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Afrocarpus falcatus (Thunb.) C.N.Page

Protologue
Notes Roy. Bot. Gard. Edinburgh 45: 383 (1988).
Family
Podocarpaceae
Chromosome number
2*n* = 24
Synonyms
Podocarpus falcatus (Thunb.) R.Br. ex Mirb. (1825), *Nageia falcatus* (Thunb.) Kuntze (1891), *Podocarpus gracilior* Pilg. (1903), *Decussocarpus falcatus* (Thunb.) de Laub. (1969), *Decussocarpus gracilior* (Pilg.) de Laub. (1969), *Afrocarpus gracilior* (Pilg.) C.N.Page (1988).


wild

Vernacular names
Yellowwood, African fern pine, weeping yew, Outeniqua yellowwood (En). Bois jaune, pin fougère africain (Fr).
Origin and geographic distribution
Afrocarpus falcatus occurs in mountain forest from Ethiopia through Kenya, Tanzania and Mozambique to eastern and southern South Africa; also in Swaziland and Lesotho. It is planted as ornamental tree in South Africa, and occasionally outside its natural area of distribution, e.g. in Australia, the United States and India.
Uses
The wood, often traded as 'podo' or 'yellowwood', is highly valued for ship building, e.g. for masts and planks, but it is also used for poles, panelling, furniture, boxes, veneer and plywood. It is suitable for construction, flooring, joinery, interior trim, mine props, vehicle bodies, railway sleepers, toys, novelties, agricultural implements, musical instruments, food containers, vats, turnery, hardboard and particle board. It is also used as firewood.
The ripe seed is edible, but resinous. Edible oil has been extracted from the seeds in Ethiopia. The

bark and seeds are used in traditional medicine. Bark decoctions or infusions are used as anodyne, also to treat stomach-ache. A bark decoction is also applied to itching rash. Pulverized seeds are applied to treat tuberculoid meningitis and sunburn. In Ethiopia the seed oil is used in the treatment of gonorrhoea. The bark has been used for tanning, although it only contains 3–6% tannin.
Afrocarpus falcatus is planted as ornamental and roadside tree; sometimes it is also used as container plant and Christmas tree. It is very useful for soil protection against water erosion. It is also planted as windbreak.

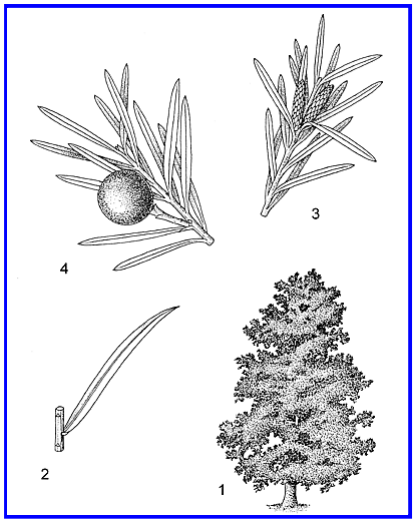
Production and international trade

The international trade in *Afrocarpus falcatus* timber is very limited. The volumes sold by auction in South Africa in the period 1996–1998 varied from 16 m^3 to 33 m^3. In 2006 the price of 2.5 cm thick boards was US$ 2280/m^3.

Properties

The heartwood is pale yellow to pale yellowish brown, and not distinctly demarcated from the sapwood. The grain is straight, occasionally spirally, texture fine and even. Reddish streaks of compression wood and darker lines resulting from year rings may be present. Resin is absent, and the wood has no distinctive odour.
The wood is moderately lightweight, with a density of 430–560(–620) kg/m^3 at 12% moisture content. It usually air dries without problems, but surface checking, splitting and distortion may occur; close stacking and heavy weighting are recommended. Kiln drying should be done at lower temperatures. The rates of shrinkage from green to oven dry are about 3.6% radial and 5.4% tangential. Once dry, the wood is stable in service.
At 12% moisture content, the modulus of rupture is 50–68(–82) N/mm^2, modulus of elasticity 7600–8900 N/mm^2, compression parallel to grain 35–42 N/mm^2, compression perpendicular to grain 6 N/mm^2, shear 7–8 N/mm^2, Janka side hardness 2840–3740 N and Janka end hardness 4000–4930 N.
The wood is easy to saw and work, both by machine and hand tools, with little dulling effects on cutting edges. It can be planed to a smooth finish. The wood has a tendency to split upon nailing, and pre-boring is recommended. The gluing, painting, varnishing and staining properties are moderately good. Steam bending gives moderate to satisfactory results. Turning gives good results. The peeling properties are good; good-quality veneer can be produced from the wood. The wood is not durable, being susceptible to blue stain, powder-post beetle, pinhole borer, longhorn beetle, termite and marine borer attacks. It is permeable to preservatives. The wood is resistant to acids.
Podolide, a norditerpene dilactone with in-vitro antileukemic properties, has been isolated from leaves of *Afrocarpus falcatus*. The tubulin-binding diterpene taxol has been isolated in small amounts from young stems and leaves.

Adulterations and substitutes



1, tree habit; 2, leaf; 3, twig with male cones; 4, twig with seed.
Redrawn and adapted by Achmad Satiri Nurhaman

tree habit

The wood of *Podocarpus latifolius* (Thunb.) Mirb. closely resembles that of *Afrocarpus falcatus* and is used for similar purposes; it is also known as yellowwood.

Description

Evergreen, dioecious, medium-sized to large tree up to 45(–60) m tall; bole branchless for up to 25 m, straight and cylindrical, up to 200(–300) cm in diameter; bark surface greyish brown to reddish brown, rather smooth, flaking in irregular pieces; twigs ridged by decurrent leaf bases. Leaves arranged spirally, simple and entire; stipules absent; petiole indistinct, short, twisted by c. 90°; blade narrowly linear-lanceolate to linear-elliptical, (1–)2–4 (–4.5) cm × (1–)2–4(–6) mm, cuneate at base, acute to acuminate at apex, leathery, glabrous, glaucous green to yellowish green, with a single main vein and single resin canal. Male cone axillary, solitary or more rarely in groups of 2–4, nearly sessile, 5–15 mm × c. 3 mm, brownish; scales many, arranged spirally, each bearing 2 pollen sacs. Female cone terminal on short, leafy or scaly branchlet, solitary, with a single fertile scale. Seed drupe-like, globose to obovoid, 12–18 mm long, glaucous to greyish green, seed coat hard, woody, warty, enclosed in a somewhat fleshy, resinous integument.

Other botanical information

Afrocarpus comprises 1–4 species, depending on the species concept, and is restricted to mainland tropical Africa. It has been separated from *Podocarpus* in 1988, mainly based on the absence of a fleshy receptacle at the base of the seed and on chromosome number, but there is still disagreement about this. However, molecular data support the recognition of *Afrocarpus* as distinct from *Podocarpus*.

On the basis of more slender leaves *Afrocarpus gracilior* (Pilg.) C.N.Page from East Africa is sometimes kept separate from *Afrocarpus falcatus* sensu stricto, which is then restricted to southern Africa.

Afrocarpus usambarensis (Pilg.) C.N.Page (synonyms: *Afrocarpus dawei* (Stapf) C.N.Page, *Podocarpus dawei* Stapf, *Podocarpus usambarensis* Pilg.) occurs in mountain forest from eastern DR Congo to Kenya and Tanzania. It is close to *Afrocarpus falcatus*, differing in its leaves more abruptly tapering at apex and slightly larger seeds with thicker woody part of seed coat. It is used for similar purposes as *Afrocarpus falcatus*; its wood is similar but more lightweight, with a density of about 420 kg/m^3 at 12% moisture content. The nomenclature is confusing and in need of clarification.

Podocarpus usambarensis has been considered a synonym of *Afrocarpus mannii* (Hook.f.) C.N.Page (synonyms: *Decussocarpus mannii* (Hook.f.) de Laub., *Nageia mannii* (Hook.f.) Kuntze, *Podocarpus mannii* Hook.f.), which has been described as an endemic from São Tomé and is planted in southern Nigeria and western Cameroon. Some authors consider *Afrocarpus* as comprising only a single, variable species.

Anatomy

obtained from Arboretum de Villardebelle

young tree

male cones
obtained from Arboretum de Villardebelle

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; 73: axial parenchyma diffuse (evenly scattered throughout the entire growth increment); (74: axial parenchyma tangentially zonate); 76: transverse end walls smooth. Ray composition: 80: ray tracheids absent or very rare; 82: cell walls of ray tracheids dentate. Cross-field pitting: (91: cross-field pits pinoid); 94: cross-field pits taxodioid; 98: 1–3 pits per cross-field (earlywood only). Ray size: 103: average ray height medium (5–15 cells). (P. Baas & I. Heinz)

Growth and development

In South Africa trees reached a height of up to 8.2 m and bole diameter of up to 14 cm 11 years after planting. On fertile soils in Rwanda the annual growth can be over 1 m in height and 1 cm in bole diameter, at least until 15 to 20 years old. The tree is very sensitive to competition, and thinning is necessary for good diameter growth.
The pollen is dispersed by wind, but most of it does not get far from the male tree. Fruiting starts when the tree is 10 years old. Seed production varies from year to year. Usually, trees bear seeds irregularly, mostly at intervals of 2–4 years. Seeds take about one year to develop. They remain on the tree for a considerable time. Fruit bats are the main dispersers; they feed on the fleshy part of the seed coat, discarding the woody part with the embryo. Colobus monkeys feed on the seeds, but also rodents, bushpig and large birds such as hornbills and turacos. However, it has been reported that seed that has passed the digestive tract of these animals usually does not germinate anymore. Seedlings seem to establish only after mast seed years, and usually close to the parent tree. Investigation of the roots revealed the presence of arbuscular mycorrhizae. Trees may reach a very high age, up to 600 years.

Ecology

In East Africa *Afrocarpus falcatus* occurs in forest in the mountains at 1500–2400(–3000) m altitude, often associated with *Juniperus procera* Hochst. ex Endl. It is characteristic for undifferentiated Afromontane forest, but it can also be found in rainforest. Locally it occurs in nearly pure stands. In southern Africa *Afrocarpus falcatus* is uncommon, usually occurring as scattered trees or in small clumps. It can be found there in moist coastal forest, as well as in patches of mountain forest and wooded ravines. It prefers places with an annual rainfall of (800–)1200–1800(–2200) mm and mean annual temperatures of 13–20°C. It is susceptible to drought; it tolerates light frost, but young seedlings are susceptible. *Afrocarpus falcatus* is characterized as a non-pioneer, shade-tolerant

young female cones obtained from Arboretum de Villardebelle

female cones obtained from Arboretum de Villardebelle

female cones

species. It performs best on well-drained, deep, humus-rich and light-textured soils with pH of 5–7.

Propagation and planting

The 1000-seed weight is 0.9–2 kg. The germination capacity of seeds varies from region to region, with a germination rate of 40–90%. Seeds collected from the ground are often infected with the fungus *Penicillium claviforme*, which reduces the germination rate. The seed coat delays germination for about one year and removal of the fleshy part promotes germination significantly. Seeds germinate best at 25°C. The germination rate of seeds stored for 12 months at room temperature dropped to below 35%. Storage at 1°C is possible and results in a germination rate of up to 60% after 2 years. Fair seed viability was also maintained at 4°C for 4 years. Seeds should be dried to a moisture content below 15% before storage.

Seeds can be sown into nursery bags or seed trays, using a 1:1 mixture of well-rotted compost and washed sand. They should be covered with a thin layer of soil. At the time of transplanting, care should be taken not to damage the taproot.

leafy stem cuttings

Methods of vegetative propagation have been investigated. Leafy branch cuttings 6–11 cm long and 2–3 mm in diameter derived from stock plants of 3 months to 2 years old showed up to 80% rooting when indolebutyric acid was applied at doses of 20–80 μg per cutting. Semi-hardwood cuttings 10–12 cm long taken from 4– 5-year-old saplings treated with 2000 ppm indolebutyric acid showed a rooting rate of 45%.

Studies in mountain forest in Ethiopia showed that natural regeneration of *Afrocarpus falcatus* was poor.

stem cuttings

Management

Enhanced nutrient supply increases the growth rate of seedlings, especially at high irradiance levels, but not on burned sites. Protection of plantations against fire is necessary. In South Africa trees planted in agroforestry systems showed better growth (average height 4.2 m and 90% survival after 7 years) than in plantations (average height 3.4 m and 58% survival).

Afrocarpus falcatus is self-pruning, but in plantations with wide spacing pruning operations are needed for proper bole development. In Rwanda thinning to 50% was carried out when the trees were 15 years old, and the response was very good: at age 26 the mean annual growth in diameter was 7 mm/year in the thinned plot and only 2.5 mm in the unthinned plot.

Diseases and pests

Fusarium oxysporum and *Polyporus* sp. are pathogenic to seeds and seedlings. An unidentified fungus causing blackish tumours on twigs and leaves causes vitality problems in relict populations of *Afrocarpus falcatus* in northern Ethiopia. Seeds are commonly attacked by insects, which may cause considerable losses.

Harvesting

In plantations on good sites, trees can be harvested for timber 40–50 years after planting.

Yield

Trials in South Africa showed that the growth rate and yield of *Afrocarpus falcatus* plantations (standing volume 47.7 m^3/ha 11 years after planting) and also wood quality compared favourably to those of commercial pine plantations. Mean annual volume increment over 20 years was calculated as 5.8 m^3/ha.

Handling after harvest

Logs are susceptible to insect and fungal attacks and should be removed from the forest and converted as soon as possible after felling, or treated with preservatives.

Genetic resources

In Ethiopia *Afrocarpus falcatus* has become threatened because of selective logging for many decades, whereas the reproductive potential has rapidly declined. In other countries populations also have diminished seriously, e.g. in Tanzania, whereas many of the larger *Afrocarpus falcatus* trees have disappeared from South Africa as well. *Afrocarpus falcatus* is included in the IUCN Red List as vulnerable. It is legally protected in South Africa. Ex-situ conservation and provenance trials have been carried out in South Africa.

In experiments in South Africa it was demonstrated that seeds from provenances near the afforestation site showed better results after germination than those from provenances from further away.

Prospects

Afrocarpus falcatus could make an excellent indigenous substitute for exotic pine tree plantations throughout its native range. Plantations have the capacity to produce valuable timber with good export prospects in rotation cycles of reasonable time, and they have important ecological value as well. Studies to determine the genetic variation, selection of provenances with superior wood characteristics and investigations on optimal silvicultural systems are needed. Immediate action is needed for in-situ conservation of the remaining natural stands.

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seedling

wood
obtained from Carlton McLendon, Inc.

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