 cm × 1.5 cm. Seed c. 2 mm long. Seedling with epigeal germination.

Other botanical information *Milicia* comprises 2 species, *Milicia excelsa* and *Milicia regia*, both in tropical Africa. The 2 species mainly differ in the venation and hairiness of the leaves. *Milicia excelsa* has 10–22 pairs of lateral veins and is short-hairy below between the finest veins, *Milicia regia* has 6–11 pairs of lateral veins and is glabrous below between the finest veins. Juvenile plants of the 2 species

can be distinguished by differences in leaf hairiness and in the colour of the midrib beneath (yellow in *Milicia excelsa*, red in *Milicia regia*), and by growth habit and leaf arrangement (in *Milicia excelsa* sympodial, leaves in 2 rows; in *Milicia regia* monopodial, with spirally arranged leaves).

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23: shape of alternate pits polygonal; 27: intervessel pits large (≥ 10 μm); (30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell); 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 32: vessel-ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade); 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; (47: 5–20 vessels per square millimetre); 56: tyloses common. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 80: axial parenchyma aliform; (81: axial parenchyma lozenge-aliform); (82: axial parenchyma winged-aliform); 83: axial parenchyma confluent; (84: axial parenchyma unilateral paratracheal); (85: axial parenchyma bands more than three cells wide); (86: axial parenchyma in narrow bands or lines up to three cells wide); 91: two cells per parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; 106: body ray cells procumbent with one row of upright and/or square marginal cells; (107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells); 115: 4–12 rays per mm. Secretory elements and cambial variants: 132: laticifers or tanniferous tubes. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells; 141: prismatic crystals in non-chambered axial parenchyma cells; (154: more than one crystal of about the same size per cell or chamber); (155: two distinct sizes of crystals per cell or chamber).
(D. Louppe, P. Détienne & E.A. Wheeler)

Growth and development Seeds normally germinate 2–4 weeks after sowing. Young *Milicia excelsa* trees grow continuously, but growth of adult trees is periodical. In the dry season *Milicia excelsa* is deciduous for a short period. From West Africa to Sudan it flowers from December to March. It takes 5–6 weeks from fertilization to fruit maturation. Seed dispersal is mostly by birds, bats and squirrels. In a 6-year-old plantation in northern Côte d'Ivoire some trees were over 6 m tall, but the variability was large. In Ghana the annual increment in diameter is 0.33–0.59 cm. In Cameroon a mean diameter growth of over 1 cm per year has been recorded for trees about 25 years old. In the south-western Central African Republic (annual rainfall 1500 mm; dry period 2 months) the average annual increment in diameter of *Milicia excelsa* trees is 0.57 cm; it decreases with age from 0.93 cm for trees with a diameter of less than 10 cm to 0.45 cm for trees with 110–120 cm diameter. On average it takes 130 years here for a tree to reach a diameter of 80 cm. In Uganda 32-year-old trees planted at a spacing of 4 m × 4 m were 18 m tall and well shaped.

Ecology *Milicia excelsa* occurs in deciduous, semi-deciduous or evergreen, primary or secondary forest, with an apparent preference for drier forest types. It often occurs in gallery forest and in forest islands or as lone trees in savanna regions, and is sometimes left as a lone tree in old cultivated areas. It is usually found up to 1200(–1500) m altitude, although it has been found at 4500 m altitude on Mount Kilimanjaro in Tanzania. In West Africa *Milicia excelsa* occurs in regions with an average annual temperature of 25–35°C and an average annual rainfall of 1150–1900 mm. It is considered a pioneer species, demanding intense light and unable to stand deep shade. In young secondary forest, for example, it cannot compete with climbers and shrubs.
Although *Milicia excelsa* grows on a large variety of soils, it is reported to be rather demanding with respect to soil fertility, especially the presence of K and P. It is considered to be an indicator of fertile soil suitable for cultivation. It prefers well-drained soils and does not tolerate impeded drainage.

Propagation and planting *Milicia excelsa* is mostly propagated by seed. The 1000-seed weight is 1–4 g. About 40 kg of fruits is needed for 1 kg of seeds. As the colour of the infructescences does not change during ripening, maturity has to be determined by cutting the infructescence to see if the pulp has softened. If unripe infructescences are picked from the tree, it is necessary to leave them in the shade

for some days to ripen. It is easier to collect them from the ground, but seeds should be extracted before the infructescences have begun to ferment. Seeds can be separated by crushing the infructescences after immersing them in water for about one day. Viable seeds sink in water and can be easily separated from floating unviable seeds. Fresh seeds normally germinate well; the germination rate may be more than 90% within 4 weeks. Seeds are best sown within 3 months after collection, because viability decreases rapidly. Seeds dried to 8% moisture content can be stored at 0–5°C for at least a year.

Seeds are sown in a seedbed and transplanted to pots or nursery beds 3 weeks after germination. Seedlings should be grown under shade to limit attacks by *Phytolyma* spp. About 4 months after sowing the seedlings are around 30 cm tall and ready for planting out in the field. Young plants transplant well. In Ghana seedlings planted during the long rainy season have shown much better growth than seedlings planted during the short rainy season. The better growth persisted for at least 9 years. Planting in a mixed stand with *Terminalia superba* Engl. & Diels (in equal proportions at planting) gave better growth than planting in pure stands.

Milicia excelsa can be propagated vegetatively by stem and root cuttings, grafting, layering and in-vitro tissue culture. Successful propagation has been achieved using stem cuttings from 1- and 2-year-old trees, but from mature trees cuttings should be taken from coppice shoots. Stakes and posts made of branches may strike root like cuttings.

The wide sapwood of *Milicia excelsa* means that thinnings in plantations are of little value, so it is recommended to plant at wide spacings.

Management *Milicia excelsa* is mostly extracted from natural forest, as plantations are severely affected by pest problems. It prunes and coppices well.

Diseases and pests The major constraint on the cultivation of *Milicia excelsa* and *Milicia regia* are gall-forming *Phytolyma* spp. (iroko gall flies). Eggs are laid on buds, shoots or young leaves, and after the emergence of nymphs galls are formed, followed by dieback of foliage down to the woody tissue. This disrupts physiological processes, causes growth reduction, and in many cases kills seedlings. Secondary infection by fungi probably aggravates the damage. Mature leaves are not seriously affected. Efforts to control this pest have had little success, but the development or selection of more resistant *Milicia* genotypes may offer prospects. Planting in light shade, in mixtures and in low plant densities seems to help to reduce damage by *Phytolyma*. Elephants eat the bark and may destroy plantations.

Yield In Gabon *Milicia excelsa* is scattered in all forest types with a commercial bole volume of about 0.1 m^3/ha.

Handling after harvest Immediately after felling, the wood of *Milicia excelsa* is too heavy to be transported by river, and transport is by trucks. The sapwood is usually removed before shipping. Bark to be used medicinally is sometimes pounded, dried and compressed into balls that are kept in wrappers.

Genetic resources Exploitation is often unsustainable: in the 1980s the extraction rate of iroko timber (from *Milicia excelsa* and *Milicia regia*) in Ghana was estimated to be about 173,000 m^3 per year, whereas the regeneration rate was estimated to be only about 29,000 m^3 per year. *Milicia excelsa* is classified as 'lower risk but near threatened' in the 2006 IUCN Red list of threatened species, the main threats being habitat loss and degradation due to expanding agriculture, overexploitation of the wood, and *Phytolyma* attacks. *Milicia excelsa* is considered a priority for in-situ conservation. As genetic diversity within populations is low, but diversity between populations large, it is recommended that different populations are included in in-situ conservation efforts. This may be facilitated by the fact that in some areas *Milicia excelsa* is conserved on farm, in sacred groves, in public places and in cemeteries. It is protected by legislation in Côte d'Ivoire and Mozambique; in Ghana and Tanzania a permit is needed for its exploitation. It is subject to a log export ban in various countries, such as Côte d'Ivoire, Ghana, Cameroon and Tanzania.

Breeding Partial genetic resistance to *Phytolyma* within natural *Milicia* populations has been identified, which may lead to the development of resistant lines for vegetative propagation. Selection work is underway in Ghana.

Prospects Iroko belongs to the most valuable timbers of Africa, due to its attractive appearance, durability, stability and good working properties. At present its exploitation is not sustainable in most countries. It requires protection and exploitation has to be limited if it is to become sustainable. Plantation is difficult due to a pest problem. The identification of sources of resistance to the iroko gall fly de-

serves high priority and can possibly be complemented by the development of effective control methods, especially the use of natural parasites or predators of the iroko gall fly.

Major references Berg, 1977; Berg, 1982; Berg & Hijman, 1989; Bolza & Keating, 1972; Burkill, 1997; Cobbinah & Wagner, 1995; Ofori, 2001; Ofori et al., 2001; Takahashi, 1978; UNEP-WCMC, 2006.

Other references Apetorgbor et al., 2001; Arung et al., 2005; Bosu et al., 2006; Durrieu de Madron, 2003; Durrieu de Madron, Nasi & Détienne, 2000; FAO, 1986; Farmer, 1972; Gérard et al., 1998; Hawthorne, 1995; InsideWood, undated; Jøker, 2005; Neuwinger, 2000; Nyong'o, Cobbinah & Appiah-Kwarteng, 1994; Ofori, Cobbinah & Appiah-Kwarteng, 2001; Ofori et al., 1997; Olajide et al., 2005; Ouinsavi, Sokpon & Bada, 2005; Padayachee & Odhav, 2001; Sales, 1979; Wagner, Atuahene & Cobbinah, 1991; White, 1966.

Sources of illustration Berg, 1977; Hawthorne, 1990; Wilks & Issembé, 2000.

Authors D.A. Ofori

MILICIA REGIA (A.Chev.) C.C.Berg

Protologue Bull. Jard. Bot. Belg. 52: 227 (1982).

Family Moraceae

Synonyms *Chlorophora regia* A.Chev. (1912).

Vernacular names Iroko, rock elm, African teak, African oak (En). Iroko, teck d'Afrique, teck kambala (Fr). Amoreira, moreira, tumbiro (Po).

Origin and geographic distribution *Milicia regia* is indigenous to the forest zone of West Africa, from Senegal and Gambia to Ghana. It has been introduced into Nigeria and South Africa.

Milicia regia – wild

Uses The wood of *Milicia regia* and the closely related *Milicia excelsa* (Welw.) C.C.Berg are not distinguished in the timber trade, and are traded under the trade name 'iroko', or 'odum' in Ghana. Iroko is a highly valued commercial timber in Africa, for which demand is large. It is used for construction work, shipbuilding and marine carpentry, sleepers, sluice gates, framework, trucks, draining boards, outdoor and indoor joinery, stairs, doors, frames, garden furniture, cabinet work, panelling, flooring and profile boards for decorative and structural uses. It is also used for carving, domestic utensils, musical instruments and toys. As it is resistant to acids and bases, it is used for tanks and barrels for food and chemical products and for laboratory benches. It is used as sliced veneer but only rarely as rotary veneer. The wood is also used as firewood and for making charcoal.

The fruit of *Milicia regia* is edible and is sometimes sold on markets in Ghana. The bark is used for dyeing leather and cloth. The latex is used as a glue, and has been used as an adulterant in rubber. The latex is credited with antiseptic and healing properties and is applied on wounds and burns. Other plant parts probably have similar medicinal uses as those of *Milicia excelsa*. *Milicia regia* is often considered a sacred tree.

Production and international trade *Milicia regia* and *Milicia excelsa* are both traded as iroko, a major timber in international trade, and the share of *Milicia regia* in that commerce is unknown. During the 1960s Côte d'Ivoire exported about 55,000 m^3 of iroko logs and 6000 m^3 of iroko sawnwood per year, and Ghana 28,000 m^3 of sawnwood. In 1973 Côte d'Ivoire exported as much as 136,500 m^3 of logs and 16,000 m^3 of sawnwood. In 1994 Ghana exported at least 47,000 m^3 of sawnwood. In 2003 Ghana exported 8000 m^3 of iroko sawnwood (US$ 754/m^3). Exportation of iroko logs is now forbidden in Côte d'Ivoire and Ghana, but export of sawnwood is allowed.

Properties The heartwood of *Milicia regia* is pale yellow to brown, darkening on exposure; it is clearly demarcated from the 5–7.5 cm wide paler sapwood. The grain is interlocked, texture medium to coarse. The wood has a strong mint-like odour and a slightly oily feel.

The wood has a density of 560–710 kg/m^3 at 12% moisture content. Shrinkage rates from

green to oven dry are 2.5–3.7% radial and 4.3–5.9% tangential. The wood seasons well, without warping or splitting. Movement in service is small.

At 12% moisture content, the modulus of rupture is 59–123 N/mm², modulus of elasticity 7450–9810 N/mm², compression parallel to grain 37–59 N/mm², cleavage 13.9–16.4 N/mm, Janka side hardness 3785 N, and Janka end hardness 4845 N.

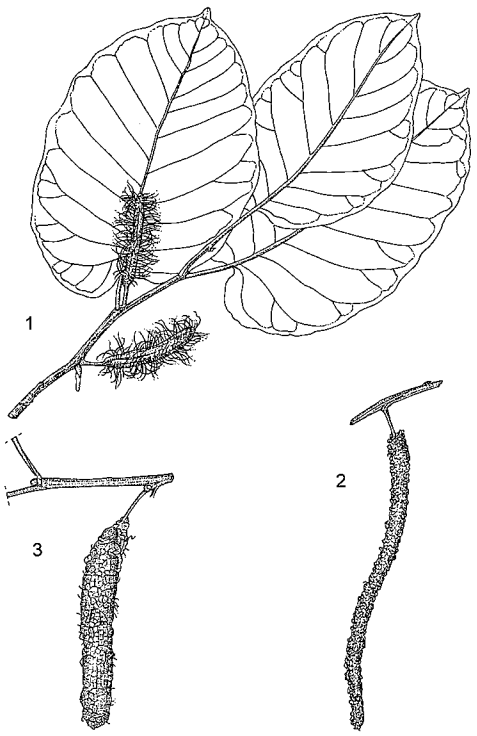
The wood is easy to saw and to work with hand and machine tools. It contains, however, hard deposits ('iroko stones', mainly consisting of calcium carbonate), which can blunt cutting edges. In planing, the interlocked grain may cause some tearing, but this can be avoided by using cutting angles of 15° or less. The wood holds nails well, but nailing may cause some splitting. It finishes well, but filler is needed. It glues easily.

The wood is very durable. The heartwood is resistant to pinhole borer attack, and only slightly susceptible to marine borers and termites. It is resistant to fungal attack. The sapwood is liable to attack by *Lyctus* beetles. The heartwood is impermeable to preservatives, but the sapwood is permeable.

The wood and sawdust may cause dermatitis, irritation to nose and throat, and asthmatic reactions. The heartwood contains 2,3',4,5'-tetrahydroxystilbene, which plays a role in the darkening of the wood on exposure.

Adulterations and substitutes The wood properties of the two *Milicia* species are similar to those of teak.

Description Large, dioecious tree up to 35(–45) m tall; bole usually straight and cylindrical, often branchless for more than 20 m, up to 2 m in diameter, without buttresses, but spurs may become very large and extend into long surface roots; outer bark dark brown to black or grey, inner bark spongy, exuding a white latex. Leaves distichously alternate, simple; stipules free, slightly clasping the stem, up to 3.5 cm × 1.5 cm, caducous; petiole 1–3.5(–6) cm long; blade oblong to elliptical, 4–20(–28) cm × 3–14 cm, base obtuse to cordate, often unequal, apex shortly acuminate, margin almost entire but wavy or toothed towards the apex, papery to thinly leathery, above glabrous or nearly so, below glabrous but sparsely hairy on the veins, pinnately veined with 6–11 pairs of lateral veins. Inflorescence a catkin, usually solitary in leaf axils or on leafless nodes at the base of twigs, white hairy, flowers numerous in longitudinal rows alternating with rows of bracts;



Milicia regia – 1, twig with female inflorescences; 2, male inflorescence; 3, infructescence.
Redrawn and adapted by Achmad Satiri Nurhaman

male inflorescence 8–20 cm × 0.5–1 cm, hanging, peduncle 1–2 cm long; female inflorescence 1–8 cm × 0.5–1.5 cm, peduncle 0.5–1.5 cm long. Flowers unisexual, 4-merous, sessile; male flowers c. 1.5 mm long, tepals 4, basally fused, stamens 4 and inflexed in bud, rudimentary pistil present; female flowers 2–3 mm long, with 4 basally fused tepals, ovary superior, c. 1 mm long, 1-celled, stigma 1, 8–10 mm long, sometimes a second stigma up to 1 mm long. Fruit an achene 2.5–3 mm long, arranged in infructescence 5–8 cm × 1.2–2 cm. Seed c. 2 mm long, pale brown. Seedling with epigeal germination.

Other botanical information *Milicia* comprises 2 species, *Milicia regia* and *Milicia excelsa*, both in tropical Africa. The 2 species mainly differ in the venation and hairiness of the leaves.

Anatomy Wood-anatomical description (IAWA hardwood codes):

Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous;

13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 27: intervessel pits large (≥ 10 μm); (30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell); 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 32: vessel-ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade); 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; 56: tyloses common. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 69: fibres thin- to thick-walled. Axial parenchyma: 80: axial parenchyma aliform; 81: axial parenchyma lozenge-aliform; (82: axial parenchyma winged-aliform); 83: axial parenchyma confluent; (85: axial parenchyma bands more than three cells wide); (91: two cells per parenchyma strand); 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 98: larger rays commonly 4- to 10-seriate; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: 132: laticifers or tanniferous tubes. Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells; 141: prismatic crystals in non-chambered axial parenchyma cells; (154: more than one crystal of about the same size per cell or chamber).

(D. Louppe, P. Détienne & E.A. Wheeler)

Growth and development Seeds normally germinate 2–4 weeks after sowing. Trees are leafless for a short period during the dry season. Flowering begins in December and may continue until March, but in Guinea and Senegal until June. It takes 5–6 weeks from fertilization to fruit maturation. Fruits are available from February onwards. Seed dispersal is mostly by birds, bats and squirrels.

Milicia regia was introduced into Nigeria from Sierra Leone: in Sapoba, on sandy soils and with 2000–2500 mm rain per year, 4-year-old trees were 9 m tall with a stem diameter of 13 cm, whereas in Ibadan, on coarse sand and gravel and with 1000–1500 mm rainfall, 4-year-old trees were only 2.5 m tall and of bad form.

Ecology *Milicia regia* occurs at lower altitudes in rainforest, but is also often found as a lone tree in cultivated areas. It demands intense light and does not tolerate deep shade. In young secondary forest it cannot compete with the climbers and shrubs. *Milicia regia* is considered to be more water demanding and less drought-resistant than *Milicia excelsa*. In Côte d'Ivoire and Liberia *Milicia regia* occurs preferentially in the wetter coastal belt and *Milicia excelsa* in the drier hinterland. *Milicia regia* does not tolerate impeded drainage.

Propagation and planting *Milicia regia* is mostly propagated by seed. The seeds are sown in nursery beds and transplanted into pots. Seeds normally germinate well. About 4 months after germination the seedlings are around 30 cm tall and ready for planting out in the field. Young plants transplant well. *Milicia regia* can also be propagated vegetatively by stem and root cuttings, grafting, layering and in-vitro tissue culture.

Management *Milicia regia* is mostly extracted from natural forest, as plantations are often severely affected by pest problems. It coppices well.

Diseases and pests The major constraint on the cultivation of *Milicia excelsa* and *Milicia regia* are gall-forming *Phytolyma* spp. (iroko gall flies). Attack leads to the formation of galls on the shoots, followed by dieback of foliage down to the woody tissue. This disrupts physiological processes, causes growth reduction, and in many cases kills seedlings. Mature leaves are not seriously affected. Efforts to control this pest have had little success, but the development or selection of more resistant *Milicia* genotypes may offer prospects. It has been reported that *Milicia regia* raised in Nigeria from seeds from Sierra Leone resists attacks by the local *Phytolyma* gall fly.

Genetic resources Exploitation is often unsustainable: in the 1980s the extraction rate of iroko (*Milicia regia* and *Milicia excelsa*) in Ghana was estimated to be about 173,000 m^3 per year, whereas the regeneration rate was estimated to be only about 29,000 m^3 per year. *Milicia regia* is classified as vulnerable in the 2006 IUCN Red list of threatened species, due to excessive exploitation. It is considered a priority for in situ conservation. As genetic diversity within populations is low, but diversity between populations large, it is recommended that different populations are included in in-situ conservation efforts. *Milicia regia* is legally protected in Gambia. In Ghana a special permit is needed for its exploitation.

Breeding Partial genetic resistance to *Phytolyma* within natural *Milicia* populations has

been identified, which may lead to the development of resistant lines for vegetative propagation. Selection work is underway in Ghana.

Prospects *Milicia regia* belongs to the most valuable commercial timber trees of Africa, due to its attractive appearance, durability, stability and good working properties of the wood. At present, however, its exploitation is not sustainable. It requires protection and exploitation has to be limited if it is to become sustainable. Plantation is difficult due to a pest problem. The identification of sources of resistance to the iroko gall fly deserves high priority, possibly complemented by the development of effective control methods.

Major references Berg, 1977; Berg, 1982; Berhaut, 1979; Bolza & Keating, 1972; Burkill, 1997; Cobbinah & Wagner, 1995; Ofori et al., 2001; Saville & Fox, 1967; UNEP-WCMC, 2006; Voorhoeve, 1965.

Other references African Regional Workshop, 1998c; Aubréville, 1959c; CAB International, 2005; FAO, 1984; Farmer, 1972; Ganda & Wright, 1992; Hawthorne, 1995; Irvine, 1961; Keay, 1958d; Keay, 1989; Morgan & Orsler, 1968; Nyong'o, Cobbinah & Appiah-Kwarteng, 1994; Ofori, 2001; Ofori & Cobbinah, 1999; Ofori, Cobbinah & Appiah-Kwarteng, 2001; Ofori et al., 2003; Takahashi, 1978; Taylor, 1960; Taylor, Kankam & Wagner, 2000; White, 1966.

Sources of illustration Berg, 1977.

Authors D.A. Ofori

MILLETTIA GRANDIS (E.Mey.) Skeels

Protologue U.S. Dept. Agric. Bur. Pl. Ind. Bull. 248: 55 (1912).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Synonyms *Millettia caffra* Meisn. (1843).

Vernacular names Umzimbeet, Kaffir ironwood (En). Songa (Po).

Origin and geographic distribution *Millettia grandis* occurs from southern Mozambique to eastern South Africa. It has been planted occasionally outside this region, e.g. in Mauritius.

Uses The wood is locally important for building poles, durable furniture, carving and implements such as walking sticks. It is suitable for heavy construction, heavy flooring, joinery, mine props, shipbuilding, vehicle bodies, furniture, cabinet work, implements, sporting goods, musical instruments, toys, novelties and turnery. It is valued as firewood. *Millettia grandis* is planted as an ornamental shade and wayside tree. It can also be used as a windbreak along pastures. Powdered seed is taken as an anthelmintic. Ground roots serve as a tranquilizer and to induce sleep. The roots have also been used as fish and arrow poison.

Properties The heartwood is dark brown and distinctly demarcated from the yellowish sapwood. The grain is straight, texture fine. The wood has an oily surface.

The wood is very heavy and hard. The density is about 1140 kg/m^3 at 12% moisture content. The wood should be dried slowly and with care to avoid serious checking. At 12% moisture content, the modulus of rupture is about 182 N/mm^2, modulus of elasticity 19,200 N/mm^2, compression parallel to grain 68 N/mm^2, shear 16 N/mm^2, Janka side hardness 15,350 N and Janka end hardness 14,100 N.

Considerable power is required in sawing and planing, but a good polish can be obtained. The wood is easy to split. It holds nails and screws well, but pre-boring is needed. It is very durable and resistant to insect attack. The heartwood does not absorb preservatives.

Botany Evergreen or deciduous shrub or small tree up to 13(–25) m tall; bark surface smooth to flaky, grey to pale brown; twigs slightly hairy or glabrous. Leaves alternate, imparipinnately compound with 4–7 pairs of leaflets; stipules absent; petiole and rachis together 10–20 cm long; stipels needle-shaped, 4–6 mm long; petiolules c. 4 mm long; leaflets opposite, oblong to lanceolate, 4–8 cm × 1–3.5 cm, acuminate at apex, glabrous above, short-hairy below. Inflorescence a terminal, spike-like panicle up to 25 cm long, with short branches, dark brown velvety hairy. Flowers bisexual, papilionaceous; pedicel 2–6 mm long, with 2 small bracteoles near apex; calyx campanulate, c. 7 mm long, tube about as long as lobes; corolla pale purple, standard orbicular, c. 15 mm in diameter, with claw at base, wings and keel slightly shorter; stamens 10, 9 fused, 1 almost free; ovary superior, hairy, style slender, curved, hairy at base. Fruit an oblong to lanceolate, flat pod up to 15 cm × 3.5 cm, with stiff wall, densely brownish hairy, dehiscent with spiralling valves, often 2-seeded. Seeds oblong, flattened, smooth, reddish brown.

Young trees grow fairly fast: 80–100 cm/year under favourable conditions. New foliage of *Millettia grandis* is dark reddish brown or coppery red. Trees flower in December–January. The fruits ripen 6–8 months later. *Millettia*

grandis nodulates with rhizobial bacteria. *Millettia* comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Ecology *Millettia grandis* occurs in coastal forest and open lowland forest up to 600 m altitude. It can be found as a pioneer along forest margins. It tolerates light frost. It often occurs on sandy soils, but also on shale, where trees are often gnarled. It grows best in deep soils where ample water is available. It is locally common.

Management Fresh seed is used for propagation; soaking in hot water for one night improves germination. Young trees transplant well. Larvae of the butterfly *Deudorix diocles* are commonly found in the pods. Baboons strip off and eat the bark.

Genetic resources and breeding *Millettia grandis* has a rather small area of distribution. Therefore, it may easily become liable to genetic erosion, although it is still locally common. In many regions it is already under pressure because it is a favoured tree for building poles and wood carving and because many forests in its area of distribution are being cleared for agricultural land. However, it seems that *Millettia grandis* could sustain current levels of exploitation in some forests in South Africa.

Prospects To meet expected demands and relieve the pressure on natural populations of *Millettia grandis*, starting planting programmes is recommended. These seem to have good prospects because the trees can be easily propagated by seed and grow fairly fast, so that harvesting of poles for construction and wood for the carving industry can be expected within a reasonable period. *Millettia grandis* also has prospects as an ornamental tree for gardens and streets and for windbreaks in agroforestry systems.

Major references Baloyi & Reynolds, 2004; Bolza & Keating, 1972; Coates Palgrave, 1983; Palmer & Pitman, 1972–1974; Takahashi, 1978.

Other references Corby, 1988; Neuwinger, 2000; Obiri, Lawes & Mukolwe, 2002; van Wyk & Gericke, 2000; van Wyk & van Wyk, 1997.

Authors R.H.M.J. Lemmens

MILLETTIA LAURENTII De Wild.

Protologue Belg. Colon. 30: 378 (1904).

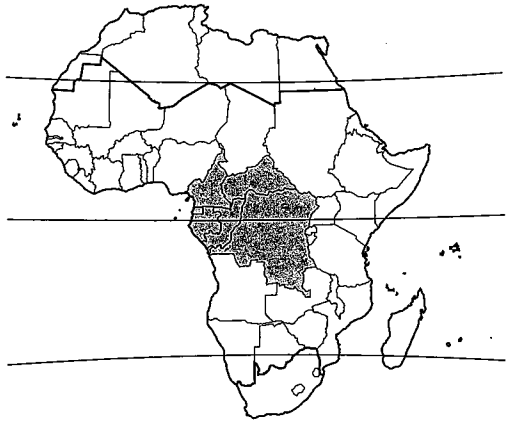
Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Vernacular names Wenge, awong, grey ebony (En). Wengé, wengué, awong, bois de fer, bois noir, palissandre du Congo, faux ébénier (Fr). Wenge, pau ferro (Po).

Origin and geographic distribution *Millettia laurentii* is restricted to a limited area in Central Africa, from the eastern parts of Cameroon, Equatorial Guinea and Gabon to the western parts of the Central African Republic and DR Congo.

Uses The wood (trade names: wenge, wengé) is commonly used for heavy flooring, interior and exterior joinery, interior and exterior panelling, cabinet work, furniture, carving, turnery and sliced veneer. It is also suitable for heavy construction, mine props, vehicle bodies, implements, sporting goods, toys, novelties, boxes, crates and railway sleepers. It is in high demand for decorative furniture and parquet flooring. It is also used for high-quality musical instruments, especially guitars; it is said to give a good and strong tone. It is popular for the production of sculptures, masks and drums.

In traditional medicine a bark decoction is used to treat liver complaints, diabetes, hernia, skin diseases, constipation, fever and rheumatism. The bark is also applied as an expectorant and emetic, and to treat epilepsy, smallpox, oedema, sores and abscesses. It is used as fish poison, an insecticide, vermifuge and arrow poison. Flowering trees provide nectar to honey bees, and edible caterpillars feed on the leaves.



Millettia laurentii – wild

Millettia laurentii is planted as an ornamental and roadside tree. Stem cuttings are planted as a live fence.

Production and international trade According to ITTO, Congo exported 2000 m³ of sawn wenge timber in 2003, with an average price of US$ 409/m³, and 1000 m³ of plywood, with an average price of US$ 354/m³. In 2004 the export of sawn timber from Congo was 4000 m³ with an average price of US$ 383/m³, and of plywood 2000 m³ with an average price of US$ 334/m³. According to ATIBT, Congo exported 4500 m³ of logs, 1900 m³ of humid lumber and 100 m³ of dry lumber in 2004. The annual export of wenge logs from Gabon averaged 4700 m³ in 2000–2004. Cameroon exported 500 m³ and 600 m³ of sawn wenge in 2003 and 2004, respectively. In Cameroon logs are banned from export. Other countries (Central African Republic, Equatorial Guinea and DR Congo) also export this timber.

Properties The heartwood is yellow when freshly sawn but darkens on exposure to dark brown or black-brown, with black streaks, and is sharply demarcated from the pale yellow, 2–5 cm thick sapwood. The grain is straight, texture medium to coarse.

The wood is heavy, with a density of 750–960 kg/m³ at 12% moisture content. The wood air-dries slowly, with slight risk of distortion and high risk of checking. The rates of shrinkage are rather high, from green to oven dry 4.5–6.2% radial and 8.6–10.0% tangential. Once dry, the wood is moderately stable in service.

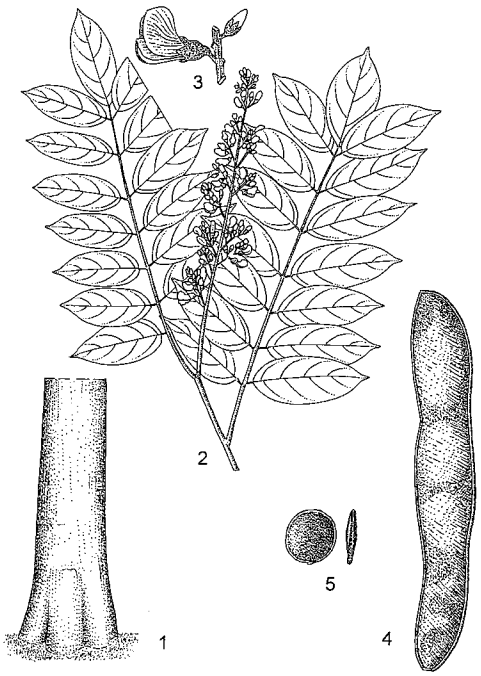
The wood is hard and elastic, but with a tendency to split. At 12% moisture content, the modulus of rupture is 123–246 N/mm², modulus of elasticity 16,500–22,400 N/mm², compression parallel to grain 69–100 N/mm², shear 11–12 N/mm², cleavage 13–22 N/mm and Chalais-Meudon side hardness 7.5–11.1.

The wood saws and works well, but force is required and sawteeth and cutting tools may blunt rapidly; stellite-tipped sawteeth and tungsten-carbide tipped cutting tools are recommended. It is difficult to polish and the use of a finishing wax is recommended. Pre-boring before nailing and screwing is needed. The wood slices well. It can also be rotary cut, but intensive steaming is then needed. The gluing and varnishing properties are poor due to the presence of resin cells, but the use of a filler improves the results considerably.

The heartwood is very durable, being resistant to fungal, dry-wood borer and termite attacks and moderately resistant to marine borers, but the sapwood is susceptible to attack by powder-post beetles. The heartwood is resistant to impregnation with preservatives, but the sapwood is permeable. Contact with fine sawdust produced during processing may cause occupational asthma and allergic dermatitis in workers. A quinone (2,6-dimethoxy-1,4-benzoquinone) has been isolated from the wood and identified as a contact allergen. Several isoflavones have been isolated from the heartwood, and several alkaloids, including guanidine alkaloids, from bark and seeds. The seeds contain about 35% oil.

Adulterations and substitutes The wood of panga panga (*Millettia stuhlmannii* Taub.) from East Africa closely resembles that of *Millettia laurentii* and is used for similar purposes.

Description Medium-sized tree up to 30(–45) m tall; bole cylindrical, often slightly bent, branchless for up to 20 m but usually much less, up to 120 cm in diameter, with small buttresses or fluted at base; bark surface greyish, rough by lenticels, inner bark yellowish, granular, with reddish exudate; branches drooping,



Millettia laurentii – 1, base of bole; 2, flowering twig; 3, flower; 4, fruit; 5, seeds.
Redrawn and adapted by Achmad Satiri Nurhaman

twigs glabrous. Leaves alternate, imparipinnately compound with (4–)6–7(–9) pairs of leaflets; stipules absent; petiole 4–7 cm long, rachis 10–18 cm long; stipels absent; petiolules 4–6 mm long; leaflets opposite, oblong to obovate, 6–15 cm × 3–4(–9) cm, abruptly acuminate at apex, glabrous. Inflorescence a terminal panicle 20–40 cm long, with branches up to 5 cm long, short-hairy. Flowers bisexual, papilionaceous; pedicel c. 3 mm long, with 2 small bracteoles near apex; calyx campanulate, 6–8 mm long, tube as long as lobes; corolla pale purple to purplish blue, glabrous, standard orbicular, c. 12 mm in diameter, with c. 3 mm long claw at base, wings and keel c. 16 mm long; stamens 10, 9 fused, 1 free, c. 15 mm long; ovary superior, c. 10 mm long, hairy, style slender, curved, glabrous. Fruit an oblanceolate to linear flat pod 15–28 cm × 3–5 cm, with stiff wall, glabrous, finely striped, dehiscent, 2–4-seeded. Seeds oblong to lens-shaped, flattened, 22–25 mm × 18–20 mm, smooth, purplish brown. Seedling with epigeal germination; hypocotyl c. 4 cm long, epicotyl 7–12 cm long; cotyledons ovate, c. 12 mm long, fleshy; first leaves opposite and simple.

Other botanical information *Millettia* comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 25: intervessel pits small (4–7 μm); 26: intervessel pits medium (7–10 μm); 29: vestured pits; 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 43: mean tangential diameter of vessel lumina ≥ 200 μm; (45: vessels of two distinct diameter classes, wood not ring-porous); 46: ≤ 5 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 70: fibres very thick-walled. Axial parenchyma: 83: axial parenchyma confluent; 85: axial parenchyma bands more than three cells wide; 89: axial parenchyma in marginal or in seemingly marginal bands; (91: two cells per parenchyma strand); 92: four (3–4) cells per parenchyma strand. Rays: (97: ray width 1–3 cells); (98: larger rays commonly 4- to 10-seriate); 104: all ray cells procumbent; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 115: 4–12 rays per mm. Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied; 121: fibres storied. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells.
(P. Ng'andwe, H. Beeckman & P.E. Gasson)

Growth and development Trees in full flower are very conspicuous, being covered by purplish blue flowers. The roots have nodules containing nitrogen-fixing bacteria.

Ecology *Millettia laurentii* occurs in rainforest, often in well-drained localities, but also in forest subject to regular inundation and in riverine forest and tree savanna.

Propagation and planting *Millettia laurentii* is propagated by seed and cuttings. In a trial in DR Congo, 48% of stem cuttings planted at the onset of the rainy season sprouted.

Management In DR Congo *Millettia laurentii* is one of the species planted for reafforestation of formerly cultivated land.

Diseases and pests Locally in DR Congo, planted trees have been completely defoliated by caterpillars of *Rhopalocampta libeon*, which are also collected as food.

Harvesting The minimum diameter for felling is 50 cm in Cameroon and 60 cm in DR Congo.

Handling after harvest Logs may have brittleheart. They can be left in the forest for some time without damage. However, borers may attack the green timber, making holes of about 0.5 cm in diameter and 1–2 cm long. The boles do not float and therefore cannot be transported by river. The timber is sawn locally and exported as strips or planks, often in sizes of about 250 cm × 20 cm × 5 cm.

Genetic resources *Millettia laurentii* has a limited area of distribution and has been subject to overexploitation in many parts of its distribution area. *Millettia laurentii* is included in the IUCN Red List as endangered due to habitat degradation and overexploitation. Special permission is needed for the exploitation of *Millettia laurentii* timber in Cameroon.

Prospects Wenge is one of the highly valued African timbers on the international market, but production is dwindling. In general, the exploitation level of *Millettia laurentii* is not

sustainable, although the timber is locally harvested from sustainably managed forests. Research is needed on natural regeneration and growth rates to establish criteria for sustainable production in natural forest. The ability to use cuttings for propagation offers possibilities for the establishment of plantations, but more research on plantation management is needed. There is a need to focus on conserving this species.

Major references ATIBT, 1986; Bolza & Keating, 1972; CIRAD Forestry Department, 2003; CTFT, 1952; Hauman et al., 1954b; Mbenkum, 1986; Phongphaew, 2003; Takahashi, 1978; Vivien & Faure, 1985; Wilks & Issembé, 2000.

Other references Adjanohoun et al. (Editors), 1988; African Regional Workshop, 1998d; ATIBT, 2004; ATIBT, 2005; Bouquet, 1969; InsideWood, undated; Kamnaing et al., 1994; Kamnaing et al., 1999; Latham, 2004; Latham, 2005; Neuwinger, 2000; Ngamga et al., 1993; Ngamga et al., 1994; Normand & Paquis, 1976; Pauwels, 1993; Richter & Dallwitz, 2000; Sabiti, Matatu & Baboy, 1992; Schmalle, Jarchow & Hausen, 1977; Tailfer, 1989; Vieux & Kabele Ngiefu, 1970; White & Abernethy, 1997.

Sources of illustration CTFT, 1952; Wilks & Issembé, 2000.

Authors A.T. Tchinda

MILLETTIA RHODANTHA Baill.

Protologue Adansonia 6: 223 (1866).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Chromosome number $2n = 24$

Origin and geographic distribution *Millettia rhodantha* occurs in the forest zone from Guinea to Ghana.

Uses The flexible branches are used in hut building. The bark is chewed to treat cough and a root decoction is taken against stomach-ache.

Properties The wood is yellowish, hard and aromatic.

Botany Small tree up to 12 m tall; bole often sinuous and low-branched, up to 30 cm in diameter; bark surface grey, with lenticels, inner bark yellowish, with reddish exudate; branches sinuous, with lenticels. Leaves alternate, imparipinnately compound with 3–6 pairs of leaflets; stipules narrowly triangular, 3–4 mm long; petiole and rachis short-hairy; stipels threadlike, 1–2 mm long; petiolules 2–3 mm long; leaflets opposite, ovate to obovate or elliptical, 3–10 cm × 1.5–4.5 cm, acuminate at apex, short-hairy below. Inflorescence a false raceme up to 25 cm long, not branched, densely hairy. Flowers bisexual, papilionaceous; pedicel 4–6 mm long, with 2 small bracteoles near apex; calyx campanulate, 3–4 mm long, hairy, tube longer than lobes; corolla pale purple, standard orbicular, 8–10 mm in diameter, glabrous, wings and keel about as long as standard; stamens 10, 9 fused, 1 almost free; ovary superior, hairy, style slender, curved, glabrous. Fruit an ellipsoid, flat pod 8–12 cm × 1.5–3 cm, with short beak at apex, glabrous, yellowish, dehiscent with 2 recurving valves, 1–2-seeded. Seeds almost orbicular, flattened, c. 1 cm in diameter. In Côte d'Ivoire trees flower in August–September. The flowers are sweet-scented and are much visited by bees, which are probably responsible for pollination. In Ghana seeds are produced throughout the year. The roots have nodules containing nitrogen-fixing *Bradyrhizobium* bacteria.

Millettia comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Some other West African *Millettia* species supply timber for local use. The flexible branches of *Millettia chrysophylla* Dunn, a liana, shrub or small tree up to 15 m tall occurring from Guinea to Gabon, are used for hut building in the same way as those of *Millettia rhodantha*. This is also the case for *Millettia lane-poolei* Dunn, a small understorey tree up to 15 m tall occurring from Sierra Leone to Côte d'Ivoire, of which the wood is additionally used for handles and implements. The twigs reportedly purify water. The branches of *Millettia pallens* Stapf, a light-demanding shrub or small tree up to 5 m tall occurring from Guinea to Côte d'Ivoire, are also used for hut building and implements, and they serve as chewing sticks. The inner bark is chewed to treat cough. *Millettia pallens* is planted in hedges.

Ecology *Millettia rhodantha* occurs in different types of lowland forest, including secondary forest, often along streams.

Management *Millettia rhodantha* is tolerant of shade. Seedlings may be found in the shade, but regeneration is probably most abundant in small gaps in the forest. Seeds germinate 2 weeks after sowing. In experiments in Côte d'Ivoire, inoculation with *Bradyrhizobium* bacteria 1 month after sowing had a positive effect

on plant height and stem diameter measured at 4 and 11 months after inoculation. At 11 months after inoculation, inoculated seedlings were 60 cm tall, uninoculated ones only 30 cm.

Genetic resources and breeding *Millettia rhodantha* has a fairly wide distribution and is locally common, e.g. in Ghana, and does not seem to be under threat of genetic erosion, also because it occurs in a variety of forest types including disturbed forest.

Prospects *Millettia rhodantha* will remain of local importance for its wood, but is not of interest to the international market because of its small tree size.

Major references Aubréville, 1959c; Burkill, 1995; de Koning, 1983; Hawthorne, 1995.

Other references Diabate et al., 2005; Hawthorne & Jongkind, 2006; Neuwinger, 2000; Saville & Fox, 1967.

Authors R.H.M.J. Lemmens

MILLETTIA RICHARDIANA (Baill.) Du Puy & Labat

Protologue Novon 5(2): 179 (1995).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Origin and geographic distribution *Millettia richardiana* is endemic to western Madagascar, where it is widespread from Antsiranana in the north to Toliara in the south.

Uses The wood is locally used for furniture, posts in house building, implements and handles.

Properties The wood is whitish, strong and flexible, but not very hard.

Botany Deciduous shrub or small tree up to 15(–20) m tall; bole up to 30 cm in diameter; bark surface crumbly fissured, pale grey-brown; twigs silky hairy, glabrescent. Leaves alternate, imparipinnately compound with 4–12 pairs of leaflets; stipules absent; petiole and rachis yellowish velvety hairy; stipels absent; petiolules up to 3 mm long; leaflets opposite, oblong to elliptical, 1.5–4(–6.5) cm × 0.5–1.5(–3) cm, obtuse to rounded at apex, slightly hairy or glabrous above, yellowish hairy below. Inflorescence a 2–4-flowered fascicle at the base of very young shoots; peduncle 1–5 mm long. Flowers bisexual, papilionaceous; pedicel up to 3.5 cm long, with 2 threadlike bracteoles near apex; calyx campanulate, 4–6 mm long, tube slightly longer than lobes; corolla pale purple, standard orbicular, 12–16 mm in diameter, with greenish yellow spot at base, slightly hairy, wings and keel slightly shorter; stamens 10, fused in basal part; ovary superior, hairy, style slender, curved, glabrous. Fruit an oblong to obovate, flat pod 5–10.5 cm × 1.5–2.5 cm, with short beak at apex, densely yellowish velvety hairy, dehiscent with 2 woody, recurving valves, 1–2(–5)-seeded. Seeds rectangular-ellipsoid, flattened, 9–12 mm × 7–10 mm, dark brown, with small aril.

Trees usually flower from August–December, at the end of the dry season and beginning of the rainy season, on new shoots emerging from the buds with leaves still very immature.

Millettia comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Two other *Millettia* species in Madagascar are sources of timber for local use. *Millettia aurea* (R.Vig.) Du Puy & Labat is a shrub or small to medium-sized tree up to 20 m tall; its stems are used for fences and cattle enclosures. It is an endangered species of western Madagascar. *Millettia hitsika* Du Puy & Labat is an endangered shrub or small tree up to 10 m tall occurring in the coastal plain near Ambila-Lemaitso in eastern Madagascar. Its wood is used in construction. Both these species are classified as endangered in the IUCN Red list of threatened species.

Ecology *Millettia richardiana* occurs in deciduous woodland up to 300 m altitude, on calcareous and sandy soils.

Genetic resources and breeding *Millettia richardiana* is not under threat of genetic erosion because it is widespread and locally common in western Madagascar.

Prospects *Millettia richardiana* will remain of local importance for its wood, but is not of interest to the international market because of its usually small bole size.

Major references du Puy et al., 2002.

Other references du Puy & Labat, 1998c; du Puy & Labat, 1998d; Labat & du Puy, 1995.

Authors R.H.M.J. Lemmens

MILLETTIA STUHLMANNII Taub.

Protologue Engl., Pflanzenw. Ost-Afrikas C: 212 (1895).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Vernacular names Panga panga, partridge wood (En). Panga panga (Fr). Jambire, panga

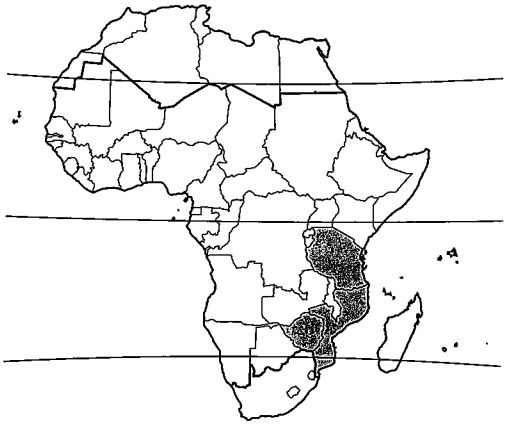
panga (Po). Mpangapanga, mpande (Sw).

Origin and geographic distribution *Millettia stuhlmannii* is restricted to southern Tanzania, eastern Zimbabwe and Mozambique.

Uses The wood (trade name: panga panga) is highly valued for light and heavy flooring and for furniture. It is popular in the veneer industry, where it is used for decorative furniture. It is also used for joinery, panelling, cabinet work, doors, staircases, window frames, carving, turnery and musical instruments. It is suitable for heavy construction, ship and boat building, mine props, railway sleepers, vehicle bodies, implements, toys, novelties, precision equipment, boxes and crates, but for many of these purposes it is no longer used because of its high price.

In traditional medicine a root decoction is drunk to treat stomach-ache. Poles planted during the rainy season serve as a live fence.

Production and international trade In Mozambique *Millettia stuhlmannii* provides one of the most important export timbers. The volumes exported are unknown because a large part of the trade is unregistered. The main importer is China, where processed wood (mainly for flooring) is not only used domestically but also re-exported to markets in the Western World. It was estimated that 4000 m^3 was traded from Zambézia province in 2004, at a price of about US$ 700/m^3. Tanzania officially exported about 2000 m^3 of sawn panga panga from June 2005 to January 2006, mainly to China. This represented about 45% of all hardwood sawn timber exported from the country, but the actual quantity is higher due to illegal logging. The export of unprocessed wood is prohibited in Mozambique and Tanzania, but there is still a lot of illegal export of logs.



Millettia stuhlmannii – wild

Properties The heartwood is dark brown or black-brown, with bands of whitish tissue giving a characteristic 'partridge-breast' figure on tangential surfaces; it is sharply demarcated from the pale yellow, 2.5–7.5 cm thick sapwood. The grain is straight, texture fine to medium. Abundant gum deposits are present. Logs may have brittleheart and ingrown bark.

The wood is heavy, with a density of 720–990 kg/m^3 at 12% moisture content. The wood usually air-dries comparatively rapidly and without serious defects, although cracks may develop. Kiln-drying should be carried out slowly, to avoid cracking. The rates of shrinkage are from green to 12% moisture content about 1.3% radial and 2.2% tangential, and from green to oven dry 2.2–3.1% radial and 3.7–5.8% tangential. Once dry, the wood is moderately stable in service, but slightly less so than that of *Millettia laurentii* De Wild.

At 12% moisture content, the modulus of rupture is about 112 N/mm^2, modulus of elasticity 13,600 N/mm^2, compression parallel to grain 69 N/mm^2, shear 16 N/mm^2, cleavage 73 N/mm and Janka side hardness 7250 N.

The wood is somewhat difficult to saw and work, and sawteeth and cutting tools may blunt rapidly; stellite-tipped sawteeth and tungsten-carbide tipped cutting tools are recommended. A 15° cutting angle is recommended in planing. The wood turns well. It can be polished to a fine surface, but this should be done carefully to avoid splinters. Pre-boring before nailing and screwing is needed; the wood holds nails well. The wood can be rotary cut for veneer, but prior intensive steaming is needed. The gluing and varnishing properties are poor due to the presence of resin cells; the use of a filler improves the results considerably.

The heartwood is very durable, being resistant to fungal, dry-wood borer and termite attacks, but the sapwood is susceptible to powder-post beetle attack. The heartwood is resistant to impregnation with preservatives, the sapwood moderately resistant. The sawdust may cause dermatitis, asthma and irritation to throat, nose and eyes.

The heartwood contains robinetin, a dye-precursor for keratin-based fibres.

Adulterations and substitutes The wood of wenge (*Millettia laurentii*) from Central Africa closely resembles that of *Millettia stuhlmannii* and is used for similar purposes. It differs in its often slightly darker colour and lack of yellowish white resin.

Description Medium-sized tree up to 20(–35) m tall; bole straight or bent, cylindrical, up to 120(–150) cm in diameter; bark surface yellow or greenish grey, smooth; crown spreading; young twigs finely white hairy. Leaves alternate, imparipinnately compound with 2–4 pairs of leaflets; stipules oblong-spatulate, c. 1 cm long, early caducous; petiole up to 10 cm long, rachis up to 20 cm long; stipels thread-like, up to 7 mm long; petiolules up to 9 mm long; leaflets opposite, elliptical to obovate, up to 13 cm × 9 cm, rounded to notched at apex, sparsely hairy below. Inflorescence a terminal pendulous panicle up to 35 cm long, with branches up to 3(–9) cm long, short-hairy. Flowers bisexual, papilionaceous; pedicel up to 9 mm long, with 2 small bracteoles near apex; calyx campanulate, 11–13 mm long, tube c. as long as lobes; corolla pale purple, glabrous, standard orbicular, c. 25 mm in diameter, with c. 5 mm long claw at base, wings and keel c. 23 mm long; stamens 10, 9 fused, 1 free, c. 25 mm long; ovary superior, c. 10 mm long, hairy, style slender, curved, glabrous. Fruit an oblanceolate to linear flat pod 25–35 cm × 3.5–5 cm, with stiff wall, yellowish brown hairy but glabrescent, with lenticels, dehiscent, 6–8-seeded. Seeds ovoid, flattened, 20–23 mm × 17–19 mm, smooth, dark brown, with small aril at base.

Other botanical information *Millettia* comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Other *Millettia* species occurring in Tanzania are *Millettia elongatistyla* J.B.Gillett, a small tree up to 15 m tall, and *Millettia sacleuxii* Dunn, a small tree up to 10 m tall. Both species yield hard and heavy wood. The wood of *Millettia elongatistyla* is used for building poles, tool handles and wooden spoons. It is also used as firewood and for making charcoal. The roots are used in the treatment of schistosomiasis. The tree is also suitable for shade and ornamental purposes. The wood of *Millettia sacleuxii* is used for building poles, fencing, tool handles and pestles, and as firewood. *Millettia sacleuxii* is also suitable for amenity planting. It is classified as vulnerable in the IUCN Red list of threatened species.

Anatomy Wood-anatomical description (IAWA hardwood codes):

Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; 23?: shape of alternate pits polygonal; 26: intervessel pits medium (7–10 μm); 29: vestured pits; 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 70: fibres very thick-walled. Axial parenchyma: 83: axial parenchyma confluent; 85: axial parenchyma bands more than three cells wide; 89: axial parenchyma in marginal or in seemingly marginal bands; 91: two cells per parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: (97: ray width 1–3 cells); (98: larger rays commonly 4- to 10-seriate); 104: all ray cells procumbent; 115: 4–12 rays per mm. Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied; 121: fibres storied. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells. (P. Ng'andwe, H. Beeckman & P.E. Gasson)

Growth and development *Millettia stuhlmannii* flowers at the beginning of the rainy season, from November–January. Leaves emerge before the flowers. In the dry season trees become leafless. *Millettia stuhlmannii* nodulates with rhizobial bacteria.

Ecology *Millettia stuhlmannii* occurs in deciduous woodland up to 900 m altitude. It develops best in high-rainfall and riverine forest, and is locally dominant.

Propagation and planting Stem cuttings planted at the onset of the rainy season usually show fair survival rates. Suckers may develop from the roots.

Management The tree coppices well.

Yield A tree with a diameter of 50 cm yields about 1.9 m^3 of wood, a tree with a diameter of 80 cm about 5.2 m^3.

Handling after harvest All panga panga exported legally from Tanzania and Mozambique is locally sawn before export.

Genetic resources *Millettia stuhlmannii* has a limited area of distribution, but is locally common or even dominant. However, several reports conclude that current harvest levels are too high and rapid depletion of many stands has been predicted.

Prospects Panga panga is one of the highly valued African timbers on the international

market, with a still fair supply. However, there are indications that the exploitation of *Millettia stuhlmannii* is not carried out on a sustainable basis. Research is needed on natural regeneration and growth rates to establish criteria for sustainable production in natural forest. Using cuttings for propagation creates possibilities for the establishment of plantations. An action plan should be developed to increase local processing, optimize the market chain and to safeguard future production of this valuable timber.

Major references Bolza & Keating, 1972; CIRAD Forestry Department, 2003; Coates Palgrave, 1983; Gillett et al., 1971; Mackenzie, 2006; Milledge & Kaale, 2005; Phongphaew, 2003; Takahashi, 1978.

Other references Bryce, 1967; Chudnoff, 1980; Corby, 1988; Ferreirinha, 1953; Hawthorne & Morgan, 1962; Hostettmann, 1984; InsideWood, undated; Lewis et al., 2005; Lovett & Clarke, 1998c; Lovett et al., 2006; Milledge, Gelvas & Ahrends, 2007; Neuwinger, 2000; Richter & Dallwitz, 2000; Scott, 1950; van Wyk & Gericke, 2000; van Wyk & van Wyk, 1997.

Authors R.H.M.J. Lemmens

MILLETTIA VERSICOLOR Welw. ex Baker

Protologue Oliv., Fl. trop. Afr. 2: 129 (1871).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Vernacular names Bois d'or (Fr). Muzumba, musumba (Po).

Origin and geographic distribution *Millettia versicolor* occurs in Cameroon, Central African Republic, Gabon, Congo, DR Congo and northern Angola.

Uses The wood is locally used for furniture, sculpture and implements. It is valued as durable building material, especially for posts, but is occasionally also used for planks and joinery. The wood is suitable for charcoal production. Poles are used to establish living fences. *Millettia versicolor* is occasionally planted as an ornamental shade tree. A root decoction is used to treat kidney complaints and cough, and also serves against sterility and impotence. Root, leaf and bark decoctions are taken in small amounts against intestinal worms; in DR Congo ruminants with worms are also treated with root decoctions. The leaves are used to relieve pain in vapour baths or externally. They are used in Congo against malaria. A leaf decoction is used in a bath to treat syphilis. Edible caterpillars of the genus *Platysphinx* feed on the leaves. Some parts of the tree are used in magic rituals and clairvoyance, and against bewitchment.

Properties The heartwood is golden brown to blackish brown. It can be polished to a smooth surface and turns well. It is resistant to insect attack.

A methanol extract of the bark showed anti-inflammatory activity, with 2-acetyl-7-methoxy-naphtho[2,3-b]furan-4,9-dione as active compound. Leaf extracts exhibited moderate antiplasmodial activity that could be due to the rotenoid usararotenoid C. The anthelmintic effect of the roots has been demonstrated in clinical trials in DR Congo, supporting their use in traditional medicine. Extracts with anthelminthic activity contained the triterpenes lupeol, taraxasterol and β-amyrine.

Botany Shrub or small to medium-sized tree up to 20(–30) m tall; bole up to 60 cm in diameter; bark surface smooth or scaly, often slightly fissured; twigs slightly grooved, glabrous. Leaves alternate, imparipinnately compound with 4–6 pairs of leaflets; stipules caducous; petiole 4–8 cm long, rachis 9–16 cm long; stipels needle-shaped, 1.5–3 mm long; petiolules c. 5 mm long; leaflets opposite, oblong to elliptical or ovate, 8–15 cm × 3.5–5 cm, distinctly acuminate at apex, glabrous above, short-hairy below. Inflorescence a terminal panicle up to 40 cm long, with branches up to 7 cm long, short-hairy. Flowers bisexual, papilionaceous; pedicel c. 4 mm long, with 2 small bracteoles near apex; calyx campanulate, c. 6 mm long, tube much longer than lobes; corolla pale purple, hairy, standard orbicular, c. 20 mm in diameter, with c. 5 mm long claw at base, with yellow spot inside, wings and keel c. 18 mm long; stamens 10, 9 fused, 1 free, c. 18 mm long; ovary superior, densely hairy, style slender, curved, c. 7 mm long, hairy at base. Fruit an oblong flat pod 10–20 cm × 1.5–4 cm, with stiff wall, densely brownish hairy, explosively dehiscent, up to 5-seeded. Seeds ovoid, flattened, smooth, reddish brown. Seedling with epigeal germination; hypocotyl 8–12 cm long, epicotyl c. 8 cm long; cotyledons c. 18 mm × 7 mm, fleshy; first leaves opposite, simple, ovate. *Millettia versicolor* flowers throughout the year. The flowers are much visited by bees, which probably are responsible for pollination. The fruits split open with a sharp crack, and seeds are shot away up to 15 m distance.

Millettia comprises about 150 species, most of them (about 90) in mainland Africa, 8 endemic

to Madagascar, and about 50 in tropical Asia. It is in need of revision and should be split into several genera based on molecular evidence.

Ecology *Millettia versicolor* occurs in secondary forest, along forest patches in savanna, at the fringe of rock outcrops in forest, and in gallery forest. It is locally very common in savanna edges.

Management Long stem-cuttings planted in the ground often take root and may develop into shrubs or trees. This may be the origin of some forest or shrub patches in savanna areas. Fences made of poles in former villages may have developed first into *Millettia versicolor* regrowth and subsequently into forest through colonization by other tree species. In a test, 64% of the stem cuttings sprouted after planting.

Genetic resources and breeding *Millettia versicolor* occurs fairly widespread in Central Africa and is locally common, also in disturbed habitats, and is consequently not liable to genetic erosion.

Prospects The use for construction and fences will remain locally important, but the wood has little prospects for the international market because of the usually small size of the tree. *Millettia versicolor* has interesting pharmacological properties, especially its anti-inflammatory and anthelmintic activities, which deserve more research attention.

Major references Batangu, 1986; Fotsing et al., 2003; Hauman et al., 1954b; Latham, 2004; White & Abernethy, 1997.

Other references Adjanohoun et al. (Editors), 1988; Bouquet, 1969; Ekouya et al., 2006; Ekouya et al., 1990; Markström, 1977; Mbatchi et al., 2006; Neuwinger, 2000; Ngavoura, 1990; Pauwels, 1993; Raponda-Walker & Sillans, 1961.

Authors R.H.M.J. Lemmens

MIMUSOPS ANDONGENSIS Hiern

Protologue Cat. afr. pl. 1: 649 (1898).

Family Sapotaceae

Synonyms *Mimusops warneckii* Engl. (1904).

Origin and geographic distribution *Mimusops andongensis* occurs from Senegal and Guinea Bissau to Cameroon, Congo, DR Congo and Angola.

Uses The wood of *Mimusops andongensis* is locally (especially in Nigeria) valued for building purposes, canoes, axe handles and carving. The latex from the bark is used to flavour palm wine, to treat malaria and as a penile stimulant. The fruits serve as an alternative for chewing gum.

Botany Shrub or small to medium-sized tree up to 20 m tall, containing latex; bole up to 100 cm in diameter but usually much less; crown dense, strongly branched. Leaves arranged spirally, more or less in tufts at the ends of branches, simple and entire; stipules absent; petiole 1–1.5 cm long; blade narrowly obovate to narrowly oblong, 6–18 cm × 2–5 cm, cuneate at base, acuminate at apex, reddish pubescent when very young but soon glabrous, with many lateral veins. Flowers in fascicles in the leaf axils, bisexual, regular; pedicel 0.5–1 cm long; sepals in 2 whorls of 4; corolla whitish, with a short tube and 8 lobes each with 2 appendages, c. 5 mm long; stamens 8, alternating with 8 hairy staminodes; ovary superior, 8-celled. Fruit a globular berry c. 1 cm long, pointed at apex, yellow to orange when ripe, 1-seeded. Seed with small circular basal scar.

Mimusops andongensis is closely related to *Mimusops bagshawei* S.Moore from East Africa, which differs in its deep purplish-brown colour of the bark of young twigs and its staminodes with shorter apex. It also resembles *Mimusops kummel* Bruce ex A.DC., which is widely distributed in tropical Africa and differs mainly in its longer pedicels.

Ecology *Mimusops andongensis* is often found in gallery forest and fringing forest along watercourses. In Côte d'Ivoire it occurs in the transition zone between savanna and forest. In periodically flooded forest on heavy clay soils in southern Benin *Mimusops andongensis* is locally fairly common, constituting about 3% of the trees. It establishes in wooded savanna or formerly cultivated land in later stages of the succession, together with *Afzelia africana* Sm. ex Pers., *Celtis prantlii* Priemer ex Engl., *Dialium guineense* Willd. and *Diospyros mespiliformis* Hochst. ex A.DC.

Genetic resources and breeding There are no indications that *Mimusops andongensis* is under threat of genetic erosion.

Prospects Although very poorly known, it is unlikely that *Mimusops andongensis* will gain importance as a timber tree due to its comparatively small size and more or less specific habitat requirements.

Major references Aubréville, 1959d; Aubréville, 1964; Burkill, 2000.

Other references Heine, 1963; Nansen, Tchabi & Meikle, 2001.

Authors R.H.M.J. Lemmens

MIMUSOPS CAFFRA E.Mey. ex A.DC.

Protologue Prodr. 8: 203 (1844).
Family Sapotaceae
Vernacular names Coastal red milkwood (En). Tinzol (Po).
Origin and geographic distribution *Mimusops caffra* occurs along the coasts of Mozambique and eastern South Africa.
Uses The wood is locally popular and used for construction and boat building. The mealy fruit pulp is agreeably sweet and starchy and is used in the production of jelly and an alcoholic beverage. *Mimusops caffra* is important for reclaiming sand dunes. The bark is used in traditional medicine to treat wounds and sores. *Mimusops caffra* is planted in South Africa and the United States as an ornamental tree.
Production and international trade *Mimusops caffra* wood of South African origin is sold on the international market in small amounts. In 2004 a few hundred m^3 were offered for sale as sawn green timber (3 cm × 15 cm). The bark is sometimes marketed for medicinal purposes.
Properties The wood is reddish, close-grained, heavy, hard, strong and elastic. It is durable when exposed to water.
Botany Shrub or small to medium-sized tree up to 15(–20) m tall, containing latex; bole up to 50 cm in diameter, often gnarled or twisted; bark thin, wrinkled longitudinally, dark grey; young branches densely pubescent. Leaves arranged spirally, more or less in tufts at the ends of branches, simple and entire; stipules absent; petiole 0.5–1.5 cm long; blade cordate to narrowly obovate, 3–9 cm × 1.5–4.5 cm, cuneate at base, notched or rounded at apex, thickened and revolute at margins, leathery, pubescent below, with many indistinct lateral veins. Flowers in fascicles of up to 8 in the leaf axils, bisexual, regular; pedicel 1.5–3 cm long; sepals in 2 whorls of 4; corolla whitish, with a short tube and 8 lobes each with 2 appendages divided almost to the base into 2 narrowly triangular lobes, c. 8 mm long; stamens 8, alternating with 8 hairy staminodes; ovary superior, 8-celled. Fruit an ovoid berry up to 2.5 cm × 1.5 cm, orange to red when ripe, 1-seeded. Seed 1–1.5 cm long, with small circular basal scar.
The seeds are dispersed by water and probably also by fruit-eating animals.
Mimusops caffra is sometimes confused with *Mimusops obtusifolia* Lam., which may also occur in coastal vegetation, but the latter differs by its longer petioles and glabrescent leaves.
Ecology *Mimusops caffra* occurs in coastal thickets on sand dunes, where it rarely exceeds 5 m tall and where its foliage suffers under salt spray and sea winds. It may be dominant in sheltered coastal forest behind the littoral zone, where it can reach 20 m in height.
Management Propagation of *Mimusops caffra* is by seed. It can be planted in full sun and is ideal for coastal areas. Young plants grown as ornamentals require regular watering during dry spells.
Genetic resources and breeding In 2004 *Mimusops caffra* has been declared a protected species in South Africa.
Prospects *Mimusops caffra* is an interesting multipurpose species for planting in coastal regions, and deserves more attention in research.
Major references Coates Palgrave, 1983; Kupicha, 1983.
Other references Meeuse, 1963; van Wyk & Gericke, 2000.
Authors R.H.M.J. Lemmens

MIMUSOPS ELENGI L.

Protologue Sp. pl. 1: 349 (1753).
Family Sapotaceae
Chromosome number $2n = 24$
Vernacular names Asian bulletwood, red coondoo (En). Coing de chine, élengi (Fr). Vonvoleiro (Po).
Origin and geographic distribution *Mimosops elengi* is native to India, Sri Lanka, the Andaman Islands, Myanmar and Indo-China, but is commonly planted as an ornamental tree throughout the tropics, also in Africa, where it has been recorded from e.g. Ghana, Tanzania, Mozambique, Réunion and Mauritius. It has become naturalized locally in Réunion.
Uses In Asia the heavy, strong and durable wood of *Mimusops elengi* is well known as suitable for heavy general construction, bridge building, boat and shipbuilding, marine construction, flooring, bearings, doors and framing. It has also been used for poles and piles, foundation sills, railway sleepers, paving blocks, mine timber, furniture and cabinet work, vehicle bodies and wheels, turnery, tool handles, walking sticks, weaving shuttles, toys, sporting goods and musical instruments. In Africa the wood is considered good for mortars. A good-quality veneer and plywood can be manufactured from the wood. *Mimusops elengi*

also yields a good fuelwood.

Mimusops elengi has fragrant flowers and is often planted as an ornamental and shade tree in gardens and along roads, also in coastal sites. In Asia the leaves are used medicinally to treat headache, toothache, wounds and sore eyes, and are smoked to cure infections of the nose and mouth. A decoction of the bark, sometimes mixed with the flowers, has been used against fever, diarrhoea, inflammation of the gums, toothache, gonorrhoea, wounds and, mixed with tamarind bark, as a lotion for skin complaints. The flowers have been used against diarrhoea. The young fruits have been employed in a gargle for treating sprue. The pounded seeds are used to cure obstinate constipation. Fresh flowers yield an oil used as perfume and are also strung in garlands or necklaces for decoration, or placed in linen-cupboards. The seeds are also used for necklaces and yield an oil on pressing, which has been used for cooking and illumination. The starchy fruits are edible, but reported as tasteless and/or astringent. According to other sources, they taste like dates but are more dry. In India the bark has been used for tanning, but the tannin content is low. In Ghana the bark is used for toughening and colouring tackle.

Production and international trade In some countries in tropical Asia (e.g. Indonesia) *Mimusops elengi* wood is a commercial wood, but it is probably traded in mixed consignments comprising the wood of many other *Sapotaceae*. In Africa it is used only very locally and not traded.

Properties The heartwood is deep red or dark red-brown, often with darker streaks, not sharply demarcated from the paler 5–7 cm wide sapwood. The grain is straight, wavy or slightly interlocked, texture very fine to fine and even; occasionally with watered-silk figure on the tangential face of sapwood. The taste is bitter and the wood contains saponin and lathers when rubbed with water.

Mimusops elengi yields a heavy hardwood. The density is 780–1120 kg/m^3 at 15% moisture content. The rates of shrinkage are moderate to very high, from green to 12% moisture content 3.2% radial and 5.1% tangential, and from green to oven dry 4.7% radial and 11.4% tangential. It takes about 2 months to air dry boards 3 cm thick from 40% to 15% moisture content. The wood is liable to end-splitting, warping and surface checking if not carefully seasoned.

In a test in Indonesia, the wood of *Mimusops elengi* showed the following mechanical properties at 15% moisture content: modulus of rupture 139 N/mm^2, modulus of elasticity 15,190 N/mm^2, compression parallel to grain 65.5 N/mm^2, shear 7.5–9.5 N/mm^2, cleavage 105 N/mm radial and 110.5 N/mm tangential, Janka side hardness 9430 N and Janka end hardness 10,270 N.

The wood is very hard, very strong and tough, and is generally considered difficult to work, especially in sawing, due to the presence of silica, but is easier to work when still green; stellite-tipped saws are recommended. It finishes very well using sharp tools.

The wood is very durable, even when exposed to the weather or in contact with the ground. It is reportedly resistant to marine borer attack and to dry-wood termites. The sapwood is susceptible to *Lyctus*. The heartwood is very resistant to impregnation with preservatives. The energy value of the heartwood is 21,340 kJ/kg, that of the sapwood 21,090 kJ/kg.

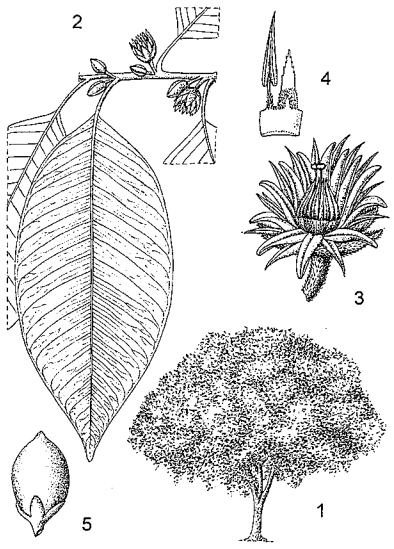
The seed kernel contains about 22% oil. The fatty acid composition of the refined oil is: oleic acid 64%, linoleic acid 14.5%, palmitic acid 11%, stearic acid 10% and behenic acid 0.5%. The nutritional quality of the refined oil was comparable with that of groundnut oil in feeding tests with rats.

Several triterpenes (e.g. β-amyrin, lupeol, α-taraxerol and ursolic acid) have been isolated from *Mimusops elengi*, as well as steroidal glycosides. The major chemical compounds in the flowers are aromatic alcohols and esters derived from the phenylpropanoid metabolism.

The ethyl-acetate-soluble fraction of an alcoholic extract of *Mimusops elengi* bark showed anti-ulcer activity against experimental gastric ulcers; this activity was attributed to a decrease in gastric acid secretory activity along with strengthening of mucosal defensive mechanisms. A methanolic extract caused hypotensive activity in anaesthetized rats; it may possess calcium-blocking activity. The saponins from the seeds are effective against *Phytophthora palmivora* and *Colletotrichum capsici*, and field trials in India showed that they can be used for control of these pathogens in betel pepper (*Piper betle* L.) plantations.

Adulterations and substitutes The wood of several *Mimusops* species indigenous in Africa probably has similar properties and possible applications.

Description Evergreen, small to medium-sized tree up to 30(–40) m tall; bole up to 100



Mimusops elengi – 1, tree habit; 2, flowering twig; 3, flower; 4, stamen and staminode; 5, fruit. Source: PROSEA

cm in diameter, often short and divided into several large main branches but sometimes branchless for up to 15(–20) m, buttresses absent or up to 2 m high; bark surface becoming deeply fissured and sometimes peeling off in thin scales, grey, brown or dark red to blackish, inner bark fibrous, pink or reddish, with scanty watery or white sticky latex; crown dense, rounded and spreading, glossy dark green. Leaves arranged spirally, more or less in tufts at the ends of branches, simple; stipules minute and caducous; petiole 1–3.5 cm long, grooved above; blade ovate to elliptical or oblong-elliptical, 4.5–17 cm × 2–7 cm, rounded at base, acuminate at apex, margins often wavy and upcurled, glabrous, with 10–20 pairs of lateral veins. Flowers in fascicles of up to 6 in the leaf axils, bisexual or functionally unisexual, regular, fragrant; pedicel 1–1.5 cm long; sepals in 2 whorls of 4; corolla white, with a short tube and 8 lobes each deeply divided into 3, c. 1 cm long; stamens 8, alternating with 8 staminodes; ovary superior, (6–)8-celled. Fruit an ovoid to ellipsoid berry 2–3 cm long, orange-red when ripe, 1–2-seeded. Seeds up to 2 cm long, laterally compressed, with small circular basal scar. Seedling with epigeal germination; cotyledons leafy; hypocotyl elongated.

Other botanical information *Mimusops* comprises about 40 species, 20 of which occur in mainland Africa, 15 in Madagascar, 5 in the Seychelles and Mascarene islands, and 1 (*Mimusops elengi*) in Asia and the Pacific. It is related to *Manilkara*, which differs in the number of sepals, corolla lobes and stamens (6) and its elongate seed scar.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 10: vessels in radial multiples of 4 or more common; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 25: intervessel pits small (4–7 μm); (26: intervessel pits medium (7–10 μm)); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 32: vessel-ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade); 33: vessel-ray pits of two distinct sizes or types in the same ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 47: 5–20 vessels per square millimetre; 48: 20–40 vessels per square millimetre; 56: tyloses common. Tracheids and fibres: (60: vascular/vasicentric tracheids present); 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; (69: fibres thin- to thick-walled); 70: fibres very thick-walled. Axial parenchyma: (76: axial parenchyma diffuse); 77: axial parenchyma diffuse-in-aggregates; 86: axial parenchyma in narrow bands or lines up to three cells wide; 87: axial parenchyma reticulate; (92: four (3–4) cells per parenchyma strand); 93: eight (5–8) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 100: rays with multiseriate portion(s) as wide as uniseriate portions; 107: body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells; 108: body ray cells procumbent with over 4 rows of upright and/or square marginal cells; (109: rays with procumbent, square and upright cells mixed throughout the ray); 115: 4–12 rays per mm; (116: ≥ 12 rays per mm). Mineral inclusions: (136: prismatic crystals present); (141: prismatic crystals in non-chambered axial parenchyma cells); 159: silica bodies present; 160: silica bodies in ray cells; 161: silica bodies in axial parenchyma cells.
(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development Seedlings and trees grow slowly, but occasionally trees may

reach a height of 34 m in 20 years with a bole diameter of 50 cm, i.e. a mean annual diameter increment of 2.5 cm. Trees may flower and fruit throughout the year. Infrequent visits of insects and bats have been observed, but pollination is most likely by wind. The stigma is receptive before the pollen is released, stimulating cross-pollination. The seed is known to be dispersed by bats, but monkeys, squirrels and wild pigs probably also eat the fruits.

Ecology In its natural area of distribution in Asia *Mimusops elengi* is fairly common near the sea, but may also be found in rocky locations and inland forest, up to 600 m altitude. It thrives in areas with perhumid or slightly seasonal rainfall types, but is usually found in seasonally dry habitats. It can stand waterlogging for up to 2 months. It requires fertile soil. It is tolerant of light frost.

Propagation and planting *Mimusops elengi* can be propagated by seed or cuttings. Seed can be stored for about 9 months and needs 'after-ripening' during the first month of storage. There are about 2000 dry seeds/kg. Seed germinates in 17–82 days and the germination rate is 70–90%. It is best sown directly in containers. Seedlings can be planted out when 20–30 cm tall. The rooting success of 10–15 cm long cuttings with a diameter of 0.5–1 cm is 70–90%.

Management *Mimusops elengi* is shade-tolerant; it retains a full crown and reproduces satisfactorily under fairly dense shade. In Myanmar and Sri Lanka plantations of *Mimusops elengi* have been established.

Diseases and pests In India a foliar disease of *Mimusops elengi* is caused by *Colletotrichum gloeosporioides*. A mortality of about 20% of one-month-old seedlings was recorded by a collar rot disease, caused by *Cylindrocladium* spp.

Handling after harvest The sawdust is irritating to nose and throat.

Genetic resources Trees may differ markedly in size depending on their origin, which offers potential for selection and possibly breeding activities. In some regions in Asia (e.g. the Philippines), *Mimusops elengi* is classified as a vanishing timber tree.

Prospects Because of its superior wood quality, it is worthwhile starting silvicultural trials with *Mimusops elengi*, which is hitherto known in Africa mainly as an ornamental and shade tree.

Major references Burkill, 2000; Friedmann, 1981; Martawijaya et al., 1992; Noorma Wati Haron, 1998.

Other references Florence & Sankaran, 1991; Ilic, 1990; Ilic, 1991; InsideWood, undated; Johri et al., 1994; Kingston & Risdon, 1961; Mandal & Maity, 1991; Pennington, 1991; Shah et al., 2003.

Sources of illustration Noorma Wati Haron, 1998.

Authors R.H.M.J. Lemmens

Based on PROSEA 5(3): Timber trees: Lesser-known timbers.

MIMUSOPS KUMMEL Bruce ex A.DC.

Protologue Prodr. 8: 203 (1844).

Family Sapotaceae

Chromosome number $n = 12$

Synonyms *Mimusops fragrans* (Baker) Engl. (1904).

Vernacular names Red milkwood (En). Foumbo (Fr). Mgambo (Sw).

Origin and geographic distribution *Mimusops kummel* occurs from Côte d'Ivoire east to Ethiopia and Eritrea, and south to Tanzania and Malawi.

Uses The wood of *Mimusops kummel* is used for construction, utensils and tool handles, and also as firewood and for making charcoal. Branches are used as arrow shafts. In Ethiopia the trees are conserved when land is cleared for planting coffee to serve as shade trees. The fruit is commonly eaten in East Africa. The roots are used in traditional medicine as a laxative and galactagogue, and the seeds to treat ascariasis.

Properties The heartwood is reddish brown, heavy and hard, and distinctly demarcated from the creamy to yellowish sapwood.

Botany Small to medium-sized tree up to 25(–35) m tall, containing latex; bole up to 100 cm in diameter; bark deeply grooved, dark grey; crown dense, ovoid; young branches densely red-brown pubescent. Leaves arranged spirally, more or less in tufts at the ends of branches, simple and entire; stipules absent; petiole 0.5–1.5(–3) cm long; blade oblong-elliptical to obovate-elliptical, 4–12 cm × 1.5–5 cm, cuneate at base, notched to shortly acuminate at apex, leathery, almost glabrous, with many lateral veins. Flowers in fascicles of up to 4 in the leaf axils, bisexual, regular, fragrant; pedicel (1.5–)2–5 cm long, slender; sepals in 2 whorls of 4; corolla creamy-white, with a short tube and 8 lobes each with 2 appendages, 9–14 mm long; stamens 8, alternating with 8 hairy

staminodes; ovary superior, 8-celled. Fruit an ellipsoid to ovoid berry up to 2.5 cm long, orange-red when ripe, 1-seeded. Seed ellipsoid, c. 2 cm long, reddish brown, with small circular basal scar. Seedling with epigeal germination; hypocotyl 4.5–5 cm long, epicotyl 2.5 cm long; cotyledons leafy, 3 cm × 1.5 cm, 3-veined from the base.

The distribution of *Mimusops laurifolia* (Forssk.) Friis (synonym: *Mimusops schimperi* Hochst. ex A.Rich.) overlaps with that of *Mimusops kummel* in Eritrea and eastern Ethiopia; *Mimusops laurifolia* is also found in Somalia and Yemen. Its pale brown to yellowish white wood is occasionally used for construction, carpentry and joinery, and as firewood. *Mimusops laurifolia* is sometimes planted as a shade or ornamental tree and its fruit is edible. It was probably already cultivated thousands of years ago in ancient Egypt, and is characterized by its long and slender leaf stalks.

Mimusops obovata Sond. closely resembles *Mimusops kummel* and *Mimusops zeyheri* Sond., but differs in its smaller, more thinly leathery leaves. It occurs in southern Mozambique, eastern South Africa and Swaziland, and also produces useful timber and edible fruits. The heartwood is pink or reddish, heavy, hard and durable, and logs are occasionally traded on the international market. The fruits taste pleasant and are used to make jellies and alcoholic drinks.

Ecology *Mimusops kummel* is widespread in riverine forest, but also occurs in upland dry evergreen forest and wooded grassland up to 2100 m altitude. It usually occurs scattered. In the southern part of the Sudanian zone in Burkina Faso where there is an annual rainfall of 1000 mm, it is characteristic of forests on the most humid soils.

Management *Mimusops kummel* is propagated by seeds and wildlings. One kilogramme contains about 800 seeds. The seeds can be stored in airtight containers at room temperature. Germination occurs 18–45 days after sowing. The tree tolerates pruning and pollarding.

Genetic resources and breeding *Mimusops kummel* is widely spread and occurs in various habitats, and is consequently not liable to genetic erosion.

Prospects Like several other *Mimusops* species, *Mimusops kummel* is an interesting multipurpose species worthy of more research.

Major references Bein et al., 1996; Burkill, 2000; Hemsley, 1968; Katende, Birnie & Tengnäs, 1995.

Other references Aubréville, 1959d; Beentje, 1994; Bekele-Tesemma, Birnie & Tengnäs, 1993; Coates Palgrave, 1983; de la Mensbruge, 1966; Friis, 1981; Kupicha, 1983; Lovett, Ruffo & Gereau, 2003; Neumann & Müller-Haude, 1999; van Wyk & Gericke, 2000.

Authors R.H.M.J. Lemmens

MIMUSOPS MAXIMA (Poir.) R.E.Vaughan

Protologue Mauritius Inst. Bull. 1: 56 (1937).

Family Sapotaceae

Vernacular names Grand natte, nattier (Fr).

Origin and geographic distribution *Mimusops maxima* is endemic to Réunion and Mauritius.

Uses *Mimusops maxima* has been heavily exploited for construction timber, and in Réunion the wood is sometimes still used for construction, joinery, furniture and wooden toys. The fruit is edible; the pulp is sweet, with an agreeable flavour. A leaf decoction is astringent and used to treat diarrhoea, dysentery and haemorrhage. The latex is used as bird lime. In Réunion the tree is planted for ecological restoration of the environment and as ornamental tree.

Properties The heartwood of *Mimusops maxima* is reddish brown, heavy and hard. It is closely grained and durable, even for exterior use (shingles).

Botany Small to medium-sized tree up to 20 m tall, containing latex; bark roughly fissured, grey to almost whitish; ultimate branches thick, up to 1 cm in diameter, with scars of fallen leaves. Leaves arranged spirally, in tufts at the ends of branches, simple and entire, dark green; stipules absent; petiole 2–5 cm long; blade elliptical, 6.5–13(–20) cm × 3–8 cm, cuneate at base, rounded at apex, leathery, initially pubescent below but glabrescent, with many lateral veins. Flowers in fascicles of 1–3 in the leaf axils, bisexual, regular; pedicel 2–4 cm long, curved; sepals in 2 whorls of 4, reddish brown pubescent; corolla pale brownish, with a short tube and 8 lobes each with 2 appendages divided almost to the base into 3–4 narrow lobes, up to 12 mm long; stamens 8, alternating with 8 hairy staminodes; ovary superior, 8-celled. Fruit a globose to pear-shaped berry 5–7 cm in diameter, bright green, 1–7-seeded. Seeds flattened, 4–5 cm long, sometimes slightly keeled, with small circular basal scar.

Mimusops maxima plants in Réunion usually

have 4–6-seeded fruits, whereas in Mauritius the fruits contain 1–2 seeds. In Réunion, recent studies showed the large variation in fruit shape and number of seeds (1–6) per fruit.
In Mauritius *Mimusops maxima* is sometimes difficult to distinguish from *Mimusops erythroxylon* A.DC. and *Mimusops petiolaris* (A.DC.) Dubard; the former differs in its smaller flowers, and the latter in its corolla lobe appendages divided into 5–8 lobes and more slender petioles. Both species are endemic to Mauritius.
Mimusops maxima flowers from November to January (February). Green fruits can be found on the trees year-round, but they ripen from November to December.

Ecology *Mimusops maxima* is characteristic of humid forest at low altitudes, in Réunion at 700–1100 m in the western part of the island, from sea-level up to 900 m in the eastern part. In more dry regions it is found along streams.

Management The fruits are collected from the ground from January to February and the seeds are manually extracted after partial fermentation of the pulp. The seeds can be stored for 6 months at ambient temperature in airtight containers. The seeds are planted by pressing them for 2/3 into the soil, the pointed end downwards. Germination starts after 2 months and takes about 1 month. It is possible to accelerate germination by scarification of the seed at its rounded end. Seeds can be sown directly in pots, but transplanting has to be done within one month as the taproot soon becomes very long. Seedlings are kept in the nursery for 8–9 months before planting out into the field. In Réunion *Mimusops maxima* has been planted in silvicultural programmes, but the results have differed widely depending on soil conditions.

Genetic resources and breeding Although apparently locally still rather common, the population of *Mimusops maxima* in Réunion has suffered from timber exploitation. Protection of the remaining stands is needed, also because the species is uncommon in Mauritius.

Prospects With the decline in natural forest area in the Mascarene Islands, the population level of *Mimusops* species has become too low to allow any sustainable utilization for timber. There is too little known about *Mimusops maxima* to judge its potential as a plantation timber tree, but probably possibilities for economical exploitation are limited by low growth rates, as is the case in other *Mimusops* species.

Major references Friedmann, 1981; Guribfakim, Guého & Bissoondoyal, 1997; Rivière & Schmitt, 2003.

Other references Agence Universitaire de la Francophonie, undated; Association Flore Réunion, 2001; Chan Ng Yok, 1977–2002; Royal Museum for Central Africa, undated.

Authors R.H.M.J. Lemmens

MIMUSOPS ZEYHERI Sond.

Protologue Linnaea 23: 74 (1850).

Family Sapotaceae

Vernacular names Transvaal red milkwood, common red milkwood, moepel (En). Mgamba kapu (Sw).

Origin and geographic distribution *Mimusops zeyheri* occurs from Tanzania and Angola to Botswana, Zimbabwe, Mozambique, northeastern South Africa and Swaziland.

Uses The wood is useful as general-purpose timber. It is used for furniture, and is also suitable for general carpentry. The fruit is edible; the yellow fruit flesh is pleasantly sweet and floury. It is eaten fresh and can be stored after sun drying. It can be used in jams and jellies, and the juice is fermented to produce an alcoholic drink. Branches are used as firesticks in traditional fire-making by friction. In Swaziland a root infusion is taken to treat candidiasis, and a bark decoction to treat wounds and ulcers. In Zimbabwe the tree is maintained in fields because it is considered to improve soil fertility. *Mimusops zeyheri* is planted as an ornamental, and plants are sometimes sold as pot plants, e.g. in the United States.

Properties The heartwood is creamy brown to reddish brown, fairly heavy and hard, and fine-grained. It is moderately durable. It works well, but fresh sawdust may cause sneezing.
The content of ascorbic acid (vitamin C) in the fruit is reportedly fairly high, about 90 mg per 100 g. The fruit has a comparatively low energy value and low content of protein, fat and carbohydrate, but contains per 100 g Ca 27 mg, P 13 mg and Fe 24 mg.

Botany Shrub or small to medium-sized tree up to 25 m tall, containing latex; bark almost smooth to roughly reticulately fissured, grey to dark brown or black; crown dense, rounded; young branches densely red-brown pubescent. Leaves arranged spirally, more or less in tufts at the ends of branches, simple and entire; stipules absent; petiole 0.5–3.5 cm long; blade oblong-elliptical to obovate-elliptical or lanceolate, 3.5–11.5 cm × 1.5–5.5 cm, cuneate at base,

usually shortly acuminate at apex but sometimes rounded or slightly notched, leathery, initially reddish brown pubescent below but glabrescent, with many lateral veins. Flowers in fascicles of up to 7 in the leaf axils, bisexual, regular; pedicel 1–3 cm long, curved; sepals in 2 whorls of 4; corolla creamy-white, with a short tube and 8 lobes each with 2 appendages, up to 10 mm long; stamens 8, alternating with 8 hairy staminodes; ovary superior, 8-celled. Fruit an ellipsoid to ovoid or almost globose berry up to 4.5 cm long, yellow-orange when ripe, 1–2-seeded. Seeds ellipsoid, 1–2 cm long, shiny pale brown, with small circular basal scar.

Mimusops zeyheri closely resembles *Mimusops obtusifolia* Lam. (synonym: *Mimusops fruticosa* A.DC.), which occurs in eastern Kenya, Tanzania, Malawi, Zimbabwe and Mozambique. In Kenya and Tanzania the wood of the latter species is used for poles, tool handles, carving, boats and dugout canoes, which have a service life of up to 8 years, whereas the sweet fruits are commonly eaten throughout the distribution area of the species. In Tanzania the roots are used to treat constipation, hernia and venereal diseases. *Mimusops obtusifolia* differs from *Mimusops zeyheri* in its leaves rounded at apex and glabrous or sparsely pubescent below, and slightly smaller fruits.

Mimusops zeyheri trees grow slowly and are long-lived. In Zambia they have ripe fruits between March and June, and flower buds develop at the end of the rainy season.

Ecology *Mimusops zeyheri* is characteristic for riparian woodland, where it is even found on sandy, infertile alluvial soils, and termite mounds, but is occasionally also found in swamp forest, thickets and rocky hill slopes.

Management The seeds are orthodox; they maintain 60% viability after one month when the moisture content is reduced to 15% and when they are stored at –20°C. They should be scarified and subsequently immersed in water during 24 hours before sowing.

Genetic resources and breeding *Mimusops zeyheri* as well as *Mimusops obtusifolia* are widespread in various habitats and not in danger of genetic erosion.

Prospects *Mimusops zeyheri* and some other *Mimusops* species have some importance for the production of general-purpose timber and as a supplier of supplementary food in the often monotonous diet of people in southern Africa. These multipurpose trees deserve more attention in research. However, the potential for domestication is limited because of the slow growth. *Mimusops zeyheri* is considered by FAO as potentially important as multipurpose tree, for which breeding programmes should be developed.

Major references Coates Palgrave, 1983; du Preez & Welgemoed, 1993; Kupicha, 1983; van Wyk & Gericke, 2000.

Other references Amusan et al., 2002; Beentje, 1994; Hemsley, 1968; Kamuhabwa, Nshimo & de Witte, 2000; Meeuse, 1963; Ruffo, Birnie & Tengnäs, 2002.

Authors R.H.M.J. Lemmens

MORUS MESOZYGIA Stapf

Protologue Journ. de Bot., sér. 2, 2: 99 (1909).

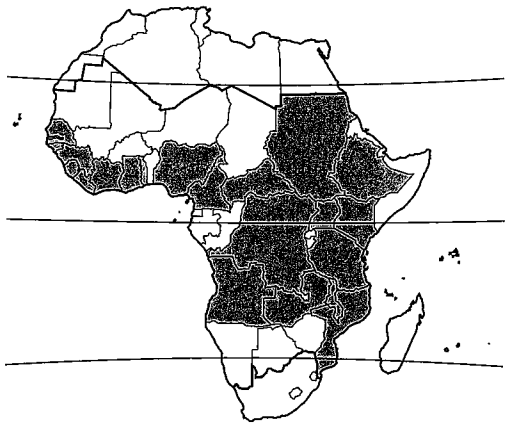
Family Moraceae

Synonyms *Morus lactea* (Sim) Mildbr. (1922).

Vernacular names East African mulberry, African mulberry, Uganda mulberry (En). Difou, mûrier du Sénégal (Fr). Chocobondo (Po).

Origin and geographic distribution *Morus mesozygia* has a wide distribution in tropical Africa, from Senegal eastward to Ethiopia and southward to Zambia, Angola, Mozambique and South Africa.

Uses The wood (trade name: difou) is especially suitable for sliced veneer, high-class furniture, flooring, staircases, joinery and turnery, but also for interior trim, sporting goods, agricultural implements, toys, novelties, carvings, boxes, crates, vats, posts, poles, piles, mine props and shingles. In Ghana the wood is used for construction, furniture, joinery, mortars and pestles. In DR Congo it is traditionally used for dug-out canoes. Stems from coppiced



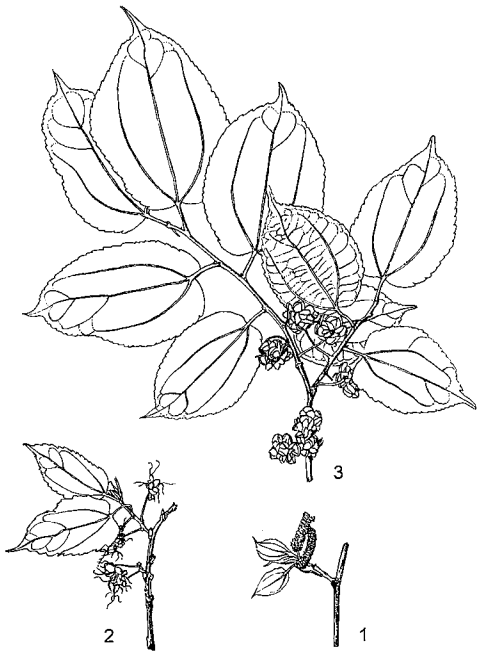
Morus mesozygia – wild

trees are used as walking sticks, ramrods for guns and palisades. The wood is used as fuelwood and for charcoal making.
The infructescense is edible and tastes like white grapes. The fibrous bark has been made into cloth and sandals. The latex is used for making birdlime and has been used as a rubber adulterant. The leaves are fodder for livestock and the flowers provide forage for honey bees.
In African traditional medicine all plant parts are used in decoctions, baths, massages and enemas against rheumatism, lumbago, intercostal pain, neuralgia, colic, stiffness, debility, diarrhoea and dysentery. The root is used as an aphrodisiac. Sap from young shoots is dropped into the nose for treatment of syphilis.
Morus mesozygia is widely planted as a wayside tree, shade and palaver tree, and along farm and field boundaries. In Uganda it is a shade tree in coffee and banana plantations, in Côte d'Ivoire in coffee and cocoa plantations. *Morus mesozygia* is often credited with magical properties.

Properties The heartwood is yellow when freshly cut, darkening to brown on exposure, and distinctly demarcated from the 5–10 cm wide, grey to white sapwood. The grain is straight to interlocked, texture fine to medium. The wood is moderately lustrous and has a mottled or ribbon-like figure.
The wood is medium-weight to heavy, with a density of 660–920(–1050) kg/m^3 at 12% moisture content. The air drying characteristics are satisfactory. The rates of shrinkage from green to oven dry are moderate: 3.2–4.3(–5.0)% radial and 5.6–6.6(–8.3)% tangential. Once dry, the wood is stable in service.
The wood is strong and hard but somewhat brittle. At 12% moisture content, the modulus of rupture is 143–213 N/mm^2, modulus of elasticity 14,500–18,500 N/mm^2, compression parallel to grain 83–92 N/mm^2, shear 8–9 N/mm^2, cleavage 16–20 N/mm and Chalais-Meudon side hardness 6.0–15.4.
The wood works moderately easily with most hand and machine tools, but with some blunting of cutting edges. It saws well, but stellite-tipped sawteeth are recommended. In planing interlocked grain may cause trouble, and quartersawn surfaces should be planed at a reduced angle (15°) to avoid picking up. Pre-boring is recommended for nailing; the nail and screw holding properties are good. Slicing properties are good, but peeling properties poor. The wood glues well and takes a good finish. Sawdust may cause dermatitis and irritation to the nose and throat.
Although the wood is sometimes said to be durable, it has also been recorded to be vulnerable to attacks by fungi, pinhole borers, marine borers, longhorn borers and termites. The sapwood is susceptible to *Lyctus* borer attack. The heartwood is extremely resistant to impregnation with preservatives, the sapwood moderately resistant.
The heartwood contains the flavonoids morin, dihydromorin and pinobanksin, the leaves a glycoside of morin. Resistance of the wood to the wood rot fungi *Coriolus versicolor*, *Lentinus squarrosulus* and *Poria* spp. is related to the presence of dihydromorin.
The chemical composition of the oven-dry wood is: cellulose 28–33%, pentosans 16–18%, lignin 26–28%, furfurals 2–10% and ash 2–3%. The solubility in hot water is 3–4%, in alcohol-benzene 13–14% and in 1% NaOH 15–20%. Sulphate pulping of the wood resulted in pulp of acceptable strength.

Adulterations and substitutes The wood resembles that of iroko (*Milicia excelsa* (Welw.) C.C.Berg) and it has sometimes been exploited as such, but it has a finer texture. In Ghana it is considered a substitute of iroko.

Description Dioecious small to fairly large tree up to 40 m tall, with white latex; bole branchless for up to 18 m, up to 90 cm in diameter, straight, usually cylindrical, with ridges at base, sometimes with buttresses; outer bark grey to brown, with paler blotches, smooth, later longitudinally fissured, with vertical rows of large lenticels, inner bark cream-yellow, exuding latex when cut; branchlets whitish hairy or glabrous. Leaves distichously alternate, simple; stipules linear-lanceolate, 4–10 mm long, membranous, caducous; petiole 0.5–2.5 cm long, glabrescent; blade elliptical to oblong, ovate or obovate, more or less asymmetrical, 2.5–15 cm × 2–8(–10) cm, base cordate to obtuse, apex acuminate to acute, margin toothed, papery to thinly leathery, upper surface hairy on the main veins, lower surface hairy in the axils of the lateral veins, 3-veined from the base and with few lateral veins. Inflorescence an axillary spike; male inflorescence 1–3 cm long, c. 8 mm in diameter, creamy white, peduncle 0.5–3 cm long, many-flowered; female inflorescences head-like, globose, c. 0.5 cm in diameter, 3–10(–15)-flowered, peduncle 0.5–2.5 cm long. Flowers unisexual, regular, 4-merous; male flowers with tepals 2–3 mm long, fused at base, pubescent, stamens free, inflexed in bud, at anthesis bending outward elastically,



Morus mesozygia – 1, twig with male inflorescences; 2, twig with female inflorescences; 3, twig with infructescences.
Redrawn and adapted by Iskak Syamsudin

ovary rudimentary; female flowers with tepals 2–3 mm long, fused at base, short-hairy, longer-hairy at margins, ovary superior, free, style with 2 stigmatic branches. Fruit an ellipsoid to globose drupe c. 5 mm × 3.5 mm, more or less compressed, enclosed in the persistent fleshy perianth, 1-seeded, several fruits together in a nearly globose infructescence c. 1 cm in diameter. Seed c. 4.5 mm × 2.5–4.5 mm, more or less compressed.

Other botanical information *Morus* comprises 10–15 species, mainly distributed in the warm temperate and subtropical regions of the northern hemisphere, with only 1 species (*Morus mesozygia*) native to tropical Africa. *Morus alba* L. and *Morus nigra* L. have been introduced into Africa, mainly for their edible fruits and as food plants for silk worms.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: 2: growth ring boundaries indistinct or absent. Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 27: intervessel pits large (≥ 10 µm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 31: vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; 43: mean tangential diameter of vessel lumina ≥ 200 µm; 46: ≤ 5 vessels per square millimetre; (47: 5–20 vessels per square millimetre); 56: tyloses common. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 69: fibres thin- to thick-walled; 70: fibres very thick-walled. Axial parenchyma: 85: axial parenchyma bands more than three cells wide; (89: axial parenchyma in marginal or in seemingly marginal bands); 91: two cells per parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; (98: larger rays commonly 4- to 10-seriate); 106: body ray cells procumbent with one row of upright and/or square marginal cells; 115: 4–12 rays per mm. Secretory elements and cambial variants: (132: laticifers or tanniferous tubes). Mineral inclusions: 136: prismatic crystals present; 137: prismatic crystals in upright and/or square ray cells; 141: prismatic crystals in non-chambered axial parenchyma cells; (154: more than one crystal of about the same size per cell or chamber).
(D. Louppe, P. Détienne & E.A. Wheeler)

Growth and development Growth is usually fast: a height increment of almost 2 m in the first year has been recorded in unshaded nursery beds. In Côte d'Ivoire and Ghana flowering is in January, when the tree is leafless, and fruiting in February–May, at the end of the dry season. In southern Africa flowering is in September–November, and fruiting in October–December. The seeds are dispersed by birds and other animals.

Ecology *Morus mesozygia* occurs up to 1700 m altitude in drier evergreen forest and semi-deciduous forest, also in secondary forest, thickets and along watercourses. It does not grow in locations liable to waterlogging. *Morus mesozygia* is a pioneer species.

Propagation and planting *Morus mesozygia* is propagated using seed, wildlings or cuttings. The 1000-seed weight is about 2 g. It is recommended to sow freshly collected seed. Seed treatment is not necessary, but germination is accelerated by soaking the seeds in water for 12 hours. Germination starts 5–12 days after sowing. Under natural conditions, seedlings are most common in very exposed sites, such as large forest gaps with substantial soil erosion.

Management In Senegal *Morus mesozygia* is

sometimes planted in cultivated fields, and in Ethiopia it is left standing when forest is cleared for agriculture. Lopping and pollarding is possible. Trees used as shade tree are sometimes topped and the branches weighted down with stones to create an umbrella-shaped crown.

Genetic resources In view of its wide distribution in tropical Africa and its wide range of habitats, *Morus mesozygia* does not seem to be threatened with genetic erosion. In South Africa it is protected.

Prospects *Morus mesozygia* is valued as a multipurpose tree, providing wood, edible fruits, fuel and traditional medicine, and as a shade and ornamental tree. The wood is not commercially important at present, but its quality is considered high, and it has potential for further domestic and export use, especially for indoor utilisation. More investigations are needed to understand the variability in the natural durability of the wood.

Major references Aubréville, 1959a; Bekele-Tesemma, 2007; Berg, 1977; Bolza & Keating, 1972; Burkill, 1997; CIRAD Forestry Department, 2003; Hawthorne, 1995; Phongphaew, 2003; Takahashi, 1978; Vivien & Faure, 1985.

Other references Asare, 2005; Beentje, 1994; Berg & Hijman, 1989; Chudnoff, 1980; CTFT, 1962g; de la Mensbruge, 1966; Déon, Chadenson & Hauteville, 1980; Durand, 1978; Fouquet, 1984; Friis, 1989; Hauman, Lebrun & Boutique, 1948; Hawthorne & Jongkind, 2006; Herzog, 1994; InsideWood, undated; Katende, Birnie & Tengnäs, 1995; Kryn & Fobes, 1959; Lovett et al., 2006; Neuwinger, 2000; Paris, Debray & Etchepare, 1966; Sekyere, 1990; Wimbush, 1957.

Sources of illustration Berg, Hijman & Weerdenburg, 1985.

Authors B. Toirambe Bamoninga & B. Ouattara

NEOHARMSIA BARONII (Drake) R.Vig. ex M.Peltier

Protologue Adansonia, ser. 2, 12(1): 150 (1972).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Origin and geographic distribution *Neoharmsia baronii* is endemic to northern Madagascar.

Uses The wood is used for furniture and carts. It also serves as firewood and for the production of charcoal.

Properties The wood is lightweight but strong.

Botany Deciduous shrub or small tree up to 10(–15) m tall; bole up to 20 cm in diameter; bark with a thick waxy coating; twigs thick and succulent, densely shortly hairy when young. Leaves alternate, imparipinnately compound with 5–11 leaflets; stipules lanceolate, 2–3 mm long, caducous; petiole and rachis shortly hairy; leaflets opposite, ovate, 3.5–11 cm × 2–6 cm, slightly cordate at base, shortly acuminate at apex, sparsely hairy below, glabrescent. Inflorescence a terminal dense raceme 3–8 cm long, many-flowered. Flowers bisexual, papilionaceous, pendulous; pedicel with small bract near the apex; calyx bell-shaped, c. 1 cm long, slightly oblique, with rounded lobes, sparsely hairy and glandular; corolla bright scarlet red, waxy, standard broadly obovoid, 2.5–3 cm long, long-clawed at base, slightly notched at apex, wings and keel narrow; stamens 11, free; ovary superior, glabrous, 1-celled, style slightly upcurved, stigma indistinct. Fruit a linear-oblong pod 7–12 cm × 1–1.5 cm, flattened, stalked, dehiscent with 2 valves, 1–5-seeded. Seeds kidney-shaped, c. 13 mm long, flattened, yellowish.

Neoharmsia baronii flowers and fruits when it is leafless. The stems are usually hollow and inhabited by ants.

Neoharmsia comprises 2 species, both endemic to Madagascar. The genus is related to *Sakoanala*, which differs in the usually larger number of leaflets per leaf, cup-shaped calyx and indehiscent pods.

Ecology *Neoharmsia baronii* occurs in dry woodland and scrubland, often near the coast, on sandy or rocky soils over limestone.

Genetic resources and breeding *Neoharmsia baronii* is classified as critically endangered in the IUCN red list of threatened species. It has a very small distribution area in which there is much disturbance.

Prospects The emphasis of research and government policies should be towards protection of *Neoharmsia baronii*. Harvesting for timber and fuel should be discouraged.

Major references du Puy et al., 2002.

Other references du Puy & Labat, 1998e; Peltier, 1972; Schatz, 2001.

Authors R.H.M.J. Lemmens

NEOLEMONNIERA CLITANDRIFOLIA (A.Chev.) Heine

Protologue Kew Bull. 14: 301 (1960).
Family Sapotaceae
Synonyms *Sideroxylon aylmeri* M.B.Scott (1915).
Origin and geographic distribution *Neolemonniera clitandrifolia* is distributed from Sierra Leone to Ghana, and in Nigeria (Calabar).
Uses The wood is recorded as being used for construction, planks and canoes, but the extent of its actual usage is unclear. The fruits are sometimes eaten. Oil from the seed is used for frying food and as hair oil.
Properties The heartwood is reddish or purplish brown, the sapwood pinkish. The grain is fairly straight; texture medium. The wood is heavy (density 900–1000 kg/m³ at 12% moisture content), tough and very hard. It requires care in seasoning. The wood is rather difficult to work, but it finishes smoothly. It is very durable.
Although the fruit pulp is edible, the presence of latex in the fruits makes them very sticky. The taste of the seed oil is said to be similar to that of coconut oil.
Botany Medium-sized to fairly large tree up to 35 m tall; bole up to 90 cm in diameter, with buttresses up to 3 m high and often extending into lateral roots; outer bark brownish grey to dark brown, smooth or scaly, with scattered brown lenticels, inner bark reddish, exuding white latex; crown dome-shaped. Leaves arranged spirally, clustered at the ends of branchlets, simple and entire; stipules short, sharp; petiole 1–3 cm long; blade lanceolate-elliptical, 7–15(–35) cm × 2.5–5(–10) cm, cuneate at base, acuminate at apex, leathery, glabrous, finely striate, pinnately veined with c. 10 pairs of indistinct lateral veins. Flowers in fascicles in leaf axils, bisexual, regular, 5-merous, c. 5 mm long; pedicel 1.5–3 cm long; sepals free, ovate; corolla with short tube and 5 lobes divided to near the base into 3 segments, white, hairy; stamens opposite each corolla lobe, alternating with large, hairy staminodes; ovary superior, hairy, 5-celled. Fruit a pendulous capsule 7–8 cm in diameter, dehiscent, 1-seeded. Seed slightly obliquely ellipsoid, c. 3.5 cm × 1.5 cm, brown, shiny, with a scar over almost the full length.
In Sierra Leone *Neolemonniera clitandrifolia* flowers in April and May, in Côte d'Ivoire in March. The seeds are reportedly dispersed over short distances by the explosively opening fruits.
Neolemonniera comprises 5 species found in West and Central Africa.
Ecology *Neolemonniera clitandrifolia* is rare and occurs scattered in dense humid forest, sometimes in small groups in hilltop forest, mainly on rocky slopes.
Genetic resources and breeding *Neolemonniera clitandrifolia* is classified as endangered in the IUCN red list of threatened species. Much of its habitat has been lost to agriculture, mining and logging, and a rapid decline in population numbers has been observed.
Prospects The wood of *Neolemonniera clitandrifolia* is hard and durable but, in view of its rapidly declining numbers, usage should be discouraged or prohibited. Particular attention should be given to planting *Neolemonniera clitandrifolia* in arboreta and botanical gardens.
Major references Aubréville, 1959d; Burkill, 2000; Heine, 1963; Pennington, 1991; Saville & Fox, 1967.
Other references Cooper & Record, 1931; Hawthorne, 1995; Hawthorne, 1998a; Normand, 1960; Normand & Paquis, 1976; Voorhoeve, 1965.
Authors M. Brink

NESOGORDONIA HOLTZII (Engl.) Capuron ex L.C.Barnett & Dorr

Protologue Kew Bull. 55(4): 985 (2000).
Family Sterculiaceae (APG: Malvaceae)
Synonyms *Cistanthera holtzii* Engl.(1907), *Cistanthera parvifolia* M.B.Moss ex Milne-Redh. (1937), *Nesogordonia parvifolia* (M.B.Moss ex Milne-Redh.) Capuron ex Wild (1961).
Vernacular names Muheru, mrunza (Sw).
Origin and geographic distribution *Nesogordonia holtzii* occurs in the coastal lowland of Kenya, Tanzania and Mozambique.
Uses The wood is used for poles and sawn timber in house building, as fuelwood and in charcoal production.
Properties The wood of *Nesogordonia holtzii* is moderately heavy, hard and tough. The heartwood is pale pink to brown, distinctly demarcated from the paler sapwood. The density is 810–900 kg/m³ at 12% moisture content. The grain is straight, texture fine. The wood surface is lustrous and greasy. The timber should be dried slowly to avoid case-hardening; there is some tendency to warp. Once dry, it is stable in service. It works well with machine

and hand tools and planes to a smooth surface. The nailing and screwing properties are good, but pre-boring is recommended. Gluing does not cause problems. The wood turns well, takes a good polish and can be painted and varnished without difficulty. It is moderately suitable for veneer production. The wood is susceptible to pinhole borer, termite and marine borer attack. The heartwood is resistant to preservative treatment.

Botany Small to medium-sized tree up to 30 m tall; bole usually straight and cylindrical, branchless for up to 20 m, slightly buttressed or fluted at base; bark smooth to rough or slightly flaking, whitish to grey or greyish brown; crown with spreading branches; young branchlets with stellate hairs. Leaves alternate, simple; stipules needle-shaped, c. 5 mm long, early caducous; petiole 0.5–4 cm long, hairy; blade ovate, 2.5–8 cm × 1–4 cm, base rounded, apex acuminate to acute, margin usually with blunt teeth, especially towards the apex, sparsely stellate-hairy, with domatia in vein axils. Inflorescence an axillary, compact, 1–2-flowered cyme; peduncle c. 1 cm long. Flowers bisexual, regular, 5-merous; pedicel 7–8 mm long, articulate; calyx lobes shortly united at base, narrowly lanceolate, c. 8 mm long, densely stellate-hairy outside; petals sword-shaped, c. 7 mm long, white or cream-coloured, glabrous; stamens 10, in 5 groups of 2; staminodes 5, linear, longer than the stamens; ovary superior, globose, minutely scaly, 5-celled, with 5 styles. Fruit an obconic capsule 2–2.5 cm long, 5-ridged, stellate-hairy, up to 10-seeded. Seeds ovoid, c. 6 mm long, with an ovate, thin wing 11–12 mm long.
Nesogordonia comprises 18 species, of which 14 are endemic to Madagascar, 1 to Mayotte and 3 occur in tropical mainland Africa. The three species in mainland Africa are closely related.

Ecology *Nesogordonia holtzii* grows in coastal evergreen forest, up to 500 m altitude, and is locally co-dominant.

Genetic resources and breeding Although *Nesogordonia holtzii* occurs in only a narrow strip along the East African coast, it has not been recorded as vulnerable.

Prospects The wood is useful for local markets and deserves wider use in the local furniture industry because it is strong, and works, planes and polishes well. The conservation status of *Nesogordonia holtzii* deserves clarification.

Major references Beentje, 1994; Bolza & Keating, 1972; Wild, 1961.

Other references Barnett & Dorr, 2000; Wild & Gonçalves, 1979.

Authors L.P.A. Oyen

NESOGORDONIA KABINGAENSIS (K.Schum.) Capuron ex R.Germ.

Protologue Fl. Congo Belge 10: 225 (1963).

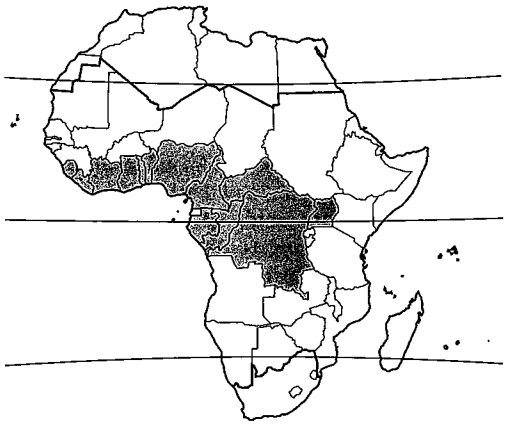
Family Sterculiaceae (APG: Malvaceae)

Synonyms *Cistanthera kabingaensis* K.Schum. (1897), *Cistanthera papaverifera* A.Chev. (1912), *Cistanthera fouassieri* A.Chev. (1917), *Cistanthera leplaei* Vermoesen (1923), *Nesogordonia papaverifera* (A.Chev.) Capuron ex Keay (1958), *Nesogordonia fouassieri* (A.Chev.) Capuron ex N.Hallé (1961), *Nesogordonia leplaei* (Vermoesen) Capuron ex R.Germ. (1963).

Vernacular names Danta, kotibé (En). Kotibé, aborbora (Fr). Kisumungu, kissinhungo (Po). Kamema (Sw).

Origin and geographic distribution *Nesogordonia kabingaensis* occurs in the semi-deciduous dense forest zone extending from Sierra Leone east to northern DR Congo and western Uganda, and south to Gabon and northern Angola (Cabinda).

Uses The wood of *Nesogordonia kabingaensis*, known as 'danta', 'kotibé' or 'aborbora', is easy to work and hard, as well as being resistant to abrasion. It is used in exterior and interior joinery, parquetry, turnery, for staircase boards, window frames, furniture, cabinets, tool handles, mallets, and also for lorry bodies, coach/wagon work and small boats. It is excellent for wood carving. In West Africa it was formerly used to make butts for rifles. The wood is suitable for making sliced veneer and



Nesogordonia kabingaensis – wild

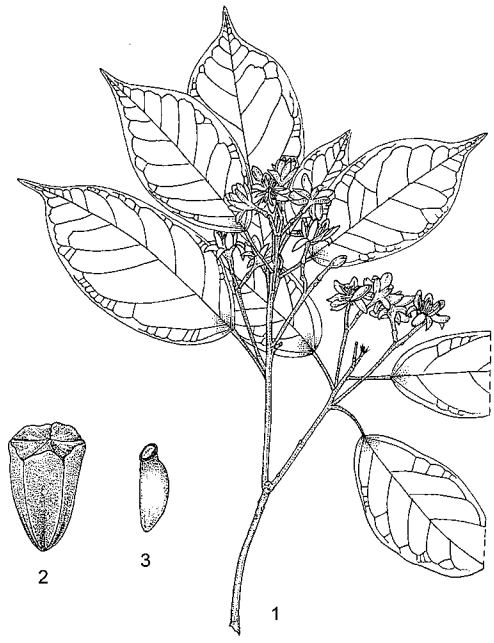
plywood.
The wood is used as firewood. In Ghana and Côte d'Ivoire twigs are used as chew-sticks and the Ando people of Côte d'Ivoire use a leaf decoction to relieve dental caries.

Production and international trade International trade in danta is limited and statistics are scarce. Export statistics for the whole of Africa are only available for 1974, when 88,000 m^3 of logs and 1000 m^3 of sawn wood were exported. International trade of danta appears to be more or less stable through the years. In 1994 Côte d'Ivoire exported nearly 10,000 m^3 as logs and 250 m^3 as veneer; Gabon exported 6200 m^3 in 1994 and 7400 m^3 in 1995, and in total 22,000 m^3 in the period 1998–2003. Cameroon exported 250 m^3 of sawn wood in 2003.

Properties The heartwood is pale brown to purplish brown with a tendency to become lighter on exposure to light, distinctly demarcated from the pale brown to pink sapwood, which is 2–5(–10) cm thick. The grain is straight or interlocked, texture fine. Growth rings mostly distinct. The wood shows a ribbon-like figure on quarter-sawn surfaces.
The wood is moderately heavy, the density is 740–830 kg/m^3 at 12% moisture content. The shrinkage rates are moderately high, from green to oven dry 5.0–6.2% radial and 6.5–9.4% tangential. The timber dries slowly, with slight risk of distortion and checking. In Côte d'Ivoire air drying of 29 mm thick boards from 64% to 16.5% moisture content took 270 days and of 50 mm thick planks from 64% to 18% moisture content about one year. Initial surface drying prior to kiln drying is recommended. Once dry, it is moderately stable in service.
At 12% moisture content, the modulus of rupture is 108–183(–231) N/mm^2, modulus of elasticity (7800–)10,900–16,200 N/mm^2, compression parallel to grain 45–75 N/mm^2, shear 8–16 N/mm^2, cleavage 13–31 N/mm, Janka side hardness 7740–9520 N and Janka end hardness 7840 N.
The wood blunts edged tools moderately rapidly. Stellite-tipped sawteeth are recommended. A cutting angle of 15–20° is recommended when planing to prevent tearing. The peeling and slicing properties are good. Treatment with steam at 100°C for 48 hours is recommended to facilitate slicing and improve the quality of veneer. The wood is easy to work. The nailing and screwing are good, but preboring is sometimes needed. Gluing does not cause problems. The wood takes an excellent polish and can be varnished and painted without difficulty. The bending properties are moderate.
The heartwood is moderately durable, but should not be used in contact with the ground. It is moderately resistant to fungi and termites, but resistant to dry-wood borers; the sapwood is liable to powder-post beetle attack. The heartwood is susceptible to marine borers. It is resistant to preservative treatment, absorbing less than 20 l/m^3.

Adulterations and substitutes Danta timber has often been sold in mixtures with African mahogany (*Entandrophragma* and *Khaya* spp.), although it has a higher density and finer texture.

Description Medium-sized to large tree up to 45(–50) m tall, mostly evergreen but sometimes shortly deciduous; bole usually straight and cylindrical, branchless for up to 25 m and 80(–120) cm in diameter, with narrow buttresses up to 3 m high; bark fissured and flaking, whitish to grey or greyish brown; crown rounded to pyramidal, small; young branchlets with brown stellate hairs. Leaves alternate, slightly clustered at the end of branchlets, simple; stipules needle-shaped, 4–9 mm long, early caducous; petiole 1.5–5 cm long, pubes-



Nesogordonia kabingaensis – 1, flowering twig; 2, fruit; 3, seed.
Redrawn and adapted by Achmad Satiri Nurhaman

cent; blade elliptical to obovate, 6–14.5 cm × 3–7 cm, base rounded or obtuse, apex acuminate and mucronate, margin entire or sinuate towards the apex and slightly revolute, glabrous but with few stellate hairs on midrib, lateral veins in 5–9 pairs, with domatia in vein axils below. Inflorescence an axillary, compact, (1–)2–3(–6)-flowered cyme; peduncle 2–4.5 cm long. Flowers bisexual, regular, 5-merous; pedicel 5–15 mm long, articulate; calyx lobes shortly united at base, lanceolate to ovate, 8–12 mm long, densely stellate-hairy outside; petals broadly obovate, 8–10 mm long, white or cream-coloured, glabrous; stamens 15, in 5 groups of 3; staminodes 5, linear, longer than the stamens; ovary superior, globose to obovoid, densely stellate-hairy, 5-celled, with 5 styles. Fruit an obconic capsule 2.5–3.5 cm long, 5-ridged, shortly brown hairy, up to 10-seeded. Seeds ovoid, c. 7 mm long, with an ovate, thin wing 12–16 mm long. Seedling with epigeal germination; hypocotyl 3–5 cm long; cotyledons leafy, kidney-shaped, 7–10 mm × 16–24 mm, palmately veined; first leaves elliptical, toothed.

Other botanical information *Nesogordonia* comprises 18 species, of which 14 are endemic to Madagascar, 1 to Mayotte and 3 occur in tropical mainland Africa. The three species in mainland Africa are closely related. *Nesogordonia holtzii* (Engl.) Capuron ex L.C.Barnett & Dorr differs from *Nesogordonia kabingaensis* in having only 10 stamens, smaller leaves and smaller fruits. *Nesogordonia perpulchra* N.Hallé differs in having 25 stamens (5 groups of 5) and larger flowers; it has only been collected once in Gabon.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; (10: vessels in radial multiples of 4 or more common); 13: simple perforation plates; 22: intervessel pits alternate; 23: shape of alternate pits polygonal; 24: intervessel pits minute (≤ 4 μm); 25: intervessel pits small (4–7 μm); 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 41: mean tangential diameter of vessel lumina 50–100 μm; 47: 5–20 vessels per square millimetre; (48: 20–40 vessels per square millimetre); (58: gums and other deposits in heartwood vessels). Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 66: non-septate fibres present; 69: fibres thin- to thick-walled; (70: fibres very thick-walled). Axial parenchyma: 77: axial parenchyma diffuse-in-aggregates; 78: axial parenchyma scanty paratracheal; 92: four (3–4) cells per parenchyma strand; 93: eight (5–8) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 106: body ray cells procumbent with one row of upright and/or square marginal cells; 115: 4–12 rays per mm; (116: ≥ 12 rays per mm). Storied structure: 118: all rays storied; 120: axial parenchyma and/or vessel elements storied; 121: fibres storied. Mineral inclusions: 136: prismatic crystals present; 142: prismatic crystals in chambered axial parenchyma cells.
(L.N. Banak, H. Beeckman & P.E. Gasson)

Growth and development The light requirement of *Nesogordonia kabingaensis* increases with age and large trees are generally exposed. Trees in the bole diameter class of 30–60 cm are more abundant in logged-over forest. Burning seems to have a negative effect on regeneration. Saplings can reach a height of 1–1.5 m in 4 years and mean annual diameter increments of 0.5 cm have been recorded. The average annual diameter growth in Côte d'Ivoire and Central African Republic was recorded as 3.5 mm, in Ghana 4 mm until 50 cm log diameter and then decreasing to 2.5 mm for logs more than 70 cm in diameter. Planted trees in Côte d'Ivoire reached 17 cm stem diameter in 14 years. In semi-deciduous forest in Ghana *Nesogordonia kabingaensis* is represented in the upper forest story by a few individual trees and in the lower canopy by many recruits. Fruits are produced throughout the year except during the dry season. The seeds are dispersed by wind. In mature forest individual trees of up to 125 years old have been recorded.

Ecology *Nesogordonia kabingaensis* occurs in dense, semi-deciduous forest with a pronounced dry season, up to 500(–1000) m altitude. Its presence in a location is often taken as an indication of fertile, base-rich soil. In West Africa it occurs in high densities in forest with *Khaya ivorensis* A.Chev., *Celtis* spp. and *Triplochiton scleroxylon* K.Schum. In Côte d'Ivoire 7–21 stems of more than 10 cm in diameter per ha have been reported for some forests. It avoids swampy localities, except in north-eastern DR Congo. It is common on hillsides.

Propagation and planting One kilogramme contains approximately 25,000 seeds. Germination of seeds takes 1–3.5 weeks and the germination rate is about 75%. Light shade seems to be needed for germination and natural regen-

eration is best in medium-large gaps in the forest; in large forest clearings, but also in small gaps and especially in dense forest, it is poorer.

Management *Nesogordonia kabingaensis* is not grown in plantations due to its shade-demanding nature when young and comparatively low growth rates. Thinning operations in natural forest may result in an increase in diameter growth of 25–50%.

Harvesting In the Central African Republic the minimum log diameter for exploitation was 70 cm until 1999, when it was reduced to 50 cm.

Handling after harvest Freshly cut logs sink in water and cannot be transported by river. The wood may cause occupational asthma in people who regularly work with it. They may also develop allergic skin reactions.

Genetic resources *Nesogordonia kabingaensis* is vulnerable in parts of its range and subject to genetic erosion in outlying populations such as in Sierra Leone, Liberia, Cameroon, Gabon and the Central African Republic. It has been classified as vulnerable by IUCN because of over-exploitation and reduction of the natural area of distribution. It is still common in Côte d'Ivoire and Ghana, but Ghana has prohibited its export as logs and in Côte d'Ivoire it is protected by law.

Prospects The prospects of *Nesogordonia kabingaensis* as a plantation tree seem limited. However, this species is still widespread and occurs locally in fairly large numbers, and its timber is of good quality. More research is recommended on growth rates and requirements for adequate natural regeneration to develop systems of its sustainable exploitation in natural forest, needed to safeguard the resources of this valuable timber species for the future.

Major references Burkill, 2000; Chudnoff, 1980; CIRAD-Forêt, 1999b; CIRAD Forestry Department, 2003; Durrieu de Madron et al., 1998b; Hallé, 1961; Poorter et al., 2004; Richter & Dallwitz, 2000; Voorhoeve, 1979.

Other references Aubréville, 1959a; Barnett, 1988; Bolza & Keating, 1972; Capuron, 1953; Détienne et al., 1998; Durand, 1977; Durrieu de Madron, Nasi & Détienne, 2000; Farmer, 1972; Germain & Bamps, 1963; Gozalo-Reques & Pelta-Fernandez, 1988; InsideWood, undated; Simpson, 1996; Takahashi, 1978; UNEP-WCMC, 2004; Visser, 1975; Worbes et al., 2003.

Sources of illustration Voorhoeve, 1979.

Authors L.P.A. Oyen

NEWTONIA BUCHANANII (Baker f.) G.C.C.Gilbert & Boutique

Protologue Fl. Congo Belge 3: 213 (1952).

Family Mimosaceae (Leguminosae - Mimosoideae)

Synonyms *Piptadenia buchananii* Baker f. (1894).

Vernacular names East African newtonia, forest newtonia (En). Mnyassa (Sw).

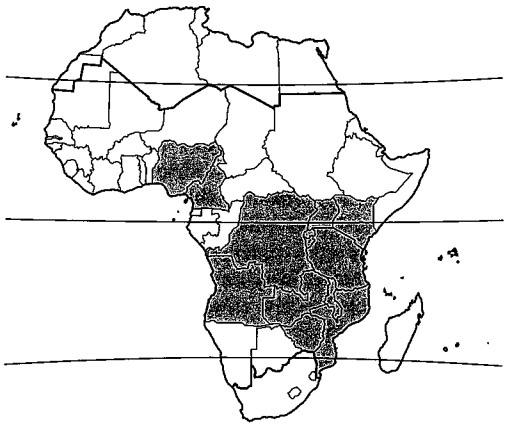
Origin and geographic distribution *Newtonia buchananii* occurs from Nigeria east to Kenya, and south to Angola, Zambia, Zimbabwe and Mozambique.

Uses The wood (trade names: newtonia, mufomoti, mafamuti) is used for tool handles, implements, carpentry, joinery, cabinet work, doors, door frames, bridges, boat building, vehicle bodies and fencing. It is suitable for light construction, flooring, interior trim, boxes, crates, veneer and plywood. It is used traditionally to make dugout canoes. It is also used as firewood and for charcoal production.

The leaves are used as fodder for livestock and as mulch, and the pods also serve as forage. *Newtonia buchananii* is planted as an ornamental tree and shade tree in coffee, tea and cocoa plantations; the crown gives a rather light shade. It can also be planted for stabilizing river banks.

In DR Congo an air-dried bark decoction is applied as powder to abscesses. The flowers are a good source of nectar and pollen for bees. In Mozambique the bark is used as an aphrodisiac.

Production and international trade There are no statistics on production and international trade of *Newtonia buchananii* timber,



Newtonia buchananii – wild

but locally it has some importance, for instance in the East Usambara Mountains in Tanzania, where it was amongst the 5 most important timber species in the mid 1980s, although its importance seemed to have slightly declined by 2001. The average price of a plank of about 3.7 m × 0.3 m was US$ 4 in Tanzania in 2001.

Properties The heartwood is pale brown, darkening to golden brown upon exposure, distinctly demarcated from the up to 5(–15) cm thick, greyish white sapwood. The grain is interlocked, texture moderately coarse to coarse. The wood has some stripe or ribbon figure and is lustrous.

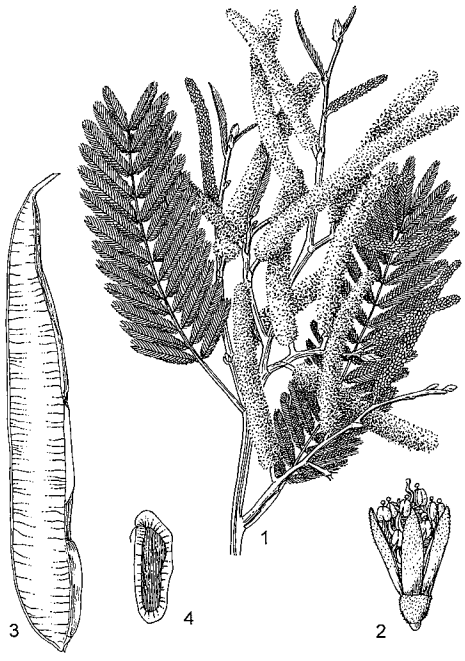
The wood is medium-weight. At 12% moisture content, the density is (415–)560–670(–740) kg/m³. The wood air dries and kiln dries satisfactorily, with little distortion but with some risk of checking. Boards 2.5 cm thick air dry in 6 weeks and boards 5 cm thick in 4–5 months. The rates of shrinkage are moderate, from green to oven dry 3.0–3.7% radial and 5.0–6.3% tangential. After drying, the wood is moderately stable in service.

The wood is fairly soft to moderately hard. At 12% moisture content, the modulus of rupture is 88–97 N/mm², modulus of elasticity 7100–10,600 N/mm², compression parallel to grain 39–50 N/mm², shear 11–14 N/mm², cleavage 11 N/mm radial and 17 N/mm tangential, and Janka side hardness 4630 N.

The wood is easy to saw, but with some tendency to split due to growth stresses. It works fairly easily by hand and machine tools, but mortising and boring are somewhat difficult. A cutting angle of 10° and sharp edges are recommended for planing of quarter-sawn stock, but for flat-sawn pieces an angle of 30° is sufficient. The use of a filler is needed to obtain a good finish. The wood holds screws and nails well, but there is a tendency to splitting; preboring is recommended. It glues more or less satisfactorily and peels well.

The heartwood is not durable to moderately durable. It showed moderate resistance to termite attacks, but is susceptible to powder-post beetle, pinhole borer and marine borer attacks. However, it is reportedly durable in fresh water, and is for that reason much used for canoes in Lake Victoria. The heartwood does not absorb preservatives, but the sapwood is only moderately resistant.

Description Deciduous, medium-sized to fairly large tree up to 40 m tall; bole often straight and cylindrical, branchless for up to 18(–25) m but often much less, up to 100(–185) cm in diameter, at base sometimes with buttresses up to 3.5 m high; bark surface smooth to slightly fissured, pale grey to greyish brown, inner bark pinkish red; crown spreading, flat; young twigs densely short-hairy. Leaves alternate, bipinnately compound with (7–)12–23 pairs of usually opposite pinnae; stipules absent or indistinct; petiole 0.5–1.5 cm long, rachis up to 25 cm long, with a stalked gland between each pair of pinnae; leaflets opposite, (24–)38–67 pairs per pinna, sessile, linear, 2–6(–9) mm × 0.5–2 mm, asymmetrical at base, acute at apex, slightly hairy at margin. Inflorescence an axillary or terminal spike-like false raceme up to 20 cm long, often many together at ends of twigs, hairy, densely flowered. Flowers bisexual, regular, 5-merous; pedicel up to 0.5 mm long; calyx with c. 1 mm long tube, slightly toothed, hairy outside; petals free, linear-oblong, 2–3 mm long, creamy to yellowish, hairy outside; stamens 10, free, c. 4 mm long, anthers with caducous gland at apex; ovary superior, ellipsoid, c. 1 mm long, with long stipe, hairy, style slender, curved. Fruit a flattened linear pod 10–32 cm × 1.5–2.5 cm, at base with stipe up to 2 cm long, brown, slightly transversely veined, dehiscent at one side, up



Newtonia buchananii – 1, flowering twig; 2, flower; 3, fruit; 4, seed.
Redrawn and adapted by Iskak Syamsudin

to 7-seeded. Seeds oblong, flat, 4–7.5 cm long including the papery wing surrounding the seed, reddish brown, attached near one end.

Other botanical information *Newtonia* comprises about 15 species and is restricted to Africa. It seems related to *Fillaeopsis* from central Africa and *Lemurodendron* from Madagascar. *Newtonia buchananii* may be confused with *Piptadeniastrum africanum* (Hook.f.) Brenan, which differs in the absence of glands on the leaves, its glabrous ovary and its seeds being attached at the middle.

Anatomy Wood-anatomical description (IAWA hardwood codes):
Growth rings: (1: growth ring boundaries distinct); (2: growth ring boundaries indistinct or absent). Vessels: 5: wood diffuse-porous; 13: simple perforation plates; 22: intervessel pits alternate; (23: shape of alternate pits polygonal); 24: intervessel pits minute (≤ 4 μm); 29: vestured pits; 30: vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; 42: mean tangential diameter of vessel lumina 100–200 μm; 43: mean tangential diameter of vessel lumina ≥ 200 μm; 46: ≤ 5 vessels per square millimetre; 47: 5–20 vessels per square millimetre; 58: gums and other deposits in heartwood vessels. Tracheids and fibres: 61: fibres with simple to minutely bordered pits; 65: septate fibres present; 68: fibres very thin-walled; 69: fibres thin- to thick-walled. Axial parenchyma: (78: axial parenchyma scanty paratracheal); 79: axial parenchyma vasicentric; (80: axial parenchyma aliform); (81: axial parenchyma lozenge-aliform); (83: axial parenchyma confluent); 91: two cells per parenchyma strand; 92: four (3–4) cells per parenchyma strand. Rays: 97: ray width 1–3 cells; 104: all ray cells procumbent; 115: 4–12 rays per mm. Mineral inclusions: (136: prismatic crystals present); (142: prismatic crystals in chambered axial parenchyma cells); (143: prismatic crystals in fibres).
(E. Ebanyenle, A.A. Oteng-Amoako & P. Baas)

Growth and development In general, seedlings grow slowly and have low survival rates. This means that special care is needed in the early years. However, once established, usually after 1–3 years, the young trees grow fairly fast. Locally trees may be found flowering throughout the year. The winged seeds are mainly dispersed by wind, but distribution by water and birds is also possible. It has been reported that the tree is relatively short lived.

Ecology In Nigeria and Cameroon *Newtonia buchananii* is restricted to forest in highland areas at 1100–1800 m altitude. In East and southern Africa it occurs in evergreen rainforest, often along watercourses and lakes, at 600–2200 m altitude. It occurs in regions with 1100–3000 mm annual rainfall. Locally *Newtonia buchananii* can co-dominate the canopy layer of the forest, e.g. in Kibale National Park in Uganda, together with *Parinari excelsa* Sabine, *Chrysophyllum gorungosanum* Engl., *Pouteria altissima* (A.Chev.) Baehni and *Olea capensis* L.

Propagation and planting One kg contains about 5300 seeds. Pods should preferably be collected from the tree when they turn brown and subsequently dried in the sun; then the seeds can be shaken out. The seeds do not show dormancy and germinate in 3–4 weeks, with usually up to 70% germination and sometimes even 90%. The seeds lose their viability quickly, and cannot be stored for more than a few weeks at room temperature. They are susceptible to insect attacks, and it is recommended to add ash for storage. Direct sowing has been tried in Tanzania, but survival of seedlings was low, up to only 26% after 10 years; a critical period for seedling survival was reached 1–3 years after sowing. Root suckers can also be used for propagation, and wildlings are occasionally collected for planting.
In regeneration studies in natural forest in Uganda, it was recorded that regeneration was poor under the parent trees and increased away from them. Regeneration of *Newtonia buchananii* seems to be stimulated by the presence of small gaps in the forest.

Management In some regions *Newtonia buchananii* occurs in high densities, as in some forests in Kenya, Uganda and Tanzania.

Harvesting The boles have a tendency to split during felling operations.

Handling after harvest Freshly harvested logs are liable to insect attacks and should be removed from the forest soon after felling to avoid damage to the wood.

Genetic resources *Newtonia buchananii* is fairly widespread and locally common. Therefore, it does not seem to be threatened at present. However, in several regions, e.g. in the East Usambara Mountains in Tanzania, it has been subject to serious over-exploitation, whereas natural regeneration is often poor.

Prospects There are certainly prospects on the timber market for *Newtonia buchananii*. This may offer possibilities for increased commercialization of the species, but research on

growth rates and propagation is needed, as well as development of suitable forest management methods to guarantee sustainable production in the future. It could be included more extensively in agroforestry systems.

Major references Bolza & Keating, 1972; Brenan, 1970; Bryce, 1967; Burkill, 1995; CAB International, 2005; Katende, Birnie & Tengnäs, 1995; Maundu & Tengnäs, 2005; Mbuya et al., 1994; Takahashi, 1978; World Agroforestry Centre, undated.

Other references Beentje, 1994; Brenan, 1959; Chifundera, 2001; Coates Palgrave, 1983; Gilbert & Boutique, 1952; InsideWood, undated; Keay, 1989; Lewis et al., 2005; Mugasha, 1978a; Parant, Chichignoud & Curie, undated; Roe et al., 2002; Tanzania Forest Division, 1962; Troupin, 1982; Villiers, 1990; Vivien & Faure, 1985; Williamson, 1955; Zambia Forest Department, 1979c.

Sources of illustration Brenan, 1959.

Authors F.S. Mairura

NEWTONIA LEUCOCARPA (Harms) G.C.C.Gilbert & Boutique

Protologue Fl. Congo Belge 3: 213 (1952).

Family Mimosaceae (Leguminosae - Mimosoideae)

Synonyms *Piptadenia leucocarpa* Harms (1915).

Origin and geographic distribution *Newtonia leucocarpa* occurs in Cameroon, Equatorial Guinea, Gabon, Congo and south-western DR Congo.

Uses The wood (trade name: ossimiale) is suitable for construction, flooring, joinery, interior trim, ship building, vehicle bodies, mine props, furniture, cabinet work, handles, ladders, sporting goods, toys, novelties, agricultural implements, food containers, carvings, turnery, veneer and plywood.

Production and international trade There are no statistics on production and international trade of *Newtonia leucocarpa* timber, but locally it has some importance, especially in Gabon.

Properties The heartwood is silvery pink to reddish brown, often with wide darker veins, fairly distinctly demarcated from the narrow, paler sapwood. The grain is straight to wavy or interlocked, texture moderately coarse, but even. The wood is lustrous.

The wood is medium-weight to moderately heavy. At 12% moisture content, the density is 630–820 kg/m^3. The wood should be dried carefully; logs should be quarter-sawn before drying and careful stacking is important to avoid serious degrade. The rates of shrinkage are rather high, from green to oven dry 3.7–4.4% radial and 6.7–8.6% tangential. Once dried the wood is moderately stable in service.

At 12% moisture content, the modulus of rupture is 132–198 N/mm^2, modulus of elasticity 10,300–15,500 N/mm^2, compression parallel to grain 52–74 N/mm^2, shear 7–13 N/mm^2, cleavage 10–27 N/mm and Chalais-Meudon side hardness 3.0–6.2.

The wood saws and works well, with moderate blunting effects on cutting edges. The use of a filler is needed to obtain a good finish, but then surfaces are very smooth and take a high polish. Moulding results are generally good, except in pieces of wood with interlocked grain. The wood holds screws and nails well, but preboring is recommended. The gluing properties are moderate. The wood is suitable for veneer production.

The wood is moderately durable. It showed moderate resistance to termite attack, but is susceptible to powder-post beetle, pinhole borer and marine borer attacks. The heartwood does not absorb preservatives, but the sapwood is only moderately resistant. Tests showed that the suitability of the wood for paper pulp production is only moderate.

Botany Medium-sized to large tree up to 45 m tall; bole straight and cylindrical, branchless for up to 27 m but often less, up to 150 cm in diameter, at base with steep buttresses up to 2 m high; bark surface smooth to slightly fissured, greyish brown, inner bark pinkish brown to red, fibrous, with yellowish, translucent exudate; crown spreading, flat; young twigs hairy, soon becoming glabrous. Leaves alternate, bipinnately compound with (8–)10–12(–20) pairs of opposite pinnae; stipules linear-lanceolate, c. 3 mm long, caducous; petiole 0.5–1 cm long, rachis 5–14 cm long, grooved above, with a short gland between each pinna pair; leaflets opposite, 15–40 pairs per pinna, sessile, linear-oblong, 5–8 mm × 1–1.5 mm, asymmetrical at base, acute at apex, glabrous but sometimes slightly hairy at margin. Inflorescence an axillary or terminal spike-like false raceme, hairy, densely flowered. Flowers bisexual, regular, 5-merous, nearly sessile; calyx with c. 1.5 mm long tube, slightly toothed; petals free, elliptical, c. 2 mm long, hairy outside; stamens 10, free, anthers with gland at apex; ovary superior, hairy in

upper part, style slender, curved. Fruit a flattened linear pod (10–)20–40 cm × 2–3 cm, at base with stipe up to 8.5 cm long, reddish brown, slightly transversely veined, dehiscent at one side. Seeds narrowly oblong, flat, 8–11 cm long including the papery wing surrounding the seed, brown, attached near one end. Seedling with hypogeal germination, with cotyledons remaining enclosed within the seed coat; first 2 leaves opposite, pinnately compound.

In Gabon flowers are produced at the beginning of the long dry season and fruits are mature around September. The winged seeds are mainly dispersed by wind.

Newtonia comprises about 15 species and is restricted to Africa. It seems related to *Fillaeopsis* from central Africa and *Lemurodendron* from Madagascar. *Newtonia leucocarpa* may be confused with *Piptadeniastrum africanum* (Hook.f.) Brenan, which differs in the absence of glands on the leaves, its glabrous ovary and its seeds being attached at the middle.

Newtonia glandulifera (Pellegr.) G.C.C.Gilbert & Boutique is a medium-sized to fairly large tree up to 40 m tall, with a similar distribution area as *Newtonia leucocarpa*. It differs in its larger leaflets, and seems to be less common in Gabon, but it is locally a common canopy tree in Bas-Congo (DR Congo). Its wood is suitable for similar purposes as that of *Newtonia leucocarpa*, but is heavier (about 900 kg/m^3 at 12% moisture content) and tougher.

Newtonia griffoniana (Baill.) Baker f. resembles *Newtonia glandulifera*, but has rhombic leaflets (oblong to elliptical in *Newtonia glandulifera*). It is a medium-sized to fairly large forest tree up to 35 m tall, distributed from Nigeria to Gabon. Its wood is also suitable for similar purposes as that of *Newtonia leucocarpa*.

Newtonia duparquetiana (Baill.) Keay occurs in the same region as *Newtonia griffoniana*, but extends into the evergreen forests of West Africa to Sierra Leone. It is a medium-sized tree up to 30 m tall, characterized by 1–2 pairs of pinnae per leaf and 2 leaflets per pinna. It is occasionally felled for its brown, moderately heavy timber, e.g. in Sierra Leone and Gabon, but is generally too scarce to be important.

This is also the case for *Newtonia aubrevillei* (Pellegr.) Keay, which occurs rather scattered in evergreen forest from Sierra Leone to Ghana. It is a medium-sized tree with an often short and irregular bole, which has been felled in Liberia to make planks and canoes. The bark is used as an aphrodisiac. Its leaves are characterized by 3–4 pairs of pinnae, each with 3–4(–7) pairs of leaflets.

Newtonia elliotii (Harms) Keay is endemic to Sierra Leone, where it occurs in gallery forest. It is a small tree up to 15 m tall, with 2–4 pairs of obovate leaflets per pinna. It differs from *Newtonia aubrevillei* in having only 1 pair of pinnae per leaf. Its seeds have been used as a laxative.

Ecology *Newtonia leucocarpa* occurs in moist evergreen rainforest, mainly secondary forest.

Management Regeneration of *Newtonia leucocarpa* in natural forest in Bas-Congo Province of DR Congo was reported as fair. However, the common occurrence in secondary forest suggests that larger gaps are needed for good regeneration. In general, larger trees of *Newtonia leucocarpa* occur scattered, but sometimes in small groups. In Gabon the average bole volume has been recorded as 0.6 m^3/ha. Freshly harvested logs are rather liable to insect attack and should be removed from the forest soon after felling to avoid damage to the wood.

Genetic resources *Newtonia leucocarpa* has a rather limited area of distribution in Central Africa, but is locally not uncommon, especially in western Gabon. It does not seem to be threatened at present, but some caution is needed to avoid over-exploitation.

Prospects There are certainly prospects for *Newtonia leucocarpa* on the timber market. This may offer possibilities for increased commercialization of the species, but research on growth rates, natural regeneration and the development of suitable management methods for forest in which it is a common constituent are needed to guarantee sustainable production in the future.

Major references Bolza & Keating, 1972; de Saint-Aubin, 1963; Takahashi, 1978; Villiers, 1989; Wilks & Issembé, 2000.

Other references Burkill, 1995; Gilbert & Boutique, 1952; Lewis et al., 2005; Pauwels, 1993; Sallenave, 1955; Saville & Fox, 1967; Tailfer, 1989; Villiers, 1990; Vivien & Faure, 1985; Voorhoeve, 1979.

Authors R.H.M.J. Lemmens

NEWTONIA PAUCIJUGA (Harms) Brenan

Protologue Kew Bull. 1955(2): 181 (1955).

Family Mimosaceae (Leguminosae - Mimosoideae)

Synonyms *Piptadenia paucijuga* Harms

(1914).

Vernacular names Mkunguni, mpilipili, mbonta, mche (Sw).

Origin and geographic distribution *Newtonia paucijuga* is restricted to coastal regions of Kenya and Tanzania.

Uses The wood is suitable for construction, flooring, joinery, furniture, interior trim, toys, novelties, boxes, crates, turnery, veneer, plywood, hardboard, particle board and pulpwood. It is traditionally used for the construction of dhows and canoes.

Properties The heartwood is pinkish brown to reddish brown, often with darker stripes or ripple marks, distinctly demarcated from the cream-coloured, 2.5–5 cm thick sapwood. The grain is wavy or interlocked, texture fine to moderately coarse, even or slightly uneven.

The wood is moderately heavy. At 12% moisture content, the density is 640–770 kg/m^3. The wood usually air dries satisfactorily, but some end splitting and distortion may occur. The rates of shrinkage are moderately low, from green to oven dry 2.5% radial and 4.5% tangential. Boards 2.5–5 cm thick take about 6 months to air dry from green to 12% moisture content.

At 12% moisture content, the modulus of rupture is 94–98 N/mm^2, modulus of elasticity 11,400–12,200 N/mm^2, compression parallel to grain 54–57 N/mm^2, shear 16–20 N/mm^2, cleavage 54 N/mm radial and 72 N/mm tangential, and Janka side hardness 6140 N.

The wood saws and works well, both with hand and machine tools. Planing is difficult because of the presence of interlocked grain. Pre-boring is recommended before nailing and screwing, but the wood holds nails well. Painting and varnishing do not cause problems. The wood is suitable for veneer production, but drying of the veneer may cause considerable splitting.

The wood is moderately durable. It showed moderate resistance to termite attack, but is susceptible to powder-post beetle and marine borer attacks. In tests it showed excellent resistance against white and brown rot fungi. The heartwood is rather resistant to impregnation by preservatives.

Botany Medium-sized to fairly large tree up to 35 m tall; bole usually straight and cylindrical, branchless for up to 12 m, up to 100 cm in diameter, at base usually without buttresses; bark surface smooth, pale grey to greyish brown, inner bark yellowish pink, with orange translucent exudate; young twigs densely reddish brown short-hairy. Leaves alternate, bipinnately compound with 1–2 pairs of opposite pinnae; stipules absent or indistinct; petiole and rachis together up to 4 cm long, with a short gland between each pinna pair; leaflets opposite, (1–)2–3 pairs per pinna, with a short gland between each leaflet pair, sessile, obovate to elliptical, 1–7 cm × 0.5–4 cm, cuneate at base, rounded or notched at apex, glabrous. Inflorescence an axillary or terminal spike-like false raceme up to 10 cm long, often many together at ends of twigs, hairy, densely flowered. Flowers bisexual, regular, 5-merous, nearly sessile; calyx with c. 1 mm long tube, slightly toothed, hairy outside; petals free, lanceolate, 2–2.5 mm long, hairy outside in upper part, whitish; stamens 10, free, anthers without gland at apex; ovary superior, hairy, style slender, curved. Fruit a flattened linear pod 23–60 cm × 2–3 cm, shortly stiped at base, reddish brown, transversely veined, dehiscent at one side. Seeds oblong, flat, 7–9 cm long including the papery wing surrounding the seed, brown, attached near one end.

Newtonia comprises about 15 species and is restricted to Africa. It seems related to *Fillaeopsis* from central Africa and *Lemurodendron* from Madagascar.

Newtonia hildebrandtii (Vatke) Torre is also found in Kenya and Tanzania, usually in riverine forest and dry bushland with high groundwater tables up to 1100 m altitude, but it is much more widespread than *Newtonia paucijuga*, south to eastern South Africa. It is a medium-sized tree up to 25 m tall; its leaves have 4–7 pairs of pinnae, each with 6–19 pairs of leaflets. The reddish brown and moderately heavy wood is used for house construction, poles, implements and carvings, and it is considered an excellent firewood and suitable for making high-quality charcoal. A root decoction is used as an anthelmintic. Bark extracts of *Newtonia hildebrandtii* showed antimicrobial activity against a range of pathogenic bacteria and fungi.

Newtonia erlangeri (Harms) Brenan is a small to medium-sized tree up to 20 m tall, with 1–4 pairs of pinnae per leaf, each with 5–12 pairs of leaflets. It occurs in coastal regions of Somalia, Kenya and northern Tanzania, in riverine forest and dry bushland with high groundwater tables. Its wood is used for house building and a bark decoction is taken for treatment of tympanites. The foliage serves as forage for livestock.

Ecology *Newtonia paucijuga* occurs in secondary forest, lowland moist evergreen forest

and riverine forest, less often in dry evergreen forest, up to 500 m altitude.

Genetic resources Although *Newtonia paucijuga* is locally fairly common, e.g. in the Shimba Hills in Kenya, it has a limited area of distribution. It occurs mainly in pockets of moist coastal forest, a type of habitat that is severely fragmented. It is classified as vulnerable in the IUCN Red list.

Prospects The wood properties of *Newtonia paucijuga* are quite good, and there is certainly interest on the international timber market. However, the declining and fragmented populations are a serious drawback for commercialization of this species, and attention should be focused primarily on its conservation.

Major references Bolza & Keating, 1972; Brenan, 1959; Dale & Greenway, 1961; Ishengoma et al., 2004; Takahashi, 1978.

Other references Beentje, 1994; Bryce, 1967; Kokwaro, 1993; Lewis et al., 2005; Lovett & Clarke, 1998d; Maundu & Tengnäs, 2005; Neuwinger, 2000; Palmer & Pitman, 1972–1974; Tanzania Forest Division, 1966; Villiers, 1990.

Authors R.H.M.J. Lemmens

NOTHOSPONDIAS STAUDTII Engl.

Protologue Bot. Jahrb. Syst. 36: 217 (1905).

Family Simaroubaceae

Origin and geographic distribution *Nothospondias staudtii* is distributed from Côte d'Ivoire eastward to DR Congo.

Uses The wood of *Nothospondias staudtii* is considered suitable for carpentry, but it seems little used.

Properties The wood is yellow, fairly hard and fibrous. It is easy to work.
Leaf extracts have shown in-vivo analgesic and anti-inflammatory activities in mice and rats.

Botany Dioecious small to medium-sized tree up to 25 m tall; bole branchless for up to 10 m, cylindrical, straight, up to 50 cm in diameter; outer bark smooth, bright grey with white and green spots; branches erect. Leaves arranged spirally, clustered at ends of branches, imparipinnately compound with 9–21 pairs of leaflets; stipules absent; petiole and rachis 50–120 cm long; petiolules 5–11 mm long; leaflets opposite to alternate, obliquely oblong-elliptical, 10–21 cm × 4–10 cm, base asymmetrical, apex acuminate, papery, glabrous, pinnately veined with c. 10 pairs of lateral veins. Inflorescence a lax terminal panicle up to 70 cm long and 80 cm wide at base, with shortly hairy axes; bracts ovate, 1–1.5 mm × 1 mm. Flowers unisexual, regular, 4-merous; pedicel 2–5 mm long, jointed at base; calyx campanulate, c. 1.5 mm long, with short, ovate lobes; petals oblong-obovate, 4–6 mm × 1.5–2 mm, yellow; stamens in 2 rows of 4, 4–7 mm long; ovary superior, consisting of 4 free carpels, 1(–2) developing into fruit. Fruit an ovoid-ellipsoid drupe 2–2.5 cm × 1.5–2 cm, yellow-orange at maturity, 1-seeded. Seeds oblong-ellipsoid, 1.5–2 cm × c. 1 cm, testa papery, brown.
Nothospondias comprises only 1 species.

Ecology *Nothospondias staudtii* occurs in the understorey of forest, often along watercourses.

Genetic resources and breeding *Nothospondias staudtii* is relatively widespread but rare in some countries, e.g. Côte d'Ivoire and Ghana. It is classified as vulnerable in the IUCN red list of threatened species.

Prospects At present *Nothospondias staudtii* seems to be not much used as a source of timber, and in view of its vulnerability and its often small size this will not change.

Major references Aubréville, 1962c; Burkill, 2000; van der Veken, 1960.

Other references Hawthorne, 1995; Hawthorne, 1998b; Keay, 1958a; Owoyele et al., 2004.

Authors M. Brink

OCHROMA PYRAMIDALE (Cav. ex Lam.) Urb.

Protologue Repert. Spec. Nov. Regni Veg., Beih. 5: 123 (1920).

Family Bombacaceae (APG: Malvaceae)

Chromosome number $2n = 72, 78, 88, 90$

Synonyms *Ochroma lagopus* Sw. (1788).

Vernacular names Balsa wood tree, corkwood, cork tree, down tree (En). Balsa (Fr). Pau de balsa, pata de lebre, pau de jangada (Po).

Origin and geographic distribution The natural distribution of *Ochroma pyramidale* is in tropical Central and South America from southern Mexico to Bolivia. It is planted in many tropical countries, including tropical Africa (e.g. Cameroon and Zimbabwe) and South Africa. It has locally become naturalized.

Uses The extremely lightweight wood (trade name: balsa) is used for buoys, life-jackets and life-belts, surf boards, aircraft construction, ship and boat building, toys, model making, laboratory mounting boards, core stock in

sandwich construction, surgical splints, packaging of fragile articles and as insulation for temperature, vibration, sound and formerly also for electricity. Slightly heavier wood is suitable for matches, popsicle sticks and toothpicks, and for the production of pulp and paper. The floss from the fruit is suitable for filling pillows and mattresses. Rope is made from the fibrous bark. The tree is sometimes planted as an ornamental or to provide shade.

Production and international trade Ecuador is the main exporting country of balsa wood, supplying 80–90% of the volume traded on the world market.

Properties The heartwood is white to grey-white, sometimes with a pinkish tinge near the heart in older trees; it is not clearly demarcated from the sapwood. The grain is straight, texture coarse and even. The wood has a silky lustre. Heartwood is too heavy to be of economic importance and most of the commercial stock is sapwood.

The wood is extremely lightweight with a density of (40–)70–250(–320) kg/m³ at 12% moisture content. High-grade timber weighs less than 150 kg/m³ at 12% moisture content and is generally produced by young trees (8–9 years old), whereas older trees produce heartwood, which is heavier and is considered of secondary quality. Large differences exist between the outermost sapwood and that from nearer the centre, the new wood (outer 3 cm) being on average 2.2 times heavier than the old wood (inner 3 cm) as determined for wood samples from Costa Rica.

Air drying from green to 15% moisture content takes 1–3 weeks. The rates of shrinkage from green to oven dry are small to medium: 2.1–3.0% radial and 2.8–7.6% tangential. Kiln drying is preferable to air drying, to minimize splitting and warping. Movement in service is small.

The wood is very soft and weak, and that from old trees tends to be brittle. At 12% moisture content, the modulus of rupture is 14–57 N/mm², modulus of elasticity 2100–6400 N/mm², compression parallel to grain 6–24 N/mm², compression perpendicular to grain 5 N/mm², shear 2–3 N/mm², cleavage 2–11 N/mm, Janka side hardness 330–450 N, Janka end hardness 2410 N and Chalais-Meudon side hardness 0.1–0.2.

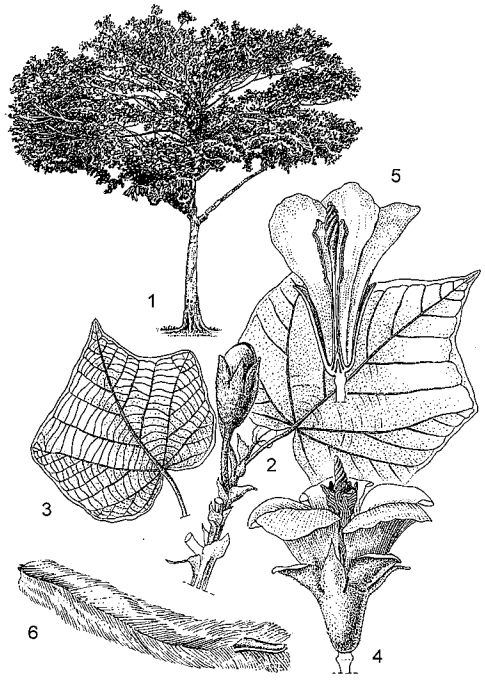
The wood is very easy to work with hand and machine tools, but sharp tools are needed to prevent crumbling. It takes nails and screws readily, but is too soft to hold them well. Planing is almost impossible. Gluing properties are good, and the wood stains, polishes and paints satisfactorily, but it is very absorbent. Bending properties are poor. The wood has good insulating properties and can be used at very low temperatures (down to –250°C). Wood from old trees is brittle and decayed.

The wood is non-durable and prone to attack by *Anobium* and *Lyctus* borers, termites and longhorn beetles. The sapwood is permeable to impregnation with preservatives, absorbing about 560 kg/m³; the heartwood is more resistant.

The average fibre length of wood from Belize is 1.9 mm, with a diameter of 36.1 µm, a lumen diameter of 28.3 µm and a cell wall thickness of 3.9 µm. The wood contains 74% holocellulose, 38% α-cellulose and 1% ash; the solubility in 1% NaOH is 21%, and that in ethanol-benzene 1%. The wood is suitable for pulping by chemical and semi-chemical processes, yielding 45–50% pulp with good strength characteristics. The pulp can be easily bleached without loss of strength, making it suitable for printing and writing papers.

Botany Deciduous or evergreen, medium-sized tree up to 30(–50) m tall; bole straight, usually short, cylindrical, up to 100(–180) cm in diameter, with short buttresses in older trees; bark surface smooth, grey-white mottled; crown spreading, large; branchlets stellate hairy. Leaves arranged spirally, simple; stipules broadly lanceolate, c. 1.5 cm × 1 cm; petiole 3–40 cm long; blade ovate, slightly 3–5-lobed, 10–40 cm × 11–35 cm, base cordate, apex acute or acuminate, margin wavy, glabrescent above, hairy beneath, palmately and pinnately veined with 7–9 pairs of lateral veins. Flowers solitary, axillary, bisexual, regular, 5-merous; pedicel 4–11 cm long; calyx tubular, 8–12 cm long, with unequal lobes 2.5–4 cm long, hairy outside and inside; petals 11–15 cm × c. 5 cm, whitish; stamens many, fused to the petals at their base, united into a briefly 5-lobed staminal column 10–12.5 cm long bearing sessile wavy anthers from the middle to the apex; ovary superior, 5-celled, style club-shaped and 9–10 cm long, stigma spiralled. Fruit an oblong capsule 12–25 cm × c. 2.5 cm, ribbed, 5-valved, dehiscent, densely woolly hairy inside, many-seeded. Seeds pear-shaped, 4–5 mm × c. 1.5 mm, covered in abundant pale brown floss.

Growth of *Ochroma pyramidale* trees can be extremely fast. In South America mean annual diameter increment is up to 10 cm, and after 10–12 years, when growth stabilizes, trees can



Ochroma pyramidale – 1, tree habit; 2, flowering twig; 3, leaf; 4, flower; 5, flower in longitudinal section; 6, dehisced fruit.
Source: PROSEA

be 20–25 m tall and about 100 cm in diameter. A mean annual volume increment of 17–30 m^3/ha can generally be expected, although increments of up to 90 m^3/ha have been achieved. After 12–15 years growth slows down and the trees deteriorate rapidly. Only under specific circumstances may trees reach 50 m in height. In Indonesia and Malaysia *Ochroma pyramidale* flowers throughout the year and is pollinated by bats. Trees start producing viable seed after (2–)3–4 years; the seeds are dispersed by wind.

Ochroma only comprises a single species. *Ochroma pyramidale* is highly variable, and the genus was formerly thought to comprise at least 11 species.

Ecology *Ochroma pyramidale* is a typical pioneer, colonizing clearings. In natural conditions it occurs up to 1000 m altitude, in areas with an annual precipitation of 1250–3000 mm and a mean annual temperature of 22–28°C. It tolerates a dry season of up to 5 months, but only if the relative humidity does not normally drop below 75%. It grows gregariously with a preference for alluvial flats, on deep, rich, well-drained or volcanic soils. Inferior sites retard growth and produce wood with a higher density (over 160 kg/m^3), which is not of commercial interest. In Cameroon *Ochroma pyramidale* is naturalized, occurring frequently in woodland and secondary forest.

Management *Ochroma pyramidale* can be propagated by seed. The 1000-seed weight is 5–15 g. The very small seeds should be collected from standing trees and can be stored for several years in jute bags or in closed containers. They can be sown directly in the field or in the nursery. Seeds contain an impervious testa which must be ruptured by heat (boiling water, fire) before they will germinate. Under natural conditions forest clearance exposes the soil to the sun and this triggers germination of the seeds. In the nursery, seeds are sown in lines 3–4 cm apart under slight shade and in sterilized soil to prevent damping-off. Pretreated seeds show 65–75% germination in 5–28 days. When they are 3–4 months old and 20–25 cm tall, the seedlings are planted out in the field at a spacing of (2–)4–5 m × (3–)4–5 m. As the roots of young plants are extremely sensitive to damage, bare-rooted plants cannot be used and direct seeding is preferred, with 15–20 seeds per hole, later thinned to one plant per hole. Plantations should be weeded 2–3 times during the first year. When the trees are about 4 years old, the density should be about 400 trees/ha, to create enough growing space for the trees to allow for rapid growth. Great care should be taken to avoid damage to the remaining trees, as they heal very poorly or not at all. Pruning should therefore not be carried out. Rotations do not generally exceed 7–8 years. At this age heartwood development starts, and heartwood has a much higher density and a darker colour rendering it less suitable for the special purposes. The tree is liable to fungal and insect attacks via damage in the bark. Throughout Central and South America a shoot borer (*Anadasmus porinodes*) causes severe damage in plantations. The wood is highly prone to blue stain, and it should be converted rapidly after felling to prevent extensive splitting and staining.

Genetic resources and breeding Differences in wood density may be a starting point for further selection and breeding.

Prospects *Ochroma pyramidale* has lost importance due to the increased use of synthetic materials, but it will probably remain the best material for some special applications, e.g. model making. Increased use for niche applica-