Common Antimalarial Trees and Shrubs of East Africa

A description of species and a guide to cultivation and conservation through use

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World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

The World Agroforestry Centre (ICRAF) is an autonomous, non-profit research organisation whose vision is a rural transformation in the developing world resulting in a massive increase in the use of trees in rural landscape by smallholder households for improved food security, nutrition, income, health, shelter, energy and environmental sustainability. The Centre generates science-based knowledge about the diverse roles that trees play in agricultural landscapes, and uses its research to advance policies and practices that benefit the poor and the environment. We are one of the 15 centres of the Consultative Group on International Agricultural Research (the CGIAR).

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The institute accomplishes its mandate through research centres that are intended to focus on certain specific areas of national and/or strategic importance. The centre that conducts research on herbal medicines is the Centre for Traditional Medicine and Drug Research (CTMDR). This centre studies the chemical composition, efficacy and safety of traditional medicines, and the socio-cultural and anthropological basis of the use of herbal remedies.

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Warning
This guide provides an overview of trees and shrubs used as antimalarial treatments. It is not a handbook for self-medication. The authors and publisher cannot be held responsible for the consequences arising from the incorrect identification or inappropriate use of a plant.

Cover photographs
Front cover (outer half circle): Azadirachta indica leaves; Erythrina abyssinica flowers; Cassia occidentalis leaves; Balanites aegyptiaca fruit; Erythrina abyssinica tree; Melia azedarach fruit.
Inner half circle: Warbugia ugandensis leaves; Artemisia annua leaves
Back cover: Seedling of Warbugia ugandensis

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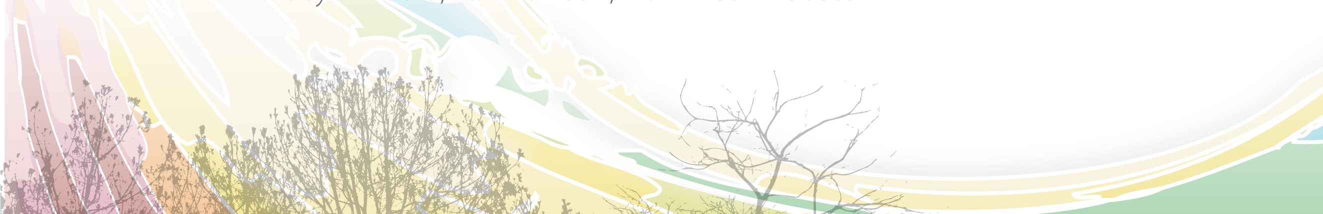

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Chapter 1




Introduction

1.1. The costs of malaria to African people

Malaria is a life-threatening disease caused by the *Plasmodium* parasite that is transmitted through the bites of infected mosquitoes. Around half of the world's population is at risk of malaria and there were around 240 million cases in 2008. Most cases (around 85%) and deaths (~ 90%) are in the low-income nations of sub-Saharan Africa (the five main contributors to global deaths are the Democratic Republic of Congo, Ethiopia, Nigeria, Tanzania and Uganda), although Asia, Latin America, the Middle East and parts of Europe are also affected. Malaria is the fifth highest cause of death from infectious diseases globally and second in Africa, after HIV/AIDS. In 2006, malaria was present in 109 countries and territories, and in the future coverage may expand further as climate change allows mosquitoes and the parasite to colonise new areas.

In 2008, malaria was estimated to have caused nearly nine hundred thousand deaths globally, mostly among African children. It is estimated that one child dies from malaria every 30 seconds, and in Africa it is the leading cause of under-five mortality. Pregnant women are also at high risk of malaria, with illness causing impaired foetal growth and high rates of miscarriage, and significant maternal deaths (up to 50% death rate in cases of severe disease), especially among HIV-infected women, as HIV/AIDS reduces immunity to malaria and results in higher treatment failure. Malaria during pregnancy often contributes to maternal anaemia, premature delivery and low birth weight, leading to increased child mortality.

The costs of malaria are not only high for peoples' health, but the disease also results in significant economic losses, with annual Gross Domestic Product (GDP) estimated to be reduced by as much as 1.3% in countries with high disease rates. In Africa it is estimated that at least USD 12 billion per year is lost directly through illness, treatment and premature death. Aggregated losses over time have resulted in substantial differences in GDP between countries with and without malaria, particularly in Africa. In some countries with a heavy disease burden, malaria accounts for up to 40% of public health expenditure, up to 50% of inpatient hospital admissions, and up to 60% of visits to outpatient health clinics. Malaria disease management is therefore an essential part of global health improvement and economic development.

1.2. Prevention and cure

Four species of *Plasmodium* cause malaria: *Plasmodium falciparum*, *P. vivax*, *P. malariae* and *P. ovale*. Of these, the most common are *P. falciparum* and *P. vivax*, and *P. falciparum* is the most deadly. Transmission of disease through mosquito bites depends on factors such as rainfall patterns (mosquitoes breed in wet conditions), how close breeding sites are to people, and the types of mosquito species in an area. Some regions have a fairly constant number of cases throughout the year ('malaria endemic' areas), while others have seasonal bouts of infection, usually coinciding with the rainy season.

Although malaria is a common disease it is both preventable and curable. Prevention focuses on reducing transmission through control of the malaria-bearing mosquito, primarily through the use of mosquito nets (treated with long-lasting insecticide) that offer overnight protection, and through indoor residual spraying of insecticides. Although in Africa, for example, more households now use nets than even a few years ago (31% of households in 2008 have at least one net, compared to 17% in 2006), overall coverage for the continent is still low. The percentage of children under five years old using a net in Africa was 24% in 2008, well below the World health Organization's target for the continent of 80%. The use of nets and indoor spraying as prevention interventions can be complemented by other vector control methods, such as the reduction of standing water where the mosquito breeds.

When malaria is contracted because prevention methods are not available or are not practiced effectively, the first symptoms of the disease – fever, headache, chills and vomiting – usually appear 10 to 15 days after infection. Treatment then needs to be prompt to minimise serious health risks and allow the majority of deaths to be avoided. Several prescription drugs have been and still are used for treatment, although resistances to some commonly used medicines have developed rapidly. In Africa, for example, *P. falciparum* has developed widespread resistance to conventional over-the-counter drugs such as chloroquine, sulfadoxine-pyrimethamine, amodiaquine and other relatively inexpensive treatment options.

In recent years, particularly for *P. falciparum* malaria, there has been an emphasis on the use of artemisinin-based medicines.

These are derived from the *Artemisia annua* shrub, although developing resistance to artemisinin monotherapies (confirmed in 2009) mean that use as single drug is not recommended. Instead, artemisinin-based combination therapies (ACTs, artemisinin taken together with other drugs) are advised. The use of ACTs can be extremely effective in treating malaria and has increased rapidly in recent years, but use remains very low in most of Africa. For example, fewer than 15% of under-five African children with fever received an ACT in a range of countries surveyed in 2007 and 2008, well below the World Health Organisation target for the continent of 80%.

1.3. Poverty, health care and traditional medicines

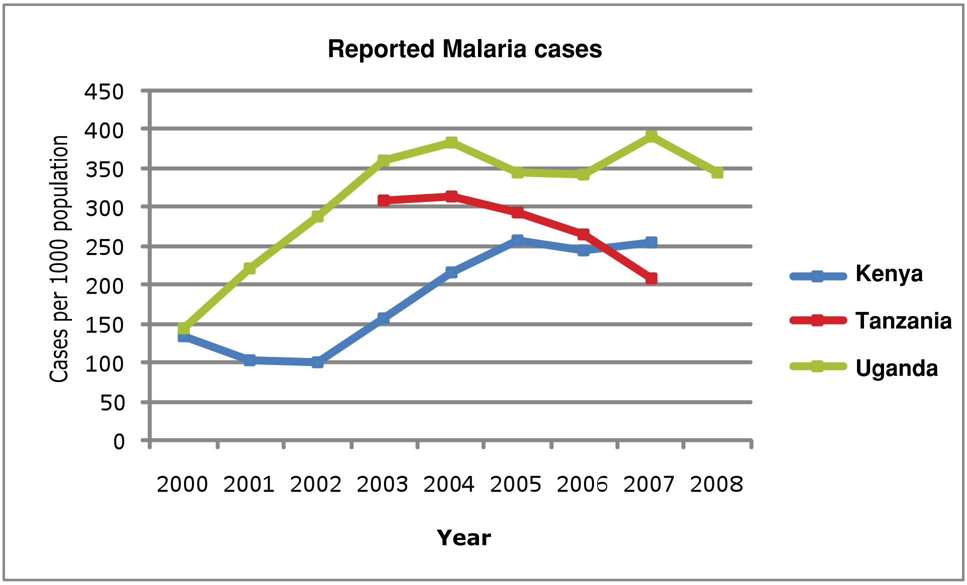
Disease disproportionately affects poor people who cannot afford treatment or who have limited access to health care facilities, and traps families and communities in a downward spiral of poor health and poverty. The high cost and limited availability of many medicines means that many populations in low-income nations often rely on traditional herbal remedies as the first line of treatment for malaria, perhaps in half or more of cases in some poor countries in sub-Saharan Africa. Medicinal plants have clearly played an important role in malarial treatment for centuries. Since at least the 15th century, local people in South America and then the Spanish (after their arrival) recognised the potency of the bark of the local *Cinchona ledgeriana* tree, which contains quinine, as an antimalarial. Various synthetic analogues of quinine have also since been developed for treatment. The use of artemisinin extracts from the *Artemisia annua* shrub – especially of artesunate, artemether and dihydroartemisinin – is another example of a traditional treatment (in this case used originally in China) that has become increasingly important worldwide in recent years (see above). The recent interest in *Artemisia annua*, developing drug resistances, and the limited access of poor communities to modern drugs, have stimulated renewed interest in the current use and future potential of other plant products in treating malaria, both as part of traditional health care practices and in developing new conventional medicines.

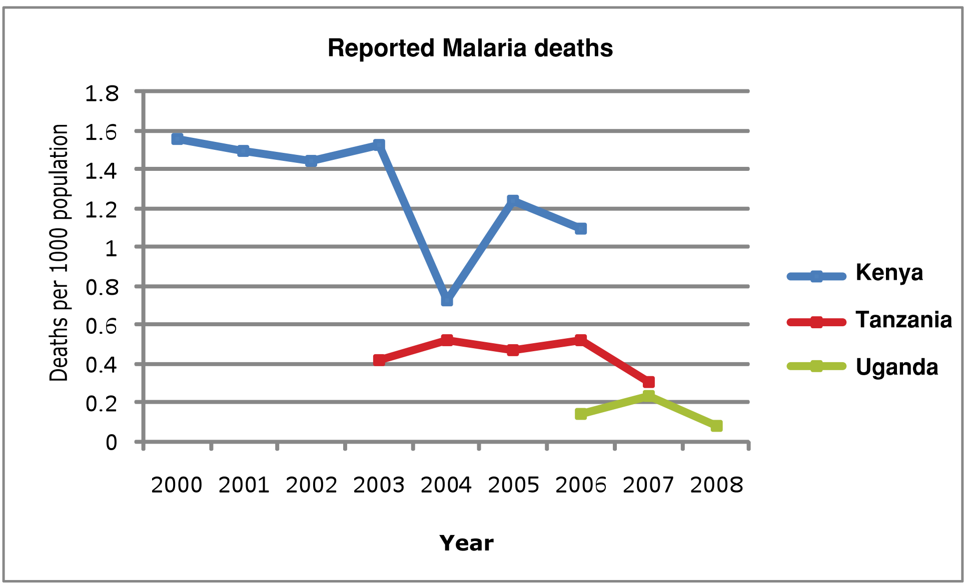
Over a thousand plant species are identified by traditional healers as effective in the prevention and/or treatment of one or more of the recognized symptoms of malaria, including the fruits, bark, roots and/or leaves of a wide range of trees and shrubs. These plants have traditionally been harvested from the wild but are now frequently subject to threat through declining wild habitats and over-harvesting; on the other hand, potential exists to cultivate species in farmland, raising and diversifying revenues for farmers as well as providing a supply of medicine to address health concerns. Work needs to be undertaken however on the efficacy of these plant treatments in order to identify which are truly effective, the active agents involved and where in the plant they are located, their safety, and the wider applicability of their use. Often, no consensus exists even among traditional healers on which plants, preparations and dosages are most appropriate, and the concentration of active components can vary depending on the source of the plant (which population material was collected from, and the conditions in which the plant grew). Traditional antimalarial medicinal plants are therefore being evaluated for their *in vitro* antiplasmodial activity and are being subject to toxicity tests, and several pharmacologically active antimalarial compounds have been isolated (see examples in the rest of this guide).

1.4. Antimalarial trees and shrubs in East Africa: the purpose of this guide

The purpose of this guide is to describe a range of trees and shrubs that are used as antimalarial treatments in East Africa. Malaria is a significant problem in the region, with 15 million cases reported in Kenya in 2006, 11 million cases in Tanzania over the same period and 12 million in Uganda in that year. At the same time, access to modern treatments for the disease is limited, with only around 8% of children under five years old that contracted malaria being treated with ACTs in Kenya in 2007. Similarly, only 22% of such children were treated with ACTs on the Tanzanian mainland in 2008, and only 3% of infected under fives received such treatment in Uganda in 2006 (data available for certain years only). Reported cases and deaths caused by malaria in these three countries are shown in the given graphs and indicate the serious extent of the disease.

The 22 tree and shrub species chosen for description here have been assigned by traditional medical practitioners, rural communities and scientists as among those that have potential for further study and development as crops by smallholders in East Africa, although this list should





Data taken from the World Malaria Report 2009, except for population data obtained from the United Nations Population Division. There are reporting differences across countries and by year within countries, which make close comparison difficult, and data are only available for certain years.

not be considered as exhaustive of all useful antimalarial plant species in the region. Extracts from a few of the species described in this guide (e.g., *Artemisia annua*, *Azadirachta indica* and *Warburgia ugandensis*) are already more widely used commercially for treatment (and/or prevention) of malaria, especially of course artemisinins.

We hope that the information provided in this guide will be useful for scientists in determining on what species to direct their research activities, and that it will support the further development of the cultivation of these trees and shrubs. This will contribute to the further use of these species, better health care in the region and higher revenues for growers, as well as improving the livelihoods of practitioners of traditional medicine. In addition, for species indigenous to East Africa, cultivation in farmland will support important efforts to conserve local biodiversity, which is currently under threat from deforestation and other challenges.

1.5. Challenges in the cultivation of antimalarial trees and shrubs

Apart from the challenges in verifying and quantifying the medicinal characteristics of species (see above), the cultivation of antimalarial trees and shrubs in smallholdings is subject to all the normal constraints faced by farmers in developing new and profitable businesses. These constraints include inadequate access to superior germplasm for planting (of high productivity and appropriate physiological quality, and that is easy to propagate), limited knowledge on appropriate methods for farm management (to maximise yield and quality, and minimise labour inputs) and the absence of well-functioning markets for products (efficient, reliable and transparent markets that favour producers rather than brokers, and provide opportunities for value addition through processing). Policies also need to be developed at national levels that provide more support for traditional medical practitioners and traditional medicine. Any programme to promote the cultivation of medicinal trees and shrubs must therefore consider these factors. ICRAF has produced a toolkit to help address the issue of planting material availability for farmers ('Tree Seeds for Farmers: a Toolkit and Reference Source') and this is available online (see www.worldagroforestry.org/af/resources/databases/tree-seeds-for-farmers). In addition, various resources are available on ICRAF's website on propagation and nursery management of trees and shrubs (see, e.g., 'Vegetative

Tree Propagation in Agroforestry: Training Guidelines and References', www.worldagroforestry.org/downloads/publications/PDFS/b14043.pdf).

The 'Gigiri Resolution' of the Africa Herbal Antimalaria Meeting held at ICRAF in 2006 identified the roles that different stakeholders should take in addressing various challenges to the wider production and use of herbal medicines. It called on international regulators to assist with the inclusion of herbals as approved treatments for malaria, on governments to accelerate policy reforms and establish appropriate regulatory and intellectual property frameworks for medicinal plants, on medical researchers to expand toxicological and clinical trials, on traditional healers to share knowledge to enable clinical trials to be designed, on botanists and biochemists to increase the screening and development of plants for antimalarial activity, on business partners to invest more in herbal antimalarial treatments, on existing malaria initiatives to share knowledge and partners more widely, and on donor agencies to increase financial support for the faster development of herbal antimalarial products (see www.worldagroforestry.org/treesandmarkets/antimalariameeting/proceedings/).

1.6. How this guide is structured

Section 2 is the main body of this guide and provides species descriptions of 22 trees and shrubs, listed in alphabetical order. For each species, included are photographs, common names, a description of the species and its ecology, its medicinal and other uses, and information on active chemical components. This is followed by information on how the species can be cultivated, including methods for propagation and management, where known. A list of references for further information is then given. At the end of Section 2, an index of common (English) names of species with page references is given, along with a table explaining the abbreviations used to refer to local languages in descriptions. For those with a wider interest in medicinal trees and shrubs for the treatment of a variety of ailments (not just malaria), general information on a greater range of species can be found in ICRAF's Agroforestree Database, which is available online (www.worldagroforestry.org/Sites/TreeDBS/aft.asp). For those wishing to source planting material of different medicinal trees and shrubs, please visit ICRAF's Tree Seed Suppliers Directory (www.worldagroforestry.org/Sites/TreeDBS/tssd/treessd.htm) to see if information on possible suppliers is given for species of interest.

Section 3 of this guide provides more detailed information on some of the compounds found in plants, such as alkaloids, terpenoids and flavanoids, which have antiplasmodial activity. It is intended for chemists and medical researchers that are interested in understanding the structure, function and efficacy of these compounds. Again, a series of references is given for further information.

1.7. General reading on malaria and medicinal plants

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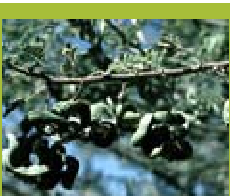
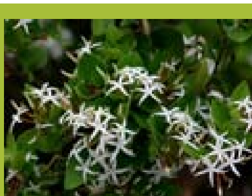
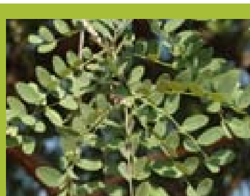
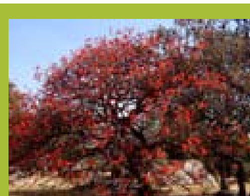
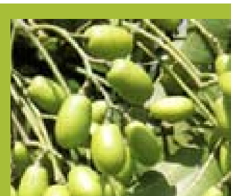
Chapter 2

Species description of antimalarial trees and shrubs

Plate 1: *Acacia mellifera* shrub

Plate 2: *Acacia mellifera* leaves

Plate 3: *Acacia mellifera* flowers

Plate 4: *Acacia mellifera* fruit

2.1 *Acacia mellifera* (Vahl.) Benth

MIMOSACEAE (Indigenous)

Common name: Wait-a-bit thorn.

Local name(s): Muthia (Kam), Muthigira (Kik), Eiti/Oiti (Maa), Kilawata/Kikwata (Swa), Mrugara (Suk), Mkambale (Gogo), Eregai (Ate), Magokwe (Lugi).

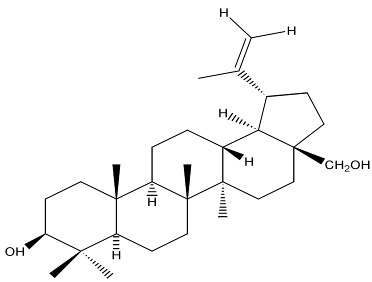
Botanical description and ecology:
Usually a low shrub, though sometimes up to 9 m tall. Bark pale grey-brown, smooth. Thorns distinctive, small to 6 mm long, hooked prickles, in pairs, grey with black tips. Leaves only 2 to 3 pairs of blue-green leaflets, each to 2 cm. Flowers white or creamy spikes to 4 cm, attracting bees. Fruit short and wide pods, tapering abruptly at both ends, flat, papery, pale brown-yellow, rarely to 8 cm long with prominent veins. A widely distributed acacia, widespread in all arid and semi-arid areas, may be dominant in dry *Acacia-Commiphora* bush land. It thrives in a variety of soils including rocky, loamy, volcanic and sandy conditions. Found growing between 300 m and 1,800 m in altitude.

Uses: Fuelwood, charcoal, timber, utensils (pestles), walking sticks, fodder (pods, twigs, leaves, flowers), bee forage, medicine, live fence, nitrogen fixing, soil conservation.

Traditional medicine: A decoction of the bark or leaves is administrated as a remedy for malaria, stomach ailments and pneumonia [1, 2].

Local languages codes are given in brackets; refer to Table 1 at the end of Section 2 for a key.

Active compounds reported and antiplasmodial activity: The methanolic extract and the lupane triterpene betulin, isolated from the stem bark, have shown considerable antimalarial activity *in vivo* [3, 4].



Betulin

Cultivation: Direct sowing of seed is possible, or seedlings can first be raised in nurseries before planting out. *Acacia mellifera* seed exhibit moderate physical dormancy, with only about 10% of fresh seed germinating without pre-treatment. Seed should be soaked in concentrated sulphuric acid for 5 to 15 min and then thoroughly rinsed in running water before sowing. Alternatively, boiling water can be poured over seed and then left to cool overnight, before planting the next day. Germination should be apparent after 5 days. Seed storage behaviour is orthodox and viability can be maintained for several years in sealed containers at 10°C, if seed moisture content is 6 to 9%. There are approximately 20,000 seed per kilo.

Young trees are subject to heavy browsing by stock and must be protected for the first two seasons. It does not coppice well. The species has a moderate growth rate of up to 50 cm per year. Flowering may start after 3 years and the period from flowering to mature fruit development takes 3 to 4 months.

Farmers leave remnants of the tree in farmland and some plant it. If left unmanaged, it can form dense thickets. No genetic improvement work has been undertaken.

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Plate 5: *Acacia tortilis* tree

Plate 6: *Acacia tortilis* fruit

Plate 7: *Acacia tortilis* flowers

2.2 *Acacia tortilis* (Forssk.) Hyne

MIMOSACEAE (Indigenous)

Common name: White-thorn.

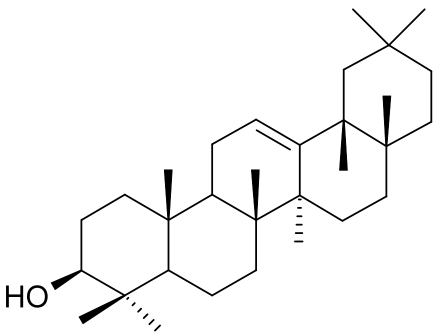
Local name(s): Kilaa/Moghaa (Kam), Oltepesi/Olgorete (Maa), Oldepesi/Olerai (Aru), Mrimba (Chag), Mgunga (Suk), Mgunga/Mugumba (Swa), Eoi (Ate-K), Etirr (Ate-T).

Botanical description and ecology: Medium- to large-sized tree, up to 20 m tall, with conspicuously flattened, spreading umbrella-shaped or sometimes rounded crown. Also sometimes grows as a small shrub or bush. Bark dark grey, longitudinally fissured. Pairs of small hooked thorns, also pairs of long white thorns to 8 cm, sometimes mixed pairs. Leaves compound, with 6 to 20 pairs, narrow and pale blue-green. Flowers white to cream heads, fragrant. Fruit greenish-yellow to yellow-brown pods, spirally twisted, sometimes in rings. Drought resistant, widespread in semi-arid savannah on river terraces, dry river courses and hillsides. Found at altitudes from sea level to 1,600 m.

Uses: Fuelwood, charcoal, timber, poles, edible pods, medicine, fodder (pods and leaves), bee forage, shade, ornamental, dune fixation, nitrogen fixing, soil conservation, fibre (strings from the bark), live fence, tannin, dye, thorn used as pins or needles, medicine (human and veterinary use).

Traditional medicine: A bark decoction is used as a treatment for malaria and stomach aches [1, 2]. Some tribes use the gum to make sweets which are given to women as a tonic after childbirth [1, 2].

Active compounds reported and antiplasmodial activity: The bark and leaves of *Acacia* species contain tannins. The bark contains benzenoids (e.g., catechol) [3], alkanols (e.g., octacosan-1-ol) [4] and triterpenes (e.g., b-amyrin) [5]. In an antiplasmodial assay no significant activity was observed for *Acacia tortilis* [6].



β-amyrin

Cultivation: To promote good germination, *Acacia tortilis* seed can be stood in concentrated sulphuric acid for 30 min and then rinsed well in running water. Alternatively, hot water (80ºC) can be poured over seed that is then left to cool overnight. Seed scarification is also an effective pre-sowing treatment. Bruchid infestation of seed can be a problem, which requires timely seed collection. Seed storage behaviour is orthodox and viability can be maintained for several years in sealed containers at 10ºC, if seed are dried to a moisture content of 5 to 9%. There are about 18,000 seed per kilo.

Planting can be carried out in pits dug to 60 cm that are filled with soil and spaced at 5 m by 5 m. Trees can grow to about 1.5 m height in 2 years, should initially be protected from grazing, should be weeded, and can be mulched. Two weedings in the 1st year and one in the 2nd year are considered sufficient.

Acacia tortilis responds vigorously to felling by producing numerous coppice shoots, provided there is no interference from browsing animals. For fodder use, a 10-year-old *A. tortilis* yields about 4 to 6 kg of dry leaf and 10 to 12 kg of pods per year. The tree develops a long lateral root system that can interfere with crop growth, and with paths and roadways.

There is some evidence of provenance variation in *A. tortilis*.

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Plate 8: *Albizia amara* leaves

Plate 9: *Albizia amara* bark

2.3 *Albizia amara* (Roxb.) Boiv.

MIMOSACEAE (Indigenous)

Common name: Bitter albizia.

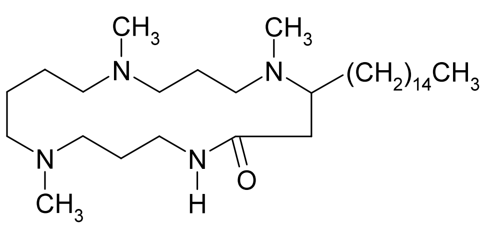
Local name(s): Ruga (Luo), Kiundwa/Mwowa (Kam), Gissrep (Som), Gotutwet (Tug), Muhogolo (Gogo), Mkengehovu (Lugu), Mpogolo/Mtangala (Nyam), Mufoghoo (Nyir), Msisiviri (Ran), Mpogolo (Suk).

Description and Ecology: A deciduous tree, often rounded or spreading crown, reaching 10 m in height but often smaller. Bark dark brown and roughly cracked. Leaves compound with numerous small leaflets, feathery. Leaves and twigs covered with distinctive soft, golden hairs. Numerous small creamy-white flowers crowded together at the ends of branches. The large pods are brown and papery, up to 20 cm by 3 cm. The species grows well at altitudes of 1,000 to 1,800 m. It is often found along dry river beds with an annual rainfall of at least 350 mm. It has a wide distribution in Africa, occurring from Sudan and Ethiopia southwards to Zimbabwe, Botswana and the Transvaal, growing mainly in sandy woodlands.

Uses: Timber for construction, farm implements, furniture, poles, fuelwood, charcoal; leaves serve as fodder and mulch; assists in soil conservation and nitrogen fixation; yields good quality resin, tannin and edible gum; bee forage and live fence.

Traditional medicine: Bark stem decoction taken three times a day serves as an emetic to induce vomiting and to treat malaria [1, 2]. Leaves are used in the treatment of wounds [1].

Active compounds reported and antiplasmodial activity: The seeds of *A. amara* contain spermine alkaloids referred to as budmunchiamines [1, 3, 5]. Some flavonoids (e.g., melacacidin) have been isolated from the heartwood [4]. Budmunchiamines (e.g., Budmunchiamine K) from other *Albizia* species have been shown to exhibit antiplasmodial activities [1,6].



Budmunchiamine K

Cultivation: *Albizia amara* can be propagated by direct sowing, through seedlings, cuttings and wildlings. Natural regeneration from seed is good in areas protected from fire and grazing. It grows very freely as coppice, producing a large number of shoots.

Seed pre-treatment involves immersion in boiling water for 5 min followed by soaking for 12 hours. Treated seed once sown will germinate within 7 to 10 days. Germination of around 80% can be expected. Seed is orthodox in character and can be stored for 2 years or more without losing viability appreciably. Seed can be stored in mud pots with wood ash or in sealed tins or gunny bags.

Seedlings planted in farmland can be spaced 9 to 10 m apart along contour lines. Young seedlings should be protected from fire and grazing livestock. Coppice can be thinned when 2 to 3 m tall a year after cutting, or when 5 to 8 m tall after three or four years of growth.

Albizia amara has been introduced into India and Indonesia. In Kenya, Tanzania and Uganda, the species is often incorporated into smallholding farming systems with corn, cassava, maize, beans and fruit trees, such as papaya, mango and orange.

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Plate 10: *Albizia gummifera* fruit

Plate 11: *Albizia gummifera* leaves

2.4 *Albizia gummifera* (J.F. Gmel) C.A.Sm
MIMOSACEAE (Indigenous)

Common name: Peacock flower.

Local name(s): Mwethia (Kam), Mukurwe (Kik), Mcani Mbao (Swa-Ken), Ol-osepakupes (Maa-Ken), Ekokwait (Tur), Sangupesi/Asangupesi (Aru), Mboromo/Mduka (Chag), Ol-geturai (Maa-Tan), Mkenge (Swa-Tan), Mshai (Samb), Chiruku/Kirongo (Lugi), Mushebeya (Ruki), Mulera/Mushebeya (Runyan), Mulongo (Ruto), Swessu (Seb).

Botanical description and ecology:
A large deciduous tree with flattened canopy, to around 15 m high and trunk up to 75 cm in diameter. Bark grey and smooth. Leaves compound with shiny, dark green leaflets up to 12 pairs. Flowers white-pink clusters, with long bright red stamens. Clusters of pods in bundles, thin, shiny brown, flat with raised edges, up to 20 cm long and 3 cm wide. A deciduous forest tree mainly found in East Africa, but also in the Democratic Republic of Congo, Madagascar and West Africa, occurring from dry or wet lowlands to upland forest edges, and also in riverine forest, at an altitude from sea level to 2400 m.

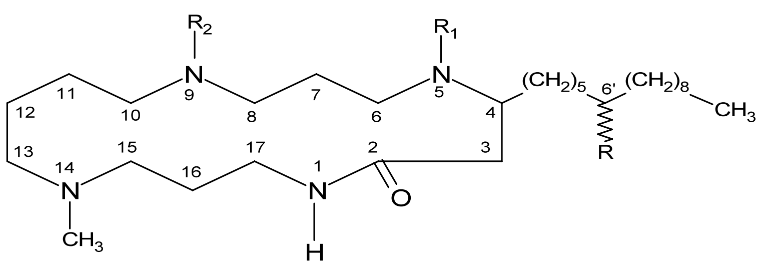
Uses: Timber, furniture, fencing, utensils, bee hives, fuelwood, boat building, medicine, fodder, bee forage, ornamental, mulch, nitrogen fixing and soil conservation. The leaves of *A. gummifera* quicken the ripening process in bananas.

Traditional medicine: Stem bark decoction is used to treat malaria and acts as an emetic [1]. An extract from the fresh crushed pods is taken for stomach pains, and roots are used to cure skin diseases such as acne, itching and eczema [2].

Active compounds reported and antiplasmodial activity: The stem bark of *A. gummifera* contains alkaloids such as budmunchiamine G [1,3] and oleanane and lupane triterpenes [4]. However, the main antiplasmodial compounds from *Albizia gummifera* are the spermine alkaloids shown below [1,5].

Cultivation: Direct sowing and use of nursery-raised seedlings as well as wildings are popular methods of propagation. Fresh seed need no pre-treatment but after storage seed should be soaked in warm water and left to cool overnight before planting. The seed coat may be nicked at the cotyledon end to hasten germination. Seed germination is generally good, 70 to 80% within 10 days.

Seed should be collected from the tree rather than the ground in order to minimise insect damage. Seed storage behaviour is orthodox and viability can be maintained for several years in sealed containers at 10^0C. Seed can be stored for at least a year at room temperature if it is kept dry and insect free through the addition of ash. There are 10,000 to 15,000 seed per kg.



	R	R_1	R_2
Budmunchiamine K	H	Me	Me
6-Hydroxybudmunchiamine K	OH	Me	Me
5-Normethylbudmunchiamine K	H	H	Me
6-Hydroxy-5-normethylbudmunchiamine K	OH	H	Me
9-Normethylbudmunchiamine K	H	Me	H

Seedlings should be planted out after they reach at least 50 cm in height. The size of holes used depends on the seedling size, but normally should be from 30 cm by 30 cm by 30 cm to 60 cm by 60 cm by 60 cm. Trees are lopped and coppiced while young to improve form.

The ability of *A. gummifera* to associate with crops is indicated by the tendency of farmers to leave the tree standing in cultivated fields. It is known as a good mulch tree in Kenya and is planted on boundaries and in fences.

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Plate 12: *Artemisia annua* shrub

Plate 13: *Artemisia annua* leaves

2.5 *Artemisia annua* L.

ASTERACEAE

Exotic: (Native to China and Vietnam)

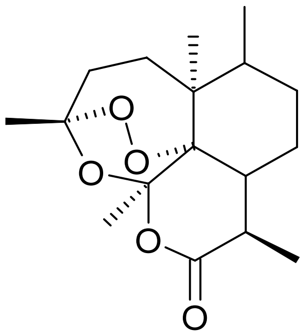
Common names: Sweet wormwood, Sweet annie.

Botanical description and ecology: A perennial woody herb or shrub, 0.7 to 2.5 m in height, many stemmed, aromatic. Leaves are soft, dark green, finely divided. Flowers are inconspicuous and borne along the branch ends, yellow and turn brown when old. Grows on well drained soils from 1,000 to 1,500 m altitude. Very common cultivated medicinal plant in Asia, Africa and elsewhere.

Uses: Used as hedge, medicinal.

Traditional medicine: Widely used antimalarial herb in Africa, can cure cerebral malaria [2, 3]. Decoction from the leaves is taken for gastrointestinal problems, indigestion, loss of appetite. It is very effective as a vermifuge (parasitic worm killer) and as an emetic [1, 2, 4].

Active compounds reported and antiplasmodial activity: The sesquiterpene artemisinin that is found in this plant is active against malaria [5]. Flavonoids, including quecetagetin 4'-methyl ether, have also been isolated from the plant. Some of these flavonoids markedly enhanced the antimalarial activity of artemisinin [5, 6].



Artemisinin

Cultivation: *Artemisia annua* has been cultivated in its native range for millennia. Seedlings are raised in the nursery before transplanting; direct seeding and cuttings are also used for commercial production. Seed are orthodox and can be successfully stored for 1 to 5 years at 4°C at a moisture content of between 7 and 9%. The species can be grown and propagated by micro-cuttings in a hormone free medium.

Cultivation of *A. annua* is presently the only commercially viable production method for active components, because the synthesis of these complex molecules is currently uneconomical. An alternative microbial-based system that synthesises an artemisinin precursor for chemical conversion is however in development. This will supplement but not replace agricultural production. There is an active selection and breeding programme for *A. annua*, including for hybrid lines with high artemisinin content, and for lines that do better in hot conditions.

Due to the low levels of artemisinin in leaves and inflorescences, large volumes of biomass are required. Plants can be spaced from 30 cm by 30 cm to 60 cm by 60 cm to achieve high biomass production. Leaves are harvested after 4 months. The plant has a short lifespan and dries out or dies after seeding, especially under hot growing conditions.

At a spacing of 30 cm by 60 cm, a yield of around 30 tonnes of leaf per ha has been recorded, producing 10 to 12 kg of oil per ha. The plant produces the maximum concentration of essential oil around the peak flowering stage. The most essential management task is weed control.

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Plate 14: *Azadirachta indica* leaves

Plate 15: *Azadirachta indica* flowers

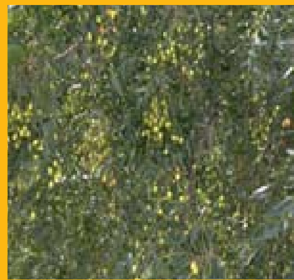


Plate 16: *Azadirachta indica* fruit

Plate 17: *Azadirachta indica* bark

2.6 *Azadirachta indica* Linn.

MELIACEAE

Exotic: (Native to India, Sri Lanka and Burma)

Common name: Neem.

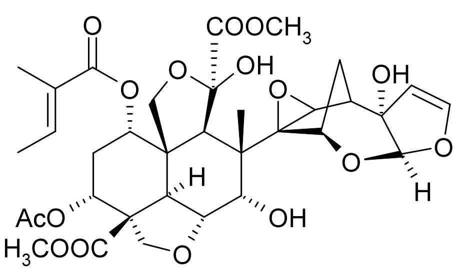
Local name: Mwarubaini (Swa).

Botanical description and ecology: A hardy, fast growing tree, up to 20 m in height, with dense, leafy, oval shaped canopy, evergreen except in the driest areas. Bark is rough, grooved, grey-brown. Leaves shiny green, compound with 5 to 8 pairs of leaflets up to 10 cm long, margin coarsely toothed. Flowers creamy white, small, sweet scented. Fruit oval, green berries at first, yellow when ripe, up to 2 cm across. Widely cultivated in Africa, Asia and elsewhere. Commonly found growing in arid and semi-arid regions; long grown at the East African coast and naturalised there; drought resistant and does well on poor soils. Grows at an altitude from sea level to 1500 m.

Uses: Timber, furniture, poles, utensils (pestles and mortars), fuelwood, charcoal, medicine, fodder, bee forage, shade, ornamental, soil improvement, windbreak, oil (seed), a powerful insect anti-feedant (azadirachtin from seed and leaves), soap manufacture.

Traditional medicine: Leaf decoction is used for the treatment of malaria [1, 2]. Aromatic neem oil features in the treatment of skin diseases such as leprosy, fungal infections and eczema [3]. Twigs contain antiseptic ingredients and are used as tooth brushes to help maintain healthy teeth and gums [3]. The bark, leaves and ripe fruit help in blood purification and are used as a remedy for intestinal worms [2, 4].

Active compounds reported and antiplasmodial activity: The insecticidal triterpenoids (e.g., azadiradione) and limonoids (e.g., azadirachtin) isolated from the seeds [3, 5] are also responsible for the antimalarial activity of the plant [6]. The plant also produces phenolics such as gallic acid and epicatechin which inhibit inflammation [6].The methanol and aqueous extracts of *A. indica* show good *in vivo* antiplasmodial activity [7]. The limonoid nimbolide isolated from *A. indica* shows very good antimalarial activity [3, 8].



Azadirachtin

Cultivation: Nursery seedlings are raised from seed, or neem is propagated vegetatively by air layering, cuttings, grafting and tissue culture. Direct sowing can be undertaken but may result in poor survival in drier zones. Neem wildlings are an inexpensive source of planting material, as natural regeneration is often abundant. Neem trees produce root suckers which mean that propagation is possible using root cuttings.

Although neem is a prolific seeder, seed availability is frequently a problem. The viability of fresh seed decreases rapidly two weeks after collection unless it is stored correctly; seed can be stored for up to four months if kept at 4°C. Ripe fruit should be collected from trees and processed immediately. The pulp should be removed and the seeds washed clean. Seed should be air dried for 3 to 7 days under shade, or until the moisture content is about 30%. If the moisture content falls below 15% seed will lose about 50% of its viability. Removal of the seed coat may increase germination rates after storage.

In nursery beds, seed should be sown in rows 15 to 25 cm apart with 2.5 to 5 cm spacing within rows. Seed should be sown at a depth of 1cm. Seedlings from fresh seed will emerge within 1 to 3 weeks. When two pairs of leaves have developed (1 to 2 months), within row spacing should be thinned to 15 cm. Alternatively, at this stage seedlings can be transplanted into bags or other containers.

Both bare-root and containerised seedlings should be raised under partial shade for the first 1to 2 months, or until about 30 cm tall, then gradually exposed to full sunlight. The roots and shoots of seedlings lifted from nursery beds should be pruned during transplanting. Seedlings can be field planted when they reach 30 to 50 cm.

Fuelwood plantations are laid out at 2.5 m by 2.5 m spacing and can later be thinned to 5 m by 5 m. The recommended spacing for windbreaks is 4 m by 2 m. When wishing to maximise fruit yield (fruiting begins after 4 to 5 years), trees should be more widely spaced in order to allow the crown to develop fully.

Young seedlings suffer from weed competition, but weed control is usually only needed during the first growing season. Neem seedlings should also be protected from fire, although mature trees can recover from fire damage. Once the root system is well established, growth is rapid for five years or so, before gradually slowing.

Neem responds well to coppicing and pollarding to produce poles, posts, or fuelwood. Coppicing to produce fuelwood is managed on a 7 to 8 year cycle. Pollarding is used to manage windbreaks and to produce posts. Wood yields vary greatly depending on site conditions, with a reported range of 6 to 57 cubic metres per ha per year.

Individual neem trees vary greatly in their morphology and perhaps in their chemical makeup. It is not yet understood whether these differences are based on genetic or environmental factors or both, although it is believed that drought stress has a dominant role. Genetic improvement through provenance selection and the vegetative propagation of elite clones has been initiated.

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Plate 18: *Balanites aegyptiaca* tree

Plate 19: *Balanites aegyptiaca* bark

Plate 20: *Balanites aegyptiaca* fruit

2.7 *Balanites aegyptiaca* (L.) Del.

BALANITACEAE (Indigenous)

Common name: Desert date.

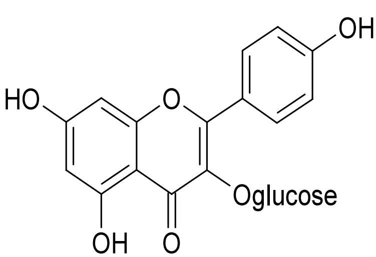
Local name(s): Mulului (Kam), Othoo (Luo), Olngoswa (Maa), Mjunju (Swa), Eroronyit (Tur), Mohoromo (Chag), Mkongo (Lugu), Myuguyugu, Nyuguyu (Suk), Echoma (Ate), Musongole (Lug), Zomai (Lugi), Mutete (Runy).

Botanical description and ecology: Evergreen shrub or tree, to 5 to 6 m high, with rounded crown and strong thorny branches. Bark smooth, green in young trees, dark and fissured when old. Leaves with distinctive pairs of grey-green, oval-shaped leaflets. Flowers yellow-green in clusters, fragrant. Fruit oblong, up to 5 cm long. Commonly found in dry bush land, wooded grassland or woodland; also grows along rivers. Found from 250 to 2,000 m in altitude.

Uses: Timber, poles, tool handles, utensils, furniture, fuelwood, charcoal, edible fruits, vegetable (leaves and young shoots), vegetable oil, edible gum, medicine, fodder (leaves, fruit), bee forage, shade (ceremonial meeting places), live fence, resin, mulch. An emulsion of fruit kills snails and fish.

Traditional medicine: An infusion of roots or bark is used as a remedy for malaria [1, 4]. An infusion of roots is used as an anthelmintic (i.e., to expel parasites) [2], purgative and to treat abdominal pains [3]. The fruit and seed are poisonous to fresh water snails and have been used for the treatment of bilharzia and as a purgative [3, 4].

Active compounds reported and antiplasmodial activity: Extracts of *B. aegyptiaca* have been reported to exhibit antiplasmodial activity [5, 6]. Several sapogenins and saponines such as diosgenin [4, 7] and cryptogenin [4, 8] have been isolated from *Balanites* species. In addition, the presence of flavonoids such as astragalin [4, 9] has been reported. The saponins furostanol and balanitesin are found in the fruit [10].



Astragalin

Cultivation: Seed may be collected directly from trees or from dung. Soaking seed in water for several hours and then stirring vigorously helps to separates the stones from the pulp. Germination can be improved by placing seed in boiling water for 7 to 10 min and then cooling slowly. The effect that passage of seed through an animal's intestinal tract has on germination is unclear. Seed behaviour is orthodox and viability is maintained for several years when seed is stored in cool conditions and if moisture content is 6 to 10%. Seed weight is from 500 to 1,500 seed per kilo.

Natural regeneration is primarily through seed, although high demand for fruit means in some locations few seed are available. The tree coppices successfully and can produce abundant root suckers. It also pollards well and can regenerate after lopping and heavy browsing.

For medicinal use, seedlings can be planted at a spacing of about 8 m by 8 m to allow crop growth underneath. Pollarding and coppicing are employed for obtaining fodder, but when fruit is the principal interest these practices are seldom employed.

Farmers in East Africa retain naturally regenerating individuals of *B. aegyptiaca* for shade and medicinal use. The species is being tested on farms in West Africa as a fruit (fresh and dried) for human consumption, and in Israel for its biodiesel potential. The best trees can yield large quantities of fruit and kernel oil content may be 45% or more (based on dry weight). The oil consists of four major fats: palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1) and linoleic acid (18:2). Linoleic acid is the most prevalent, ranging from 31% to 51% of total fats, which is very similar to the oil profile of soybean.

Favourable research results in Israel show that the species has further potential in East Africa for food oil and biodiesel production.

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Plate 21: *Carissa edulis* flowers

Plate 22: *Carissa edulis* fruit

2.8 *Carissa edulis* (Forssk.) Vahl

APOCYNACEAE (Indigenous)

Common names: Natal plum, Simple-spined Carissa.

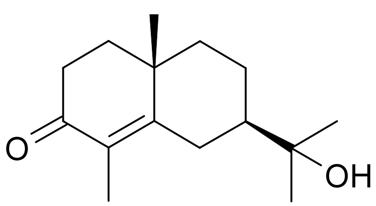
Local name(s): Mukawa (Kam, Kik), Ochuoga (Luo), Olamuriaki (Maa), Legetetuet (Nan), Mtanda-mboo (Swa), Manka (Chag), Muyanza/Muyonza (Haya), Mfubeli (Nyam), Mkabaku (Ran), Emuriai (Ate), Muyonza/Nyonza (Lug), Mutulituli (Ruki), Muyonza (Runy).

Botanical description and ecology:
A spiny evergreen shrub or a scrambling bush, growing to 5 m in height. Bark grey, smooth, with straight woody spines, sometimes forked up to 5 cm long. Leaves glossy green, base rounded and apex pointed. Flowers reddish pink outside, white inside when open, highly scented, in terminal clusters. Fruit round or ellipsoid up to 2 cm in diameter, green often tinged red or purple when ripening, turning dark purple (almost black) and glossy when ripe. Widespread in bush land and dry forest edges at altitudes from sea level to 2,000 m.

Uses: Fruit edible (ripe and unripe), flowers edible, flavouring (soup, stew), medicine (human and veterinary), fodder, bee forage, ornamental, dye (ripe fruit), live fence.

Traditional medicine: Root decoction is used to treat malaria [1], headaches and fever in children [2]. Ripe fruits used to treat dysentery and gastrointestinal problems [1, 3]. Decoction from the roots is used for treating chronic chest pains [1, 2], dysentery and diarrhoea.

Active compounds reported and antiplasmodial activity: Compounds isolated from the roots include benzenoids (e.g., 2-hydroxyacetophenone) [4] and sesquiterpenes (e.g., carissone) [1, 4]. In antiplasmodial assays, aqueous extract of root has shown very weak activity, while the methanol extract was inactive [5]. About 5% of the methanol extract from roots is made up of sesquiterpenes. Other compounds isolated for this plant include cryptomeridiol and β-eudesmol [6].



Carissone

Cultivation: *Carissa edulis* can be propagated from seed, which should germinate in 2 weeks or so. The species can also easily be propagated vegetatively, through cuttings, air layering, ground layering, and shield budding. Wildings collected from under parent bushes may also be used. Seed viability is high when fresh, but storage behaviour is recalcitrant. There are approximately 28,000 to 30,000 seed per kilo.

Carissa edulis is slow-growing but responds well to pruning. It is one of a number of thorny species that is planted to form dense hedges. It is used mainly for boundaries to household plots and for cattle enclosures on farms, and is very common throughout East Africa. Surveys of farmers indicate that food (fruit for local use and sale) and medicinal uses are important in the region.

Carissa edulis shows some variation in spine structure (some individuals have almost all spines forked), fruit shape (while some are almost spherical, others have a slightly pointed base) and leaf type (some are glabrous while others are hairy, while some conspicuously narrow towards the apex). Genetic variation in other traits also exists.

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Plate 23: *Cassia abbreviata* leaves

Plate 24: *Cassia abbreviata* fruit

2.9 *Cassia abbreviata* Oliv.

CAESALPINIACEAE (Indigenous)

Common name: Long pod cassia.

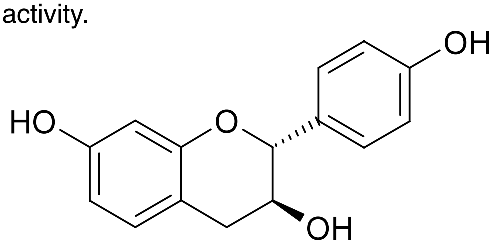
Local name(s): Mbaraka (Swa), Malandesi (Kam), Domader/ Domaderi/Rabuya (Som), Msoko/Mkangu (Tai), Mulimuli (Gogo, Hehe), Nundalunda (Suk).

Botanical description and ecology:
A shrub or small many branched tree, grows to 7 m in height, with a rounded crown. Bark reddish when young, becomes brown and cracked when old. Leaves compound, with 5 to 12 pairs of leaflets, each up to 6 cm long. Flowers yellow, in heads to 9 cm, usually seen on bare tree. Fruit brown-black pods, 30 to 90 cm long, thick, cylindrical, with many seeds. Commonly found in coastal areas and in dry thorn bush, especially in *Acacia-Commiphora* bush land, often in woodland or wooded grassland. Ranging in altitude from 50 to 1500 m.

Uses: Fuelwood, timber, construction poles, furniture, carving, medicine, ornamental, tannin.

Traditional medicine: A decoction of the root is used to treat malaria, pneumonia and other chest complaints [1, 2]. Leaf, root or stem bark infusions are used in the treatment of stomach disorders [3].

Active compounds reported and antiplasmodial activity: Flavonoids in the bark *of Cassia abbreviata* include (2*R*, 3*S*)-guibourtinidiol [2, 4]. The dried leaves and dried roots show antimalarial activity against multi-drug resistant *Plasmodium falciparum* [5]. No specific compound has been associated with antiplasmodial activity.



(2R, 3S)-guibourtinidiol

Cultivation: Seed are orthodox and can be stored successfully for over a year if at 6 to 8% moisture content. Pouring hot water (80°C) over seed and allowing to cool overnight improves germination. Seed should germinate 4 to 10 days after sowing.

Seed should be sown in a sand: compost mixture (1:1) and kept warm and moist. It is best to plant seed in pots rather than in nursery beds, because of a long tap root that develops early and that can make transplanting difficult. Root pruning of potted seedlings may be necessary.

Seedlings grow quickly and need to be kept in the nursery for only a few months before planting out. A spacing of 6m by 6m allows cultivation with crops in farmland. Pollarding, coppicing, trimming and pruning are recommended management strategies.

Over-watering of the species can result in poor flower display. Little or no genetic improvement of the species has been carried out to date.

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Plate 25: *Cassia occidentalis* leaves and fruit

Plate 26: *Cassia occidentalis* leaves and flowers

2.10 *Cassia occidentalis* L.

CAESALPINIACEAE (Indigenous)

Common name: Stinking Weed.

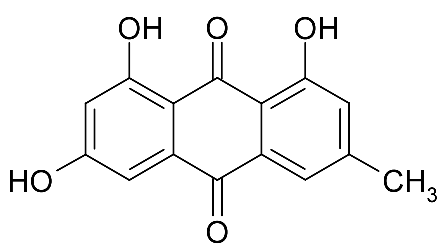
Local name(s): Mwengajini (Swa), Segusse (Suk), Imindi (Luny).

Botanical description and ecology: An erect herb, sometimes slightly woody shrub, up to 2 m tall. Stem greyish–black, slightly hairy. Leaves with 3 to 6 pairs of leaflets, ovate–elliptic or sometimes lanceolate, non-hairy, 5 to 10 cm long. Flowers yellow, in short racemes from upper axils. Seed pods narrow and semi-flattened. Found in grassland and on lake shores, at altitudes from sea level to 1800 m.

Uses: Medicinal use for humans, hedges, ornamental.

Traditional medicine: Leaf decoction is used for the treatment of fever. The dried entire plant is used as a diuretic and treatment against intestinal parasites [1]. Fresh leaves can be applied directly as poultices on the affected part of the skin for the treatment of fungal diseases, inflammation and swellings, bruises, furuncles and sprains [1, 2]. An infusion of the roots is used to treat malaria, kidney disease, fatigue, indigestion, colic and stomach ache [1, 3].

Active compounds reported and antiplasmodial activity: The ethanol, dichloromethane and lyophilized aqueous extracts of root bark show antimalarial activity [4]. Ethanol and dichloromethane extracts from leaves show antiplasmodial activity [5]. Terpenoids, flavonoids and anthraquinone derivatives have been detected in active fractions obtained from the leaf extract [5]. In a separate investigation, new *C*-glycosidic flavonoids (cassiaoccidentalins A, B and C) were isolated from the plant [6]. A biologically active component was isolated and identified as emodin by spectroscopic analysis [1, 7, 8].



Emodin

Cultivation: *Cassia occidentalis* can flower and fruit throughout the year or only periodically, depending on rainfall and temperature conditions and seasons. In seasonally cold or dry climates, the life cycle of *C. occidentalis* is complete in 6 to 9 months. In warm, continually moist areas, however, plants may last a full year and possibly grow through a 2nd year, exceptionally through 3rd and 4th years.

Well-dried seed stored in airtight containers remain viable for more than three years. There are around 60,000 seed per kilo. Seed should be treated to enhance germination. The distal end of each seed should be nipped, or the seed can be immersed in concentrated sulphuric acid for 10 min and then rinsed with plenty of water. Alternatively, seed can be immersed in warm water (80°C) that is then allowed to cool overnight to give 80 to 100 percent germination. Seed should germinate between 5 and 36 days after sowing.

Cassia occidentalis is planted in hedges and as an ornamental, but has the potential to become a weed in farmland, and is often found in disturbed areas. It should therefore be managed carefully. The species can be controlled with broadleaf herbicides.

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Plate 27: *Ekebergia capensis* tree

Plate 28: *Ekebergia capensis* fruit

Plate 29: *Ekebergia capensis* bark

2.11 *Ekebergia capensis* Sparm.

MELIACEAE (Indigenous)

Common names: Ekebergia, Dogplum

Local name(s): Mukongu (Kam), Mununga (Kik), Manuki-masi (Tai), Ol-subukiai (Maa-Ken), Tido (Luo), Mfuare/Msisi (Chag), Mvumba (Gogo), Musimbi (Haya), Osongoroi (Maa-Tan), Mnu/Mtarima (Ran), Umuyagu (Zin), Musalamumali (Lugi), Mufumba (Ruki).

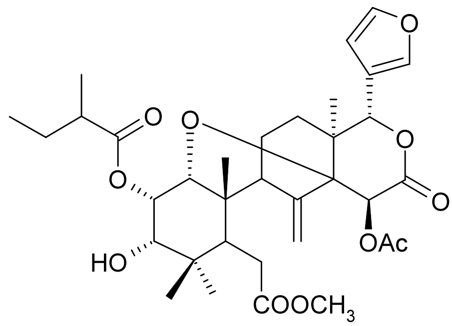
Botanical description and ecology:

A semi-deciduous tree to 30 m tall, with a large spreading crown. Bark grey-brown and rough with age. Leaves compound, up to 30 cm long, crowded at the ends of branches, leaflets thin, up to 5 pairs, with terminal leaflet. Flowers small, white tinged with pink, in loose sprays, up to 8 cm, sweet scented. Fruit rounded, 1 to 2 cm long, fleshy, orange-red. Found in a variety of habitats from lowland scrub, woodland, wooded grassland to highland forest; more common in dry forest than moist forest; seen growing at forest edges; from coast to 2600 m in altitude. In scrubland it may be stunted or gnarled. Considered to be a threatened species in Uganda and is a protected tree in South Africa.

Uses: Timber for construction, fuelwood, charcoal, furniture, poles, tool handles, medicine, bee forage, shade, ornamental, windbreak and erosion control.

Traditional medicine: Leaf decoction is used as a vermifuge [1, 2]; bark and root decoction is used to cure dysentery, malarial fever and as an emetic. A root infusion is used for chronic coughs, dysentery and scabies [1, 2, 3].

Active compounds reported and antiplasmodial activity: Seed of *E. capensis* yielded a limonoid called ekebergin [1, 4, 5]. Limonoids are known for their high antiplasmodial activity. Organic and aqueous extracts show good antiplasmodial activity [5, 6]. Twenty seven triterpenes were isolated from the stem bark of *E. capensis*, including 10 newly identified compounds. In an *in vitro* antiplasmodial assay against *Plasmodium falciparum*, these compounds showed activity with 7-deacetoxy-7-oxogedunin and 2-hydroxymethyl-2,3,22,23-tetrahydroxy-2,6,10,15,19,23-hexamethyl-6,10,14,18-tetracosatetraene being the most active, with IC_{50} values of 6 and 7 μM, respectively. 7-Deacetoxy-7-oxogedunin at a dose of 500 mg/kg showed moderate parasitemia suppression of 53% against *P. berghei* NK 65 in a mouse model [7].



Ekebergin

Cultivation: Trees can be propagated from wildings, cuttings or fresh seed. Seed do not require pre-treatment, although the fleshy part of the fruit should be removed. Seed can take 8 to 9 weeks to germinate. Seed can be collected from the ground around trees or, better (up to 90% germination), by picking ripe fruit directly from trees. Seed storage behaviour is uncertain, although germination drops after 9 months storage at 4°C. There are 2900 to 8600 seed per kilo.

Seed can be sown in flat seedling trays filled with a mixture of river sand and compost (5: 2), covered with sand not deeper than 5 mm and kept moist. Seedlings should be planted out when they are 10 to 15 cm tall.

Young trees should be protected from animals for the first two years. Trees can grow quickly, at a rate of up to 1 m per year. The species responds well to watering. Trees may be planted with coffee, maize, beans, bananas and other crops. *Ekebergia capensis* can tolerate some drought and light frost but is tender to severe frost.

The lowland type is inferior in growth and will not yield timber, but can be useful for medicinal purposes.

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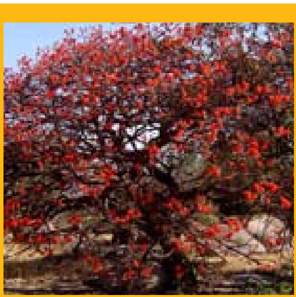


Plate 30: *Erythrina abyssinica* tree

Plate 31: *Erythrina abyssinica* bark

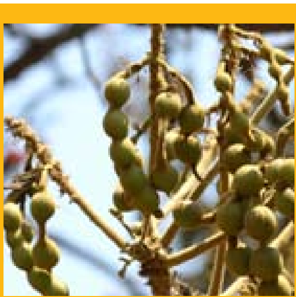


Plate 32: *Erythrina abyssinica* fruit

Plate 33: *Erythrina abyssinica* flowers

2.12 *Erythrina abyssinica* DC.

PAPILIONACEAE (Indigenous)

Common names: Flame tree, Lucky bean tree, Red hot poker tree.

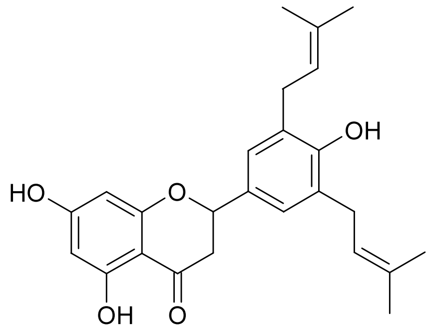
Local name(s): Muvuti (Kam), Muthuti (Kik), Olepangi (Maa-Ken), Muuti (Mer), Mwamba-ngoma (Swa-Ken), Miriri (Chag), Ol-ngaboli (Maa-Tan), Mkalalwanhuba/Pilipili (Suk), Mjafari (Swa-Tan), Muyirikiti (Lug), Oluo/Olugo (Lugb), Cheroguru (Lugi).

Botanical description and ecology:
A deciduous tree with a short trunk and thick spreading branches and rounded crown, to 12 m in height. Bark yellowish brown, thick, corky and fissured, with or without woody spines. Leaves compound, with three leaflets, broadly ovate. Flowers orange-red heads. Fruit woody pods, straight or curved, up to 10 cm long with bright red seeds with a black patch. Found throughout East Africa, commonly occurring in open savannah woodland, grassland and scrubland; not found in very dry areas; altitude ranges from sea level to 2000 m.

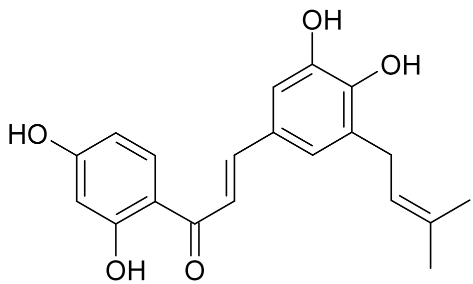
Uses: Timber to make doors, furniture (stools), beehives, carvings, utensils (mortars, drums), fuelwood, medicine (human and veterinary use), bee forage, ornamental, mulch, soil fertility improvement and soil conservation.

Traditional medicine: Root and stem bark decoction is used to treat malaria and syphilis [1, 2, 3]. In paste form, powdered bark is applied to burns and is used for general body swellings, rheumatism and arthritis [2, 3]. Extract of the dried leaves in water is used for the treatment of leprosy (applied externally) [3, 4] and fever (taken orally) [5].

Active compounds reported and antiplasmodial activity: Several tetracyclic isoquinoline alkaloids (known as Erythrinan alkaloids) have been reported from the seed, roots and flowers of *Erythrina* species [6, 7]. Typical compounds isolated from the roots of *E. abyssinica* are flavanones (e.g., abyssinone IV) and pterocarpans (e.g., phaseollin) [8]. The stem bark also contains flavanones such as 5-deoxyabyssinin II [3, 9]. The ethyl acetate extract of stem bark shows antiplasmodial activity: a new chalcone (5-prenylbutein) and a new flavanone (5-deoxyabyssinin II) are among the antiplasmodial principles [9]. The crude extract of the roots is more potent, with the flavanones abyssinone IV and V being the most active [10].



Abyssinone IV



5-prenylbutein

Cultivation: *Erythrina abyssinica* grows easily from truncheons (2.5 m long and 8 to 10 cm in diameter) that are stripped of leaves and are planted at the onset of the rainy season. Propagation may also be carried out by direct sowing, by raising potted or bare-rooted nursery seedlings, and from cuttings. Seed may be stored for long periods without losing viability if kept cool, dry and insect free. Seed that have been damaged by insects should be discarded. On average, there are around 6,800 seed per kilo.

Seed have a hard coat that should be scarified before germination in order to allow moisture to penetrate. This will lead to more uniform germination of a seed lot. Seed can be scarified by rubbing with sandpaper or nicking the distal end of each seed. Seed should be immersed in cold water for 24 to 48 hrs after scarification, until they begin to swell. Alternatively, pour warm water over scarified seed and stand for 12 hours.

Immediately before planting, seed should be inoculated with rhizobium bacteria to ensure nodulation and nitrogen fixation. Seed can be germinated in trays or may be sown directly into nursery beds or pots, using a mixture of soil, sand and compost (in a ratio of 2: 1: 1). Seed should be sown just below the surface, with the hilum facing downward. Nursery-grown plants are ready for transplanting when 20 to 30 cm tall. If using bare-rooted seedlings that have been raised in nursery beds, all leaves should be removed before planting.

Growth of the species is slow. Pollarding and coppicing are suitable treatments, although trees should not be pruned until they are one year old. Frequent pruning reduces competition with crops and increases the ratio of leaves to stems, but increases labour costs. It may be advisable to grow the tree with shade-tolerant crops, rather than imposing a severe pruning regime. With its soft wood, the species is somewhat easier to prune than other species used in alley farming. In Kenya, the species is often used to make cattle enclosures, and living fences are established from cuttings.

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Plate 34: *Harrisonia abyssinica* shrub

Plate 35: *Harrisonia abyssinica* unripe and ripe fruit

2.13 *Harrisonia abyssinica* Oliv.

RUTACEAE (Indigenous)

Common name: Hook-thorn.

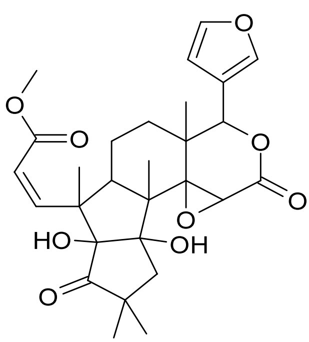
Local name(s): Mulilyyulu (Kam), Pedo/Omindi (Luo), Mkidunya (Luh), Mukurkona (Pok), Msamburini (Swa), Ekalale (Tur).

Botanical description and ecology:
Evergreen shrub or tree (sometimes climbing), to 6 m tall. Bark with conical corky bosses to 2 cm, rarely unarmed; branches with straight or curved spines to 8 mm, usually in pairs. Leaflets 7 to 15, apex slightly pointed or rounded. Flowers are cream or yellow, in 5 to 15 cm long panicles. Fruit red, a round berry. It is commonly found growing in riverine vegetation, in dry bush land and wooded grassland; also on coastal forest margins. Altitude from coast to 1600 m. The species is threatened due to over-exploitation as a medicinal plant in some areas.

Uses: Bee forage, shade, ornamental, live fence, dry fencing (withies) and medicine (human and veterinary use).

Traditional medicine: Root and bark decoctions are used for the treatment of malaria, abdominal pain, haemorrhoids and snake bites [1, 2]. Leaf extract alone or together with roots is used to treat snakebites [3]. A decoction of young leaves is drunk as an aphrodisiac, while a decoction of old leaves is drunk for women's abdominal pains during menstruation [1, 4].

Active compounds reported and antiplasmodial activity: Terpenoids (e.g. harrisonin) have been isolated from the root bark [1, 5]. Compounds such as harrisonin are known to exhibit antiplasmodial activities. Other isolates include prenylated polyketids [6] and a new cyclotriterpene [7], both from stem bark. Methanolic extracts show antiplasmodial activity [8].



Harrisonin

Cultivation: Can be propagated through nursery seedlings or root suckers. Fresh seed germinate best and seed cannot be stored for long periods. Fruit are red to black when ripe, with 4 to 8 seeds.

Harrisonia abyssinica is a fairly fast growing shrub with potential as a shade. The main stem is initially weak and sticks are used to support the plant until it can stand on its own. Lower branches should be pruned regularly. The plant coppices very easily.

A number of herbal practitioners in Eastern Kenya cultivate the species around their homesteads to ensure availability. This prevents them from having to travel significant distances to find it.

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Plate 36: *Melia azedarach* tree


Plate 37: *Melia azedarach* flowers


Plate 38: *Melia azedarach* fruit


Plate 39: *Melia azedarach* bark

2.14 *Melia azedarach* L.

MELIACEAE

Exotic: (Native to Asia and Australia)

Common names: Indian lilac, Persian lilac.

Local name(s): Dwele (Luo), Mmelia/Mwarubaini nusu (Swa), Lira (Lug, Lugb).

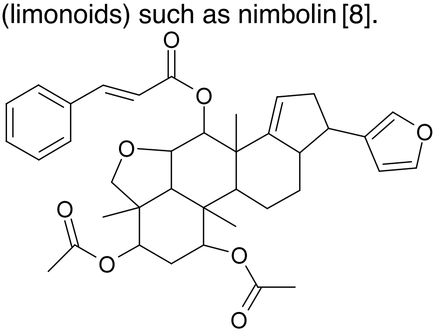
Botanical description and ecology:

A tree that can reach 40 m in height, with sparsely branched limbs and a spreading crown. Bark grey, smooth when young, rough and brown when older. Leaves compound with 3 to 9 leaflets, narrow, wavy margins and pointed tips. Flowers small, fragrant, pale lilac, in profuse rounded clusters, each with a dark purple staminal tube. Fruit yellow-orange berries, fleshy, oval shaped, to 1.5 cm in diameter. Can grows in acidic and saline conditions, at an altitude from sea level to 2000 m. Native to India but now grown in many warmer parts of the world. In several exotic locations it has become naturalised.

Uses: Fuelwood, timber, furniture, poles, posts, tool handles, medicine, bee forage, shade, ornamental, beads (seed).

Traditional medicine: An infusion of powdered leaves, root or stem bark is used to treat malaria and to expel parasitic worms [1, 2, 3]. Oil from the seed is used to treat skin rashes and itching [1, 3]. Leaves are used to cure infected wounds. Bark decoction is used as a remedy for fever, aches and pains [1, 3, 4].

Active compounds reported and antiplasmodial activity: Contains triterpenoids (e.g., amoorastatone) [3, 5] and quinoids (e.g., 1-8-dihydroxy-2-methyanthraquinone) in stem bark [6], and flavones (e.g., apigenin-5-*O*-b-D-galactoside) in roots [3, 7]. The main antiplasmodial agents are tetranoterpenoids (limonoids) such as nimbolin [8].



Nimbolin

Cultivation: The berries are poisonous to humans, livestock and poultry if large amounts are ingested. Fruit drop is limited, with ripe fruit clinging to the branches of the tree for several months, even after leaves have fallen. Propagation is by direct sowing or planting out of seedlings. For fresh seed, 85% germination may be expected 3 weeks after planting. Seed storage behaviour is recalcitrant, although seed can be stored in a well ventilated, shaded area at room temperature for at least two weeks. On average, there are 5,000 seed per kilo.

Excellent coppice can be obtained from cut trees and the species pollards well, making it suitable for pole production. Under optimal conditions, *M. azedarach* grows quickly. It is generally deciduous, but some forms in the humid tropics (e.g. in Malaysia and Tonga) are evergreen.

Research is currently being undertaken on grafting *Azadirachta indica* (neem, see Section 2.6) scions onto *Melia azedarach* rootstocks. The grafted tree could combine both the good characteristics of *A. indica* (superior medicinal properties) and *M. azedarach* (good timber and fast growth).

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Plate 40: *Ocotea usambarensis* tree

Plate 41: *Ocotea usambarensis* flowers and leaves

2.15 *Ocotea usambarensis* Engl.

LAURACEAE (Indigenous)

Common names: Camphor tree, East African Camphor-wood.

Local name(s): Muthaiti (Kik), Muura (Mer), Miseri/Muwong (Chag), Muheti (Hehe), Msibisibi (Nyak), Mwiha (Ruki).

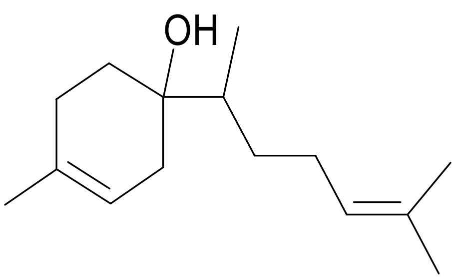
Botanical description and ecology:

A large, majestic, evergreen timber tree with a massive trunk, up to 3 m diameter, with a spreading crown. The mature tree may reach to 45 m in height. Young trees are green-grey with a conical shape. Bark reddish brown, granular, scaly or flaky. Leaves are oval to rounded, up to 8 cm long. Flowers separate male and female, small, greenish-white. Fruits smooth and green, oval shaped, very small, to 6 mm diameter. Grows in wet montane forest (1,600 to 2,600 m). It is found mainly in Kenya and Tanzania and sparsely in Uganda. Rare in many areas where was once common, due to over-exploitation (for timber).

Uses: Timber (joinery), poles, veneer, plywood, panelling, fuelwood, charcoal, medicine.

Traditional medicine: Root infusion taken as a remedy for backache and also to treat malaria. Powdered bark is used as a dressing for wounds and to cure abscesses [1, 2].

Active compounds reported and antiplasmodial activity: Both organic and water extracts of bark of *O. usambarensis* are reported to exhibit antiplasmodial activity [3]. The bark is rich in volatile compounds such as monoterpenoids (e.g., b-pinene) and sesquiterpenes (e.g., b-bisabolol) [1, 4]. However, none of these compounds have been associated with the medicinal properties of the tree.



β-bisabolol

Cultivation: The tree seeds only once every 8 to 10 years and most seed drops while immature due to attack by gall-insects and birds [5]. Seed are sensitive to desiccation and should be sown when fresh. If necessary, however, seed can be stored in containers with moist sawdust for a few days. On average, there are between 1,500 and 2,000 seed per kilo. The expected germination rate of mature, healthy and properly handled seed is 45%. Pre-treatment is not necessary. Under ideal conditions, seed germinate in 30 to 45 days. Regeneration by root suckers is also possible, as the tree develops suckers easily after felling. Propagation through cuttings is currently the subject of research.

Since the tree has a large crown, it may interfere with some light-requiring crops. Rotation length for timber production is between 60 and 75 years. Most trees found on farms are either forest remnants or from naturally dispersed wildings.

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Plate 42: *Olea africana* leaves and flowers

Plate 43: *Olea africana* bark

2.16 *Olea europaea* L. subsp. *africana* Mill.

OLEACEAE (Indigenous)

Common name: African wild olive.

Local name(s): Muthata (Kam, Mer), Mutamaiyu (Kik), Ol-orien (Maa), Tamiyai (Sam), Mlamuru/Msenefu (Chag), Murama (Runyan), Muhagati (Zig).

Botanical description and ecology:

An evergreen tree to 15 m in height, with a rounded crown. Bark grey-brown and rough, longitudinally fissured. Leaves stiff, narrowly oval and sharply pointed with prominent midrib. Flowers small, white to cream. Fruit purple, fleshy, oval to 1 cm long. Widely distributed in dry upland evergreen forest and on forest margins, often associated with *Juniperus procera*. Found at altitudes of 750 to 3,000 m above sea level. Over-exploitation (for timber) has made the tree rare in parts of its range.

Uses:

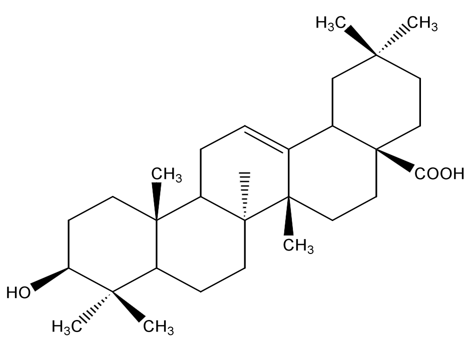
Timber (house construction), furniture, flooring, panelling, carvings, utensils, walking sticks, fuelwood, charcoal, seasoning, edible fruit, soup, bee forage, shade, ornamental, wind break, ceremonial, toothbrushes, medicine.

Traditional medicine: Root, bark or leaf decoction is used to treat malaria and other fevers [1, 2]. Bark decoction helps in the healing of skin rashes and other irritations, and is also used as a laxative and as an anthelmintic (i.e., to expel parasites), especially as a remedy for tapeworms [2].

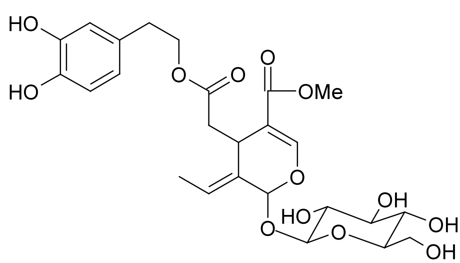
Active compounds reported and antiplasmodial activity: The organic extracts from the leaves of *O. europaea* have been shown to exhibit significant antiplasmodial activity [3]. The leaves contain the triterpenes oleanolic acid and ursonic acid [2, 4, 5]. Leaves also contain several other secoiridoids, terpenoids (e.g., oleuropein) and flavonoids [6]. Africanol, olivil and 8-hydroxypinoresinol derivatives have also been isolated from the bark of *Olea* [7]. It is not clear which compound or mix of compounds provides the medicinal properties reported.

Cultivation: Orthodox seed storage behaviour means that viability can be maintained for several years in hermetic storage at 4°C and with a seed moisture content of 6 to 10%. There are approximately 14,000 seed per kilo. The germination of seed is greatly enhanced by removing the endocarp, germination then reaching up to 92% in seed stored for 18 months. The endocarp imposes a mechanical constraint to germination rather than a chemical one. Cracking with a hand vice or rolling a stone over seed can cause the endocarp to break along or across its suture line. Cuttings root fairly easily; rooting and the growth of new leaves are strongly influenced by the nutrient status of the parent plant and by the application of rooting hormone to the base of cuttings.

The use of fertiliser with adequate watering results in greatly increased shoot growth, but little change in root growth. This can result



Oleanolic acid



Oleuropein

in fertilised seedlings being less tolerant to drought. Fertilisation and irrigation need to be carefully managed to ensure optimum growth and survival.

Spacing on farm can be 6 m by 6m for medicinal use, but trees should later be thinned to a spacing of 10 m by 10m to provide good timber. Farmers indicate the tree as a priority for planting for timber production, although access to planting material is a constraint to cultivation.

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Plate 44: *Trichilia emetica* flowers

Plate 45: *Trichilia emetica* leaves

2.17 *Trichilia emetica* Vahl.

MELIACEAE (Indigenous)

Common name: Cape mahogany.

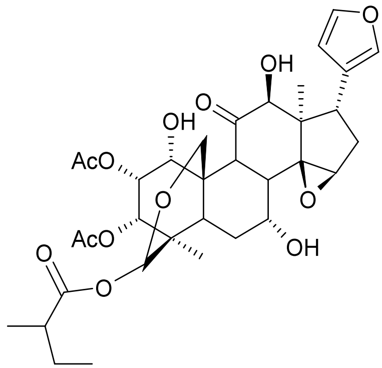
Local name(s): Mururi (Kik), Musambo (Kam), Ochond-Rateng' (Luo), Muwamaji (Swa-Ken), Mchengo/Mututu (Chag), Mtengotengo (Lugu), Sungute (Suk), Mkungwina/Mtimaji (Swa-Tan), Sekoba (Lug).

Botanical description and ecology:
A large evergreen tree, growing to 30 m in height, with dark hanging foliage, pyramid shaped when young, rounded when old. Bark grey-red-brown, finely grooved, rough and scaly with age. Leaves compound, brownish green to pale brown, with 3 to 5 pairs of leaflets, crowded towards the ends of branches and twigs. Flowers in inconspicuous clusters, creamish-white, sweet-scented. Fruit round, red-brown hairy capsules. Commonly found growing in savannah, often by rivers. It prefers well-drained, rich alluvial or sandy soils and high ground water. Found throughout East Africa at altitudes from sea level to 1,800 m.

Uses: Furniture, poles, posts, tool handles, carvings, boat building, fuelwood, medicine (both human and veterinary use), fodder, bee forage, shade, ornamental, soil conservation, windbreak, oil (seed), soap (seed and leaves).

Traditional medicine: An infusion of the roots, stem bark or leaves is used to cure malaria [1, 2]. A decoction of roots is taken as a remedy for colds, as a diuretic, or to induce labour in pregnant women [1]. An infusion of roots, stem bark or leaves is used as a remedy for intestinal complaints, including indigestion and parasitic infestations [1, 3]. The seed coat is poisonous.

Active compounds reported and antiplasmodial activity: Several limonoids such as trichilin A and dregeanin have been isolated from the seed oil of *Trichilia* species [2, 3, 4, 5]. The root bark of *T. emetica* contains the limonoid trichilin [3, 4] and the leaves show antiplasmodial activity against both chloroquine-sensitive (Dd2) and chloroquine-resistant (3D7) strains of *Plasmodium falciparum* [2, 6]. The antiplasmodial activities of limonoids are well documented.



Trichilin A

Cultivation: Fresh seed should not be allowed to dry and should be sown as soon as possible because it is recalcitrant. Well-handled seed germinates 10 to 20 days after sowing. 1,000 seed weigh around one kilo. Propagation is possible from cuttings, which can be taken from branches, roots or one year old coppice shoots.

Nursery seedlings can be planted out when 6 to 8 months old and initially require some shade. Recommended spacing in agroforestry systems is 6 m by 6 m. The tree can be planted in groups, in lines or scattered through farmland. The species grows quickly, up to 1 m per year in colder areas, 2 m in warmer regions. It can survive periods of drought.

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Plate 46: *Vernonia amygdalina* shrub

Plate 47: *Vernonia amygdalina* leaves

2.18 *Vernonia amygdalina* Del.

ASTERACEAE (Indigenous)

Common name: Bitter leaf vernonia.

Local name(s): Musuritsa (Luh), Omororia/Olusia (Luo), Mtukutu (Swa), Mululuza (Lug), Muuluza/Luluza (Lugi), Labori (Luo-A), Okelo-okelo (Luo-L), Mululuza (Lug), Kibirizi (Runyo).

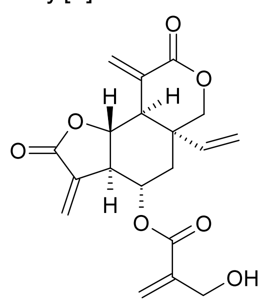
Botanical description and ecology:

A woody shrub to 3 m, sometimes a tree to 10 m with a wide bole and brittle branches. Young stems hairy. Leaves alternate, oval-shaped, tapering both ends, 10 to 20 cm long. Flowers tiny, white-green-pink, in small heads, sweet-scented in the evenings. Fruit small nutlets, bristly, hairy. Widely distributed through tropical Africa. Commonly found in wooded savannah and forest edges, often left as dispersed trees in pasture land. It may form dense thickets and is a coloniser of disturbed land and abandoned cultivation. Found from 1,300 to 2,300 m in altitude.

Uses: Fuelwood, vegetable (leaves), medicine (for both human and veterinary use), ornamental, soil conservation, live fence, toothbrushes, stakes (branches).

Traditional medicine: Root bark or leaf decoction is used in the treatment of malaria [1]. *Vernonia* also helps in the treatment of dysentery, and gives relief from abdominal pain and constipation [1].

Active compounds reported and antiplasmodial activity: Leaves of *V. amygdalina* contain sesquiterpenoid lactones (e.g., vernodalin) [1, 2] and flavones (e.g., luteolin [1, 3], vernonioside A-1 [1, 4]). Extracts of the leaves and root bark of *V. amygdalina* show antimalarial activity [5].



Vernodalin

Cultivation: *Vernonia amygdalina* can be propagated from nursery seedlings, wildings and cuttings. To collect seed, dry mature flower heads are harvested, dried in the sun, crushed, and seed cleaned by winnowing. Seed does not require any treatment before sowing. Germination rate is low and it is best to use fresh seed. There are approximately 850,000 seed per kilo.

Vernonia amygdalina is medium to fast growing and coppices very well. It can be planted along contour ridges and grass strips and is cut for mulching/green manure. In Western Kenya it is widely harvested as a vegetable.

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Plate 48: *Vernonia lasiopus* leaves and flowering buds

Plate 49: *Vernonia lasiopus* branches with flowers

2.19 *Vernonia lasiopus* O. Hoffm.

ASTERACEAE (Indigenous)

Common name: Common vernonia.

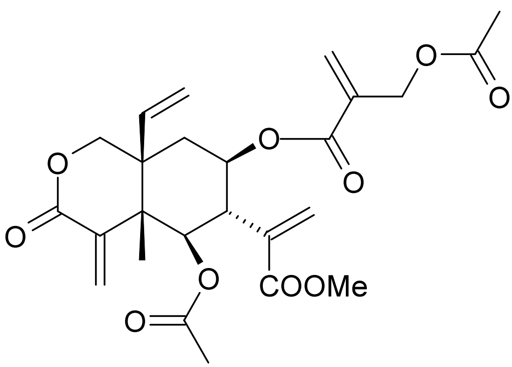
Local name(s): Muvatha (Kam), Mucatha (Kik), Olusia (Luo), Ol-euguru (Maa), Nkaputi (Sam).

Botanical description and ecology: Woody herb or semi-climbing shrub that reaches 3 m in height. Bark greyish brown, smooth. Leaves oval-shaped, densely hairy. Flowers pale mauve or white, in heads, flat or slightly rounded, 5 to 10 mm across. Found in disturbed areas, bush land, grassland and riverine woodland or forest. Found growing between 1,000 and 2,500 m in altitude.

Uses: Twigs are used as kindling, fodder, leaves and stems used in the construction of huts, medicine.

Traditional medicine: An infusion of powdered leaves is used to cure indigestion, severe stomach-ache, malaria and also as a purgative [1]. A root decoction is said to be one of the most effective treatments for stomach-ache [1].

Active compounds reported and antiplasmodial activity: Organic extracts of leaves of *V. lasiopus* show significant antimalarial activity [2, 3, 4]. Two new elemanolides, epivernodalol and lasiopulide, were isolated from alcoholic extracts of the dried aerial parts of the plant. These elemanolides are C-10 epimers of the sesquiterpene lactones vernodalol and demethylacroylated vernodalol that have been isolated from other species of *Vernonia* [5].



Epivernadol diacetate

Cultivation: *Vernonia lasiopus* is easily grown from seed, wildings and cuttings. Seed do not require pre-treatment. Cuttings are sometimes planted along field boundaries for use as fodder and for medicine.

Vernonia lasiopus is medium to fast growing. It is considered to be a weed in some areas because it can colonise disturbed land and cultivated ground.

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Plate 50: *Warburgia ugandensis* fruit

Plate 51: *Warburgia ugandensis* leaves

2.20 *Warburgia ugandensis* Sprague

CANELLACEAE (Indigenous)

Common names: East African greenheart, Pepper-bark tree.

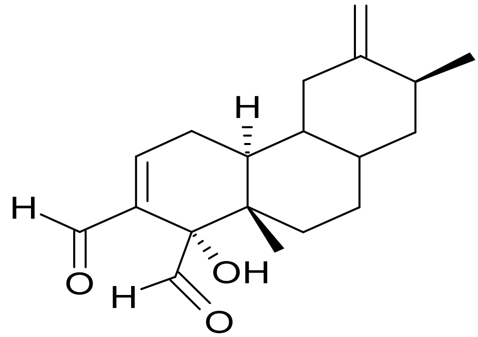
Local name(s): Muthiga (Kik), Moissot (Kip), Sogo-maitha (Luo), Ol-sogunoi (Maa-Ken), Muhiya (Haya), Olmsogoni (Maa-Tan), Msokonoi (Rang), Mukuzanume/Muwiya (Lug).

Botanical description and ecology:
An evergreen tree to 25 m in height, with a dense leafy rounded canopy. Bark rough, black-brown, cracked in rectangular scales. Leaves shiny, dark green above, to 10 cm long. Flowers inconspicuous, greenish to cream. Fruit round to egg-shaped, hard, 3 to 5 cm long, green, turning to black-purple on ripening. All parts of the tree have a hot peppery taste. Widely distributed in lower montane rainforests and in drier highland forest areas. Also found in riverine forest and in *Acacia xanthophloea* woodland, from altitude 1,000 to 2,000 m.

Uses: Timber, furniture, tools, fuelwood, seasoning (leaves in curry), soup (roots), fruit edible, medicine (for both human and veterinary use), toothbrushes, shade, ornamental, mulch, resin, insecticide.

Traditional medicine: A decoction of the bark or leaves is administered as a cure for malaria (though it causes violent vomiting) [1]. An infusion of bark or roots is taken as a cure for stomach-ache, tooth-ache, malaria, colds and general muscular pains [1, 2].

Active compounds reported and antiplasmodial activity: *Warburgia* species are known to be rich in sesquiterpenes with drimane and coloratane skeletons [1, 3, 4, 5]. Sesquiterpenes isolated from the bark or other parts of *W. ugandensis* include: cinnamolide-3β-acetate; muzigadial; muzigadiolide [3]; 11-hydroxymuzigadiolide; cinnamolide; 7-hydroxy-8-drimen-11,12-olide; ugandensolide; mukaadial; and ugandensidial [6]. Flavonol glycosides have been reported from the leaves [5]. The sesquiterpenes of *Warburgia* species are known to possess insect antifeedant, antimicrobial, antiulcer, molluscicidal and antifungal properties [1, 3]. Methanol extracts from various parts of the plant have shown antiplasmodial activity with an IC_{50} value of less that 5mg/mL against both chloroquine-sensitive (D6) and chloroquine-resistant (W2) strains of *Plasmodium falciparum* [7]. Extract of *Warburgia ugandensis* also shows moderate *in vivo* antiplasmodial activity in mice infected with *P. burghei* [7].



Muzigadial

Cultivation: *Warburgia ugandensis* can be propagated from cuttings, nursery seedlings and through direct sowing. The timing of seed collection is important and ripe fruit should be picked directly from trees or by shaking branches and collecting it from the ground. Seed pre-treatment is not necessary and under ideal conditions seed should germinate within 15 days, though it can take up to 45 days. The average germination rate of mature, healthy, freshly collected seed is 70%. Although the seed is classified as recalcitrant, it can be stored in moist sawdust at room temperature for two weeks whilst maintaining viability. It can also be stored for longer periods at cooler temperatures. There are on average 10,000 seed per kilo. Seedlings are ready for planting after 3 to 4 months in the nursery.

Research at the Kenya Forestry Research Institute shows that propagation through tissue culture is possible. This can support rapid multiplication, as one explant should produce hundreds of plantlets over a period of four months.

The tree is fairly slow growing. It should be planted with a wide spacing of 6 m by 6 m to10 m by 10 m. Once established it is hardy and coppicing can be practised. When removing bark for medicinal use, it is important to collect only opposing strips from around the trunk of the tree, in order to prevent die off (i.e., must not remove all bark from around the circumference).

Although propagation of the species for medicine is on the rise and it is becoming popular with farmers, there is a need to give advice on which provenances are most suited for different sites, and which produce the right quality and quantity of active medicinal components. Medicinally, some provenances are considered more effective than others, but the basis for this is not well understood (whether it represents genetic or environmental differences, or a combination of both). Using molecular markers, a clear split in genetic composition is seen across the Rift Valley in Kenya, but how this relates to the chemistry of the species is not known.

A deliberate effort has been made toward the conservation and sustainable use of *W. ugandensis in situ* (in forest), *circa situ* (in farmland) and *ex situ* (in live gene banks) in the East Africa region. Another member of the genus, *W. salutaris*, is a protected species in South Africa.

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Plate 52: *Zanthoxylum chalybeum* stem

Plate 53: *Zanthoxylum chalybeum* leaves

Plate 54: *Zanthoxylum chalybeum* fruit

2.21 *Zanthoxylum chalybeum* Engl.

RUTACEAE (Indigenous)

Common name: Knobwood.

Local name(s): Mukenea/Mukanu (Kam), Roko (Luo), Oloisuki (Maa), Loisugi/Loisuki (Sam), Mjafari (Swa), Entare/Yeirungo (Haya), Mulungu (Ran), Eusuk (Ate), Ntaleyedungu (Lug), Roki (Luo-A).

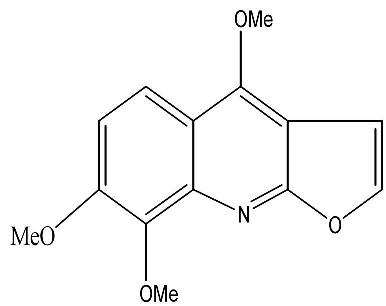
Botanical description and ecology:

A spiny deciduous shrub or tree to 8 m in height, with a rounded open crown. The bole has characteristic large, conical woody knobs with sharp prickles. The branches also bear scattered thorns with conspicuous dark scales. Bark pale grey, fissured. Leaves compound, with a strong lemon smell if crushed, 6 to 9 pairs of shiny leaflets. Flowers yellow-green, in short heads below leaves on new branchlets. Male and female flowers are on different trees. Fruit red-brown-purple, berry-like, splitting to allow the shiny black seed to partly protrude. Found in dry woodland, bush land or grassland, often on termite mounds and in rocky areas, on the coast and also in dry forest and closed thicket. Altitudinal range from sea level to 1,800 m.

Uses: Timber, furniture, construction poles, carving, fuelwood, charcoal, drink (dried leaves used to infuse tea), flavouring (stem pieces for soup), fragrance (crushed seed), medicine (human and veterinary use), fodder (leaves and fruit), toothbrushes, seed used as beads in traditional garments.

Traditional medicine: A decoction from leaves, bark or roots is used to treat malaria and fever [1]. Bark or root decoction is also used as a cure for coughs, colds, chest pains and respiratory diseases such as asthma and tuberculosis [1, 2].

Active compounds reported and antiplasmodial activity: Stem bark from *Z. chalybeum* shows strong antimalarial activity [3]. *Zanthoxylum usambarense* (see Section 2.22) and *Z. chalybeum* contain similar alkaloids, but coloured protoberberines have been found in *Z. chalybeum* only [4]. Phytochemical investigations of *Z. chalybeum* seed have yielded the alkaloid skimmianine [5]. However, it appears that the antiplasmodial principles have not yet been identified.



Skimmianine

Cultivation: Seed exhibit strong dormancy that appears to be imposed by the seed coat. Treatment with concentrated sulphuric acid for 10 to 15 min followed by thorough washing in running water gives reasonable germination results. Sowing of seeds immediately after collection is recommended. There are approximately 30,000 seed per kilo.

Propagation by root cuttings and suckers is also practised. The plant seems to propagate naturally by root suckers and pollards and coppices easily.

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[4] Kato A *et al*. (1996) Isolation of alkaloidal constituents of *Zanthoxylum usambarense* and *Zanthoxylum chalybeum* using ion-pair HPLC. J. Nat. Prod., 59, 316 -318.

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Plate 55: *Zanthoxylum usambarense* leaves

Plate 56: *Zanthoxylum usambarense* bark

2.22 *Zanthoxylum usambarense* Engl.

RUTACEAE (Indigenous)

Common name: Knobwood.

Local name(s): Muvuu/Muvulu (Kam), Muguchua/Muheheti (Kik), Roko (Luo), Oloisungi (Maa), Mugucua (Mer).

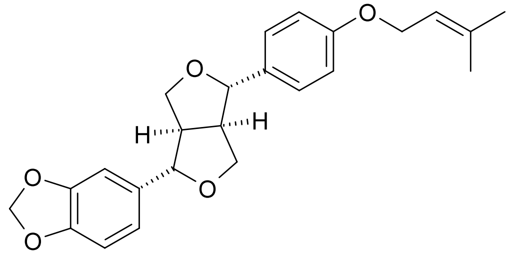
Botanical description and ecology:

A prickly shrub or tree, usually 5 to 8 m high, occasionally up to 14 m, often multi-stemmed and rather straggling, with a spreading crown and drooping branches. Bark greyish brown, deeply fissured branchlets with straight or slightly up-curved dark red prickles. Leaves compound, to 24 cm long, with 5 to 16 leaflets, oval-shaped up to 5 cm long. Flowers cream, small, in much branched terminal heads, 10 to 15 cm long. Fruit rounded, about 1 cm across, paired, sharply tipped. The species is found in highland zones, especially in dry forest edges or as remnants, in secondary bush land or grassland. Common between 1,600 and 2,600 m in altitude.

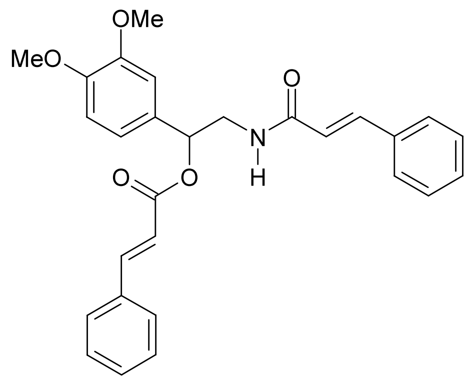
Uses: Timber (house construction), furniture, bows, medicine, live fence, fuelwood, toothbrushes (twigs).

Traditional medicine: The leaves are used in soup as a treatment for colds and flu. An infusion of the bark is used for coughs and rheumatic pains [1]. Leaf, bark or root decoction is taken for the treatment of malaria.

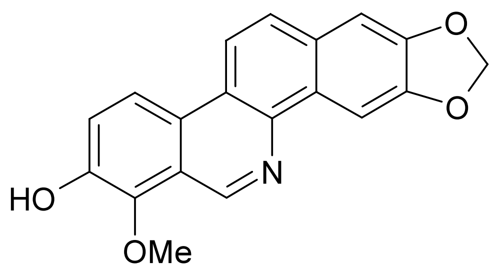
Active compounds reported and antiplasmodial activity: The methanol and aqueous extracts of *Z. usambarensis* show *in vitro* antiplasmodial activity [2]. Bioassay-guided fractionation of the dichloromethane extracts of the roots and bark have led to the isolation of two physiologically active compounds, canthin-6-one (a fungicide) and pellitorine (an insecticide). Oxychelerythrine, orchelerythrine, sesamin, and piperitol-3,3-dimethylallyl ether, have also been isolated from the plant [3, 4]. Although the antiplasmodial principles of *Z. usambarensis* have not yet been identified, syncarpamide and decarine isolated from Z. *syncarpum* have shown good antiplasmodial activity, with IC_{50} values of 2.0 and 1.4 µM against *Plasmodium falciparum* D6 clone, and 3.1 and 0.9 µM against *P. falciparum* W2 clone, respectively [5]



Piperitol-3,3-dimethylallyl ether



Syncarpamide



Decarine

Cultivation: *Zanthoxylum usambarensis* can be propagated by raising nursery seedlings from seed, or by transplanting wildings. Seed appear to be recalcitrant and should be sown immediately.

Seedlings can be planted in farmland at a spacing of 4 m by 4 m and later thinned to 7 m by 7 m, or more, in order to allow crop growth underneath. Trees can be pruned to guide branches and control growth. Farmers sometimes protect natural regeneration and/or remnants in farmland.

Little work on propagation or genetic improvement has been undertaken.

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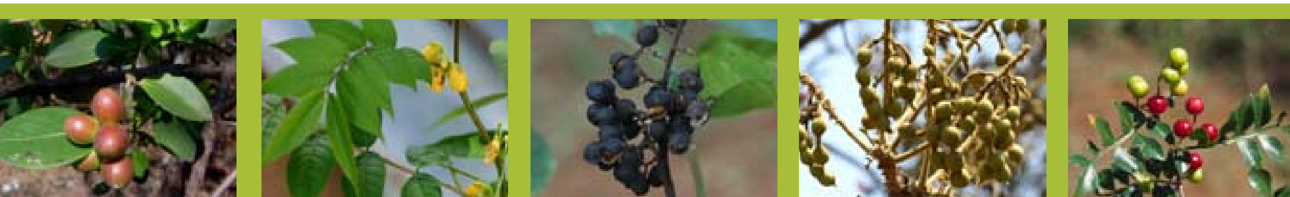
2.23 Index of common names

2.24 Key to language codes used in Section 2

Code	Language	Country
Aru	Arusha	Tanzania
Ate	Ateso	Uganda
Ate-K	Ateso (Karamogong)	Uganda
Ate-T	Ateso (Tororo)	Uganda
Chag	Chagga	Tanzania
Gogo	Gogo	Tanzania
Haya	Haya	Tanzania
Hehe	Hehe	Tanzania
Kam	Kamba	Kenya
Kik	Kikuyu	Kenya
Kip	Kipsigis	Kenya
Lug	Luganda	Uganda
Lugb	Lugbara	Uganda
Lugi	Lugishu	Uganda
Lugu	Luguru	Tanzania
Luh	Luhya	Kenya
Luny	Lunyoro	Uganda
Luo	Luo	Kenya
Luo-A	Luo (Acholi)	Uganda
Luo-L	Luo (Lango)	Uganda
Luo-Ugan	Luo	Uganda
Maa	Maasai	Kenya/Tanzania
Maa-Tan	Maasai	Tanzania
Maa-Ken	Maasai	Kenya
Mer	Meru	Kenya/Tanzania
Nan	Nandi	Kenya
Nyak	Nyakyusa	Tanzania
Nyam	Nyamwezi	Tanzania
Nyir	Nyiramba	Tanzania
Rang	Rangi	Tanzania
Ruki	Rukiga	Uganda
Runy	Runyoro	Uganda
Runyan	Runyankore	Uganda
Ruto	Rutoro	Uganda
Sam	Samburu	Kenya
Samb	Sambaa	Tanzania
Seb	Sebei	Uganda
Som	Somali	Kenya
Suk	Sukuma	Tanzania
Swa	Swahili	Kenya/Tanzania
Swa-Ken	Swahili	Kenya
Swa-Tan	Swahili	Tanzania
Tai	Taita	Kenya
Tug	Tugen	Kenya
Tur	Turkana	Kenya
Zig	Zigua	Tanzania
Zin	Zinza	Tanzania

Chapter 3



Antiplasmodial activity of plant compounds

Antiplasmodial activity has been linked to several classes of secondary plant metabolites, including alkaloids, terpenoids, coumarins, flavonoids, chalcones, quinones and xanthones. Of these, the antiplasmodial activity of the alkaloids is the most recognised (Caraballo *et al*. 2004, Saxena *et al*. 2003, Rukunga and Simons 2006).

3.1 Alkaloids

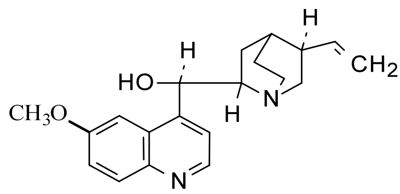
One of the oldest and most important antimalarial drugs, quinine, is an alkaloid, a naturally occurring physiologically active nitrogenous base. Alkaloids are divided into a number of sub-groups and antiplasmodial activities have been reported for most of these.

3.1.1. Naphthylisoquinoline alkaloids

These alkaloids show remarkable activity against *P. falciparum*, both *in vivo* and *in vitro*. For example, dioncopeltines A, B and C isolated from *Triphophyllum peltatum* (Dioncophyllaceae) exhibit high antiplasmodial activity (Francois *et al.* 1997). Recently, a novel hetrodimeric antiplasmodial napthylisoquinoline alkaloid, korundamine A, has been isolated from another species of Dioncophyllaceae, *Ancistrocladus korupensis*. It is one of the most potent naturally occurring antiplasmodial napthylisoquinoline dimers yet identified by *in vitro* screening, with an EC_{50} value of 1.1 µg/ml against *P. falciparum* (Hallock *et al.* 1997).

3.1.2. Quinoline alkaloids

Historically, quinine has been an important drug for the treatment of malaria, and remains so with the widespread occurrence of chloroquine-resistant strains of *P. falciparum* (Kayser *et al.* 1998). Using quinine as a lead structure, synthetic derivatives such as chloroquine and mefloquine with higher antimalarial activity have been developed. Other natural quinoline derivatives, such as 2-*n*-propylquinoline, chimanine B and 2-*n*-pentylquinoline, have been shown to exhibit EC_{50} values of 25 to 50 µg/ml against parasites causing cutaneous leishmaniasis (Kayser *et al.* 1998).



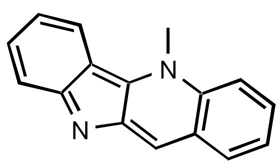
Quinine

3.1.3. Bisbenzylisoquinoline alkaloids

A number of bisbenzylisoquinolines with antiprotozoal activity have been identified. Most have an IC_{50} value for *in vitro* antiplasmodial activity of below 1.0 μg/ml. For instance, pycnamine from *Trichilia* sp. was found to have an IC_{50} value of 0.15 μg/ml. On the other hand, monomeric benzylisoquinolines do not have antiplasmodial activity (Kayser *et al.* 1998).

3.1.4. Indole alkaloids

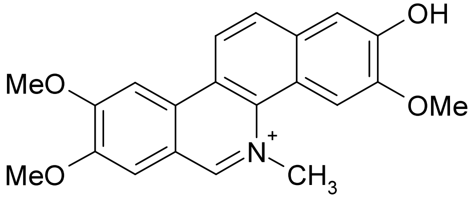
The indole substructure is widely distributed in the plant kingdom. Some indoles are reported to possess antiplasmodial activity. For instance, cryptolepine and related indole-quinolines isolated from *Cryptolepis sanguinolenta* were active *in vitro* against the W2, D6 and K1 strains of *P. falciparum*, with IC_{50} values ranging from 27 to 41 ng/ml (Kayser *et al.* 1998).



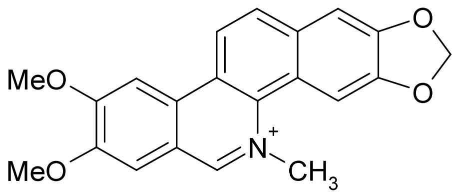
Cryptolepine

3.1.5. Phenanthridine and benzophenanthridine alkaloids

These alkaloids are mostly found within three plant families: the Papaveraceae, Fumariaceae and Rutaceae (Krane *et al.* 1984). Examples of antimalarial benzophenanthridine alkaloids obtained from plant sources are fagaronine and nitidine. The IC_{50} value of these alkaloids ranges from 9 to 108 ng/ml against *P. falciparum* (Gakunju *et al.* 1995).



Fagaronine

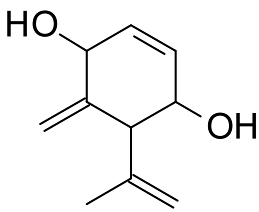


Nitidine

3.2 Terpenoids

3.2.1. Monoterpenes

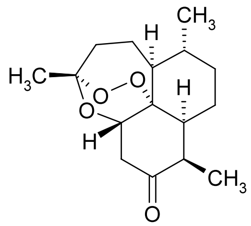
Monoterpenes constitute structurally simple antiprotozoal compounds. Piquerol A, isolated from *Oxandra espinata*, has been shown to exhibit low activity against *P. falciparum* isolates, with an IC_{50} value of 100 μg/ml (Kayser *et al*. 1998).



Piquerol A

3.2.2. Sesquiterpenes

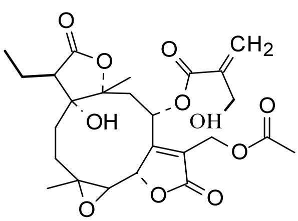
The discovery of artemisinin (qinghaosu), a sesquiterpene lactone endoperoxide, as an antimalarial constituent in the Chinese plant *Artemisia annua* (see Section 2.5) has prompted the investigation of other naturally occurring compounds with peroxide groups (O-O bonds) for their antiplasmodial activity. The 1,2,4 trioxane ring in artemisinin is essential for activity. After being opened in the *Plasmodium* cell it liberates singlet oxygen which is a strong cytotoxin. In addition to sesquiterpene endoperoxides, other sesquiterpenes with antiplasmodial activity have been reported. For example, activity has been documented for the germacranolide sesquiterpene lactones neurolenin A and B from *Neuroleaena lobata*, a medicinal plant used in Guatemala for the treatment of malaria infection (Francois *et al.* 1996).

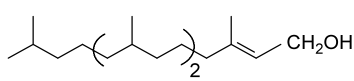


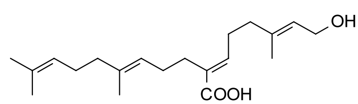
Artemisinin (qinghaosu)

3.2.3. Diterpenes

Diterpenes from many plant species are well known for their antiplasmodial properties (Kayser *et al*. 1998). However, most combine high antiparasitic activity with high cytotoxicity to mammalian cells (Oketch-Rabah *et al*. 1998). For example, the macrocyclic germacrane dilactone 16,17-dihydrobrachy-calyxolide from *Vernonia brachycalyx* shows antiplasmodial activity (IC_{50} = 17 µg/ml against *P. falciparum*) but also inhibits the proliferation of human lymphocytes at the same concentration (Oketch-Rabah *et al*. 1998). Other examples of antiplasmodial diterpenes are *E*-phytol and 6-*E*-geranylgeraniol-19-oic acid, isolated from *Microglossa pyrifolia* (Köhle *et al.* 2002).





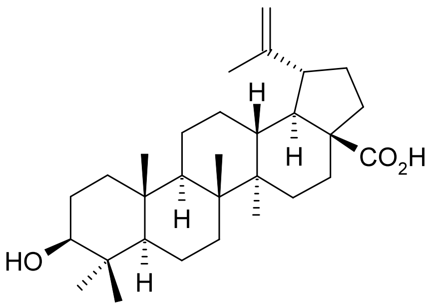


16,17-Dihydrobrachy-calyxolide **_E_-phytol** **6-_E_-geranylgeraniol-19-oic acid**

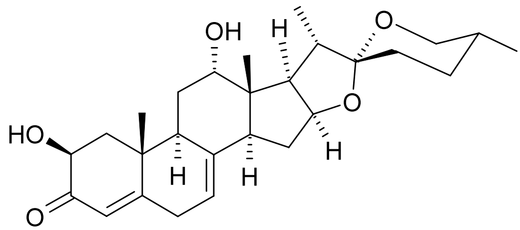
3.2.4. Triterpenes and saponins

Triterpenes and saponins are known for their antiplasmodial activities, but exhibit some toxicity for humans and other mammals. Their antiprotozoal activity was first properly described in the late 1970s (Kayser *et al*. 1998). Betulinic acid, also known for its anti-neoplastic effect, was identified to be the antiplasmodial principle of *Triphyophyllum peltatum* and *Ancistrocladus heyneanus*. Bringmann *et al*. (1997) reported an IC_{50} value of

10 μg/ml for betulinic acid against *P. falciparum in vitro* and moderate cytotoxicity (IC_{50} > 20 μg/ml). The use of saponins as drugs is limited due to poor availability, limited absorption in the gastrointestinal tract and haemolytic toxicity. The plant *Asparagus africanus* has yielded a new steroidal saponin, muzanzagenin, with antiplasmodial activity (IC_{50} = 61 μM against the K39 isolate of *P. falciparum*; Oketch-Rabah *et al*. 1997a).



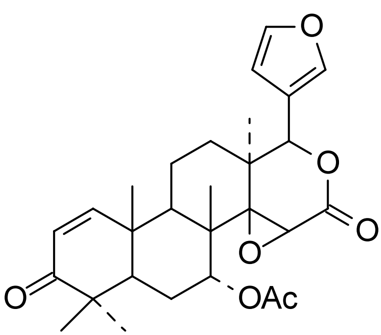
Betulinic acid



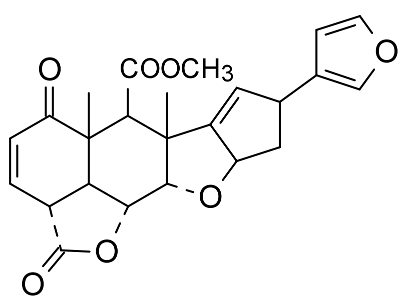
Muzanzagenin

3.2.5. Limonoids

Limonoids are also known as bitter terpenoids (Kayser *et al.* 1998). One well known plant family rich in limonoids is the Meliaceae, of which *Azadirachta indica*, the neem tree (see Section 2.6), which is widely used as an antiplasmodial plant, is a representative. Nimbolide (IC_{50} = 0.95 ng/ml, *P. falciparum* K1 strain) was the first agent to be identified as an active antiplasmodial principle in neem (Rochanakij *et al*. 1985). Subsequently, gedunin was also found to be active *in vitro* against *P. falciparum*, with IC_{50} values in the range of 0.7 to 1.7 μg/ml (Khalid *et al*. 1989, MacKinnon *et al*. 1997).



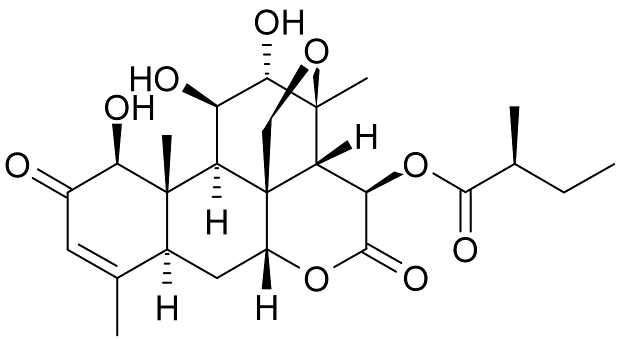
Gedunin



Nimbolide

3.2.6. Quassinoids

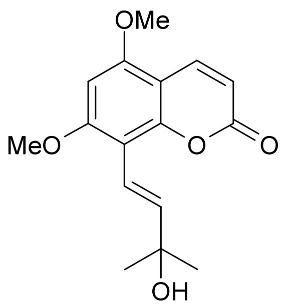
Quassinoids are heavily oxygenated lactones, the majority with a C_{20} skeleton referred to as picrasane. However, C_{18}, C_{19} and C_{25} quassinoids are also known. They are biosynthetically related to triterpenes, sharing the same metabolic precursors. A wide spectrum of antiplasmodial activities has been reported. The most active compound in the group is reported to be simalikalactone D from *Simaba guianensis*, with an IC_{50} value of less than 1.7 ng/ml (Cabral *et al*. 1993). The activity of compounds in this group is due to the oxymethylene bridge. Other quassinoids such as brusatol, bruceantin and bruceins (A, B and C) have been isolated and their antimalarial activity determined.



Simalikalactone D

3.3 Coumarins

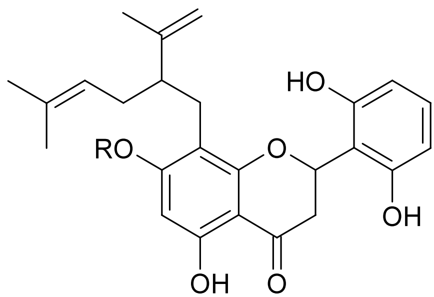
The antiplasmodial activity of 2'-epicycloisobrachycoumarinone epoxide and its stereoisomer, isolated from *Vernonia brachycalyx*, has been reported. Both sterioisomers show similar *in vitro* activity against chloroquine-sensitive and chloroquine-resistant strains of *P. falciparum* (Oketch-Rabah *et al*. 1997b). A new coumarin derivative, 5,7-dimethoxy-8-(3'-hydroxy-3'-methyl-1'-buteneyl)-coumarin, was isolated from *Toddalia asiatica* and was found to have IC_{50} values of 16.2 and 8.8 μg/ml against chloroquine-sensitive and chloroquine-resistant strains of *P. falciparum*, respectively (Oketch-Rabah *et al*. 2000).



5,7-dimethoxy-8-(3′-hydroxy-3′-methyl-1′-buteneyl)-coumarin

3.4 Flavonoids

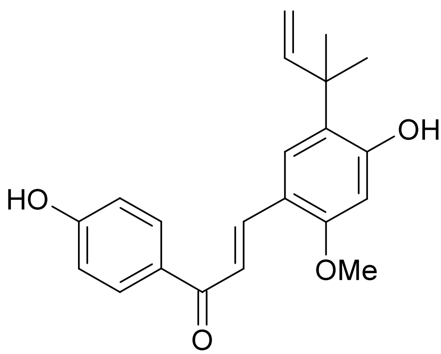
Flavonoids are widespread in the plant kingdom. Following the detection of antiplasmodial flavonoids in *Artemisia annua* (see Section 2.5) there has been renewed interest in these compounds. As part of a research programme on antiplasmodial drug discovery, additional *Artemisia* species have been screened. Exiguaflavanones A and B isolated from *Artemisia indica* exhibited *in vitro* activity against *P. falciparum*, with EC_{50} values of 4.6 and 7.1 μg/ml, respectively (Chanphen *et al*. 1998).



R = H **Exiguaflavanone A**
R = CH_3 **Exiguaflavanone B**

3.5 Chalcones

Phlorizidin, from *Micromelum tephrocarpum*, was one of the first chalcone glycosides reported to exhibit antiparasitic activity (Kayser *et al*. 1998). In traditional medicine, *M. tephrocarpum* is used to treat malaria because of its bitter taste, a property shared with quinine and other antimalarial herbs. Phlorizidin inhibits the induced permeability in *Plasmodium* infected erythrocytes to various substrates including glucose. The most promising compound in this class of natural products is licochalcone A isolated from *Glycyrrhiza glabra*. This compound has been the subject of intensive preclinical studies (Chen *et al*. 1994).

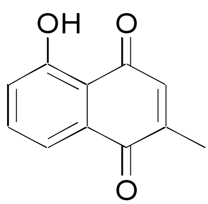


Licochalcone A

3.6 Quinones

3.6.1. Napthoquinones

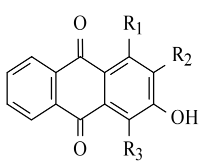
Plumbagin , a cytotoxic napthoquinone isolated from *Plumbago zeylanica*, has been found to exhibit antiplasmodial activity against chloroquine sensitive (D6) and resistant (W2) strains of *P. falciparum*, with IC_{50} values of 178 and 189 ng/ml, respectively (Lin *et al*. 2003).



Plumbagin

3.6.2. Anthraquinones

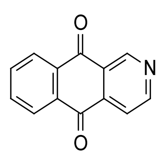
These compounds are related to napthoquinones in structure and mode of biological activity. The main chemical difference from napthoquinones is the tricyclic aromatic system with a *para*-quinoid substitution. Anthraquinones isolated from the tropical tree *Morinda lucida* have been tested for antiplasmodial activity *in vitro*: digitolutein, rubiadin-1-methyl ether and damnacanthal show activity on chloroquine-resistant *P. falciparum* ($EC_{50} \approx 21$ to 83 μM) (Sittie *et al*. 1999). The anthraquinone benzoisoquinoline-5-10-dione has been isolated from *Psychotria camponutans* and tested against *P. falciparum* (EC_{50} = 0.84 μg/ml) (Solis *et al*. 1995).



$R_1 = H; R_2 = CH_3; R_3 = OCH_3$

$R_1 = OCH_3; R_2 = CH_3; R_3 = H$

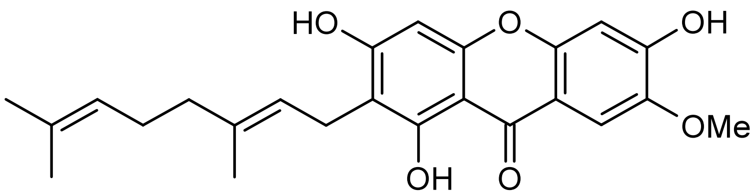
$R_1 = OCH_3; R_2 = CHO; R_3 = OCH_3$



Benzoisoquinoline-5-10-dione

3.7 Xanthones

Antiplasmodial xanthones have been isolated from *Garcinia cowa*. Preliminary screening of five prenylated xanthones demonstrated significant activity against *P. falciparum in vitro*, with IC_{50} values ranging between 1.5 and 3.0 μg/ml. Cowaxanthone was found to display good antiplasmodial potential (EC_{50} = 1.5 μg/ml) compared to pyrimethamine (IC_{50} = 2.8 μg/ml) (Likhitwitayawuid *et al*. 1998).



Cowaxanthone

3.8 References on chemical activity

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Most of the hundreds of millions of cases of malaria each year are in sub-Saharan Africa, where it is the second highest cause of death from infectious diseases. In 2008, malaria was estimated to have caused nearly nine hundred thousand deaths globally, mostly among African children, in which continent it is the leading cause of under-five mortality.

Although malaria is a common disease it is both preventable and curable. Several prescription drugs are used for treatment, although resistances to some commonly used medicines have developed rapidly. In recent years, there has been an emphasis on the use of artemisinin-based medicines based on the Artemisia annua shrub. The recent interest in Artemisia annua, developing drug resistances, and the limited access of poor communities to modern drugs, have stimulated renewed interest in the current use and future potential of other plant products in treating malaria, both as part of traditional health care practices and in developing new conventional medicines.

This guide describes a range of trees and shrubs that are used as antimalarial treatments in East Africa. The 22 species chosen for description have been determined by traditional medical practitioners, rural communities and scientists as among those that have potential for further study and development as tree and shrub crops. The intention of this guide is to support the further development of the cultivation of these species by smallholders in the East Africa region.

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