

Cinchona pubescens

Quinine tree

Rubiaceae

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OVERVIEW

Cinchona pubescens, native from Andean South America north to Costa Rica, has been cultivated in various tropical regions of the world mainly for use in the production of quinine, a medicine used to treat malaria, which is obtained from the root and bark of the tree. In some places where *C. pubescens* is cultivated, such as Galapagos and Hawai'i, it is spreading from initial plantings, invading nearby forests, forming dense thickets, and crowding out native plants. In Hawai'i, *Cinchona* plantations were planted as early as 1868 on Maui with later plantings by state foresters on O'ahu, Maui, and Hawai'i in the first half of the 1900's (Wagner et al. 1999). *C. pubescens* was reported as naturalized in 1978 from the island of Hawai'i and in 1987 from Maui (Wagner et al. 1999). On Maui, *C. pubescens* is locally abundant in the Makawao Forest Reserve of East Maui in areas near original plantings and alien forestry plantations, along old roads, and in thick native mixed mesic to wet forests. Though seed production is heavy, this species does not seem to disperse very far from original plants. Though locally abundant, it is fairly far along in its invasion process, and the terrain is very difficult, including steep gulches and thick under-story vegetation, making control of this species difficult. While eradication of *C. pubescens* in the Makawao Forest Reserve would be difficult, controlling small populations in pockets of rich native vegetation may help contain the infestation and slow the degradation of the remaining native forests in the area.

TAXONOMY

Family: Rubiaceae (Coffee family) (Wagner et al. 1999).

Latin name: *Cinchona pubescens* Vahl (Wagner et al. 1999).

Synonyms: Numerous synonyms are listed by various sources. The W3Tropicos nomenclatural database (Missouri Botanical Gardens 2002) lists 104 different synonyms. Some of these include the following: *C. succirubra* Pav. ex Klotzsch, *C. asperifolia* Wedd., *C. caloptera* Miq., *C. chomeliana* Wedd., and *C. cordifolia*. Some of the synonyms listed by the Global Invasive Species Program database (GISP 2002) include the following: *C. decurrentifolia* (Pavon in Howard), *C. hirsuta* (Ruiz & Pavon), *C. lechleriana* (Schlechtendal), *C. lutea* (Pavon in Howard), and *C. ovata* (Ruiz & Pavon).

Common names: Quinine tree, quinine, quinoa, red cinchona, (Wagner et al. 1999, GISP 2002,). It was formerly called sacred bark and Jesuits bark (Bailey & Bailey 1976).

Taxonomic notes: *Cinchona* is a genus of about 40 species native mostly to Andean South America north to Costa Rica. According to Bailey & Bailey (1976), the species are difficult to distinguish and the nomenclature is confused. They recognize the

following four species of economic importance. "*C. Calisaya* Wedd. [syn. *C. Ledgerana* Moens ex Trimen], from the East slopes of the Andes, south Peru, and Bolivia, the inner bark is the yellow calisaya or Ledger quinine bark of commerce, this species is the main source of high yielding cultivars that were developed in Indonesia and elsewhere. *C. micrantha* Ruiz & Pav., from montane rainforests of south Ecuador to Bolivia, called the gray cinchonine bark of commerce. *C. officianalis* L., [syn. *C. condaminea* Humb. & Bonp. may be a synonym or form of *C. officianalis*], a variable species from Colombia to north Peru, the bark is the crown of Loja quinine bark of commerce. *C. pubescens* [syn. *C. succirubra* Pav.ex Klotsch probably belongs here as a well marked variety], a variable and widespread species from Costa Rica and Venezuela south to Bolivia, with inner bark the red quinine of commerce."

Nomenclature: The plant is named in honor of Ana de Osorio, Countess of Cinchon, wife of the viceroy of Peru, who was cured of a fever in 1638 by a remedy which was derived from *Cinchona* plants (Wagner et al. 1999).

Related species in Hawai'i: Wagner et al. (1999) report that *Cinchona calisaya* Wedd. [*C. ledgerana* Bern. Moens ex Trimen] and *C. officianalis* L. have also been planted by state foresters on several of the main islands and have not become naturalized. An unknown species (*Cinchona* sp.) is reported in Skolmen (1960).

DESCRIPTION

"Trees usually 4-10 m tall. Leaves broadly elliptic-ovate or sometimes sub-orbicular, 10-20 cm long, 7-10.5 cm wide, upper surface puberulent, sometimes primarily along veins, or glabrate, lateral veins usually 9-11 pairs, margins entire, apex rounded, base broadly to narrowly cuneate, petioles 1.5-4.5 cm long, stipules ovate, caducous. Flowers numerous in panicles up to 20 cm long or slightly longer; calyx ca. 1 mm long, densely appressed pubescent, the teeth deltate; corolla pink (or red outside Hawai'i), appressed pubescent, the tube 10-12 mm long, the lobes ca. 4-5 mm long, villous within. Capsules lanceoloid to oblong, 1-2 cm long, dehiscent from base to apex. Seeds ca. 2 mm long, with a broad ciliate wing." (Wagner et al. 1999).

BIOLOGY & ECOLOGY

Cultivation: The following historical timeline below is derived from Raintree (2001) to illustrate *Cinchona's* remarkable history and cultivation.

Quinine History Timeline:

1638 -- Legends say that the Countess of Chinchon, the wife of a viceroy of Peru, was cured of a malarial type of fever by using the bark of the *Cinchona* tree.

1640 – The cure was supposedly introduced to European medicine in 1640 by the Countess Chinchon.

1658 -- Quinine bark was used by the Jesuits very early in its history, first advertised for sale in England. Several years after the "Countess's powder" arrived in England, it arrived in Spain where the virtues of these bark were rapidly recognized, from the "tree of fever of the region of Loxa". Rapidly and due to the influence of the Company of Jesus, the "jesuits' powder" became known all over Europe. Physicians gave credit to the

drug, and because of the specificity of its action on malaria, it was recognized officially even while the identity of the producing species remained unknown.

1677 -- Quinine made official in the London Pharmacopoeia.

1737 – Botanists discover the plant source and supposedly named the plant, *Cinchona*, after the Countess almost a hundred years later for her contribution.

1600's to 1800's -- Quinine Bark was the most used treatment for malaria, evidencing remarkable results, as well as being used for fever, indigestion, mouth and throat diseases, and cancer.

1820 -- Two scientists, Pelletier and Caventou, isolated a quinoline alkaloid in the bark which provided the highest anti-malarial effect and name it *Quinine*. Once discovered, methods were developed to extract the quinine from the natural bark to sell as an anti-malarial drug. The South American rainforests benefited from the income generated by harvesting this resource discovered in their territory up until the end of the 19th century. Mid 19th century – Seeds of *Cinchona calisaya* and *Cinchona pubescens* were smuggled out by the British and the Dutch. The *calisaya* species was planted and cultivated in Java by the Dutch and the *pubescens* species in India and Ceylon by the British. However, the quinine content of these species was too low for high grade production of quinine cost effectively. The Dutch then smuggled out seeds of *C. ledgeriana* out of Bolivia and established extensive plantations of high grade *Cinchona* trees in Java, soon dominating the world production of *Cinchona* and the quinine market.

1918 – Production of quinine under the total control of the Dutch "kina burea" in Amsterdam. Huge profits were reaped, but Bolivia and Peru, saw none of it.

1942 – The Japanese take possession of Java during WWII, resulting in a severe shortage of quinine on the side of the Allies, and South American sources of *Cinchona* trees were once again sought and new African plantations were planted. This shortage also fueled research and development of producing synthetic anti-malarial drugs.

1944 – Scientists synthesize the quinine alkaloid. The use of the common bark and the natural quinine fell out of use.

Today – Indonesia and India still cultivates *Cinchona* spp. but Zaire has become the top supplier of a world market which is also supplied by other African countries such as Burundi, Cameroon, and Kenya. Some South American countries still produce, such as Peru, Bolivia, and Ecuador. *Cinchona* spp. have also been cultivated, to a lesser extent, in various other tropical regions of the world. Most of the *Cinchona* today is used for food preparation in tonic waters and bitter additives, in the production of *Quinidine*, used for cardiac problems, and in the production of quinine, for use in natural remedies and because some malaria strains have grown resistant to synthetic quinine. It is thought that 300 to 500 metric tons of quinine are extracted annually from 5,000 to 10,000 metric tons of bark.

Invasiveness: *C. pubescens* has several invasive characteristics. It is known to spread and become invasive in areas where it is planted, including Hawai'i and Galapagos (GISP 2002). It produces numerous seeds that rain from parent trees. Trees reach seed production within four years (GISP 2002). In Hawai'i, seedlings are capable of germinating in fairly dense understory vegetation in both disturbed alien forests as well as in relatively rich native moist to mesic forests. This broad leaf tree with a dense

canopy grows rapidly, about 1-2 m per year (GISP 2002), out-competes, shades out, and replaces desirable native vegetation.

Pollination: *C. pubescens* is possibly insect pollinated as flowers are sweetly fragrant and tube shaped, though this is just speculative.

Propagation: *C. pubescens* can be propagated from seeds or cuttings of ripe wood (Bailey & Bailey 1976). GISP (2002) reports that *C. pubescens* also produces root suckers and readily re-sprouts from damaged stems.

Dispersal: Seeds of *C. pubescens* are surrounded by a papery like wing and are wind dispersed (GISP 2002). From observations of the *C. pubescens* infestation in the Makawao Forest Reserve, East Maui, seeds do not appear to be able to travel very long distances, and most seedlings are found nearby parent trees (within 100 m).

Pests and Diseases: None known.

DISTRIBUTION

Native range: All *Cinchona* species are indigenous to the eastern slopes of the Amazonian area of the Andes growing at elevations between 1,500 to 3,000 ft (457-914 m) from Colombia to Bolivia (Raintree 2001). *C. pubescens* is native from Costa Rica to Venezuela and Bolivia (Wagner et al. 1999). The native range is located in South America on both sides of the equator in mountainous highlands and tropical rain forest regions with annual rainfalls ranging from about 40 in (102 cm) upwards to over 80 in (203 cm) (Hammond 1986). *C. pubescens* locations listed by the Missouri Botanical Garden specimen database (2002) include the following (various locations were noted for each country, a range is given here): Costa Rica, 800-1,600 m (2,625-5,249 ft), 8.47.20N-10.18N, 82.51W-85.15W; Bolivia, 620-2,500 m (2,034-8,202 ft), 13.53S-17.48S, 64.15W-76.10W; Colombia, 1,150-3,300 m (3,773-10,827 ft), 2.18N-6.34N, 75.35W-76.42W; Ecuador, 300-3,900 m (984-12,795 ft), .55S-.25N, 77.55W-79.09W; Peru, 325-3,200 m (1,066-10,499 ft), 3.48S-13.09S, 71.31W-75.28W; Venezuela, 1,500 m (4,921 ft), 9.18N, 70.06W.

Global distribution: In the Pacific, *C. pubescens* is known from Tahiti, Galapagos, and Hawai'i (PIER 2002). Apparently, *C. pubescens* was introduced to Palau by the Japanese but is not present now (Fosberg et al. 1993). In Santa Cruz, Galapagos, *C. pubescens* was introduced in 1946 by a private farmer, as a cash crop (GISP 2002). The crop was not economically viable and production never commenced there. It has now spread from initial plantings and invades several types of humid highland forest habitats, including: moist tropical montane cloud forest, moist tropical montane fern-sedge pampa, moist upland pastures, moist upland mixed agriculture, fragmented tropical forests with crops, field crops, moist tropical montane rainforest (*Scalesia* dominated), and moist tropical montane scrub (*Miconia* dominated) (GISP 2002). *C. pubescens* locations for Africa listed by the Missouri Botanical Garden specimen database (2002) include Tanzania, 1,100 m (3,609 ft), 5.03S, 38.23E.

State of Hawai'i distribution: According to Skolmen (1960) four *Cinchona* species have been planted in the state of Hawai'i by state forestry (*C. ledgeriana* [syn. *C. calisaya*], *C. officinalis*, *C. sp.*, and *C. succirubra* [syn. *C. pubescens*]). A total of 5,357 trees of *C. calisaya* were planted in the state of Hawai'i during 1944-1946, (200 on Kaua'i, 106 on O'ahu, 449 on Maui, and 4,602 on Hawai'i) (Skolmen 1960). A total of only 27 trees of *C. officinalis* were planted on O'ahu (Skolmen 1960). A total of 4,010 trees of one other unknown species, *C. sp.* as listed by Skolmen (1960) was planted in 1944-1945 (22 on O'ahu, and 3,988 on Hawai'i). Wagner et al. (1999) report that *C. pubescens* was planted by state foresters on O'ahu, Maui, and Hawai'i between 1928 and 1947. Skolmen (1960) reports a total of 486 *C. pubescens* [listed under the syn. *C. succirubra*] planted in the state of Hawai'i (33 on O'ahu in 1944, 17 on Maui from 1941-1947, and 436 on Hawai'i in 1928 and from 1940-1945). *C. pubescens* is now naturalized in the Makawao Forest Reserve, Maui, and South Kona District, Hawai'i (Wagner et al. 1999). Current distribution of *C. pubescens* on the island of Hawai'i and of the aforementioned *Cinchona* species on all islands is uncertain and worthy of investigation.

Island of Maui distribution: On Maui, *C. pubescens* is locally abundant in mesic to wet forests of the Makawao Forest Reserve at approximately 2,600-3,800 ft (792-1,158 m) elevation. The average annual rainfall in this area is about 80-120 in (203-305 cm) (Juvik and Juvik 1998). *C. pubescens* was first reported as naturalized from this area in 1987 by R. Hobdy (Wagner et al. 1999). Some surveying of the area to refine the current distribution has been done, however, the terrain is difficult making it hard to be certain of its true distribution, especially to the east. Seedlings seem to grow nearby adult trees (within 100 m) rather than disperse over long distances (miles away). Seed production is prolific and this species easily invades adjacent areas made up of dense native understory vegetation, such as uluhe fern (*Dichanopteris linearis*), and mixed wet to mesic native forest canopy vegetation, such as koa (*Acacia koa*). It also readily invades non-native forested areas, such as *Eucalyptus* spp., and can be observed along old bulldozed forestry roads. Trees are fairly conspicuous, especially when their broad leaves are turning red. Sweetly fragrant pink flowers born on panicles also allow this species to be readily identified. *C. pubescens* aggressively invades and out-competes other plants. Other *Cinchona* species documented from Maui include *C. calisaya* and *C. officinalis*. A few large trees of *C. calisaya* are present in the Makawao Forest Reserve. The other report of *Cinchona* on Maui is from Ulupalakua, where a small *Cinchona* plantation was started at in 1868 (Wagner et al. 1999). Specimens housed at Bishop Museum from Ulupalakua were determined to be *C. officinalis*. Current status and distribution of this population is uncertain and needs investigation.

CONTROL METHODS

Physical control: *C. pubescens* will produce root suckers and resprout from damaged stems (GISP 2002). Control information from the Galapagos (GISP 2002) reports that manual methods include felling and pulling out or grubbing out of stumps and saplings have mixed success. Removal of saplings is reported as effective, but adult trees can resprout from cut stumps. De-barking is ineffective, even if bark is removed from up to 1 m of stem. The bark will re-grow and repair the wound, and the tree will survive.

Chemical control: Management information from the Galapagos (GISP 2002) reports that this species is resistant to many herbicides, so chemical control requires the use of moderately toxic formulations such as tripclopyr, picloram, 2, 4-D or Tordon. Application methods include cut stump, basal bark and hack and squirt. Control trials in Hawai'i have not been done yet, but the methods mentioned above should be effective.

Biological control: No known biological controls have been introduced to Hawai'i. There are no native *Cinchona* spp. in Hawai'i, though many native plants in the family Rubiaceae do occur in the same area.

Cultural control: The residents of Maui could be discouraged from using *Cinchona* spp. in future plantings.

Noxious weed acts: None known. Perhaps this species should be included in the Hawai'i Department of Agriculture's state noxious weed list to prevent future propagation, sale, and possession.

MANAGEMENT RECOMMENDATIONS

C. pubescens has long been cultivated as the source of quinine, an anti-malarial drug. It was introduced to a number of tropical areas worldwide and has become invasive in Hawai'i and Galapagos where it spreads rapidly from initial plantings via numerous wind dispersed seeds and out-competes native vegetation (GISP 2002). On Maui, the rich mesic and wet forests of the Makawao Forest Reserve are threatened by invasion of aggressive non-native plants such as *C. pubescens*, many of which were planted in the 1900's by forestry efforts. Other mesic and wet forest currently free of *C. pubescens* are potentially threatened by invasion in the future. Total eradication of the species from Maui seems difficult due to numerous plants covering large areas of tough terrain. Local control of *C. pubescens* in pockets of the richest vegetation may help to slow the invasion of this species while preserving several rare native species in the area. Populations of *C. pubescens* on other Hawaiian Islands needs to be further investigated to provide updated information on distribution and status. In addition, information updating the status of the other species of *Cinchona* (*calisaya* and *officinalis*) that were planted during forestry efforts on other Hawaiian Islands is needed. *C. pubescens* should not be further sold or planted in the Hawaiian islands or other similar places where it could cause potential harm.

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