cides is becoming more frequent. In older plantations on sloping land a grass cover is often maintained to control erosion. Ring weeding is then often practised, to reduce damage by diseases and pests. Irrigation is mostly by overhead sprinklers, but in the oldest groves basin irrigation is still practised. The amount of irrigation water applied annually in Italy is about 600 mm/ha. The amount of fertilizer applied and its timing varies from place to place and from farmer to farmer.

Diseases and pests Little is known about diseases and pests affecting bergamot. Apart from diseases and pests attacking citrus in general, it is particularly sensitive to stylar end rot, a physiological disease affecting the fruit.

Harvesting In Italy, fruits of bergamot are picked during winter (November–February) when the peel has turned yellowish and the fruit is fully grown but still unripe. Manual harvesting is still common, but tree shakers are occasionally used where possible. After picking, fruits are kept in the shade and quickly transported to the factory for processing.

Yield The average annual fruit yield of bergamot in Italy is less than 12 t/ha with an essential oil yield of about 0.55%. In well-managed plantations yield per tree may reach 200–300 kg of fruit, yielding on average 300–600 g oil.

Handling after harvest In Italy, bergamot oil is almost exclusively obtained by the 'Pelatrice' method, only a small amount is still produced by the traditional 'Calabrese' process. In the 'Pelatrice' process the essential oil is obtained by rasping the rind of whole fruits to cause the oil glands to break and release the oil. To remove the oil, rasping is done under water sprayers. The oil is extracted from the water by centrifugation. The residual peel is subsequently distilled, yielding a 'distilled essence' of slightly lower quality. The 'Calabrese' method is a 'sponge process', which gives low yields and requires much labour.

Genetic resources and breeding No extensive germplasm collections and breeding programmes for bergamot are known to exist.

Prospects Selection of cultivars of bergamot with a lower content or free of the toxin bergapten is important to improve the quality of the essence. Replacing the oldest groves with newly planted ones could increase yields and reduce production costs. However, the lack of relevant information on cultural practices, e.g. propagation, training, nutrition, irrigation, pest control and harvesting holds down production, therefore research in these fields is urgently needed. The growing interest in natural essential oils and the success of bergamot in tropical Africa justifies research into its suitability for South-East Asia.

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Sumeru Ashari

Clausena anisum-olens (Blanco) Merrill

Bur. Gov. Lab. (Publ.) 17: 21 (1904).

RUTACEAE

$2n = 18$

Synonyms *Cookia anisum-olens* Blanco (1837), *Clausena laxiflora* Quis. & Merrill (1928), *Clausena sanki* (Perr.) Molino (1994).

Vernacular names Philippines: anis, kayumanis (Tagalog), danglais (Bagobo).

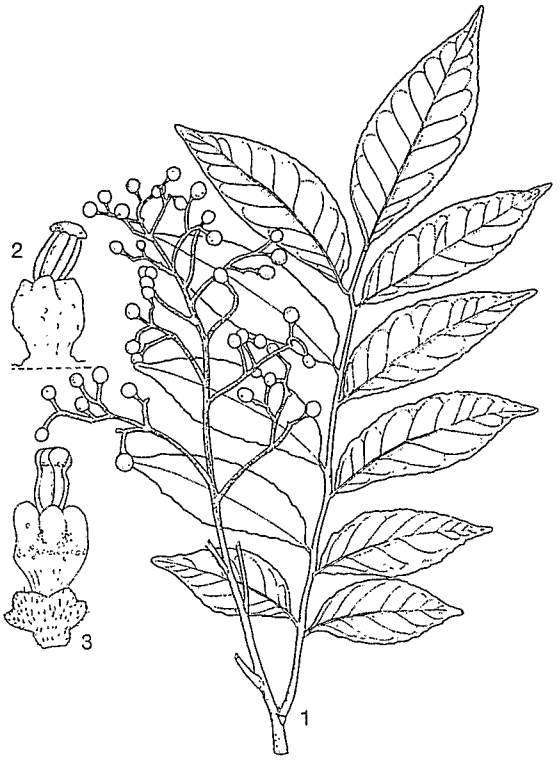
Origin and geographic distribution *C. anisum-olens* is endemic to the Philippines and Borneo. In the Philippines it is distributed all over the archipelago and is also cultivated occasionally. It is sporadically cultivated in gardens in China, Taiwan, Vietnam and Indonesia. In China (Guangxi, Guangdong, Yunnan) it seems to occur naturalized as well.

Uses In the Philippines leaves of *C. anisum-olens* are used as a condiment in preparing local dishes and beverages and to flavour cigarettes. The essential oil from the leaves is a potential substitute of anise oil, e.g. for the preparation of the Philippine drink 'Anisado'. It is also well known in traditional medicine in the Philippines: the leaves are stuffed into pillows for a soporific effect, they are used in baths against rheumatism, or in decoction for nausea during pregnancy. Cough with fever is treated with a decoction of the roots and fruit.

Production and international trade *C. anisum-olens* is of local importance only and is not traded internationally. Production and trade statistics are not available.

Properties On steam distillation or alcoholic extraction, the leaves of *C. anisum-olens* yield 1–3.5% essential oil. The oil is a mobile pale-yellow liquid with an odour similar to that of star-anise oil. The physical characteristics of an oil distilled in Java are: specific gravity (26°C/4°C): 0.96, optical rotation: –0.1°, refractive index (30°C): 1.56. The chemical composition of the oil varies among individual plants from almost pure methyl chavicol (estragol) to almost pure anethol. A minor component is anisaldehyde.

Description Evergreen shrub or small tree, 2–6(–15) m tall, bearing essential-oil glands on all aerial parts which emit a strong anise or anise-like smell when crushed. Leaves alternate, imparipinnately compound, 20–55(–100) cm long, glabrous to villose; petiolules 1–5 mm long; leaflets 7–13(–19), alternate to subopposite, ovate to lanceolate, 3–25 cm × 1–10 cm, the largest ones near the apex, base oblique, margin undulate-crenulate, apex acute-acuminate, densely dotted with pellucid glands. Inflorescence a terminal (rarely axillary), conical panicle, 6–40 cm long; pedicel up to 2 mm long; flowers globose in bud, when opened 6–8 mm in diameter, regular, 5-merous, fragrant; calyx 5-lobed, 0.5–1 mm long, green; petals 5, free, ovate-elliptical, 4–5 mm long, membranaceous, whitish-green; stamens 10, free, filaments geniculate, white, anthers yellow; ovary globose to somewhat pentagonal, about 1 mm long and wide, 5-locular, born on gynophore 0.3–0.5 mm long, style 1 mm long, stigma slightly 5-lobed. Fruit a globose (rarely ovoid) berry, 0.8–1.6 cm in diameter, whitish-green turning pinkish at maturity, 1(–3)-seeded. Seed green.



Clausena anisum-olens (Blanco) Merrill – 1, branchlet with immature fruits; 2, pistil (var. anisum-olens); 3, calyx and pistil (var. mollis (Merrill) Molino).

Growth and development No data are available on growth and development of *C. anisum-olens* in its natural habitat. In the Bogor Botanical Garden cultivar Clausanis produced only few viable seeds and seedlings grew slowly, attaining barely 3 m height in 3 years. Better results were obtained when 'Clausanis' was grafted on *Clausena excavata* Burm.f.: in 2 years a height of 4.5 m was reached. *C. excavata* is widespread in most parts of South-East Asia; it flowers year-round, so seed is always available and seedlings can be grafted when they are 6–12 months old. Healthy plants of *C. anisum-olens* including those grafted on *C. excavata* tolerate pollarding fairly well. Weak plants, however, suffer severe setback from

low pollarding, especially when cut back to less than 50 cm in height.

Other botanical information *C. anisum-olens* (Blanco) Merrill is formally invalidated by *Clausena sanki* (Perr.) Molino (based on *Illicium sanki* Perr. (1824), a name that antedates the basionym *Cookia anisum-olens* Blanco of 1837). In order to avoid an unnecessary name change, it has been proposed that *Illicium sanki* Perr. be rejected, also because it is based on material of 2 different species.

C. anisum-olens is subdivided into 3 botanical varieties:

- var. *anisum-olens*: distributed as the species, except Borneo; whole plant subglabrous; leaves up to 50 cm long with 7–13(–15) leaflets; fruit globose, up to 1 cm in diameter;
- var. *calciphila* (B.C. Stone) Molino: synonym: *C. calciphila* B.C. Stone; occurring in Borneo (Sarawak and Kalimantan); whole plant subglabrous; leaves up to 1 m long with 11–19 leaflets; fruit ovoid, 1.5–1.6 cm × 1–1.1 cm;
- var. *mollis* (Merrill) Molino: synonym: *C. mollis* Merrill; occurring in the Philippines (Luzon, Mindanao); almost whole plant densely golden-yellow pilose; leaves with 11–15(–19) leaflets.

All information about uses and essential oil content refer to var. *anisum-olens* only. Data on cultivation refer to only a single cultivar of this variety: 'Clausanis'. 'Clausanis' developed from plants collected in the Philippines in 1820 that were subsequently taken to Réunion Island and Paris. From Réunion a few plants were taken to the Botanical Garden in Bogor. There, through cultivation and successive self-pollination it developed its typical character: a very short and asymmetrical style, an unusual feature in *Clausena* Burm.f. 'Clausanis' has been cultivated and studied from 1905 onwards in Bogor as *C. anisata*. However, *C. anisata* (Willd.) Hook.f. ex Benth. (synonyms: *C. dentata* (Willd.) M. Roemer, *C. dunniana* A. Léveillé) is a related, but completely different species occurring in tropical and southern Africa, southern India and from Bangladesh to southern China and Thailand. It has only axillary inflorescences. Its leaves yield an essential oil very rich in anethol and similar to the oil of *C. anisum-olens*.

Ecology *C. anisum-olens* grows naturally in the understorey of rainforest, on various soil types (including limestone), up to 1500 m altitude. In cultivation in Indonesia it only performed well up to 500 m altitude. In Solok (west-central Sumatra) it grows well with 2000 mm annual rainfall with maxima in March and November and a minimum of about 75 mm per month from June to August, with maximum temperatures of about 30°C and minima of about 20°C throughout the year, and on poor, acid (pH 4.0–4.2) soils.

Propagation and planting 'Clausanis' produces very little seed and is propagated vegetatively. Grafting 'Clausanis' on a rootstock of *C. excavata* is the easiest and most efficient way of propagation. Other rutaceous rootstocks (*Citrus* spp., ×*Citrofortunella* spp.) have also been tested, but gave poorer results. Propagation by cuttings proved to be very difficult, as it requires constant high temperatures (above 23–25°C) and adequate soil moisture. Budding onto *C. excavata* has given poor results. In vitro propagation of 'Clausanis' has also been tested in Bogor, with promising preliminary results.

In Solok, densities of 10 000–15 000 plants/ha have given good results; earlier about 3000 plants/ha had been recommended in Java.

Husbandry In Solok, plants of 'Clausanis' grafted on *C. excavata* are pruned back to a height of about 1 m once or twice a year after harvest. If this pruning process starts early, it leads to the formation of a flat-topped, sometimes bushy shrub, from which leaves can be picked easily from above (as in tea plantations).

Harvesting At high planting densities, all leaves of *C. anisum-olens* above 0.8–1 m can be plucked 2–4 times per year. Trees should be maintained at about 1 m height by means of post-harvest prunings. Frequency and timing of harvests should be guided by the rate of regrowth and depend on the availability of water. When water and nutrient requirements are met, leaf production is highest under unshaded conditions. The first harvest can be 1 year after grafting on 2–4-year-old rootstocks.

Yield The first year, a single harvest amounts to 0.6–1 kg leaves per tree. In the second year 1.7–2.2 kg are collected in two harvests. In subsequent years a tree yields 2.5–4 kg leaves annually, independent of the frequency of harvesting.

Handling after harvest After harvesting the leaves it is recommended to extract the oil as soon as possible. Fermentation of the leaves should absolutely be avoided because it leads to production of unpleasant notes in the essential oil. If necessary, it is possible to store the leaves for 2–3 days in a properly ventilated room where they may slightly dry without fermentation. A too strong desiccation would lead to a severe loss of the oil by evaporation, either directly through the thin walls of the pellucid glands or by crumbling them dur-

ing handling of the fragile dried leaves. Essential oil is mostly extracted from the leaves by steam distillation. Distillation for 4–5 hours in a still with a 120 kg capacity yields more than 90% of the total essential-oil content. Prolonged distillation would negatively affect the quality of the oil. Oil yield is 1.6–2 kg oil from 100 kg fresh leaves. Preliminary estimates for production of essential oil per ha suggest that yields of 350–750 kg per year may be possible.

Genetic resources and breeding Little is known about wild representatives of *C. anisum-olens* from the Philippines. They may be more vigorous, have a higher growth rate, produce more seed and have a higher essential-oil content than 'Clausanis', and could be used for breeding and genetic improvement. However, no germplasm collections or breeding programmes are known to exist.

Prospects The essential oil from the leaves of *C. anisum-olens* has potential use as a cheap source of natural anethol. It could compete not only with star-anise and anise oils in food, beverage and pharmaceutical industries, but also with semi-synthetic anethol, a by-product of the turpentine-oil industry in the United States, in soaps, detergents and cosmetics.

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J.-F. Molino

Corymbia citriodora (Hook.) K.D. Hill & L.A.S. Johnson

Telopea 6: 388 (1995).
MYRTACEAE
$2n = 22$

Synonyms *Eucalyptus citriodora* Hook. (1848), *E. melissiodora* Lindley (1848), *E. maculata* Hook. var. *citriodora* (Hook.) Bailey (1900).

Vernacular names Lemon-scented gum, spotted gum, lemon-scented iron gum (En). Thailand: yukhalip. Vietnam: b[aj]ch d[af]n d[or], b[aj]ch d[af]n chanh.

Origin and geographic distribution *C. citriodora* is endemic to Queensland (Australia). It occurs mainly in the region from north-west of Maryborough to north of Rockhampton and west for up to 400 km. There are also extensive stands on the tablelands inland between Mackay and Cairns, and an occurrence west of the Great Dividing Range north of Hughenden.
C. citriodora has been extensively planted as an ornamental tree in many regions of the world, and has been planted for commercial purposes in South America, especially Brazil (6 million trees), southern China, India, Sri Lanka, Congo (Zaire), Kenya and most countries in southern Africa and in Fiji. In South-East Asia it is mainly planted in Peninsular Malaysia. In Thailand it was introduced in 1949, but commercial plantations no longer exist.

Uses The pleasant, lemon-scented essential oil from the leaves of *C. citriodora* is widely used in less expensive perfumes, soaps and disinfectants. It has antibacterial and insecticidal activity. The citronellal-rich oil is a preferred natural source for the production of hydroxycitronellal, citronellylnitrile and menthol. Hydroxycitronellal is one of the most widely used of all perfumery materials. Other minor constituents recovered during fractionation of the essential oil, such as citronellol, are also used by the fragrance industry.
The timber of *C. citriodora* is used for general and heavy construction such as frame and bridge construction, flooring, cladding, tool handles and case manufacturing. The wood of young trees has been successfully used for certain grades of pulp and paper, but wood from old trees is generally not suitable because of its high extractive content and high density. Young trees or coppice stems produce straight poles or posts which can be pressure impregnated with preservatives for many industrial purposes. In Brazil large plantations have been established for charcoal production.
C. citriodora is widely used in park and avenue

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No 19

Essential-oil plants

L.P.A. Oyen and Nguyen Xuan Dung (Editors)

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