Conservation and Sustainable Use of Genetic Resources
of Priority Food Tree Species in sub-Saharan Africa

SAFORGEN

Sclerocarya birrea

Marula

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Marula tree in a parkland

Common name
Marula, maroola plum, jelly plum, maroola nut, cat thorn, morula, cider tree, and elephant tree (English)

Prunier d'Afrique (French)

Scientific name
Sclerocarya birrea (A. Rich.) Hochst

Synonyms
Commiphora subglauca Engl.; *Poupartia caffra* (Sond.) H. Perrier; *Sclerocarya caffra* Sond.; *Sclerocarya caffra* Sond. var. *dentata* Engl.; *Sclerocarya caffra* Sond. var. *blongifoliata* Engl.; *Sclerocarya schweinfurthiana* Schinz.

Family
Anacardiaceae

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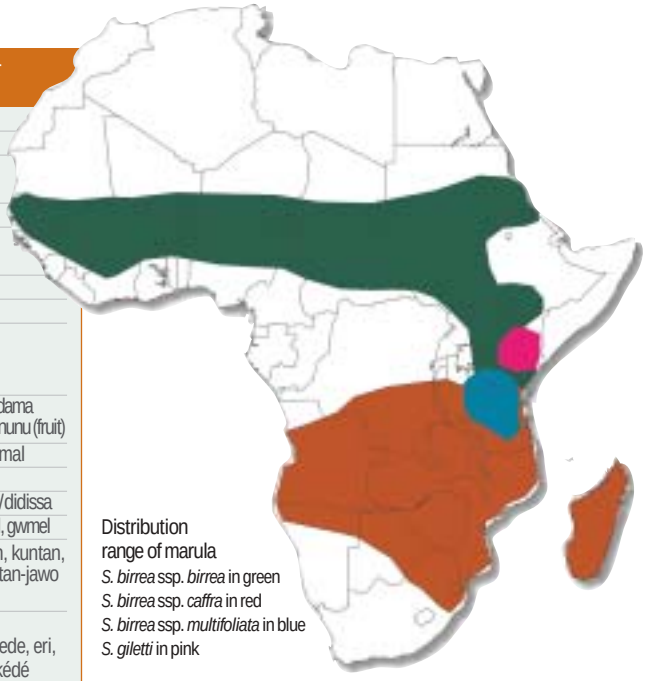
This leaflet highlights the nutritional and socio-economic potential of marula and provides information to assist those working with the species. The focus is on conserving genetic diversity and promoting sustainable use of marula. The leaflet presents a synthesis of current knowledge about the species. The recommendations provided should be regarded as a starting point, to be further developed according to local or regional conditions. These guidelines will be updated as new information becomes available.

Socio-cultural group	Country	Vernacular name
Tswana	Botswana	Morula
Senufo-Tusia	Burkina Faso	Kegue
Moore	Burkina Faso, Ghana	Nobéga, nobiga
Fufulde	Cameroon	Edi, dougouas
Koma	Cameroon	Kampé, diko, zagbé, yakgo
Mofou	Cameroon	Lalaway
Toupouri	Cameroon	Teengui
Arabic	Cameroon, Mauritania, Nigeria	Homeid
Hausa	Cameroon, Niger, Nigeria	Danya, danyaá, dama (tree), ludu, lule, nunu (fruit)
Amhara	Ethiopia	Gomales, kummal
Mursi	Ethiopia	Cobwe
Oromo	Ethiopia	Didigssa,didisa/didissa
Tingrinya	Ethiopia	Abengl, abengul, gwmel
Manding	Gambia, Guinea, Mali, Senegal	Konnan, kunan, kuntan, kuntango, kuntan-jawo kuta, mguna
Fula	Gambia, Guinea-Bissau, Niger, Nigeria, Senegal	Béri, eedere, eede, eri, hédéhi, hédi, kédé
Diola	Gambia,Senegal	Findibasu
Wolof	Gambia,Senegal	Bér, bièt, bir, bör
Dagbani	Ghana	Mu-mugga
Nankanni	Ghana	Nanogba
Sisaala	Ghana	Burunogo
Boran	Kenya	Didissa
Digo	Kenya	Mngongo
Kamba	Kenya	Muua
Luo	Kenya	Ngongo
Maasai	Kenya	Ol-mangwai
Meru	Kenya	Mura
Tugen	Kenya	Tololokwo
Kiswahili	Kenya,Tanzania	Mngongo
Malagasyan	Madagascar	Sakoa
Dogon	Mali	Bíí,
Tamachek	Mali	Tuila
Songhai	Mali, Niger	Dineygna, díinéy, dinégna, lúuley
Shangaan	Mozambique	Nkanyi, inkanyi
Gurma	Niger	Bunamabu
Kanuri	Niger, Nigeria	Ke_máà
Soce	Senegal	Kutan dao, kuten dao
Basari	Senegal	A-ngú_y, a-nguit, a-nguk
Bedik	Senegal	Gi-kú_y
Konyagi	Senegal	A-tema
Non	Senegal	Arid, arik, indarid
Serer	Senegal	Ari, aritj
Serer-Non	Senegal	Sugu, sungul
Soninke-Sarakole	Senegal	Nôné
Zulu/ Ndebele	South Africa	Umganu
Shona	Zimbabwe	Mufura, mafuna, marula



Distribution range of marula
S. birrea ssp. *birrea* in green
S. birrea ssp. *caffra* in red
S. birrea ssp. *multifoliata* in blue
S. giletti in pink

Geographical distribution

Marula is very widely distributed through most of the African continent. It occurs in 29 African countries stretching from Ethiopia in the east to Senegal in the west, and from Niger to South Africa.

Importance and Use

Marula is widely used by rural populations in most of the countries in which it is found.

The fruit has a high vitamin C content and can be eaten fresh, used to make juice or fermented to make alcoholic drinks. It can also be processed to make jam and jelly, extending the shelf life of the product and prolonging availability and consumption beyond the two to three month fruiting season. Marula kernels are rich in protein (28–31%), oil (56–61%), magnesium, phosphorus and potassium. Other important nutritional components include trace elements and vitamins such as iron, calcium, copper, zinc, thiamine and nicotinic acid.

Uses	Part of plant
Food	Fruit, pulp, kernel
Fodder	Fruit, leaves
Fuel wood or construction	Stem, branches, shell of nuts
Medicines	Roots, leaves, bark
Recreation	Whole tree
Soil protection	Leaves and roots
Wood carving	Stem, branches
Cultural uses	Tree, bark
Dyeing	Wood ashes
Ink	Gum

Kernels can be eaten or oil can be extracted from them for cooking or for use in the cosmetic industry. Fruit and leaves are browsed by livestock and have a variety of medicinal uses, as do the roots and the bark.

Socio-economic value

Marula is a valued fruit tree and all parts of the fruit are edible, either raw or cooked. They are mature when the fruits have turned yellow. At this stage, they have already been abscised, so fruits are normally collected from the ground. Fruit and kernels form an important component of the diet of the rural people. Fresh fruit is widely consumed, particularly by children, providing a rich source of vitamin C. Fruits are also collected and processed into juice, alcoholic beverages (wine and beer) and jam, extending the shelf life of the product and prolonging availability and consumption beyond the two to three month fruiting season. The kernel is crushed to remove the seed, which is then pressed to produce oil which can be used as edible oil or in the cosmetic industry. The endocarp is oily and edible, occasionally sold on local markets, and contains up to 6% oil.

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Marula fruits, jelly and oil


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Processing marula fruits after collection

Marula is one of the most commonly used wild fruit species in South Africa, where 59–77 % of households reported consuming marula fruit between four to five times per week during fruiting season. This figure does not reflect the opportunistic consumption by children when they are away from the homestead, either herding livestock or walking to and from school, so consumption rates are likely to be considerably higher. About 2% of households sell marula products, mainly beer and kernels.

In West Africa, marula is one of the ten most-used species and sources of income. It is used for both food and medicine.

Marula fruit and products, including alcoholic drinks, jams and fruit juice, have been traded locally, regionally and internationally since the 1990s. Consequently, several domestication

initiatives have emerged, such as efforts at Pretoria University to develop cultivars from superior trees—so-called 'plus-trees'—using grafting techniques.

Ecology and biology

Marula commonly occurs in arid and semi-arid areas. It is common in coastal and adjoining areas, but is found from sea level to 1600 m in wooded grasslands, riverine woodland and open bush land, especially on sandy loam soils and rocky hillsides.

There are three recognized subspecies of marula:

- *S. birrea* subsp. *caffra* (Sond.) is the most ubiquitous and occurs in tropical East Africa (Kenya and Tanzania), tropical southern Africa (Angola, Malawi, Mozambique, Zambia and Zimbabwe) and southern Africa (Botswana, Namibia, South Africa and Swaziland). It is also recorded from Madagascar. It is common in savannah areas in South Africa and Zimbabwe. In Ethiopia it is found in northern and southern parts of the country at altitudes of 500–1600 m.
- *S. birrea* subsp. *multifoliolata* (Engl.) occurs in mixed deciduous woodland and wooded grassland in Tanzania and perhaps in southern Kenya.
- *S. birrea* subsp. *birrea* occurs through tropical areas of West, north-east and East Africa. It is found across a range of vegetation types, principally mixed deciduous woodland, wooded grassland, riverine woodlands, bushlands and the open dry savannahs of tropical northern Africa and the Sahelian region.

The importance of marula to local rural human population is well documented. It is also important in the ecology of other plants and animals. It grows into a large tree and often dominates the community in which it grows with more than 20% woody biomass. Because of the large size, it produces a large area with a cool sub-canopy environment. In arid and semi-arid areas sub-canopy environments are key resource areas, characterized by higher moisture and nutrient levels than in open environments. These conditions are conducive to different assemblages of sub-canopy woody plants, grasses and forbs. Removal of a large dominant species may result in the loss of these sub-canopy species.

Marula may have a considerable ecological impact. It is often a dominant species in woodlands where it occurs, comprising more than 20% of total woody biomass. Its large size and dominant canopy results in large areas having a cool subcanopy environment. In arid and semi-arid areas subcanopy environments are key resource areas, characterized by higher moisture and nutrient levels than open environments. These conditions support different assemblages of subcanopy woody plants, grasses and forbs. Removal of a large dominant species reduces availability of habitat for associated subcanopy species.

Reproductive biology

Marula is generally dioecious—male and female flowers on separate trees. Although the flowers are usually one sex or the other, occasionally single flowers are both male and female. Although scentless, marula flowers are very attractive to bees and other insects, including flies, hoverflies and, less commonly, wasps.

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Marula flowering

These insects are believed to be the main means of pollination.

Phenology

In the Sahel, marula flowers from January to March, triggered by increasing air humidity at the end of dry season. Fruiting occurs in March and April. Leaf flushing also follows the dry season, when the first rains prompt the first real growth. In Sudan, flowering occurs in January to April and fruiting from April to June. In South Africa, flowering occurs in September to November and fruiting in February to June. The firm green fruits fall from the trees before they are mature and final ripening takes place on the ground, fruits turning yellow and softening. Trees can begin to set seed as early as 5 years old. There is some evidence that fruit yield is highly variable from year to year.

Related species

Sclerocarya gillettii is the only other species of genus Sclerocarya. It is endemic to central eastern Kenya.

Morphological traits and their variation

Marula has a long taproot which enables it to survive in semi-arid environments. The leaves are compound, with 3–7 pairs of opposite to subopposite leaflets. They are arranged spirally and crowded near the ends of the branches. The outer skin of the fruit is described as having a pungent apple-like odour and the pulp flavour is described as a mixture of litchi, apple, guava and pineapple.

High morphological variation has been observed within and among marula populations in Kenya, but it is not known if this was between or within subspecies. This variation includes leaf size and shape, fruit size, kernel and shell mass, colour and taste and general form.

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Differences in fruit colour

Large tree-to-tree variation has been found in fruit traits and oil content of kernels. For example, mean kernel mass of a tree selected for superior qualities was more than twice that of the mean kernel mass per nut of most other trees, indicating the potential for individual tree selection for cultivar development.

Genetic knowledge

The level of genetic diversity in DNA markers has been found to be closely related to geographic distance for 12 marula populations of subspecies *caffra* sampled from seven countries (Kenya, Tanzania, Namibia, Malawi, Zambia, Botswana and Swaziland) although in some cases, geographically close populations were also genetically distinct. The relationship between genetic diversity and distance means that in most cases, the movement of genetic material (seeds and pollen) throughout the range of the species is geographically limited to populations that are close to each other. Genetic analysis of nuclear DNA which is found in seed and pollen, and chloroplast DNA found only in seed, suggests that pollen is more effective than seed for transporting genes among populations.

Genetic differences between marula populations are greater in Tanzania and Kenya than in other countries, and both countries may be considered to be centres of genetic diversity for the species. Two populations in Kenya had the highest genetic diversity among trees within populations. Variation observed in Kenya raises the possibility that the country could be host to all three subspecies.

No information is available on the genetic basis of variation for characters such as tolerance to environmental stress and fruit size and yield.

Local practices

In southern Africa, variation among trees is well known by local farmers. In the Northern Province of South Africa, for example, Pedi people recognize three varieties of marula tree based on the scent and flavour of the fruit: *morula o mobose*, which bears sweet, palatable fruits; *morula wa gobaba*, which has sour, unpopular fruits; and *morula wa go nkga*, which bears fruits that are disliked due to their objectionable odour.

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One-year old tree left in cropland

Threats

Agricultural expansion and livestock grazing

Due to rapid population growth in sub-Saharan Africa, agricultural activities are increasingly expanding into more marginal areas in the arid and semi-arid zones. This often leads to the destruction of the natural woodland, soil erosion, land degradation and erosion of genetic resources.

Marula is particularly disadvantaged in its natural habitat because it is dioecious (male and female flowers on different trees). Studies undertaken in fields in northern Namibia showed that the sex ratio of larger trees was significantly skewed in favour of females. When regeneration does occur under trees growing on farmland, the seedlings are commonly destroyed by grazing or cultivation.

Harvesting fruit and other products

It is considered unlikely that collection of marula fruit poses a direct risk to the species, given the large number of fruit produced by each tree. It is estimated that 92% of fruit could be removed without reducing regeneration. The impacts of harvesting bark for medicines and wood for carving and firewood vary according to the frequency, intensity and extent of harvesting, at the level of both the individual tree and the population. These forms of marula resource use need to be monitored to limit negative impacts.

Conservation status

Natural stands of marula are under threat due to agricultural expansion, overgrazing and exploitation for other uses, calling for urgent

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Marula branches lopped for fodder in Baringo District, Kenya

conservation and management of remnant populations.

Marula seed is considered orthodox and so can be maintained in seedbank collections. Germplasm collections of marula have been made across the whole range of the species as the first step in a domestication strategy, but also serve as important materials for conservation. Marula seed has been collected in Burkina Faso, Kenya, Tanzania and Togo, for their tree seed centres.

It is unknown whether marula can be found in protected areas such as national parks.

Management and improvement

Selection and domestication

Large differences have been found in size of fruit and fruit yield between trees in farmers' fields and those in communal areas and natural woodlands, with trees in farmer's fields yielding up to five times as much as those in natural woodlands. This suggests that farmers have selected trees for large fruit and high yield over many generations. Male trees do not produce fruit, so selection has focused on only half of the population from a genetic perspective. However, as no genetic tests have been conducted, it is not known how much of the difference is due to cultivation rather than genetic improvement.

Marula has high potential for domestication. The World Agroforestry Centre (ICRAF) has been running a programme of participatory domestication since 1995 to benefit subsistence farmers in dryland agroforestry systems. Pretoria University (South Africa) has developed cultivars from plus-trees using grafting and work is ongoing in Botswana. The tree has been introduced for cultivation in several non-African countries, including Israel, Oman and the USA. Studies from South Africa and Namibia indicate the possibility of selecting trees for either pulp or kernel production. Selection programmes aim to increase product uniformity, increase productivity and foster conservation through use by providing an incentive for farmers to plant the species.

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Seedling emergence

Marula parkland in Tindangou (Burkina Faso)

Propagation from seed

Marula populations mainly comprise trees left growing in farmers' fields. The few attempts to produce marula seedlings in a tree nursery have encountered problems such as low rates of seed germination. Propagation from seed requires several steps to break dormancy and ensure a good germination rate (outlined below). Storing seed for one or more years may also increase germination rate. Germination takes 2–4 weeks, and under the right conditions rates of up to 100% can be achieved. Stems should reach knee height before seedlings are transplanted to the field. This will take 3–6 months, depending on the climate, the substrate and the watering regime. Once the taproot is established, growing seedlings in small pots can be detrimental to healthy tree development in the field due to root curling and damage.

Seedlings should be planted at the onset of the rainy season in direct sun in deep, well-drained soil in areas that are protected from strong wind and frost, especially in the early years after planting. The young trees can survive drought. Fruit yields are highest on dry, sandy soil. Compost or manure should be applied in the first year after planting. Young trees must be protected from livestock. A mycorrhizal fungus associated with marula roots has been shown to improve tolerance of marula to environmental stresses such as water stress, salt stress and flooding. Intercropping marula with millet or maize has been shown to aid establishment of this mycorrhizal association.

Marula seed shows strong dormancy and this must be broken to achieve good levels of germination:

A marula tree in North-West Benin

- Carefully remove the skin and pulp from the seeds.
- Dry the seeds in the sun for seven days.
- Store the dry seeds in a well-aerated, shady place and expose them to cold temperatures (<10°C) in winter. Ensure the seeds are kept dry.
- Remove the shell before sowing the seed using a knife or a small chisel and soak the seed in water before planting.

Recommended conditions for germination

- Sow the seeds at the onset of the rainy season (October, November or December in southern Africa, October or March in East Africa).
- Use a loose sandy mixture (such as rich soil mixed with sand or vermiculite) as the substrate and ensure that it is kept moist but not waterlogged.
- Sow the seeds into large (4 litre) plastic bags or pots.
- Or sow seed in deep (>50 cm) seedbeds for germination and later bareroot transplanting.

Vegetative propagation

Vegetative propagation is an attractive option for marula cultivation for at least two reasons. First, farmers are more interested in female trees than male ones and trees must be mature before the sex is evident. Second, vegetative propagation allows farmers to capitalise on genetic variability of the species by selecting trees with superior qualities. Grafting seems to be the most promising method of vegetative propagation with marula. However, vegetative propagation will reduce the genetic diversity of marula populations in farmers' fields by propagating only female trees and by reducing the number of genetically distinct trees.

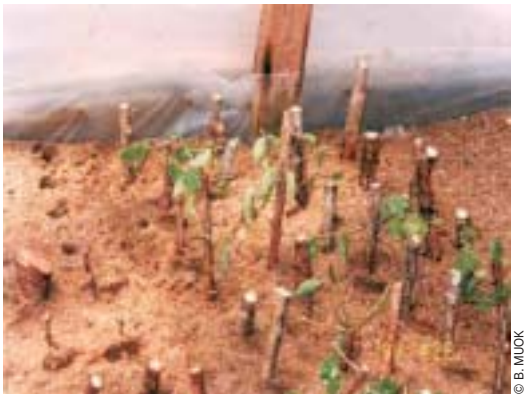
Guidelines for conservation and use

Kenya and Tanzania are considered to be centres of genetic diversity for marula so populations in these countries should be the first focus of attention for conservation programmes. However, genebanks should aim to establish collections covering the whole of the species range in order to capture the full range of genetic variability in species.

Natural regeneration should be encouraged in farmers' fields where isolated trees remain. Survival and growth of the seedlings can be improved by transplanting them from under the mother tree canopy to provide more sunlight and space. Water-harvesting structures should be constructed around each seedling, and the seedlings must be protected from animals. Weeds should be removed to reduce competition.

Planting marula would help to restore this important tree and could also provide future ecological niches for a wide range of wildlife, above and below ground.

For the immediate future, reliance on wild or spontaneously established trees will continue throughout the range in spite of the obvious potential for planted trees to become commercially important. In remote areas supporting sparse human population, natural marula populations are likely to remain important resources in the long term. Management strategies are urgently needed to



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Marula cuttings

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Marula young plants

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Young marula graft

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Natural regeneration of marula in Migori (Southern Kenya)

ensure sustainable use of natural marula populations.

The sparse distribution of marula in wooded farmland has resulted in the species' neglect. It also affects pollen flow to female trees, especially in areas where many of the male trees have been cut down. It is very important to maintain male trees in the population. There are fewer male trees near homes on privately owned land than on communal land and in natural woodlands. Re-establishing male trees in these areas may be the biggest conservation challenge.

Research needs

- Determine the number of viable populations in protected natural areas such as national parks
- Determine genetic variation in production and adaptive traits
- Determine effective population sizes in semi-natural farmland populations and minimum viable populations for conservation and long-term sustainable use
- Identify pollinator species, investigate effective pollen flow and determine threats to pollinator species
- Investigate effectiveness of seed dispersal and degree of dependence on fauna that are rare or threatened
- Develop seed handling procedures for long-term storage and enhanced germination.
- Develop best practices for nursery propagation
- Investigate reproductive phenology. ■

Sclerocarya birrea **Marula**

SAFORGEN

This leaflet was produced by members of the SAFORGEN Food Tree Species Working Group. The objective of the working group is to encourage collaboration among experts and researchers in order to promote sustainable use and conservation of the valuable food tree species of sub-Saharan Africa.

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