Eucommiaceae

Eucommiaceae Engl., Syllabus (ed. 5): 139 (1907), nom. cons.

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Deciduous trees. Leaves alternate, simple, pinnately veined, serrate, petiolate, without stipules. Flowers unisexual, dioecious, borne near base of current year's branchlets and appearing from the scale-like buds before or together with leaves, without perianth, wind-pollinated. Flowers in the axil of bracts. Male flowers fascicled, on short pedicel; stamens 5–10, linear, filaments very short, anthers tetrasporangiate and longitudinally dehiscent; female flowers solitary in lower part of branchlets, on short pedicel; ovaries unilocular, flat, stipitate, of two fused carpels, bifid at apex, 2-ovulate; ovules anatropous, pendulous from the top of the ovary. By abortion of one ovule the ovary develops into one-seeded samara; samara oblong-elliptic, non-dehiscent, flat, bifid at apex, pericarp thinly coriaceous. Seeds compressed-oblong, pendulous, seed coat membranous; endosperm copious; embryo erect, of same length as endosperm; cotyledons fleshy, flat.

One species, *Eucommia ulmoides* Oliv., distributed in C, W, SW and NW China and cultivated extensively in China.

Vegetative Morphology. *Eucommia ulmoides* is a deciduous tree with a height of up to 20 m and a girth of up to 1.2 m. The trunk is gray, smooth when young and rough when old. There are white thread-like strands between the two portions when sapwood or bark is pulled apart. Young branches are covered with brown hairs and become glabrous with age, old branches with conspicuous whitish lenticels. An annual flowering twig is 1.5–10 cm long with 1–6 leaves above the flowering portion (Fig. 37A). Winter buds are brown and conic-ovoid, covered by 6–8 imbricate ciliate scales. The leaves are exstipulate and petiolate. The petioles are 1–2 cm long, 1–1.5 mm thick, sparsely hairy. Leaf blades are elliptic, ovate or oblong, thinly coriaceous, 6–15 cm long, 3.5–6.5 cm wide, rounded or broadly cuneate at the base, acuminate at the apex, the acumen 5–15 mm long, margin dentate with 20–40 teeth on each side of the blades. The upper surface of the blade is dark green, with brown hairs when young, glabrous later, rugose when old. The lower surface is pale green, hairy when young, later only sparsely hairy on the nerves. There are 6–9 pairs of lateral nerves.

Vegetative Anatomy (Including Ultrastructure). According to Hu (1979), the cork tissue has many layers of compressed cells with the inner walls thickened and suberized, the cork cambium has 2–3 layers of small compressed cells with conspicuous nuclei, the cortex consists of 10 or more layers of parenchyma cells and stone cells mixed with some fibres, forming a ring near the phloem, the phloem consists of thin-walled cells and rays 2–3 cell-layers in thickness and there are irregular lumps of gutta-percha in the phloem and near the stone cell bands. All the parenchyma cells are devoid of calcium oxalate crystals, but some of them contain starch grains. Old bark contains partially degenerated cortex, thicker phloem with 5–6 bands of thick-walled stone cells, and much gutta-percha material. In longitudinal section, cork cells have thick lignified walls and small pores. In the cork there exist many stone cells of irregular shape with prominent lumen which are of various size and up to 120 μm long and 30 μm wide. The white thread-like gutta-percha material is about 14 μm thick, twisted or straight. Fibres are short and rare. Articulated laticifers are present in

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Fig. 37. Eucommiaceae. *Eucommia ulmoides*. **A** Flowering branch. **B** Fruiting branch. **C** Male flower. **D** Female flower. **E** Stamen in lateral view. **F** Ovary in longitudinal section. (from Zhang et al. 2003, fig. 25, artists: Feng Zhongyuan and Cai Shuqin, with permission from Missouri Botanical Garden Press, St. Louis, and Science Press, Beijing)

the leaves and in the pith and bark of the stem. The wood is diffuse-porous. Its vessel members have simple perforation plates, with end walls being oblique, lateral walls with bordered pits and spiral thickenings. Leaves have one leaf trace, sieve-tube plastids are of the S-type, and diffuse sclerenchyma is present in the secondary phloem (Zhang et al. 1990).

Inflorescence Structure. Male flowers occur in clusters and female flowers are solitary in the axils of bracts.

Flower Structure and Anatomy. The flowers are small, without perianth, and unisexual with dioecious distribution. The male flowers have a glabrous pedicel of ca. 3 mm length, their are spoon-shaped, 6–8 mm long, rounded at the apex, ciliate on the margin, and caducous. Stamens are linear, 5–10 per male flower, ca. 1 cm long, glabrous, with ca. 1 mm long filaments. Anthers are ca. 8 mm long, acuminate and mucronate at the apex. The female flowers are solitary in the axils of ovate bracts with ca. 8 mm long pedicels. Ovaries are glabrous, unilocular, flat and narrow, bifid at the apex and with very short stalk. There are two stigmas which are decurrent and reflexed spreading, and two anatropous pendant ovules. One of the ovules is aborted so that each ovary develops into a 1-seeded samara (Fig. 37B).

Embryology. The glandular tapetal cells of the anthers are usually multinuclear. Cell formation after meiosis of pollen mother cells is simultaneous. Microspores are arranged tetrahedrally. Ovules are anatropous, weakly crassinucellate, and unitegmic. Parietal cells are of 2–3 layers. The embryo sac is of the monosporic Polygonum type and the proembryo is of the Solanad type (Zhang et al. 1990). The embryo consists of a large, stout, white radicle, two cotyledons ca. 8 mm long, and is embedded in an endosperm of uniform thickness beneath a delicate structure which is hardly separable from the endosperm. Endosperm is cellular. Both the cotyledons and the endosperm are rich in oil (Hu 1979).

Pollen Morphology. The pollen grains are tricolporate, prolate, the polar axis 32.7 (30.5–54.8) μm and the equatorial axis 29.3 (27.8–31.1) μm long. The colpi are narrow, unequal in length, often two long and one short or two short and one long. The exine is psilate under LM, granulate under SEM, and shortly baculate under TEM. The tectum is thin and with dense and small granules, the columellae layer consists of short bacula, and the foot layer is very thick (Zhang et al. 1988).

Karyology. The chromosome number of *Eucommia* is $2n = 34$ (Steshina in Fedorov 1974; Tanaka and Oginuma 1983). Chromosomes vary in length from about 0.8 μm to 1.6 μm. The chromosome complement was categorized as symmetric in terms of arm ratio. Satellites were found in the distal regions of the short arms of one chromosome pair (Tanaka and Oginuma 1983).

Phenology, Pollination and Reproductive Systems. *Eucommia* flowers in early spring, with or slightly before the young leaves appear. The genus is

anemophilous, and individuals first flower when seven years old.

Fruit and Seed. The fruits of *Eucommia* are samaras which are compressed, oblong-elliptic, 3.5–4 cm long, 1–2 cm across the middle, cuneate at the base, notched at the apex, and contain a central elongated seed. The wing of the samara is papery. The pericarp is very rich in gutta-percha. The seed is compressed, linear, 1.4–1.5 mm long, ca. 3 mm across the broad side, rounded at both ends, and with a conspicuous raphe along the entire length of one side. It contains ca. 27 % oil. Fruits are ripe in late fall.

Dispersal. The fruits may be wind-dispersed.

Phytochemistry. *Eucommia* contains alkaloids, cyanidin, flavonols (e.g. kaempferol, quercetin), iridoids (e.g. aucubin, eucommioside, eucommiol), loliolide, proanthocyanidins and saponins/sapogenins, but lacks arbutin, ellagic acid and verbascosides. *Eucommia* further contains 2.5 % gutta-percha in the leaves, and 27 % of gutta-percha in the fruit. The threads in the bark of *Eucommia* consist of caoutchouc. *Aucuba*, *Garrya* and *Eucommia* share the chemical character of not being able to synthesise catalpol (Grayer et al. 1999). The unusual iridoids eucommioside and eucommiol occur only in *Aucuba* and *Eucommia* (Hegnauer 1989).

Affinities. On the basis of the apiculate anthers and free carpels, Oliver (1895) placed *Eucommia* in Trochodendraceae together with *Cercidiphyllum*, *Euptelea*, *Tetracentron* and *Trochodendron*, and suggested a closer relationship to *Euptelea* and *Cercidiphyllum* than to *Tetracentron* and *Trochodendron*. He also placed Trochodendraceae between Saxifragaceae and Hamamelidaceae. Solereder (1899) separated *Eucommia* and *Cercidiphyllum* from the other genera of Trochodendraceae and placed them in Hamamelidaceae based on the 2-carpellate connate ovary. Later, van Tieghem (1900) suggested that *Eucommia* should be placed as only genus in its own family, which was described by Engler (1907). Tippo (1940) suggested that Eucommiaceae form a connecting link between Urticales and Hamamelidales, on the basis of the anatomical structure of the simple perforation plates of the vessels, the alternate intervascular pitting, the laticiferous cells, and flower morphology. Varossieau (1942) considered that Eucommiaceae should be placed in Urticales, near Ulmaceae. Hu (1979) and others placed it in the Rosales between Hamamelidaceae and Rosaceae. Dahlgren (1983) considered it close to Cornales. Zhang et al. (1988) considered that Eucommiaceae are related to Hamamelidales because Eucommiaceae have tricolporate pollen grains which are similar to some members of Hamamelidales. Later, according to anatomical and embryological characters, Zhang et al. (1990) further suggested relatively close relationships with Hamamelidales. APG I (Angiosperm Phylogeny Group 1998) placed Aucubaceae, Eucommiaceae, Garryaceae and Oncothecaceae together in Garryales based on molecular data. Also based on molecular data and unisexual flowers and apical placentation, APG II (2003) and III (2009) re-circumscribed Garryales to consist of Eucommiaceae and Garryaceae (incl. Aucubaceae), and suggested that family limits require further phylogenetic work.

Distribution and Habitats. *Eucommia ulmoides* is endemic to China and naturally distributed in the Anhui, Gansu, Guangdong, Guangxi, Guizhou, Henan, Hubei, Hunan, Sichuan, Shaanxi, Yunnan and Zhejiang provinces, at altitudes of 300–500 m.

Palaeobotany. In the Tertiary, species of *Eucommia* were widely distributed in the northern Hemisphere. The earliest fossil records of *Eucommia* were found in Atlantic North America and dated to the Eocene and Oligocene. Five species of *Eucommia* were recognized in North America by Call and Dilcher (1997): *E. constans* from Neogene rocks in central Mexico, *E. eocenica* from middle Eocene strata of the Mississippi Embayment in Missouri, Tennessee and Mississippi, *E. jeffersonensis* from the latest Eocene or earliest Oligocene of the John Day Formation of Oregon, *E. montana* from early Eocene to early Oligocene localities in British Columbia, Washington, Oregon, Utah, Colorado and Montana, and *E. rolandii* from Eocene localities in British Columbia, Mississippi and Oregon. Fruit evolution in *Eucommia* may have involved increases in samara size and symmetry and reduction in seed number from two to one,

perhaps in adaptation to wind dispersal (Call and Dilcher 1997).

Economic Importance. Apart from its importance in landscape engineering, *Eucommia* is used as an antihypertensive drug with pinoresinol di-β-D-glucoside as pharmacologically active principle (Hu 1979). Further, *Eucommia* contains 3 % gutta-percha which is used for insulation of wire-ropes, submarine cables, and for dental supplies. Additionally, *Eucommia* fruit contains 27 % oil, and this oil has various industrial uses. The wood is used for making wooden clogs and shoes (Hu 1979). Usually, the bark of larger trunks is collected for medicinal uses, and smaller trunks, branches and leaves are used for the production of gutta-percha.

Conservation. Because of its economic value *E. ulmoides* is widely cultivated in China. There is no threat of extinction but its natural habitats are under threat.

One monospecific genus:

Eucommia Oliv. Fig. 37

Eucommia Oliv. in Hook. f., Hooker's Icon. Pl. 20, t. 1950 (1890).

Characters as for family.

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