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African Sandalwood or Nepalese Sandalwood: a Brief Synthesis

Jaime A. TEIXEIRA DA SILVA[1]*, Mafatlal M. KHER[2],
Deepak SONER[2], Murugan NATARAJ[2]

[1]*Miki-cho post office, Ikenobe 3011-2, P. O. Box 7, Kagawa-ken, 761-0799, Japan; jaimetex@yahoo.com (*correspondence author)*
[2]*Sardar Patel University, B.R. Doshi School of Biosciences, Sardar Patel Maidan, Vadtal Rd., P.O. Box 39, Vallabh Vidyanagar, Gujarat, 388120, India;*
mafatlalmkher@gmail.com, deepaksoner@gmail.com, mnatarajspu@gmail.com

Abstract

African sandalwood or East African sandalwood (*Osyris lanceolata* Hochst. & Steud.; Santalaceae), also known as Nepalese sandalwood (*Osyris wightiana* var. *rotundifolia* P.C. Tam), is a hemi-parasitic tree known for its fragrant wood. The essential oil is extracted from the root bark for the perfume industry and different parts of the tree have various medicinal uses. African sandalwood contains an array of phytochemicals such as dihydro-β-agarofuran polyesters, agarofuranases, polyesters, other sesquiterpenes and bisabolanes. This mini-review focuses on the general biology, traditional uses, phytochemical properties, propagation for conservation, and hemiparasitism of *O. lanceolata*.

Keywords: conservation, East African sandalwood, fragrant wood, hemiparasite, sandalwood oil, Santalaceae

Introduction: taxonomy, habitat and basic biology

Osyris lanceolata Hochst & Steudel [synonyms: *O. abyssinica* Hochst. ex A. Rich, *O. arborea* Wall. ex A.DC. *O. arborea* var. *rotundifolia* P.C. Tam, *O. arborea* var. *stipitata* Lecomte, *O. densifolia* Peter, *O. laeta* Peter, *O. oblanceolata* Peter, *O. parvifolia* Baker, *O. quadripartite* Salzm. ex Decne., *O. rigidissima* Engl. *O. tenuifolia* Engl., *O. urundiensis* De Wild., *O. wightiana* Wall. ex Wight (also known as Nepalese sandalwood), *O. wightiana* var. *rotundifolia* P.C. Tam, *O. wightiana* var. *stipitata* (Lecomte) P.C. Tam] (Global Plants, 2016; The Plant List, 2016), which belongs to the Santalaceae, is most commonly known as East African sandalwood and Nepalese sandalwood. *O. lanceolata* is adopted, for uniformity, throughout this review and information from references of sandalwood with the above-listed synonyms are presented as *O. lanceolata* according to The Plant List (2016).

Osyris lanceolata is a shrub or small deciduous tree that grows to 1-7 m in height depending on the soil type, climatic conditions and genetic variation, and has a wide geographic distribution in Africa from Algeria to Ethiopia and south to South Africa, Europe (Iberian peninsula and Balearic Islands), Asia (India to China), and Socotra (von Breitenbach, 1963; Teklehaimanot *et al*., 2004; Giathi *et al*., 2011; Kamondo *et al*., 2012; Gathara *et al*., 2014; Global Plants, 2016). *O. lanceolata* is distributed in African countries such as Tanzania and Kenya and is frequently found in arid to semiarid areas, primarily on stony and rocky soils (Kokwaro, 2009), or sporadically in rocky sites and along the margins of dry forests, evergreen bushland, grassland, and thickets at an altitude range of 900-2250 m above sea level (Giathi *et al*., 2011; Kamondo *et al*., 2012).

However, large trees can occur in humid climates, preferentially in low soil pH andsufficient soil nitrogen (Mwang'ingo *et al*., 2003). *O. lanceolata* has yellow-green hermaphroditic flowers with small round heads, fruits are round, about 1 cm in diameter, green when unripe, orange to red when ripe, and contain one whitish seed (Mwang'ingo *et al*., 2008; Kamondo *et al*., 2012; Global Plants, 2016). Female flowers of plants growing in Spain flower for nearly six months from March to September while male flowers show almost year-round flowering (Herrera, 1984). Plant size exhibits dimorphism: males are significantly larger than females (Herrera, 1988a). Insects are not responsible for pollination and frugivorous birds are involved in seed dispersal (Herrera, 1985; Herrera, 1988b). *O. lanceolata* is a protected species under CITES appendix II (CITES, 2016).

Parasitism

Hemiparasitic plants of the Santalaceae draw water and nutrients from host roots by means of root haustoria, providing a conduit between the parasite and host (Irving and Cameron, 2009; Teixeira da Silva *et al*., 2016). This hemiparasitic requirement establishes diversity when farming *O. lanceolata*.

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Mwang'ingo *et al.* (2005) found several ideal hosts (*Aphloia theiformis* (Vahl.) Benn, *Apodytes dimidiata* Meyer ex Arn, *Brachystegia spiciformis* Benth., *Dodonaea viscosa* (L.) Jacq., *Rhus natalensis* Bernh. ex C. Krauss, *Tecomaria capensis* (Thunb.) Spach, *Maytenus acuminata* (L.f.) Loes) for *O. lanceolata*. Among these, *B. spiciformis*, *Casuarina equisetifolia* and *R. natalensis* promoted the early growth of seedlings most efficiently, stimulating plant height and diameter, and root and shoot biomass, which were attributed to, in *C. equisetifolia*, the host's nitrogen-fixing potential (Mwang'ingo *et al.*, 2005).

Traditional uses

In East African countries, *O. lanceolata* constituted an important source of medicine but also has other minor uses such as fodder (Mwang'ingo *et al.*, 2010). A decoction of the bark and root is considered to be useful for treating diarrhoea, gonorrhea, chronic mucus infections, and urinary diseases (Teklehaimanot *et al.*, 2004; Kokwaro, 2009), a decoction of the bark in boiling water is used to treat candidiasis and related fungal infections (Masevhe *et al.*, 2015) while the essential oil extracted from the bark is used to treat diarrhoea, chest problems, and joint pains (William, 2010). In addition, *O. lanceolata* is used as an antimalarial in Kenya (Njoroge and Bussmann, 2006). Fibers from the roots are used in basket making while the strong red dye from the bark and roots is used in skin tanning (Mbuya *et al.*, 1994). Since *O. lanceolata* is an evergreen tree with long flowering periods, it is a good forage plant (Fichtl and Adi, 1994). The utilization of *O. lanceolata* in the perfumery and fragrance industries (Ochanda, 2010) in the early 1900s followed a decline in the resource base of Indian sandalwood (*Santalum album* L.) (Rai and Sarma, 1990; Mbuya *et al.*, 1994). Several communities in Kenya also use *O. lanceolata* to produce dyes, to treat various ailments, and to brew herbal tea (William, 2010; Kamondo *et al.*, 2012). An infusion (250 ml) consisting of a handful of roots cooked in water for 5 min or pounded with warm water, is administered three times a day to treat diarrhoea (Semenya and Maroyi, 2012). In South Africa, roots are traditionally used to treat menorrhagia (Arnold and Gulumian, 1984; Steenkamp, 2003). The antimicrobial activity of hexane, dichloromethane, aqueous methanol and water extracts from the stem, roots and stem bark was shown by Ooko (2008) against five bacteria and three fungal strains. Roots and leaves have antifungal and antibacterial activities (Mulaudzi *et al.*, 2011). A large population of the residents (64%) of Chyulu hills in Eastern Kenya use *O. lanceolata* for commercial purposes and 21.2% use the tree for medicinal purposes to treat animals and humans, e.g. to treat snake bites (Ochanda, 2010). An extract from shoots is used as an antipyretic agent for cattle (Thanner, 1908). The root bark is used to treat indigestion (Manandhar, 1993) and to cure body pain and bone fractures in Nepal (Gautam, 2013). A leaf extract, when mixed with cow's butter or Indian rape oil (*Brassica napus* L. var. *napus*) forms an ointment used to treat sprains (Bhattarai, 1990). Young leaves are poisonous to livestock (Shrestha and Dhillion, 2003), but when boiled, dried and powdered, they are used as herbal tea (Shrestha, 1988; Paudel and Gyawali, 2014). This tea also acts as a labour-inducing agent to treat fractured bones (Paudel and Gyawali, 2014). The methanolic extract of leaves can inhibit the growth of *Pseudomonas aeruginosa*, *Proteus mirabillis*, *Salmonella typhi* and *S. paratyphi* (Paudel and Gyawali, 2014). The leaf extract induced weight loss in mice and serves as an effective parasitemic agent (Girma *et al.*, 2015). The methanolic extract of aerial parts during the fruiting period is rich in flavonoids and effectively reduces inflammation (Gómez *et al.*, 1995).

Phytochemical research

Osyris species contain hexyl and hexenyl derivatives, sesquiterpenes, dihydro-β-agarofuran sesquiterpenes, phenolic acids, flavonoids, pyrrolizidine and quinolizidine alkaloids, lignans, β-carboline alkaloids, iridoids, norisoprenoids, phenylpropanoids, long chain hydrocarbons, carbohydrates, amino acids, and halogenated pyrimidine alkaloids (Shyaula, 2012). *O. lanceolata* is among the sandalwood species known for producing fragrant-scented wood from which sandalwood essential oil, which contains tenuifolene and *ar*-tenuifolene (bisabolanes), is extracted (Kreipl and König, 2004). The essential oils from male and female trees differ significantly in terms of both yield and quality (Mwang'ingo *et al.*, 2010). For example, male flowers from Nundu (Tanzania) yielded 8.40% essential oil while female flowers yielded 9.32%; in a different location (Lushoto), male flowers yielded 12.01% santalol while female flowers yielded 10.2%, indicating the importance of location and selection plant tissues as the source of essential oils. Yeboah and Majinda (2009) studied the free radical-scavenging properties of the powdered root bark of *O. lanceolata* using *n*-hexane, chloroform, methanol and 90% methanol/water extracts. A separate supercritical fluid extraction (SFE) of the root bark was also conducted. The 90% methanol/water and methanol extracts showed several components with high antioxidant activity displaying fast kinetics while the chloroform, SFE, and *n*-hexane extracts exhibited antioxidant activity with slow kinetics. Yeboah *et al.* (2010) isolated three dihydro-β-agarofuran polyesters (1α,9β-difuranoyloxy-2-oxodihydro-β-agarofuran, 1α,9β-difuranoyloxy-2-oxo-3-enedihydro-β-agarofu-ran, and 1α,9β-difuranoyloxydihydro-β-agarofuran) from the chloroform extract of the root bark together with two known pentacylic triterpenoids. All five compounds displayed antifungal activity against *Candida albicans*. Agarofuran sesquiterpene polyesters were isolated from root and stem bark extracts (Yeboah and Majinda, 2013). The dichloromethane extract from the aerial parts contains lignans, (±) lyoniresinol, (±) syringaresinol, 5,5'-dimethoxylariciresinol, and 5-methoxyla-riciresinol (Shyaula *et al.*, 2011). The butanolic extract of the dried aerial parts of the plant yielded a phenyl propanoid, a benzyl alcohol, an iridoid and megastigmanes (Shyaula *et al.*, 2013).

Propagation and conservation

O. lanceolata products in the international markets in Europe and Asia have increased in demand, recently leading to an increased rate of utilization and exploitation, to an extent that its survival in natural habitats is severely threatened (William, 2010). The traditional mode of propagation is by seed or root suckers (Kokwaro, 2009). Propagation by seeds is difficult due to a limited supply and availability of seed at the right time (being a dioecious species, the spatial distribution of trees affects the reproductive outcome; Mwang'ingo *et al*., 2008), storage difficulties and thus poor germination (Mbuya *et al*., 1994). Consequently, several interventional measures are required to conserve *O. lanceolata*. A study by Mwang'ingo *et al*. (2004) on the storage and pre-sowing treatments on seed germination demonstrated that the testa covering the embryo plays a significant role in limiting germination by restricting gas and water entry and also acts as a mechanical barrier to embryo growth. However, complete removal of the testa and soaking the zygotic embryo in hot water enhanced seed germination by 66.5%, shortened the time to seedling emergence and promoted early seedling growth (Mwang'ingo *et al*., 2004). Stem cuttings (8-10 cm long with 3-4 leaves from young trees or seedlings) could be induced to root with a maximum of 15% rooting when dipped first in a fungicide (Bavistin) for 5 min, then in 1% indole-3-butyric acid (IBA) for 6 h, but "this concentration could be increased to 32.5% when 75% of the original leaves were left intact" (Giathi *et al*., 2011). In the same study (Giathi *et al*., 2011), the choice of substrate was shown to affect the rooting ability of cuttings, with 30% of cuttings rooting in vermiculite, which was superior to sand, vermiculite + sand (1:1), activated coconut peat and peat. Teklehaimanot *et al*. (2004) used 50-150 mg/L IBA to enhance root production in young stem cuttings collected in early spring. Mwang'ingo *et al*. (2006) initiated air layers that were left on parent trees for eight weeks and watered every two days to allow root initiation with the help of three concentrations (50, 100 and 150 mg/L) of IBA during February, June, September, and December: 50 mg/L IBA was optimum for root initiation and June to September was best for air layering with about 80% rooting success after potting plants in sand, forest soil and animal manure (2:1:1) and fertilizing with 5 g/container of NPK (nitrogen: phosphorus, potassium) fertilizer. Machua *et al*. (2008) achieved 60% rooting success through air layering.

Future perspectives

Tissue culture serves as one potential means of propagating and conserving *O. lanceolata* by drawing from experience on *S. album* (Kalabamu Xavery and Feyissa, 2015; Teixeira da Silva *et al*., 2016). Molecular markers can differentiate adulterants and distinguish among different sandalwood extracts (Bhat *et al*., 2006). Plants can accumulate heavy metals (Pb, Cu, and Zn) (Liu *et al*., 2008), suggesting that African sandalwood could be explored for phytoextraction or phytoremediation.

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