Fruits for the Future 8

Monkey Orange

Strychnos cocculoides

C. K. Mwamba

DFID Department for International Development

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Monkey orange
Strychnos cocculoides

Author:
Charles K. Mwamba

Editors:
J. T. Williams (chief editor)
R. W. Smith
N. Haq
Z. Dunsiger

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International Centre for Underutilized Crops
@ International Water Management Institute
127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka

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The International Centre for Underutilised Crops (ICUC) is an autonomous, non-profit, scientific research and training centre. It was established in 1992, based at the University of Southampton in the UK. In 2005 ICUC was transferred to the International Water Management Institute (IWMI), Sri Lanka. The centre was established to address ways to increase the use of underutilised crops for food, nutrition, medicinal and industrial products. The enhancement of currently underutilised crops is a key to food security, to the conservation of biological diversity and to the preservation and restoration of fragile and degraded environments throughout the world.

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The World Agroforestry Centre (ICRAF), established in Nairobi in 1977, is an autonomous, non-profit research body supported by the Consultative Group on International Agricultural Research (CGIAR). ICRAF aims to improve human welfare by alleviating poverty, improving food and nutrition security and enhancing environmental resistance in the tropics.

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PREFACE

Trees which produce edible fruits or seeds are important in tropical regions because they supplement and improve the quality of diets. Only a limited number have been fully domesticated and improved through selection and breeding; although a large number have been domesticated and are cultivated locally in traditional cultures.

Many of the latter species are considered incipient domesticates and they remain genetically wild even through they are protected by rural people, often around homesteads and their cultivated fields.

With limited resources for plant breeding in developing countries many of the species considered to have potential for focused and relatively rapid improvement do not receive the attention they deserve. Plant breeders have little choice other than to place their limited resources on improving field crops.

Taking this into account the International Centre for Underutilised Crops has developed a series of priority species on which it is felt more effort would be justified because it would repay results in generating incomes, alleviating poverty and providing more balanced diets.

In the case of woody fruits of the tropical and subtropical regions there are a number of these priority species considered as components of land use systems where they can help to stabilise environments in agroforestry systems. *Strychnos cocculoides* is a prime example and this monograph attempts to summarise what is currently known about the species.

The preparation and publication of this monograph has been funded by the Department for International Development (DFID), UK as part of a project entitled “Fruits for the Future”.

The World Agroforestry Centre (ICRAF) is a partner organisation in this endeavour as are numerous national programmes. This book is the 7th in a series of monographs; a parallel series of extension manuals is being issued.

It will be noted that there are many gaps in our knowledge and further basic as well as applied research is needed. It is hoped that making this monograph available to teachers, students, extensionists, policy makers, growers and others will promote further production and marketing and will stimulate scientists to address some of the knowledge gaps.

We are grateful to the late Dr. C. Mwamba who produced the manuscript. We regret that he was not able to see his work published and dedicate the book to his memory. We also thank Miss Rosemary Wise for the illustration of the plant, and Miss Angela Hughes and Mr. Berekhet Berakhy, former staff members of ICUC, for their advice and efforts in seeing the manuscript through to finalisation.

Editors 2005

CHAPTER 1. TAXONOMY

Edible fruit-bearing species of *Strychnos* belong to the family Loganiaceae, which includes tree, shrubs and liana species distributed throughout the warm tropical and subtropical region of Asia, Africa and the Americas and occasionally in the warmer temperate regions. Many species of *Strychnos* produce alkaloids such as strychnine and resinous substances such as the South American arrow poison curare. Similarly, in Malaysia, species have been used to produce dart poisons. Such poisonous properties were alluded to when the name *Strychnos* was coined, recalling the properties of poisonous nightshade, called strukhnos in Greek. One species has been domesticated and cultivated in several continents: *S. nux-vomica* L. whose seeds were extracted for strychnine, used in medicine since 1640.

S. cocculoides Baker, the monkey orange, produces a locally traded fruit which is especially popular in Eastern and Southern Africa. Another African species of monkey orange, *S. spinosa* Lam, is widely gathered throughout Sub-Saharan Africa from drier savannah habitats.

Few other genera of the family are economically important although many are used locally for dyes, medicine and wood. The genus *Buddleja* has provided species traded internationally for ornamental purposes, as has *Spigelia*. *Gelsemium* has similarly provided ornamentals, such as *G. sempervirens* L. of the Eastern USA but it was probably more important as a source of medicinal alkaloids.

This monograph describes the properties and uses of *S. cocculoides* because it has been widely recognised to be a species worthy of further exploitation for its fruit and one recognised as currently neglected (Maghembe *et al.*, 1998; Leakey and Newton, 1994). Reference is also made to *S. spinosa* since this has similar recognition (e.g. Haq and Atkinson, 1999; a European Union project coordinated by the University of Turin, Italy: see http://www.divapra.unito.it/; Maghembe *et al.*, 1998).

1.1 The family Loganiaceae

The family was originally included in the order Gentianales along with Oleaceae, Salvadoraceae, Apocynaceae, Asclepiadaceae and Gentianaceae, in the system of Bentham and Hooker. Later many other orders were established, that of Loganiales retaining Loganiaceae. Hutchinson (1969) then split the Loganiaceae into several families and *Strychnos* with some related genera became Strychnaceae. This split was based on long-existing evidence that the original classification was not natural. Work by Scott and Brebner (1889) had shown *Buddleja* was different to all the other genera of Loganicaceae in anatomical characteristics and some morphological characters; and *Spigelia* had had claim to being part of a separate group since Martius described Spigeliaceae in 1827.

For the purpose of this monograph the short description of the family below is for Loganiaceae *sensu lato* (Hutchinson, 1973). Nonetheless it is also helpful to consider the Strychnaceae because, as a family in its own right or as a subfamily of Loganiaceae, it contains a limited number of genera, all with only 1-5 species, plus *Strychnos* with about 200 species distributed through tropical regions.

1.1.1 Loganiaceae s. l.

This group includes trees, shrubs, which are often climbing, or herbs.

Leaves are opposite sometimes whorled, simple, generally connected by interpetiolar stipules often much reduced or by a raised line.

Inflorescence is usually cymose. Flowers are regular, usually hermaphrodite, 4-5-merous. Calyx is gamosepulous and usually imbricate. Corolla is hypogynous, valvate or imbricate. Stamens are epipetalous inserted on corolla tube, alternating with the corolla lobes.

Ovary is free, 2-celled. Ovules are one or more in each cell. Style is simple, stigma is capitate or bi-lobed.

Fruit is a berry, capsule or drupe, seeds with straight embryo in copious albumen.

There are up to 35 genera and over 550 species, mostly tropical but some warm temperate.

1.1.2 Strychnaceae s. s.

This group of genera is typified by possessing indehiscent drupaceous or baccate fruits. Leaves are 3-5 nerved from or above the base. Branchlets are often armed with spines, or there are tendrils often in the herbaceous species.

There are 3 groups of genera:

(i) Baccate fruit and entire leaves 3-5 nerved from or above the base, *Strychnos* L. with species spread across most tropical regions.

(ii) Drupaceous fruit, with pinnately nerved leaves: Couthovia A. Gray, 5 species in Malaysia to Polynesia; Crateriphytum Scheff., ex Koord., 1 species in Moluccas.

(iii) Baccate fruit, climbers with pinnately nerved leaves. Gardneria Wall, ex Roxb., 3 species in India and Japan; Scypho*Strychnos* Moore, 1 species in Nigeria; Pseudogardneria Raciborski, 2 species in East Asia.

When Strychnaceae and 5 other families (Potaliaceae, Antoniaceae, Spigeliaceae amd Buddleiaceae) were split from Loganiaceae the remaining family (Loganiaceae s.s.) was left with 7 genera and over 90 species (Hutchinson, 1969).

1.2 The genus *Strychnos* L.

(*Species Plantarum* 1:159:1753)

The following description is based on Leeuwenberg (1983), Hutchinson and Dalziel (1963) and White (1962).

Trees or shrubs are erect or climbing by hooked tendrils or lianas with curled tendrils. Trees are usually less than 10 m tall in savannah or up to 35 m in forests. Bark is usually thin and smooth, but thick and corky in some species; in lianas often with large lenticels. Branches with axillary or a terminal straight spine. Branchlets are terete, sometimes sulcate.

Leaves are opposite, sometimes decussate, stipules are reduced to ciliate rim joining petiole bases; petioles are inserted on a leaf cushion. Laminae are often variable in shape but broadly orbicular to narrowly elliptic and mostly coriaceous. Leaf shape varies between plants in shade and open sun and for woody species between original growth and re-growth after cutting and/or fire. Leaves are entire, rounded and slightly mucronate or emarginate to acuminate at apex; glabrous or pubescent. Venation with 1, 2 or 3 pairs of secondary veins from the base curving along the margins, usually not as far as the apex and anastomosing with the other veins; in rare cases pinnately veined.

Inflorescence is cymose either terminal or axillary or both tending to be thyrsoid and 1 to many flowered, lax or congested, simple or condensed, shorter or larger than the leaves. Bracts are small or very small.

Flowers are 4-5-merous, regular or with the sepals unequal. Calyx lobes are triangular, ovate, rarely narrow to linear, imbricate; free or connate up to half their length and green or coloured with the outside hairy or glabrous.

Corolla is a tube, rotate or sub-campanulate with lobes valvate in bud becoming spreading or reflexes or rarely sub-erect; lobes are triangular, oblong, entire, acute; whitish to yellow or pale green, sometimes orange in colour; sometimes with a corona at the mouth. Corolla on both sides is glabrous or hairy but at inner base always glabrous.

Stamens are exserted or included, inserted on the corolla tube usually adnate to corolla throat, rarely low down in tube. Filaments are filiform, usually short, anthers ovate to narrowly oblong, cordate, sometimes sagittate at the base.

Ovary is 2-celled (rarely 1-celled due to breakdown and absorption of the dividing wall); style is straight; stigma is terminal, usually capitate.

Fruit is a globose berry usually 2-celled, mostly yellow or reddish when mature but occasionally greenish or blue-black; subtended by the persistent calyx. Small fruited species usually have thin, soft walls but large fruited species have thicker, harder, indehiscent walls. Pulp is juicy; seeds variously compressed, globose or oval in shape, embedded in the pulp; seeds are 0.5-3.0 cm long with testa thick or membranous; embryo is straight. Cotyledon is flat and leafy.

Estimates of number of species vary greatly: 179 (Leeuwenberg, 1983), 200 (Willis, 1957) or 400 (Hutchinson, 1969).

1.3 Species of the genus

It is not known with certitude how many species comprise the genus, although large numbers are quoted from the warm tropical and subtropical parts of Australia, Asia, Africa and the Americas. In Africa there are probably about 75 species. There has been no continent-wide assessment of the species and at present information is drawn from national and regional floras, hence it is to be expected that a degree of synonymy is built into the estimates. The two most important African species for fruits are described below.

1.3.1 *S. cocculoides*

Synonym: *S. tuberosa* T. R. Sim

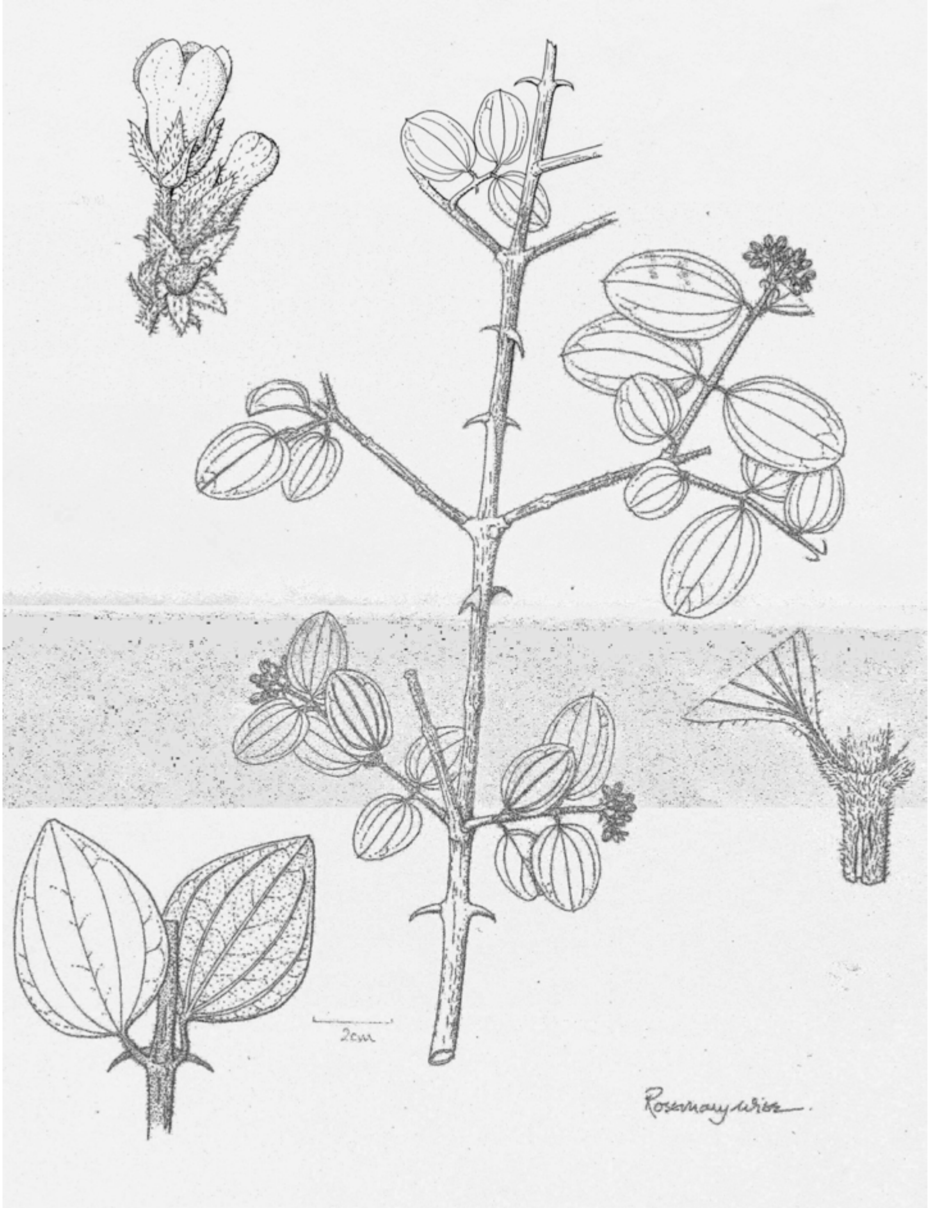

Figure 1.1 Flowers and leaves of *S. cocculoides*

A deciduous tree about 5 (1-8) m tall, occasionally semi-lianoid with a spreading open crown and one or several trunks, frequently suckering.

The bark is thick, corky and ridged, brown and not lenticillate. Branchlets are dark brown and densely pubescent when young with pale longitudinal corky, non-powdery ridges which later coalesce. Spines terminate branches, 1.0-1.5 cm long, occasionally curved but usually straight.

Leaves are up to 6 cm long and about 4 cm wide; orbicular to ovate-elliptic, pubescent but sometimes hairy on both sides. 1-3 pairs of secondary veins from the base curved along the margin.

Flowers are in terminal inflorescences which are thyrsoid i.e. main branch racemose and laterals cymose, seemingly umbellate and congested. Male and female flowers are borne on the same tree. Sepals are greenish, hairy or glabrous about 2 mm long. Corolla is a tube, green to orange in colour, always glabrous at the base but may be hairy above, lobed with a white penicillate corona at the mouth. Ovary is 2-celled.

Fruits are 6-12 cm diameter, round; blue-green mottled white when young turning mottled green-yellow to yellow orange when ripe with a granular skin, hard-shelled (shell about 2-5 mm wide); containing many (10-100) subglobose irregularly curved, flattened seeds. The pulp is the edible part; seeds are non-toxic. Pulp has a sweet taste.

It is regarded as semi-cultivated in numerous parts of northern-southern Africa but it remains essentially a wild species.

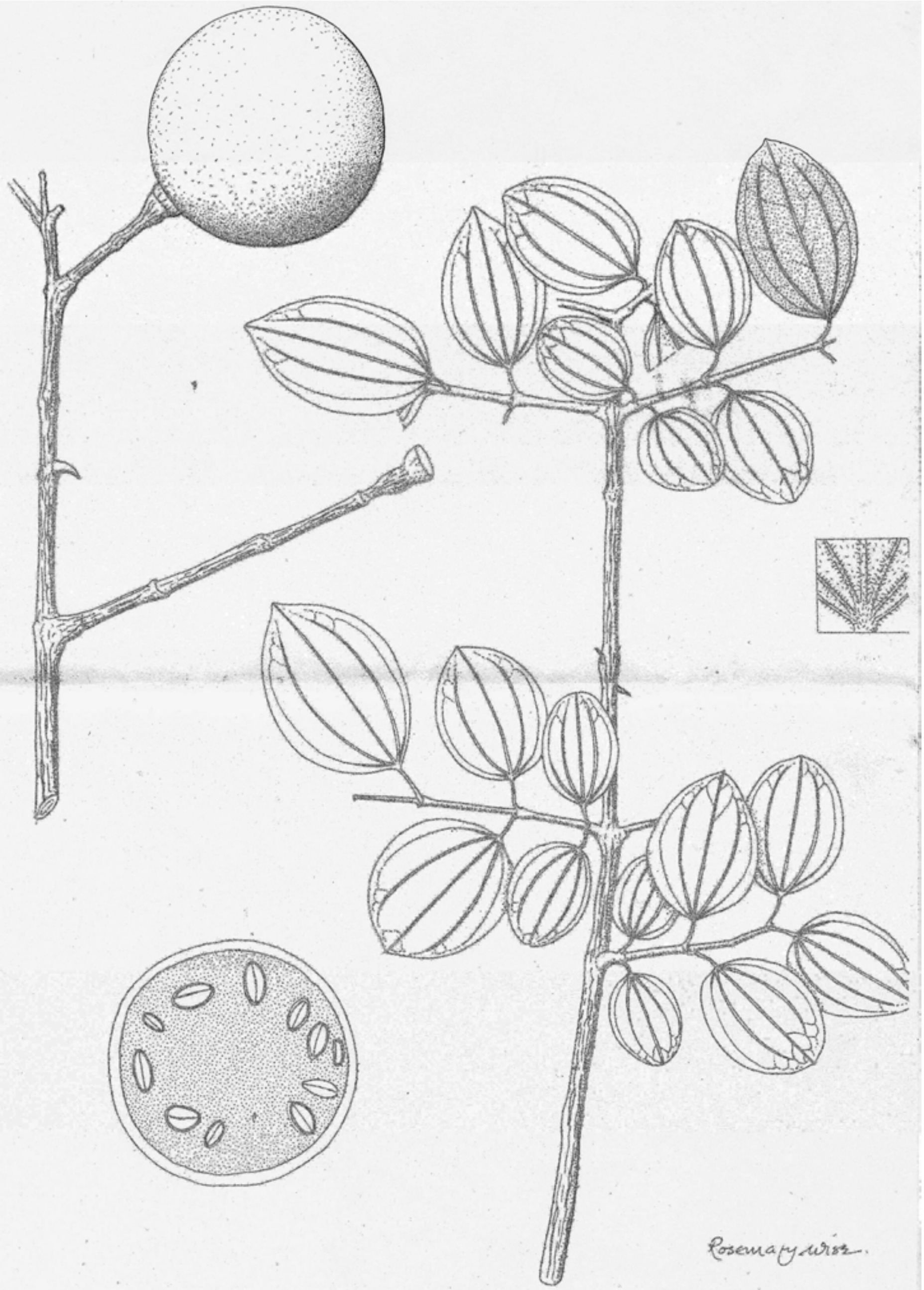

Figure 1.2 Fruit and leaves of *S. cocculoides*

1.3.2 *S. spinosa*

Synonyms: *S. buettneri* Gilg, *S. cardiophylla* Gilg, *S. arvalhoi* Gilg, *S. courteti* Chev., *S. cuneifolia* Gilg, *S. emarginata* Bak., *S. gracillima* Gilg, *S. harmsii* Gilg, *S. laxa* Solered., *S. leiosepala* Gilg, *S. lohua* A. Rich., *S. radiosperma* Gilg, *S. rhombifolia* Gilg, *S. tonga* Gilg, *S. volkensii* Gilg.

A deciduous shrub or tree about 5 (0.5-10) m tall with rounded crown from one or several trunks, frequently suckering. The bark is somewhat scaly and grey-buff in colour, shallowly fissured, very rarely slightly corky, not lenticellate. Branches can be robust or not, sometimes deeply ringed at nodes, often with straight or recurved axillary spines.

Branchlets are hairy or not, often ending in a straight spine.

Leaves are extremely variable, to 6-10 cm long and about 4 cm wide; petioles 2-10 mm; lamina is coriaceous, obovate to suborbicular to ovate-elliptic, apex subacute and very shortly cuspidate to retuse occasionally acuminate, glabrous or hairy beneath, 1-3 pairs of distinct secondary veins from the base curved along the margin.

Flowers in terminal cymes often looking rare like an umbel, small, greenish-white. Sepals connate at the base, 5 mm long, sub-equal, pubescent on the outside. Corolla a tube with lobes hardly split and hardly spreading with white penicillate corona at the mouth, lobes of tube triangular. Ovary 1-celled, stigma oblong. One basal placenta with 60-120 ovules.

Fruits are large, up to 10 (7-15) cm diameter, with 10-100 flattened seeds, round often shining; apple-green and somewhat knobbly often with yellow spots when young, turning yellow or brown when mature; hard shelled (shell about 5 (0.8-8) mm wide). Seeds are toxic when eaten. Pulp has an acid-sweet taste.

It is regarded as semi-cultivated, particularly in West Africa, and numerous parts of Central, Eastern and Southern Africa.

1.3.2.1 Subspecies *S. spinosa*

This subspecies has been described with fruit shell only about 4 mm thick and with the leaf apex acuminate when the typical forms of *S. spinosa* have leaves less pointed to rounded. It is unlikely to be a valid taxon and using the name *cocculoides* is confusing. The species *S. spinosa* shows a great deal of phenotypic variation especially in hairiness of various plant parts, leaf shape and size, re-growth after cutting or fire and in flowering patterns. Infraspecific taxa based on morphology are not helpful: patterns of genetic variation across distribution and ecologies need to be assessed.

1.3.3 Other edible fruited species

There are not many other large-fruited *Strychnos* species prized for their fruits in Africa. They include *S. pungens*, *S. innocua*, *S. lucens* and *S. madagascariensis*. There are even fewer small-fruited species widely prized but two important ones are *S. caespitosa* Good (now regarded as *S. gossweileri*) and *S. stuhlmanii* Gilg (now regarded as *S. potatorum*), the latter being prized for cooking but not eaten fresh.

An additional species, *S. dysophylla* Benth., thought to be related to *S. innocua*, is now regarded as part of *S. madagascariensis*.

These taxa are described below.

1.3.3.1 *S. gossweileri* Exell

Synonym: *S. caespitosa* Good

A small rhizomatous shrub species with a woody base producing a climbing shrub or liana which can reach 1-3 m in height or straggle up to 20 m. Leaves petiolate (2-5 mm) a little over 2-5 x as long as wide, usually about 7 (2-10) cm long and 2.5 (1-5) cm wide, glabrous; very variable in shape, oblong-elliptic to narrowly elliptic with apex rounded apiculate or sub-acuminate.

Flowers are 4(-5)-merous, corolla white, lobes oblong.

Fruits are ellipsoidal, small, 1.5 x 1.0 (2-1.5) cm, orange-yellow in colour, soft shelled with a smooth skin, one seeded, pulp is eaten fresh.

Distributed in woodlands and gallery forests in tropical Africa, particularly the northern part of Southern Africa at altitudes up to 700 m.

1.3.3.2 *S. innocua* Del.

Synonym: *S. alnifolia* Bak., *S. triclisioides* Bak., *S. unguacha* A. Rich.

A shrub or much branched tree up to 13 (2-16) m tall. The trunk branches from low down. The bark is cream to orange-green and powdery and flakes near the base of the trunk. Branches powdery or not, branchlets glabrous but hairy in var. pubescens.

Leaves with short petiole (2-7 mm) elliptic to obovate, 8 (4-16) x 5 (2-9) cm rounded (but acute on sucker shoots) at the apex, glabrous or pubescent on both surfaces. Venation includes 2 pairs of secondary veins from the base curved along the margins and prominent tertiary reticulate venation.

Flowers 4-merous, corolla cream green with a ring of hairs in the throat, lobes triangular not thick. Fruits are round 5-7 cm diameter, yellow or orange in colour, thick walled, pulp eaten fresh. Seeds toxic (Irvine, 1961).

Widespread in savannah from Guinea to Ethiopia and Sudan, through Eastern Africa, Congo and northern Southern Africa.
A variety *pubescens* Solered. appears to equate to *S. unguacha* A. Rich. recorded as distributed in West Africa and *S. triclisioides* Bak. recorded as distributed in East Africa to Angola and Zimbabwe. This variety has pubescent branchlets.

S. dysophylla Benth., was later considered as a subspecies of *S. innocua* (subsp. *dysophylla* (Benth.) I.Verd.). The fruit is black, sweet and well tasting. This taxon is synonymous with *S. randiaeformis* Baill. See *S. madagascariensis* below.

1.3.3.3 *S. lucens* Bak.

A woody evergreen climber with bifurcate tendrils. Branches are closely lenticellate.

Leaves are 3.5 x 13.0 cm long and 1.8-5.0 cm wide and glaucous.

Fruits are round, about 4.0 cm diameter, orange in colour, 7-seeded and eaten fresh.

This is a species of northern Southern Africa especially Zambia and Zimbabwe.

1.3.3.4 *S. madagascariensis* Poir.

Synonym: *S. innocua* subsp. Burtoni (Bak.) Bruce and Lewis, *S. burtoni* Bak., *S. dysophylla* Benth.

A multi-stemmed and branched deciduous shrub or tree 2-10 (-20) m tall. The trunks branch from low down. The bark is pale grey to grey-white and smooth. The branches are powdery or not and hairy or not.

Leaves with short petiole, 1-5 mm, lamina elliptic to obovate 2-10 x 1-4 (-5) cm rounded, shiny and dark green above distinctly paler beneath, glabrous or pubescent on both surfaces. Venation includes 2 pairs of secondary veins from the base curved along the margins and not very prominent tertiary reticulate venation especially above it.

Flowers are 4-merous, corolla white or green-yellow with a ring of hairs in the throat, lobes triangular and thick, spreading.

Fruits are round, 2-8 cm diameter blue green turning yellow or orange when mature, thick walled; pulp eaten fresh orange and slimy containing 2-50 seeds.

Distributed in Eastern (northwards to Malawi) and Southern Africa and Malagasy.

1.3.3.5 *S. pungens* Solored.

Synonym: *S. occidentalis* Solored.

A deciduous shrub or tree 6-8 (2-16) m tall. The trunk’s bark is grey-brown and granular, not corky and becomes smooth on the branches.

Leaves with short petiole, 1-4 mm, lamina 8.0 x 3.5 cm, usually but not always glabrous beneath, shining dark green above, slightly paler beneath, elliptic to obovate, apex ending in a sharp spine. Venation includes one pair of secondary veins from the base curved along the margin.

Inflorescence axillary usually congested. Flowers 5-merous, corolla cream-green or yellow with a ring of hairs in the throat, with thick triangular spreading lobes.

Fruits are round, large 5-10 (-15) cm diameter, blue black turning orange or yellow, calyx lobes notably accrescent. Fruit thick walled; pulp eaten fresh, sweet and fragrant containing 20-100 seeds.

Distributed in Central, northern Southern Africa and Eastern Africa in Brachystegia woodland up to 2000 m above sea level.

1.3.3.6 *S. stuhlmannii* Gilg

A deciduous much branched shrub or tree 4-18 m tall. The bark is grey-brown, very thin and smooth, lenticellate. Dead bark separates in small circular scales. Branches many and branchlet spines 1-3mm long.

Leaves with a petiole 1-7 mm, lamina dark-green above, paler densely velvety beneath, elliptic or ovate 12 (6-15) x 6 (3-9) cm. Venation includes 2 pairs of distinct secondary veins.

Flowers 5-merous (occasionally 4), corolla white or yellow, pilose inside the tube, lobes oblong spreading. Inflorescences in axis of scales at bases of branches.

Fruits round, small up to 1-2 cm in diameter, blue-black, thin walled; purple pulp (only eaten cooked) containing 1 seed.

Distributed in Eastern and Southern Africa from Malawi to South Africa, widespread in miombo woodlands, Brachystegia woodlands along rivers and in semi-evergreen bush up to 1600 m above sea level.

This species has recently been treated as a synonym of *S. potatorum* L. f., which also occurs in India, Sri Lanka and Myanmar (Leeuwenberg, 1983).

1.4 Vernacular names

It has proved difficult to be confident of the usage of many local names. Those given below in Table 1.1 appear valid.

Table 1.1 Vernacular names of *Strychnos* species

Species	Language/ Area	Name
S.cocculoides	English	Corky-bark monkey orange, Monkey apple, Bush orange
	Afrikaans	Klapper Suurklapper
	Zambia	Akaminu, Akasangole, Latongo, Muhuluhulu, Muwi
S. spinosa	English	Kaffir orange, Monkey orange
	Ghana	Akankoa, Afankuru Pumpologoru, Kampoye, Katupwaga, Pumponsia
	Uganda	Lombo, Arwalarwala-Lyech, Shiunwa
	Zimbabwe	Mutamba, Muzhumi, Umkomatsane
	Zulu	Umhlala
	Zambia and Malawi	Kampobera, Muhuluhulu, Muwi, Muyimblii, Sansa, Umasaye
	Other West African	Kokhyo (Hausa), Katenpuanga, Katerpwinga (More), Datokulewi, Marbatahi, Norbotahi, Uormatabe, Noyabata (Peulh), Ngoba (Serer), Ramboet, Tobé (Wolof)
S. innocua	Zambia	Kutane, Mongolo, Umulungi
	Uganda	Langoro, Unde, Akwalakwala, Erwalakawala, Eturukutsuti, Mkukulu
S. pungens	English	Kaffir orange
	Zimbabwe	Matamba, Umhlale
	Zambia and Malawi	Ifufuma, Muwawa, Umukome
S. stuhlmanni	Zambia	Mulombelcombe, Musisi, Umubangachulu
S. potatorum	India	Nirmali (Hindi), Uriya (Kotako), Tel (Chilla), Tam (Tetay Kottai)

(data from various floras and von Maydell, 1986)

1.5 Key to the species

1a. Fruit large, 4-12 cm diameter, containing 5 to many seeds

2a. Small trees without tendrils, with paired spines Inflorescences terminal. Calyx lobes narrowly deltoid to linear Corolla campanulate

3a. Branches and branchlets with corky ridges. Unripe fruit blue green……………………………………………………….*S. cocculoides*
3b. Branches and branchlets without corky ridges. Unripe fruit apple green……………………..…………………………………....*S. spinosa*

2b. Small trees without tendrils or spines or evergreen climbing shrubs with tendrils. Inflorescences axillary. Calyx lobes ovate or sub-orbicular. Corolla cylindrical

4a. Leaves with a sharp spine at the apex..……………….*S. pungens*
4b. Leaves without apical spine

5a. Scandant shrub with tendrils…………………………....*S. lucens*
5b. Erect shrub or tree without tendrils..………………….*S. innocua*

1b. Fruits small < 4 cm diameter containing 1 to many seeds

6a. Fruits 1-2 seeded

7a. Rhizomatous suffrutex habit……..………..…….. *S. gossweileri*
7b. Trees ………………………………………...*S. stuhlmannii*

6b. Fruits many seeded……………….……………..*S. madagascariensis*

CHAPTER 2. DISTRIBUTION

The genus plays an important role in agricultural areas subjected to periodic drought (Taylor, 1986). Species are adapted to harsh environments such as soils with very poor fertility and dry climates, and may even produce fruit during years when traditional crops fail. *Strychnos cocculoides* is ideally suited to the use made of it by rural communities. It is widely distributed as a scattered tree in the Miombo and Savannah woodlands of tropical Southern Africa and Malagasy, occurring at a range of elevations, mainly on sandy areas (Pardy, 1953).

S. cocculoides is found in warm to hot tropical savannah and other woodland regions with 600-1500 mm rainfall, but with a prolonged dry season. It occurs between 400 and 2000 m above sea level. Fire is an important part of the environment. Since both trees and grasses must be resistant to drought and fire, the number of species in the vegetation may not be large in sharp contrast to adjacent tropical forests. *S. cocculoides* is adapted to the drier tropical regions by growing only when there is adequate moisture in the soil. The species is adapted to drought by its ability to become dormant when water is not available, rather than wilting and dying as would be the case with drought-sensitive plants. The plants lose their leaves and show only green buds and stems thus showing high transpiration efficiency (Lange *et al.*, 1969).

S. spinosa also occurs in savannah forest woodlands and sometimes gallery forests all over tropical Africa and Southern Africa, Malagasy and the Seychelles, from 0-2200 m above sea level, in areas with more than 600 mm annual rainfall. The species tends to occur on hills and slopes.

2.1 Regional distribution of *S. cocculoides*

More detailed information on the distribution patterns of *S. cocculoides* in Southern Africa is provided by country in Table 2.1.

Table 2.1 *S. cocculoides* in countries of Southern Africa

Country	Latitude	Longitude	Habitat
Angola	12 º 0’S	18 º 0’E	Miombo woodland (and other variants) and grassland savannahs, with patches of lowland rainforest in the north. Intermediate elevation forest on the western escarpment, Montane forests in the highlands, and desert and sub-desert formations in the southwest.
Botswana	22 º 0’S	24 º 0’E	Open wooded grassland and deciduous bush land in the southwest on Kalahari sands, Zambezian woodland in the north and east, with extensive wetlands in the Okavango Delta and halophytic flora in the Magadigadi pan.
Lesotho	29 º 40’S	28 º 0’E	Predominantly Montane grassland with occasional patches of woodland in ravines and river valleys.
Malawi	11 º 55’S	34 º 0’E	Predominantly Miombo woodland, with drier Zambezian woodland in the south, Montane forest and grassland at higher elevations, and patches of lowland forest on the shores of the Northern part of Lake Malawi, Nyika Plateau, and the lower slopes of Mount Mulanje.
Mozambique	19 º 0’S	35 º 0’E	Miombo woodland, with Mopane woodland in the Zambezi and Limpopo valleys. Montane forests and grasslands found at higher elevations. Mosaic of coastal woodlands, as well as forest/mangrove patches.

Country	Latitude	Longitude	Habitat
Namibia	22 º 0’S	18 º 9’E	Dry woodland in the Northeast, becoming drier towards the South and the coast, through bushland and wooded grassland to the desert. The escarpment transition between the coastal desert and the savannahs of the interior.
South Africa	32 º 0’S	23o 0’E	Fynbos and its variants in the southwest, arid (succulent Karoo) and semi-arid Karoo shrub land and grassy shrub land in northern and central Cape, highveld grassland over much of the central plateau, open savannah woodland on the eastern plateau, Montane forest and grasslands in enclaves, savannah and low-lying forest on the east coast.
Swaziland	26 º 30’S	31º 30’E	North-eastern mountain grassland to the west of the country with pockets of Afromontane forest merging eastwards into savannah shrub woodlands (mainly sour lowveld bushveld, sweet lowveld bushveld and Lebombo arid mountain bushveld).
Zambia	15 º 0’S	28 º 0’E	Miombo woodland, with drier Mopane woodland in the Luangwa and Zambezi Valleys and parts of the West on Kalahari sands. Patches of lowland forest in the northwest, and Montane forest and grassland in the northeast.
Zimbabwe	19º 0’S	30 º 0’E	Dry Miombo woodland, with Mopane woodland and other woodland types dominating. Serpentine grasslands in the Great Dyke. Montane forest interspersed among high altitude grasslands and heath in the Eastern Highlands.

Sources: Golding (2002) and Hilton Taylor (1996)

2.2 Sampling the distribution patterns

As expected with such a wide distribution, *S. cocculoides* exhibits a great deal of phenotypic variation. Like most trees the species is expected to vary broadly between and within provenances and sites. A limited amount of experimentation has been carried out in this area, noteworthy being work by Veld Products Research and Development of Botswana to identify superior phenotypes (Mateke, 1998); and research on the differences in fruit characters of provenances from Zambia, Zimbabwe and Tanzania (Mwamba, 1983). Both projects identified patterns of genetic variations which can be used in improvement. Recently, international provenance trials have been established in Malawi, Tanzania, Zambia, and Zimbabwe under the auspices of ICRAF and the Danish/FAO Tree Seed Centre.

2.3 Distribution in relation to habitation

S. cocculoides is a natural pioneer on abandoned cultivated sites (Plate 10). It is also a tree typically left growing near farms on cultivated areas and in communal woodlands. This is because it provides a sustainable source of fruits. Trees of *Strychnos* are a common feature along the main roadsides. Almost certainly the major stimulus for their growth in such conditions comes from women, who collect wild fruits with children from locally preserved trees and also dominate the selling in markets.

2.4 Distribution outside Africa

S. cocculoides has been introduced to South America and India and *S. spinosa* has been tested for adaptability in the USA (Florida) and Israel. However, neither species has been exploited in these countries.

The odd distribution of *S. potatorum* L. f. in central provinces, Bihar, Orissa and the western peninsula of India, and in Sri Lanka and Myanmar, as a species now thought to be synonymous with *S. stuhlmannii* Gilg of Africa (see Chapter 1) and recorded under this name in the Flora Zambesiaca requires further elucidation. However, this wild species is not of major relevance to this monograph.

CHAPTER 3. PRODUCTION AREAS

Although *S. cocculoides* is widespread in Africa, most produce is gathered from natural populations, supplemented with produce from trees which have been locally protected near habitations and on abandoned cultivated land. The same is true for *S. spinosa*, whereas other species important to rural people, such as *S. gossweileri, S. innocua, S. lucens* and *S. madagascariensis* are virtually only gathered from natural populations.

The domestication of *S. cocculoides* is in its early stages and stems from the wider recognition of the needs to ensure household food security and to reduce environmental degradation around villages and settlements. Local fruit tree species have been accorded priority for satisfying these needs in part. Most of the species recognised as priority for enhanced domestication, including *S. cocculoides*, are multipurpose (Kadzere *et al.*, 1998; Maghembe, 1995; Maghembe *et al.*, 1998).

It is to be expected that within a very short time *S. cocculoides* will be integrated into agroforestry systems in at least Botswana, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. The reasons for this relate to wide recognition in the early 1990s that the Miombo woodlands of Southern Africa contain fruit species that are widely harvested and eaten. Moreover some national programmes, e.g. that of Zambia, have initiated research on domestication of indigenous fruit tree species and have accumulated a number of years of experience.

ICRAF developed a project, specifically for the Miombo woodland species, and donor governments (Germany, Canada, Norway, Denmark and Sweden) as well as the Rockefeller Foundation helped the partnership with national programmes (Akinnifesi *et al.*, 2002). Under an EC project, work started on production potential of *S. cocculoides* (and *S. spinosa*) on the drylands of Namibia and Botswana.

Research is now active on propagation (Mateke, 1998), agronomy, community processing of fruit (Saka *et al.*, 2001) and selection (see subsequent chapters).

The identification of future production areas will depend on combining high fruit production genotypes with suitable adaptation of planting material. In view of the wide natural and semi-natural distribution of *S. cocculoides*, it is expected that suitable patterns of genetic variation will be readily identified.

CHAPTER 4. PROPERTIES AND USES

4.1 Fruits for food use

Fruits of *S. cocculoides* are fleshy inside a woody shell (Plate 7). It is considered one of the most pleasing of the *Strychnos* species when eaten, as well as *S. spinosa*. The pulp is eaten when fruits are ripe and the pips spat out. *S. cocculoides* tastes sweet, *S. spinosa* is more acid-sweet.

The pulp is brown and gelatinous. Normally fruits are ripe in the period of October to December, when they are offered for sale throughout Central and Southern Africa.

4.1.1 Fruit composition

There are differences in the amount of pulp per fruit depending on geographic origin. Pulp equates to 34-48% of total fruit in Zimbabwean samples, 47-57% in those from Zambia and 50-57% in Tanzanian samples (Mkonda *et al.*, 2002). The rest of the fruit is made up of shell and seeds. Mean average in the northern parts of Southern Africa is 44% pulp, 41% pericarp (shell) and 15% seeds.

Unripe fruits are considered somewhat toxic because of their saponin content and presence of an alkaloid, the latter apparently being converted to non-toxic substances as fruits ripen (Williamson, 1995). There are conflicting reports about the presence or absence of alkaloids in the fruit pulp of a range of species. This needs to be investigated.

4.1.1.1 Pulp

The pulp contains over 30% fat, 45% crude fibre, high carbohydrate levels as well as saponin, citric acid and vitamin C (providing the taste). The physiochemical composition of pulp of *S. cocculoides* and two other species of *Strychnos* is shown in Table 4.1. Their mineral content is shown in Table 4.2. In both cases, figures are only indicative and more systematic analyses are needed. Detailed analyses of fruits have not been performed, although they provide good sources of Vitamin C, citric acid, zinc and copper. Pulp of *S. cocculoides* also contains about 0.85% of fixed reddish oil, with higher content (3.8%) in *S. innocua* (Laidlaw 1951).

Table 4.1 Physiochemical composition of fruit pulp

Species	% Component						Ascorbic acid (mg/100g)	Energy Value (kJ/100g)
	DM	**Ash**	**Crude Protein**	**Fat**	**Fibre**	**Total Carbohydrates**		
S. cocculoides	19.6	0.5	1.3	0.1	0.9	16.8	6.7	308
S. spinosa	22.2	1.8	2.7	0.1	1.4	15.2	10.6	305
S. pungens	27.9	1.0	1.1	0.8	6.2	18.9	10.7	367

Source Arnold *et al.* (1985)

Table 4.2 Mineral composition of fruit pulp (mg/g)

Species	P	Ca	Mg	Fe	K
S. cocculoides	20.2	9.41	26.9	0.18	188
S. spinosa	22.6	45.8	43.6	0.75	328
S. pungens	27.1	29.3	38.1	0.62	478

Source Arnold *et al.* (1985)

4.1.1.2 Dried fruits

There is some evidence that fruits of *S. cocculoides* can be dried for later use (PhytoTrade, 2003). This is also recorded for other species including *S. pungens* and *S. innocua* (Codd, 1951; Greshoff, 1900). Some wild species such as *S. gerrardii* N.E. Br. and *S. shumanniana* Gilg - two wild species of South Africa - are gathered and buried in sand to ripen, if found unripe (Galpin, 1925).

There appears to be a wide range of local practices which have not been thoroughly documented. For instance, in Botswana, dried *Strychnos* fruits are usually used for medicinal rather than food purposes. In Swaziland, the Swati people store dried fruits as an emergency food for use in times of famine. The Shangana people of Tanzania and the Swati of Swaziland only eat fruits of *S. spinosa* when fresh and not when dried (Codd, 1951). In Mozambique, dried ripe pulp of fruits of *S. gerrardii* is valued for making porridge (Almeida, 1930).

4.1.2 Toxicity of Fruits

Pulp of ripe fruits appears non toxic but a number of wild species may be toxic even when ripe. *S. stuhlmannii* is an example and local people cook the pulp before eating. The cooking must denature any toxins (Miller, 1948). The fruit of this species when crushed is used as a fish poison in the Kruger National Park of South Africa, the poison thought to be due to saponin (Codd, 1951).

4.1.3 Processing

Fruits of *S. cocculoides* are processed into juice, jam and fritters of mixed fruits (FAO, 1996; Swai, 2001; Saka *et al.*, 2002; Sufi and Kaputo, 1977; Mbiyangandu, 1985) especially in Malawi, Zambia and Zaire. Preservation of processed juice is achieved through the use of benzoic acid and sodium sulphate additives.

Fruits of *S. innocua* are also processed into jam. Species which are more acid are often processed into marmalade.

Urgent work is needed on assessing the organoleptic properties, such as flavour, texture, consistency and palatability of *Strychnos* products (Watts *et al.*, 1989).

Locally, fruits are used to produce alcoholic beverages, notably pulp of *S. spinosa* in Malagasy (Wildemann, 1946). In Malawi and Zambia government research has looked at the potential of *S. cocculoides* for wine production but has emphasised other tree fruits such as *Uapaca kirkiana* and *Zizyphus mauritiana*. In Namibia a traditional strong alcoholic drink is distilled from *Strychnos* fruits called kashipembe. A small enterprise was set up in 1988 in the Kavango region to develop this and use juice from *Strychnos* fruit, which are abundant in the region, to flavour a cane and wine-based liqueur. (Schreckenberg 2003).

4.2 Seeds

Although seeds are not used as food, when large numbers are present, some may get consumed when fruits are eaten fresh. Hence it is important to know something about their safety.

Characteristically, the seeds contain alkaloids, saponins and various acids and polysaccharides. Each seed of *S. cocculoides* weighs ca. 0.6g fresh weight (Uronu and Msangu, 2003) but usually less; the weight of 1000 fresh seeds varies from 382-600 g (Fletcher and Pritchard, 2000).

Seeds of *S. cocculoides* contain small quantities of strychnine ($C_{21}H_{22}N_2O_2$), making the seeds slightly toxic. There is no brucine (an alkaloid resembling strychnine) present.

In contrast the alkaloid is apparently not present in seeds of *S. spinosa* nor in *S. madagascariensis.* Seeds of *S. pungens* and *S. innocua*, though bitter tasting, apparently have no alkaloids.

As stated earlier, the data are not comprehensive enough to gain a clear picture of seed composition. Much of the pharmacological interest has resulted from the use and cultivation of *S. nux-vomica* L. from India and Sri Lanka as a source of strychnine and brucine. The original species in which strychnine was identified was *S. ignatii* Berg. from the Philippines.

Seeds in some cases contain reddish oil which might be of value commercially (Gunstone *et al.*, 1972) and is currently being considered for the cosmetic industry by PhytoTrade Africa. Additionally galactomannan, a polysaccharide with industrial applications is known in seeds of *S. potatorum* and *S. innocua* (Corsaro *et al.*, 1995).

4.3 Leaves

Leaves are not normally eaten, except for cases of *S. spinosa* leaves being used in couscous in the Sahel. Leaves of *S. innocua* are used as stockfeed.

Interestingly, in Tanzania, the leaves of *S. spinosa* are reported to be toxic and in Mauritius they are said to produce narcotic effects. The presence of strychnine is reported by Githens (1949) but no alkaloids have been isolated from plants grown in Florida, USA.

4.4 Medicinal uses of *Strychnos cocculoides*

4.4.1 Fruits

Green, unripe fruits of *S. cocculoides* are used to induce vomiting. The whole fruit is mashed in a mortar, steeped in water and then drunk (Leger, 2003; Palgrave, 1992). The emetic effect is probably due to toxins in unripe pulp and in the seeds. In Zambia, powder from unripe fruits is added to milk and drunk as a purgative. Pulp of ripe fruits, mixed with honey or sugar, is used to treat coughing.

4.4.2 Leaves

Fresh leaves are pounded and the mash mixed with water, heated and simmered to make a leaf porridge. This is applied to wounds to prevent infection and promote healing (Leger, 2003).

4.4.3 Bark

The middle part of the bark is cooked in water and the decoction is drunk as a cure for stomach pains (Fanshawe and Hough, 1960).

4.4.4 Roots

Roots are chewed as an alleged cure for gonorrhoea and also to alleviate eczema (FAO, 1983). In Zambia, local healers called Nganga use roots widely to treat sexually transmitted infections and often combine this treatment with regular purging using immature fruits.

4.5 Medicinal uses of other *Strychnos* species

In terms of medicinal potential, African *Strychnos* species have been documented as folk medicinal data with no commercial value to date. Emphasis on potential medicinal use has focussed on *S. spinosa* from the drier zones of Africa and *S. icaja* Baill., a liana species of rainforest, secondary forest and swamp and gallery forests with rainfall of 1350-2500+ mm throughout the year (FAO, 1986, 1988).

4.5.1 *S. spinosa*

The fruits and roots are widely used for gastrointestinal ailments as a laxative or emetic throughout Sub-Saharan Africa. Roots and leaves are used in treating venereal diseases (Zambia and West Africa) or as a febrifuge (Nigeria). A bark decoction is used for fever in the Ivory Coast and as ear drops. In Tanzania grated root mixed with coconut oil is applied locally to remove jiggers (larvae of mites of the family Trombiculidae) (Brennan and Greenway, 1949) and leaves are used in other regions for this purpose. In Zambia and neighbouring countries, leaf or root decoctions are used as an analgesic.

Roots and green fruit are used as snake-bite remedies especially in Eastern Africa (Bally, 1937), the Sahelian zone of West Africa (von Maydell, 1986) and South Africa (Bryant, 1909).

Leaves are used to treat conjunctivitis in Central Africa and Ivory Coast (Wildermann, 1946) and venereal diseases in Zambia.

4.5.2 *S. innocua*

Seeds are used as an emetic (Gilhens, 1949).

4.5.3 *S. madagascariensis*

In Angola, fruit pulp is used as a treatment for dysentery and in Eastern Africa the bark is used in obstetrics (Watt and Breyer-Brandwijk, 1962).

4.5.4 *S. pungens*

Leaves are used to make a decoction to ease coughing (Gilges, 1953). Unripe fruit pulp is used as an emetic and for snake bites. Roots are used for a variety of ailments; stomach ache, fever, inflamed eyes, bronchitis, and to make ear drops (Bally, 1937).

4.5.5 Other wild species

S. icaja is a species of West and Central Africa and the pharmacologically active alkaloids are described in Sandberg *et al.*, (1969) and Lamotte *et al.*, (1979); and saponins, iridoids and phenolics are described in Denoel *et al.*, (1953).

There are numerous references to medicinal uses of a range of other *Strychnos* species. However, in many cases, the correct or validated identity of the species is not confirmed.

4.6 Other uses of *S. cocculoides*

Wood is used in local construction and to make posts and tool handles. The wood is somewhat soft, fine pored and a whitish colour. *S. spinosa* is similarly used but is harder and yellowish.

The fruit shell is used as a resonance board for musical instruments as are those of *S. spinosa* (von Maydell, 1986) and *S. pungens*.

The fruit is used to make a dye for colouring fruit trays and containers are made from the shells. Fruit pulp can be used as a soap for washing clothes due to the saponin content.

4.6.1 Other uses of other *Strychnos* fruits

Pulp of *S. potatorum* is also used as a soap.

Plate 1. Fruit and spines of monkey orange

Plate 2. Fruit and rounded leaves of monkey orange

Plate 3. Mottled unripe fruit of monkey orange

Plate 4. Fissured bark

Plate 5. Variation in fruit of *Strychnos* species

Plate 6. Variation in leaves of *Strychnos* species

Plate 7. Brown jelly-like pulp surrounding the seeds which can be processed

Plate 8. Pale seeds of monkey orange


Plate 9. Monkey orange height and form at maturity


Plate 10. Monkey orange: A pioneer on abandoned cultivation sites

Plate 11. Deciduousness in monkey orange

Plate 12. Monkey orange growing and fruiting on limestone parent material

Plate 13. Grass providing partial shade to young monkey orange trees

Plate 14. Sapling on abandoned cultivation site

Plate 15. Effect of fire on saplings

Plate 16. Coppice sprouts in monkey orange after fire

Plate 18. Coppice shoots

Plate 17. Grafted plant flowering after one year

Plate 19. Coarse and fine roots of mycorrhizal root system

Plate 20. Termite damage of a seedling

Plate 21. Powdery mildew on bottom fruits while in storage

Plate 22. Monkey orange chopped for firewood and fruits scattered on the ground.

Plate 23. Extraction of roots for medicinal uses.

Plate 24. Monkey orange and Masuku (*Uapaca kirkiana*) wine

Plates courtesy of C. Mwamba

CHAPTER 5. ECOLOGY

5.1 Introduction

Strychnos cocculoides typically occurs in areas that are characterised by having two main seasons, a wet one and a dry one, in tropical Central Africa. The wet season lasts from November to April. During this period, rainfall occurs for an average period of 114 days and is modified by elevation. In January, the rainfall is around 250-500 mm and the mean monthly maximum and minimum temperatures are 26°C and 16°C respectively. The dry season occurs from May to October. In the first cool part of the dry period in May-September, there is no rainfall and the mean monthly extreme temperatures are 26°C and 6°C respectively. During the second part of the dry season (September to October), warm conditions prevail with extreme temperatures of 32°C and 14°C during October.

In other regions, such as in West Africa, the genus *Strychnos* occurs in climatic conditions which do not vary in extremes, but there are three geographical zones: a dry desert zone prevalent in the north, a middle belt savannah region and a rain forest region of the south.

Strychnos cocculoides is a remarkably unexacting species. It tolerates both the hot and dry summers of the tropics by being deciduous (Plate 11). It sheds its leaves during the dry season and, unlike many other wild fruit trees, it does not produce new leaves until the rains. It occurs from high rainfall tropical forests to more desert climates of Southern Africa, at a range of altitudes, and can colonise dry sandy soils including calcareous ones. It is, therefore, most frequent where more demanding trees fail to grow.

The estimated areas of the natural tropical forests in which the genus *Strychnos* is endemic are presented in Table 5.1.

Table 5.1 Principal biomes in which the genus *Strychnos* is endemic, prevailing climate and dominant growth forms
(adapted from Burley and Styles, 1976; Jensen and Salisbury, 1972).

Biome	Area (million ha)	Climate		Dominant Growth Form
		Temp. (ºC)	Rainfall (mm)	
Tropical Zone				
Wet evergreen	560			Trees, both evergreen and deciduous
Wet evergreen	308			Trees, broad leaved deciduous
Dry deciduous	588			Trees, grass and shrubs
Total	1456	18-35	1000-12500	
Subtropical Zone				
Wet evergreen	8			Trees, evergreen
Subtropical moist	20			Trees, broadleaved deciduous
Subtropical dry	196			Trees, grass and shrubs
Total	224	13-40	250-900	
Desert				
Tropical warm	*			Shrubs, succulents
Temperate warm	*			Shrubs, succulents
Total	448	2-57	0-250	

* data unavailable

5.2 Rainfall

Under arid conditions, *Strychnos cocculoides* and *S. spinosa* tend to develop deep root systems. This confers an ecophysiological advantage in accessing the available water and they are able to use periodic rainfall quickly and effectively, especially small quantities of water before it evaporates. *S. cocculoides, S. spinosa* and *S. pungens*, were tested for growth under different desert ecozones in the Negev desert, Israel (Mizrahi *et al.*, 2002). *S. pungens* did not survive the arid conditions. *S. cocculoides*, which is considered the best of the three in terms of eating quality, survived only in the Besor region because of good quality water (not saline) and moderate temperatures. The best of the three species to grow under desert conditions was *S. spinosa*. Mizrahi and his co-workers successfully established about 15 fruiting trees, but with a high variability in growth, yields, fruit size, ripening season and taste. Some of the trees bore astringent, bitter fruits, while others bore very sour fruits and only two trees bore fruits which were of excellent taste.

S. cocculoides occurs in areas where rainfall is restricted for part of the year, and the plant survives long periods of drought. Minimum annual rainfall per year is 600 mm and maximum annual rainfall per year is 1200 mm. The seed is desiccation tolerant (Pritchard *et al*. 2004).

5.3 Light

S. cocculoides is a light- demanding species. The effect of light intensity on growth and root/shoot ratio in the species were evaluated by Mateke (1998) in Botswana, who grew seedlings under 50% and 25% shade and full direct sunlight for six consecutive summer months. Seedlings grown under 50% shade netting grew fastest, followed by seedlings grown under 25% shade netting. Table 5.2 shows the performance of *S. cocculoides* seedlings compared to those of *Sclerocarya birrea* under different light regimes. For *S. cocculoides*:

(i) Height increased with increased level of shading;
(ii) There was a weak negative linear response in stem diameter, root and shoot weight with the level of shading;
(iii) Root/shoot ratio decreased with increased level of shading.

Table 5.2 The performance of *S. cocculoides* and *Sclerocarya birrea* seedlings under different shading regimes
Source: Mateke, 1998

Parameter	***Strychnos cocculoides***			***Sclerocarya birrea***			
	Shade (%)			**Shade (%)**			
	0	**25**	**50**	**0**	**25**	**50**	**LSD**
Survival (%)	100	100	100	100	100	100	NS
Height (cm)	11.2	12.9	14.9	20.6	29.3	37.8	2.1
Stem (mm)	3.3	3.7	3.1	9.6	8.3	7.5	1.0
Shoot weight (g)	1.4	1.0	1.4	11.6	11.4	11.0	1.6
Root weight (g)	5.5	3.1	2.5	89.9	72.0	67.0	4.3
Root/shoot ratio	3.9	3.1	1.8	7.8	6.3	6.1	2.7

Shade therefore has a negative effect on the growth of seedlings of *S. cocculoides*. Grasses normally provide limited shade in natural communities (See Plate 13).

The effects of light intensity on height, dry weight and root/shoot ratios given in Table 5.2 are typical (Kramer and Kozlowski, 1960). They suggest that *S. cocculoides* has a low capacity to endure shade, in part explaining its occurrence as a pioneer tree in old cultivated fields and open woodlands. Seedlings appear to develop root biomass before producing a lead stem.

5.4 Wind

The effect of wind on *S. cocculoides* is twofold:
(i) It tends to decrease leaf temperature, which reduces transpiration, but also removes water vapour from the vicinity of leaves. This helps to maintain a steep vapour-pressure gradient from the leaf to air and therefore tends to increase the rate of transpiration.

(ii) Winds of high velocity sometimes cause reduction in transpiration, apparently because they cause closure of stomata.

5.5 Soil requirements

S. cocculoides grows well on sites with deep sandy soils and on well-drained slopes. It is also found on black to dark grey clays and yellow-red loamy sands derived from limestone parent material (Plate 12)

The general soil physical characteristics are summarised in Table 5.3.

Table 5.3: Soil physical requirements of *S. cocculoides*

Characteristic	Requirements
Soil type (texture)	• Deep sandy soils • Black to dark-grey clays • Yellow-red loamy sands • Red yellow-red loams
Topography	• 0-13% slope
Rooting depth	• Restricted by aeration • Restricted by rock outcrops
Drainage	• Well drained
Terrain	• Flat woodlands and savannahs • Hilly woodland slopes • Rocky slopes
Soil pH	• Acidic, pH 4-6

In an effort to recognise the potential management advantages and any dangers of extending the genus *Strychnos* beyond its natural distribution limits, Mwamba (1983) related the stocking density (or number of trees) per hectare with soil properties in areas of natural occurrence of *S. cocculoides* and *S. pungens* in Zambia. The results are summarised in Table 5.4 and reveal that maximum stocking density for *Strychnos cocculoides* is obtained on loamy soil with cation exchange capacity (CEC) of 5-10 meq/100 g clay, base saturation of 60-80 % and soil pH 5.0-6.0.

Table 5.4: Stocking densities of *S. cocculoides and S. pungens* on soil with varying properties (Source: Mwamba, 1983)

Soil Property	Stocking Density/Hectare	
	S. cocculoides	*S. pungens*
Texture		
Sandy	0	3
Loamy	3	35
Clay	0	17
CEC (meq/100 g clay)		
<5	2	52

5-10	4	10
10-15	0	2
>15	0	0
Base Saturation (%)		
<20	2	2
20-60	3	17
60-80	4	2
>80	0	0
Soil pH		
<4.0	0	0
4.0-5.0	1	2
5.0-6.0	6	52
>6.0	0	0

S. pungens also shows maximum stocking density on loamy soils, but with CEC of less than 5 meq/100 g clay, base saturation of 20-60% and pH of 5.0-6.0. The high base saturation and CEC requirements of *S. cocculoides* suggest that this species requires richer soils than *S. pungens*, and this may explain why *S. pungens* is more widely distributed on poor sandy soils. However, both species are characteristic of nutrient poor soils derived from granites, coarse schists, sandstones, quartzites, limestones, Pleistocene sands and gravel parent materials.

Bonifacio *et al.*, (2000) reported *S. cocculoides* and *S. spinosa* on soil types as shown in Table 5.5. The chemical characteristics of these soils are summarised in Table 5.6. Although optimal conditions for the growth of these trees are practically unknown, the species is among the dominant woody plants of the vegetation communities in various tropical areas (Malaisse *et al.*, 1999).

Table 5.5: Soil types that support *S. cocculoides* and *S. spinosa* in Botswana (adapted from Bonifacio *et al.*, 2000)

Species	Soil Classification	Land System Division	Soil Parent Material
S. cocculoides	Typic Torripsamments	Sandveld	Sandstone
	Lithic or Typic Torripsamments	Sandveld	Sands
	Lithic or Typic Torripsamments	Hardveld	Basalts
	Typic Quartzipsamments	Sandveld	Kalahari Sands
	Typic Torripsamments	Hardveld	Red Sandstones
	Typic Quartzipsamments	Sandveld	Kalahari Sands
S. spinosa	Typic Torripsamments	Sandveld	Sandstone
	Typic Torripsamments	Sandveld	Sandstones and conglomerates

Table 5.6: Chemical soil properties that support *S. cocculoides* and *S. spinosa* in Botswana (adapted from Bonifacio *et al.*, 2000)

Species	Site	pH	Clay (%)	Organic C (%)	N (g/kg)	P (g/kg)	CEC (C mol./kg)
S. cocculoides	Serowe 1	5.9	3.0	0.35	0.4	1.8	2.3
	Serowe 2	5.2	4.0	0.27	0.3	1.4	1.8
	Serowe 3	7.2	4.1	0.92	0.9	22.0	22.0
	Shakawe	5.4	1.7	0.19	0.2	ND*	0.8
	Manyana	4.7	5.9	0.55	0.5	3.7	3.3
	Hamoye	5.7	7.4	0.21	0.2	0.5	1.0
Mean		**5.7**	**4.4**	**0.42**	**0.42**	**5.8**	**5.2**
Standard deviation		**±0.8**	**±2.0**	**±0.28**	**±0.26**	**±9.1**	**±8.3**
S. spinosa	Serewe 1	5.9	3.0	0.35	0.4	1.8	2.3
	Pilikwe 1	5.7	5.1	0.45	0.5	19.4	3.8
Mean		**5.8**	**4.0**	**0.40**	**0.45**	**10.6**	**3.0**
Standard deviation		**±0.1**	**±1.5**	**±0.07**	**±0.07**	**±12.4**	**±1.1**

* ND: Not determined

5.5.1 Details of soil types

Strychnos cocculoides trees occur on a variety of soil-forming rocks which may be grouped into four major ecological divisions on the basis of their contribution to soil fertility (Wilde, 1958) as below:

5.5.1.1 Siliceous Rock Parent Material

It occurs on siliceous parent materials, including sandstones, siliceous shales, conglomerates and quartzites. These rocks generally produce soils which are poor in nutrients and of low exchange capacity. Such soils are suitable for less nutrient-exacting tree species. A locally high base saturation as a result of the presence of lime in the profile and/or higher clay content may considerably raise the productive capacity of these soils.

5.5.1.2 Orthoclase – Feldspathic Rock (Acid Igneous Rock) Parent Material

Soil parent materials, granite, syenite, granitic porphyry, orthoclase felsites and gneisses weather into sandy loams or loam soils believed to be well supplied with potassium, but low in calcium and magnesium. Where rainfall is not intensive, sufficient quantities of phosphates may be expected. These soils are generally well adapted to all forest trees, except for a few lime-demanding species.

5.5.1.3 Ferromagnesian Rock Parent Material

These parent rocks gabbro, diorite, diabase, basalt, andesite and schists enriched in augite, amphibole or olivine, upon sufficient weathering, produce fine-textured soils with an abundant supply of calcium, magnesium, phosphorus and other essential nutrient elements.

5.5.1.4 Calcareous Rock Parent Material

These parent rocks include limestone, dolomitic limestone, chalk and calcareous shales. These rocks have given rise to soils of greatly variable productive potential, determined by climatic conditions, degree of weathering and clay content. The deficiency of potassium and phosphorous, the high content of carbonates, and the alkalinity are among the adverse factors that affect tree production (Wilde, 1958).

5.6 Ecotypic differentiations

It is thought that there are distinct ecotypes adapted to different environments. More research is needed, however, on the patterns of genetic variations within and between populations of *S. cocculoides* and any correlations with geographic, climatic or ecological parameters.

5.7 Mycorrhizae

The fine root systems of *Strychnos* fruit trees are reported to form symbiotic associations with some beneficial fungi (Munyanziza,1994; Mwamba, 1995). The failure to cultivate some of the wild fruit tree species in areas where they have never existed before is attributed to the lack of natural mycorrhizal symbionts (Bowen, 1980; Munyanziza, 1994).

Some research has been carried out in this respect on Kalahari sandy soils (McGonigle, 1997; Sinclair, 1998; Mateke, 1998a). Seedlings of *S. cocculoides* when artificially inoculated with isolated cultures of arbuscular mycorrhizal fungi (AMF) from soils taken beneath parent trees in their natural habitat resulted in better growth (Table 5.7).

Mateke (1998a) concluded that artificial inoculation of the seedlings with the right AMF at planting stage may play a significant role in the promotion of initial growth.

Table 5.7: Effect of mycorrhizal inoculation on initial growth of outplanted indigenous fruit tree seedlings (Source: Mateke, 1998)

Species	**Average Plant Height (cm) at 100 Days**		
	Control	Inoculated	Increase over control (%)
Azanza garckeana	8.1	17.5	116
Vangueria infausta	7.4	13.8	86
Sclerocarya birrea	19.5	35.3	81
Strychnos cocculoides	9.2	15.0	63

5.8 Fire

S. cocculoides grows in environments vulnerable to fire and is capable of bearing fruit afterwards. The vulnerability of a species to damage by fire is linked to its environment and to the rates at which flammable materials accumulate.

Individual trees are readily killed by fire, but *Strychnos cocculoides* regenerates readily from shoots (see Plate 16). It can also regenerate from seed as the woody fruits tend to be held on the tree and survive fire.

Detailed observations of succession after fire in woodlands containing *S. cocculoides* have not been recorded. In the drier forests, where *S. cocculoides* typically occurs, most fires have relatively little effect on the tree stratum; it is the herb and shrub layers and the seedlings of tree species that are heavily impacted by fires.

Fire appears to be a factor essential to maintenance of the natural community where *S. cocculoides* occurs because reduced fire frequencies may lead to premature die-back.

CHAPTER 6. AGRONOMY

6.1 Seed propagation

Fruit production in *S. cocculoides* commences between 4 and 6 years of age in open-grown stands, but several years later in denser re-growth. In general, flowering is continuous, but with light to moderate flowering in some years followed by heavier flowering in others.

The fruits of *S. cocculoides* contain from 10 to 100 (usually 25-30) pale seeds (Plate 8). The average seed weight varies between 0.3-0.6 g with moisture content 25-30% of fresh weight. Fruits begin development in July-September, mature about June of the following year and are available thereafter and even up to December. Hence opening can be ca. 8 months from pollination.

6.1.1 Seed collection and handling

When attempting to collect seed samples over a wide range, the total time allowed by the length of the fruiting season can be a severe constraint. Determination of the most appropriate sequence of collecting sites, difference in fruiting times and also the available means of transport between sites can be a complex problem. Adverse climatic conditions may greatly alter the time needed at a given site, by hampering travel, collection and seed extraction. The preparation of alternative plans to cover such contingencies is particularly important when synchronisation of the work between separate teams is needed.

The physiologically mature fruits, light green or yellow, may have to be picked from the tree or they may drop on their own (at full maturity) after separating from the fruit stalk. Fruits are cracked open using a gentle tap on a stone or by hitting the fruits with a stick. The seeds which are embedded in the brown pulp do not adhere to the sides of the fruit shell and thus can be removed readily. After collection, seeds are thoroughly cleaned by scraping them over a wire mesh with sand. Seeds may be bulked for each tree or for all the trees of a population.

6.1.2 Seed treatment and germination

Normally freshly harvested seeds give up to 75-80% germination but occasionally this can be lower, usually because some seeds are immature.

There are differences of opinion as to whether seeds should be treated prior to sowing. Some say no treatment is necessary, others suggest soaking seeds in hot water for 24-48 hours prior to sowing (Taylor and Kwerepe, 1995). Seeds appear to have hard coats and in nature annual fires are thought to soften seed coats. Treatments by soaking seeds with potassium nitrate or thiourea have not had beneficial effects (ICRAF, 2000).

Seeds are sown at a depth of 2-3 cm in pots or seedbeds (or even direct sowing into an orchard). Time to germination varies greatly. In Botswana, germination of 80% has been reported in 3 weeks when sown in summer propagation boxes, but seeds sown in winter took more than 9 weeks to germinate (Taylor, 1983). Seeds stored dry at room temperature (23-28°C) for 8-12 months gave good germination (Mateke, 1998). Tests show that the seeds are desiccation tolerant and storage at 15-16°C after drying results in good germination after 3-6 months (Fletcher and Pritchard, 2000). After desiccation to 5% moisture content, germination falls to 59% (Uronu *et al*. 2005).

Sizes are extremely variable, differing year to year from tree to tree and even with location in the fruit. The largest seeds are usually produced in the largest fruits and those near the middle of the fruit are larger than those at the ends.

6.2 Vegetative propagation

S. cocculoides coppices readily (Plate 18). Shoots arise from the stumps of trees that have been cut down, or killed-back during burning. It would seem, therefore, that propagation should be possible by taking cuttings of re-growth shoots. However, cuttings appear not to produce roots, even if kept in shade and shoots sprout (Taylor, 1983).

Additionally there are no reports of air layering. Thus low-cost vegetative propagation is not possible. Nonetheless, grafting and budding techniques are possible (see below).

6.2.1 Grafting

Two approaches are being taken at present. In the first, Veld Products Research and Development of Botswana has developed techniques of grafting seedlings with productive parts of mature trees. This has resulted in improvement in the growth of the trees (Mateke, 1998). The wedge method is preferred. This research has been focused on identifying superior cultivars and development of mass propagation methods.

In Zimbabwe, research has focused on collecting a wide range of germplasm from the Southern African region and carrying out grafting when evaluated ecotypes or superior genotypes are identified (Nyamutowa and Mushonga, 1995).

6.3 Orchard establishment

6.3.1 Site preparation

S. cocculoides is a light-demanding tree. The best preparation of planting sites is complete clearing, ploughing and/or ridging, and elimination of herbaceous weeds, especially grasses for 2-3 years.

6.3.2 Planting

Planting is usually by hand, ideally when the soil is at or near field capacity. Planting holes are spaced at 5 x 5 m to provide 400 trees per ha.

If direct seeding is practiced, two seeds are planted per hole and 2 months after emergence one seedling is rogued. There are no reasons to support direct seeding due to the variation in germination and establishment rates.

It is better practice to use nursery-raised seedlings produced from containers. Initially seeds are sown in trays at 2-3 cm depth, and resultant seedlings transplanted to tubes, sleeves or pots containing sterilized nursery soil. Polythene bags are cost effective.

6.3.3 Seedling survival

Addition of soil from local *S. cocculoides* sites will enhance the possibility of mycorrhizal associations (see 6.3.4 below). Seedlings need to be transplanted with minimal damage to the root system.

Survival is in excess of 80% providing adequate watering is carried out, weeds are controlled and seedlings are protected from livestock. A great deal of training of smallholder farmers is necessary in this area.

6.3.4 Mycorrhizae

Research has shown the beneficial results of artificial inoculation at transplanting time with cultures of arbuscular mycorrhizal fungi from soils taken from beneath parent trees in their natural habitat. This work has been carried out with the University of Pretoria (Mateke, 1995, 1998a).

It appears that transplanted seedlings of *S. cocculoides* can pick up indigenous mycorrhizae at the planting site, but attention to this need at the nursery stage could reduce any transplanting stress.

6.4 Orchard management

6.4.1 Stand density

Depending on the intensity of management, stands originally established at 5 x 5 m spacing may be thinned to 10 x 5 m or 10 x 10 m providing 200 or 100 trees per ha. This would be done after the second year assuming the trees start bearing fruit at about 5 years (but as early as 3 years) following transplanting. Intensity of management relates to the use of fertilizers (6.4.2) and pruning (6.4.3).

6.4.2 Fertilizers

S. cocculoides responds well to inorganic fertilizers. Seedlings in net-house nurseries treated with super phosphate and nitrosol grew rapidly in height in 3 months compared to untreated seedlings (38-76 cm compared to 20 cm untreated: Taylor and Kwerepe, 1995). More detailed analysis of fertilizer regimes has not been reported.

Such treated nursery-raised stock should be transplanted to the field holes to which a little organic manure has been added to aid the transplanting. Treatment with inorganic fertilizers at the start of the wet season and half way through it is recommended.

However, it is essential that water stress is avoided and that any water deficit in dry summers is not exacerbated by the presence of recent inorganic fertilization.

At present, less than 1% of local smallholders apply inorganic or organic fertilizers to farm-forestry trees (Mango and Akinnifesi, 2000).

Additionally, severe deficiency of nitrogen or phosphorus reduces mycorrhizal formation and overall growth of the trees although a moderate deficiency can stimulate mycorrhizal formation. It is better to consider this at the nursery stage rather than changing orchard management.

6.4.3 Pruning

In natural stands, ‘pruning’ in *S. cocculoides* involves several sequential phases. These include weakening of branches, infection with wood-decomposing fungi, wood decay, severance of the branch from the tree, and wound healing. Natural pruning is set in motion in dense stands with low rates of photosynthesis in leaves of heavily shaded lateral branches.

Since *S. cocculoides* is widely and variably spaced in the forests, natural pruning takes place within the canopy, starting with more shaded branches and is generally very slow. Water deficits also contribute to natural pruning. Death of branches is preceded by an extended period of retarded growth. After the branch is severed, a protection layer develops between the outer dead stub and the inner living part of the branch.

Pruning in orchards should remove any dying side shoots and create a good crown shape permitting light entry. At present information is not available on the effects of decreasing the numbers of fruit spurs to increase size of fruits. Current efforts are under way to use genotypes for orchard planting that inherently produce larger and better quality fruits.

6.4.4 Weeding and intercropping

Weeding is crucial at the transplanting and establishment phase. In subsequent years attention might focus on the possibilities of intercropping.

ICRAF has adopted a holistic approach to intercrop indigenous fruit trees, including *S. cocculoides*, with agricultural crops on farmers' fields. Since 1998-99, 35,000 selected, but unimproved, seedlings have been planted by almost 3,000 farmers in pilot areas in southern Malawi (Mango and Akinnifesi, 2000). This was part of a project in which seedlings of different indigenous fruit trees were raised at Makoka Agricultural Research Station for distribution to farmers. Farmers were selected on the basis of their interest in growing these trees. The farmers were all drawn from areas where ICRAF already undertakes agroforestry work in Machinga and Zomba districts of the Machinga Agricultural Development Division and part of the Blantyre Agricultural Development Division, Chiradzulu district. It is expected that clear recommendations for intercropping packages will be forthcoming from this experience.

6.4.5 Protection from pests and diseases

There appear to be no major pests and diseases other than at seed germination (Taylor and Kwerepe, 1995). Termites can be a problem, however, for both seedlings and mature trees - usually when trees are in a poor physiological condition. Termites feed on dead bark hence good husbandry practices go a long way to eliminate such damage (Plate 20).

The species does not appear to be commonly attacked by insect defoliators. Animal browsing can be a problem with young trees but is not serious for mature ones.

The major fungal problems are root rot and damage from fungi during germination and emergence, as for any other tree or crop species.

Fruits may be attacked by powdery mildews when in storage (Plate 21).

6.4.6 Physical stresses

S. cocculoides is killed by fire at the small sapling stage but mature trees are more resistant and tend to recover. Wind causing stem breakages can be a problem on shallow soils but this can be avoided by good site selection.

Frost may be a limiting factor since light frosts are experienced in some parts of the natural distribution of the species. However, fertilized seedlings can withstand temperatures a few degrees below freezing.

6.4.7 Growth rates

Not enough data are available on growth rates particularly for species which can grow in areas with long dry periods, e.g. the Kalahari sands of Southern Africa (Mateke, 1998).

However, major differences have been noted across regions and these appear to depend on differences in soil types and temperatures during the winter months. In reasonable sites trees can reach over 2 m in 4 years and have a crown size of 1.5 m per tree, similar to *S. spinosa*.

6.5 Agroforestry

A range of agroforestry systems can be developed using *S. cocculoides* as a component.

In Botswana, a trial was established in a 6 year old orchard of *Sclerocarya birrea* trees which were in rows 15 m apart with trees 12 m apart. Interplanted in the 12 m between trees were *S. cocculoides* and *Vangueria infausta* within a contour bund system. Arable crops such as sorghum, cowpea and watermelon were incorporated. Results so far seem promising and this type of dryland agroforestry provides a range of fruits.

6.6 Ongoing research

Agronomy practices, plant soil relationships, mycorrhizae and other aspects relevant to this chapter are under active investigation through an EU cooperative programme with researchers in Holland, Germany, Israel, Botswana and Namibia. See http://www.divapra.unito.it/res/en0035

CHAPTER 7. REPRODUCTION AND HARVEST

7.1 Reproduction

S. cocculoides bears female (pistillate) and male (staminate) flowers on the same plant. Much more research is needed on breeding systems of the African species of *Strychnos*: most appear to be naturally outcrossing through the development of mechanisms to minimise self fertilising but mating systems can include up to 20% self fertilisation.

It is thought that flowers are mostly pollinated by a range of insects. Fruit (and seed) dispersal is by mammals. Fruits in the wild simply drop from the trees and are gathered, particularly by monkeys.

7.2 Harvesting

7.2.1 Harvesting practices

The cycle of harvesting varies from a few weeks to longer because of variation in time of ripening. There are two methods of harvesting fruits. The first is to wait for physiological maturity and natural separation of the fruit from the fruit stalk when the fruit drops to the ground. The mature fruit may be yellow or still green at the time it drops. The second method is to use an implement to knock the green fruit onto the ground.

The fruits are collected from the ground, mostly by women and children, since they are usually eaten raw immediately after collection. The green fruits may require incubation until ripe, before they are to be eaten. Both people and monkeys incubate the fruits under the sand.

7.2.2 Yields

The total weight of fruits produced per tree is influenced by the provenance. When grown in favourable conditions total weight of fruits can vary from 40-100 kg. Fruit numbers vary from 300 to 700 per tree.

S. spinosa can produce up to 180 kg per tree and 350-850 fruits per tree. Comparisons between four populations in Zambia showed variation from

158-296 g weight of fruit. Pulp made up 47.6 to 52.8% respectively. The heaviest seeds were also found in the heaviest fruits (Mkonda *et al*. 2003).

7.2.3 Post-harvest handling

After harvest the fruits may be washed with water to remove any debris from the soil, and used immediately or air-dried and stored for processing. Air-drying fruits can prevent some surface infection by powdery mildew and extends shelf-life.

Storage facilities are often lacking: the fruit industry needs to be transformed so that such durable fruits can be kept for longer periods. Currently for example in Zambia, there is a lot of wastage due to lack of storage technology. Hence, many fruits rot in the field or while in storage. At present, fruits which could be consumed throughout the year are actually consumed in 3-4 months before many rot and go to waste. The other constraints include lack of accessibility by roads and high transportation costs because the fruits are heavy and large trucks are needed.

7.3 Processing

In some areas processing is not recommended because fresh values are so high and there is a reasonable shelf-life. In Botswana, each fruit is worth US $ 0.45 (Taylor *et al.* 1996). As a result Zimbabweans drive truckloads across the border to sell them fresh rather than providing fruits for processing.

Nonetheless, processing adds value. Immediate processing includes washing, shelling and pulping. Juices and jams are produced using heating for sterilization. Alcoholic drinks are produced in Tanzania and Malawi.

Availability of skilled labour to apply appropriate technology, management expertise and capital for investment and marketing of processed products is still at a low level in Southern Africa.

Almost certainly the major processing will relate to making juices. Other products, such as dry fruit rolls, have potential but have not yet been explored.

A pilot enterprise set up in Namibia in 1988 used monkey orange fruit to flavour liqueur. The fruit was exported to South Africa for processing, which required five permits, including a collection permit from the Ministry of Environment and Tourism, a phytosanitary certificate and an import permit from the South African Ministry of Agriculture. Costs included transport to South Africa, covered by a Small Business Credit Guarantee Scheme. Promotion of the business is now needed to increase monthly turnover and allow development of a factory in Namibia.

7.4 Economics

A case study on marketing is under way in Zimbabwe which will generate baseline information on the incentives and constraints of the current marketing system. This includes assessment of the market structure and assessment of consumers' willingness to pay. A parallel study is assessing the economics of returns on plantings, what levels of tree improvement are needed to induce farmers to invest and what competition there is with other on-farm activities.

These studies are being carried out of at the Institute of Economics in Horticulture at Hannover University, Germany and greatly adds to technology generation in Africa (See: http://www.uni-hannover.de/en/internat/kooperat/int_forschproj/e_proj_wiwi04.htm)
The majority of rural households were shown to benefit from the consumption and sale of indigenous fruits, collected from wild sources. Indigenous fruit is generally consumed as a snack, with children being the main consumers (See Table 7.1).

Table 7.1 Percentage of households consuming indigenous fruits as a snack or main meal during normal, bumper and disaster harvest seasons for maize in two areas in Zimbabwe.

	Murhewa			Takawirwa		
Success of maize harvest	**No consumption**	**Main meal**	**Snack**	**No consumption**	**Main meal**	**Snack**
Normal	22.6	0.5	76.9	0	0	100
Bumper	21.7	0.5	77.8	0	0	100
Disaster	21.7	0.5	77.8	0	34.1	65.9

Source: Mithöfer and Waibel (2003)

The activity of wild fruit collection was compared in this study to production of field crops, household gardens, livestock rearing, growing exotic fruit trees and indigenous fruit trees and household tasks such as brick-making. Collection of tree products was found to be an efficient activity relative to other income generating activities. Gross margins for the collection of indigenous fruits were lower than for livestock and crop production. Collection provided greater returns for labour allocation than from crop growing and livestock rearing, demonstrating that it is an efficient use of labour. Since labour is generally the limiting factor in rural Africa (Upton 1987), it is an important criterion in the choice of activities.

Fruit sale is done by women of a household to provide cash income to purchase household goods. Fruit selling also bridges a gap in cash supply, which can be used for farming and household activities. Indigenous fruits are available during the dry season, when food availability is low, and at the beginning of the wet season when labour for agricultural activities reach a peak. However fruit collection can be combined with other activities in the field. The average farm gate price for *Strychnos* fruit was 1.5 ZWD per fruit. 37% of households in Murehwa District Zimbabwe receive 0-500 ZWD for fruit selling. In addition the wood is also valued for timber and the leaves as a source of nitrogen for growing vegetables. Fruit selling is related to the proximity of wild grown fruits to the village and to the market.

Currently collecting fruits is more profitable than planting trees. Technical change and reduced tree density would lead to greater incentive to plant indigenous fruit for its products and for biodiversity conservation. It was found that collection costs would need to rise or the performance of domesticated trees would need to improve to make planting a viable option. Improved performance consisted of, increased yield, reduced time to fruit bearing, and improved fruit quality.

Increasing population pressure, and intensification of land use have caused severe deforestation of woodlands in southern Africa. Traditionally indigenous fruit trees were preserved when land was cleared for agricultural production (Clarke *et al.* 1996), but they are under increasing pressure. Farmers have rarely planted indigenous fruit trees and continued collecting from communal areas (Campbell 1996). Deforestation of natural forests increases the collection costs and reduces labour productivity.

Expected returns from planting depend on the number and value of products that could be obtained from the tree. Investment in tree planting is long-term. In this study costs of land were assumed to be nil because it can be borrowed from neighbours or allocated from the village chief free of charge. Planting could be an alternative in areas of low abundance of fruit trees particularly in southern Africa, and if breeding efforts were to reduce the age and maturity and significantly increase the yield.

Table 7.2 Domesticated IFT planting dependent on age to maturity, yield increases and collection cost.

Maturity (years)	2	4	6	8
Yield increase (times non-domesticated level)	9-30	10-40	12-56	16-80
Collection cost (times level of survey year)	2.7-3.0	-	-	-

Source: Mithöfer *et al*. (2004)

CHAPTER 8. SELECTION AND GENETIC RESOURCES

8.1 Background

Unfortunately research on patterns of genetic variation between and within populations has not been carried out. Additionally chromosome counts are woefully lacking, not only for *S. cocculoides*, but many of the other edible species.

To-date, phenotypic selection has been used to identify superior phenotypes. In order to proceed with this a series of surveys were carried out in Botswana, Malawi, Tanzania, Zambia and Zimbabwe using participatory appraisal tools and structured questionnaires (Kadzere *et al.*, 1998).

8.2 Surveys

8.2.1 Botswana

Veld Products Research and Development organized a series of countrywide competitions among school children to identify the largest and sweetest fruits. These competitions were a resounding success.

The provenances which produced the biggest and sweetest fruit on healthy trees were selected as baseline materials for germplasm collection. Variations in tree height, branching characteristics, time of fruiting, fruit production, fruit size and quality were recorded.

8.2.2 Malawi

In Malawi, farmers were requested to give preferences and prioritise wild fruits found in Malawi (Maghembe *et al.*, 1995). The most important criteria used in selecting priority species were the contribution made to household food security, market potential, length of fruiting period, fruit quantity and quality, ease of management and possibility of preserving the fruits. See also Maghembe *et al.* (1998).

8.2.3 Tanzania

Ethnobotanical surveys using farmer's choice and participatory rural appraisal tools helped determine the importance of the species to the local people based on the criteria of taste, multiple use marketability, food security in famine or hunger periods and yield potential. (Maghembe *et al.*, 1998)

8.2.4 Zambia

The National Institute for Scientific and Industrial Research started work on indigenous fruits in 1978. In association with surveys in other countries, priority-setting surveys identified tree size and height, fruit size, yield and precocity as the characteristics which require improvement in *S. cocculoides*. Bigger fruit was the trait most desired.

8.2.5 Zimbabwe

S. cocculoides was the most preferred wild fruit tree (Kadzere *et al*. 1998). This could be due to its versatility in processing or its ability to do well in marginal areas where rainfall is erratic. Farmers wanted better fruit size and yield, taste, flesh-to-seed ratio and fruiting precocity. Some farmers, however, did not see the need to improve wild fruit trees and preferred them in their present state. From surveys of local communities in five districts throughout Zimbabwe it was recommended that S. cocculoides could be prioritised for domestication, due to its ease of establishment and also for the improvement of the crop (Rukuni and Mukwekwerere, 2002).

8.3 Summary selection criteria

The surveys gave clear evidence for the following criteria:

- Good fruit size
- Sweet pulp taste
- High flesh to seed ratio
- Higher yields per tree
- More rapid tree growth
- Easily accessible crown
- Fruiting precocity

8.4 Germplasm

The use of seed from identified superior trees selected from wild populations can produce notable improvement in *S. cocculoides*. Seed orchards are then established using grafts. However, the conditions of selection, particularly phenotypic selection from the wild, limit the use of these favourable results for predicting the amount of genetic improvement to be obtained (Burley and Styles, 1976). There is therefore, no firm assurance of genetic improvement in *S. cocculoides* and this can only be achieved by genetic evaluation and selection: however, the constraints to this have been noted above. Once sufficiently variable germplasm has been collected and the breeding system studied, then genetically-based improvement can be put in place. Table 8.1 shows the current holdings of *Strychnos* species in Africa.

In addition, germplasm is also held by ICRAF in Kenya and institutes linked to the ARC Plant Genetic Resources Unit in South Africa. A list of the institutions in Table 8.1 and others is to be found in Appendix 1.

Table 8.1 Institutional germplasm collections in Africa

Species	Institute	Accessions	Propagation
Strychnos cocculoides	HRC, Zimbabwe	30	Seed
	ICRAF, Malawi	<20	Seed/grafting
	ICRAF, Tanzania	<20	Seed/grafting
	ICRAF, Zambia	<20	Seed/grafting
	VPR, Botswana	29	Seed/grafting
Strychnos spinosa	HRC, Zimbabwe	80	Seed
	VPR, Botswana	50	Seed/grafting

8.5 Conservation

There is a regional agreement on the transfer of germplasm (especially seed, vegetative clones and mycorrhizae, amongst the SADC countries and this determines “who pays” and “who benefits” from the germplasm and its information. Following an agreed regional plan, each country is responsible for collecting and evaluating its own germplasm. All the SADC countries should share the germplasm equally on a progressive basis. Following regional initiatives to promote *Strychnos* planting and use, ICRAF is acting as a trustee of the germplasm and has no ownership rights.

However, comprehensive storage of genetic resources samples is hardly in place. Some aspects to be considered are noted below.

8.5.1 Methods of storage

It appears that seeds can be stored when dried to 6.2% and kept at -20ºC (Fletcher and Pritchard, 2000). However seed viability can be reduced in storage and Uronu and Msanga (2005) recommended that seed be kept at 10-30% moisture content, above 0 ºC. This is probably going to be most useful for storage of planting materials rather than long-term conservation. For a genepool naturally distributed over a vast area, in which the patterns of diversity are poorly understood, there will be the need for targeted ecogeographic collecting and maintenance of materials in field genebanks (orchards) complemented by a strategy for *in situ* conservation (Smith *et al.*, 1992).

8.5.2 *In situ* conservation

This will take a two-pronged approach. Firstly, materials will be conserved in areas designated as reserves. These will need comprehensive documentation with data relevant to *Strychnos* and its improvements being maintained by the relevant national programme. Secondly, there will be populations managed intentionally by villagers and societies. At present, intentional customary conservation practices include widespread social conservation that often prevents the felling of fruit-bearing trees and the maintenance of favoured types. Campbell (1986) noted this in Zimbabwe; but in considering this to be widespread in Africa, Cunningham (1989) stressed that for a resource to be of value to society it must be of value and must be perceived to be in short supply and/or vulnerable to over exploitation.

CHAPTER 9. POTENTIAL IMPACT AND MARKETING

This monograph has shown that there is interest in expanding the production of *S. cocculoides*, and to some degree also *S. spinosa*. To date, technology development has focused on identifying suitable germplasm and the promotion of the most suitable methods of propagation. This technology development has benefited from a regional approach under the guidance of ICRAF and interested donors (e.g. SIDA, CIDA, GTZ and DFID).

This chapter summarises the approaches needed to reach the goal of wider cultivation of *S. cocculoides* and the sustainable use of its products, whether fruits or other plant parts. This is followed by a discussion of research gaps and what needs to be done to bridge them.

9.1 Potential for widening the cultivation of *S. cocculoides*

A major constraint in production of fruits lies in the locally accepted concept of tenure. The right to harvest fruits is determined by a complex of factors which vary from region to region. In some areas all the trees are held to be common property and the fruit is not owned until harvested. Such a system reduces incentives for planting of the trees, and this problem has to be tackled by extension agents.

9.1.1 Educating farmers

Before a farmer will invest in cultivating *S. cocculoides* the following have to be considered:

- Will the returns on sales outweigh the costs and give a suitable profit?
- What agricultural inputs are required and what are the costs?
- What is the price for fruits likely to be in 3-4 years time?
- Will cultivation of the fruit be the most efficient way to use the land and what options (e.g. agro-forestry) are available?
- Will there be continued market potential?

There is more to be done in educating rural people on the short and long term benefits of sustainable production of indigenous fruit trees.

9.1.2 Marketing potential

The presence of local markets selling *S. cocculoides* fruits can be used as an indicator of the commercial potential of the species. It is important, however, to establish the size of the market, the target consumer and whether processed products are in demand. Preliminary marketing studies conducted in Central and Southern Africa (Minae *et al.*, 1995) have shown some interesting gender and age factors. For instance, in Malawi 37% of traders are female collectors, 32% are middlemen and 31% are male collectors. About 63% of the traders were young, being less than 30 years old. In most cases the harvesting is done by poor and marginalised groups.

The fruits are currently harvested from farmers' fields, homestead gardens and neighbouring forests. In Malawi, the farmers sell their fruits along the roadsides or at local markets. About 20% of the fruit is sold directly to consumers, and the remaining 80% is sold to traders.

The main marketing cost is transportation. Marketing margins indicate that the mark-up by traders is usually higher compared to marketing costs. This could be due to the current small quantities of fruits handled and wastage.

Consumer perception is also important. Many urban populations consider it backward to eat "wild" fruits. In rural areas such fruits may be considered to be children's food or food to be eaten only in times of hardship or drought. However, perceptions change. Twenty years ago these fruits were not acceptable in Gaborone, Botswana; now there is a demand (Taylor, 1995). In South African townships, where people have lived with little contact with the countryside, there remains a substantial demand due to the perception that traditional foods are strength-giving and the white man's food results in weakness (Taylor, 1983).

9.1.3 Pricing

Current pricing and variations in price levels do not accurately reflect the supply and demand situation. Competition among suppliers is minimal and is not a determinant of price. Extension activities will need to support the sales of fruits in markets as an incentive to reinforcing sustainable production and income distribution. Farmers need to be advised on how to develop production in an incremental way without putting other parts of the farm system at risk (Arnold, 1996; Scherr, 1995).

At the same time, forest departments need to consider policy constraints. In markets, farmers can encounter forms of competition and policy constraints that can make it difficult for them to compete. In many situations, urban markets for most wild fruit products are still supplied by harvesting natural stocks, with minute payments to harvesters of the raw materials, so that the cost of the product delivered to the market consists mainly of transport costs.

In addition, in many countries, products from state forests and plantations can be sold at “administered” prices. Private producers are also frequently subjected to produce controls originally designed to protect against illegal felling from state forests. The resulting bureaucratic procedures lead to private producers having to depend on intermediaries to market their produce. Unless impediments can be reduced or removed, urban markets are likely to be less important than local markets.

In Botswana the street value for *Strychnos* was 40 US cents each, giving a value of 140 US$ per tree (Taylor *et al*. 1996). In Zimbabwe the average price was 1.5 ZWD per fruit (Mithöfer and Waibel, 2003).

9.1.4 Markets in the region

Local markets generally share similar characteristics throughout the Eastern and Southern African region, with the possible exception of those in Botswana, where informal markets did not exist until after Independence (Taylor *et al.*, 1996). Marketing channels for informal markets vary according to the product and from place to place, but in general, they will still have commonalities.

Regional and sub-regional markets comprise a level that have received very little attention. In these cases shared preferences and common tastes often make it feasible to develop products for a larger market. Examples of two regional markets are: SADC (Southern African Development Community), and EADC (East Africa Development Community).

It is widely recognised that producers, extension agents and research and development for any plant product, have to work against a background often distorted by policy barriers. High priority has to be accorded by official organisations to changing policies and practices which constrains farmers' access to markets for tree products. Removing barriers is usually more effective than subsidies to promote tree planting and husbandry.

9.2 Potential for off-farm income based on products other than fruits

9.2.1 Prospects for extraction of chemicals from African *Strychnos*

The occurrence of chemicals such as strychnine and brucine in *Strychnos* species raises potential interest in use of these and many other components such as polysaccharides and saponins for their pharmaceutical and industrial uses. Ongoing research, usually in developed countries, has a spin-off to local use in Africa especially in promotion of traditional medicinal treatments. However, the prospects for provision of raw material for extraction are not high.

Most research appears to focus on the synthesis of the *Strychnos* alkaloids (e.g. Diez *et al.*, 1994) or the testing of such alkaloids for anti-malarial use, especially in the light of growing resistance to chloroquine. In such research, plant sources are taken from all areas of distribution of the many *Strychnos* species. The indolomonoterpenoid alkaloids exist in many chemical forms and *S. potatorum* and *S. pungens* have been used as sources, along with several other African wild species (e.g. Frédérich *et al.*, 2002).

There is less interest in the chemical strychnine as extracted from Asian *S. nux-vomica*. Once used medicinally for its central nervous system (CNS)-stimulating properties, to treat chronic heart disease, as a stomachic and in the treatment of asthma and epilepsy, it is now only used as bait to trap animals.

9.2.2 Prospects for enhanced uses in local medicine

In KwaZulu-Natal (South Africa) commercialisation of indigenous plants is well developed in the informal sector, with a large and active trade. An extensive network exists, which harvests large volumes of plants from wild populations throughout the sub-region and distributes them to the consumers, who may be both rural or urban. The trade network has a number of key components, it includes collectors, transporters, hawkers, wholesalers, retailers, mail-order companies, traditional healers and exporters (Mander *et al.*, 1996).

In the medicinal plant trade, several large urban street markets exist within the Durban metropolitan areas of South Africa and numerous stores or informal street sellers are found in almost every town and village in the region. Some 60-70% of urban communities are believed to make use of traditional medicine.

However, traditional medicinal uses of *Strychnos* are still poorly documented, and require validation and the development of guidelines for the production of standard preparations with known efficacy. This requires cooperation between traditional healers, agronomists and local universities with capacity for such work. The framework for the production and marketing of traditional remedies has been well promoted by the World Health Organization, which has highlighted the great need for quality control and standardisation of herbals.

Information that currently exists on the indigenous knowledge of *S. cocculoides* as a medicinal includes old colonial records and the writings of early settlers often endlessly repeated. Indigenous knowledge needs to be gathered from the communities noting that gender balance in gathering information is important, as men and women often value and use plants differently, and, even when available, the information can be site-specific, depending on ethnic groups and ecogeographic zones. Moreover, the success of medicinal products may be affected by psychological and cultural factors (Leeson and Frankenberg, 1977) and cures used by local healers are often made by mixing products of several plants species together with a synergy between them. In some cases a synthesis of information already exists, e.g. in the case of treating sexually transmitted diseases in Zambia (Ngubani and Hojer, 1999).

CHAPTER 10. RESEARCH NEEDS

A list of the institutions involved in *S. cocculoides* research and development is shown in Appendix 2. There are currently several African countries pursuing cooperative research, with the help of international organisations and collaborators in developed countries.

In essence, the collaboration to date has resulted in research on rapidly identifying a limited number of superior forms, and making them available as planting materials. Much more collaborative research is needed to fill gaps in information and appropriate technology. These are grouped in the discussion below.

10.1.1 Understanding the genepool

Chapter 1 has pointed out that the taxonomy of the species is imperfectly known and it is not yet possible to say which species are closely related to the major genepools of *S. cocculoides* or *S. spinosa* nor to know how other useful species such as *S. innocua*, *S. potatorum*, or *S. madagascariensis*, fit into the overall classification and relationships. Filling this gap will require extensive field work backed by laboratory research on counting chromosomes and Restriction Fragment Length Polymorphisms (RFLP) analysis of seedling materials.

There is a need to understand the patterns of variation in a target genepool. This necessitates survey and assessment of patterns of eco-geographical variation backed by laboratory analysis using molecular methods. The results could be used to identify targets for germplasm collecting. Collected germplasm should then be used to obtain information on variation within and between populations so that materials used for selection would be genetically based. In order for this to be as useful as possible, research is needed on the plant's reproductive biology since the extent of inbreeding is not known.

10.1.2 Developing technology

Attention has to be given to rooting cuttings, a technique which is not successful at present. This would greatly aid germplasm collection and permit evaluation trials using specific mother trees as entries. This could result in rapid identification of superior genotypes. The biggest gains were made in this way for rubber and oil palm and it has been proposed for perennials such as bamboo. Identification of superior genotypes could result in the development of cultivars and this would enhance any cooperative work on species improvement.

More research is needed on the range of agroforestry models which can be applied by farmers.

10.2 Backing the R&D

Education, particularly of farmers, is essential. The accompanying practical manual to this book will be helpful in this respect. Nonetheless this cannot take the place of extension which can discuss, within the limits of farm production budgets, the most efficient management systems for production, distribution and marketing of fruits and/or products.

10.3 Adding value to certain products

Strychnos products will continue to play an important role in local health care. There is a need to assess all available indigenous knowledge and current uses by traditional healers and to focus on a limited number of remedies especially in relation to primary health care. The collaboration of a university department of pharmacology is needed to make recommendations on the standard preparation of these remedies.

There will also be the need to educate collectors of plant products for medicine, in association with the healers, to ensure quality material. When *Strychnos* is cultivated, farmers need to be aware of the value added for particular plant products and to know the actors in the supply chain in order to programme off-farm income.

10.4 Development of new products

Technology is in place for the normal processed products from fruits (jam, juice, wine, etc.). The major imperative remains the raised production of fresh fruits to satisfy demands. However, there may be opportunities to develop new products particularly if these can be sold in more affluent urban areas.

Apart from herbal remedies (section 9.5 above), there may be cosmetic uses and this is certainly the case in parts of Asia for *Strychnos* (Riswan and Sangal-Roemantyo, 1991).

APPENDIX I. INSTITUTIONS WITH GERMPLASM OF *STRYCHNOS COCCULOIDES*

Botswana

- Department of Integrated Agricultural Research
  Gaborone
  Botswana

- Veld Products Research and Development
  P.O. Box 2020
  Gaborone
  Botswana

Malawi

- Malawi Plant Genetic Resources Centre
  Forestry Research Institute of Malawi
  P.O. Box 270
  Zomba
  Malawi

South Africa

- ARC Plant Genetic Resources Unit
  P.O. Box X05, Lynn East
  South Africa

Tanzania

- Horticultural Research Institute
  P.O. Box 1253, Tengeru
  Arusha
  Tanzania

- National Plant Genetic Resources Centre
  P.O. Box 3024
  Arusha
  Tanzania

Zimbabwe

- SADC – Tree Seed Centre Network
  Private Bag: BW 6238
  Borrowdale
  Harare
  Zimbabwe

APPENDIX II. INSTITUTIONS AND INDIVIDUALS ENGAGED IN *STRYCHNOS* RESEARCH AND DEVELOPMENT

Botswana

- University of Botswana (Baone Kwerepe)
  Botswana College of Agriculture
  P. O. Box 0027
  Gaborone
  Botswana

- Veld Products Research and Development (Frank W. Taylor, Karen J. Butterworth, S.M. Mateke)
  P.O. Box 2020
  Gaborone
  Botswana

Germany

- Institute of Economics in Horticulture
  Faculty of Business Administration and Economics
  Hannover University
  Germany

Israel

- Institute for Agriculture and Applied Biology
  Ben Gurion University of the Negev (G. Bohrer, V. Kugan Zur, Y. Mizhrahi)
  Israel

Kenya

- World Agroforestry Centre (ICRAF)
  PO Box 30677
  00100 GPO
  Nairobi
  Kenya
  icraf@cgiar.org

Malawi

- Department of Forestry
  P.O. Box 30048
  Zomba
  Malawi

- Forest Research Institute of Malawi (L. A. Sitaubi, L. Mwabumba)
  P. O. Box 270
  Zomba
  Malawi

- ICRAF – Agroforestry Research Project (S. Minae)
  P.O. Box 31188
  Lilongwe 3
  Malawi

- ICRAF, SADC Agro-forestry Project (F.K. Akinnifesi, J. Moyo)
  P.O. Box 134
  Zomba
  University of Malawi
  Malawi

- Bunda College of Agriculture (M. Kwapata, S.S. Munthali)
  P.O. Box 219
  Lilongwe
  Malawi

South Africa

- Agricultural Research Council of South Africa
  Institute for Tropical and Sub-tropical Crops
  Nelspruit – 1200
  South Africa

- Plant Genetic Resources (PGR) Unit
  P.O. Box X05, Lynn East, 0039
  South Africa

Swaziland

- Malkerns Research Station
  P.O. Box 4,
  Malkerns

Swaziland

Sri Lanka

- International Centre for Underutilised Crops
  International Water Management Institute
  127 Sunil Mawatha
  Pelawatte
  Battaramulla
  Sri Lanka

Zambia

- Division of Forestry Research
  P.O. Box 22099
  Kitwe
  Zambia

- Tree Improvement Research Centre
  National Institute for Scientific and Industrial Research (NISIR)
  P. O. Box 21210
  Kitwe
  Zambia

- Zambia/ICRAF Agroforestry Project (P. L. Mafongoya, S. Lungu, S. Mwanza)
  Msekera Agricultural Research Station
  P. O. Box 510046
  Chipata
  Zambia

Zimbabwe

- Department of Research and Specialist Services (E.Nyamutowa, J. N. Mushonga)
  Horticultural Research Centre
  P.O. Box 3748
  Marondera
  Zimbabwe

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