Dyes and tannins of Tropical Africa

Conclusions and recommendations
based on PROTA 3: 'Dyes and tannins'

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PROTA Foundation
Wageningen, Netherlands, 2006

Contents

1. Contents and justification

1.1 Scope

In September 2005, PROTA 3: 'Dyes and tannins' was published. PROTA 3 consists of 73 review articles (English & French) on the dye and tannin producing plants of tropical Africa. The information is freely accessible in a Webdatabase (www.prota.org) and can be obtained as a low-price book + CD-Rom (for information see inner frontcover).

Vegetable dyes and tannins have played a large role in the international trade till the end of the 19th century. Progress in chemistry at that time had made it possible to produce synthetic colouring substances in factories. The profitable international trade in vegetable dyes and tannins collapsed almost completely following a breakthrough in the production of synthetic colourants. Consumer demands lead to a revival of natural products and plant derived dyes and tannins may regain importance.

Although PROTA 3 forms a synthesis of thousands of scattered publications, reducing the world literature to manageable proportions, 73 review articles (106,000 words) still constitute an enormous amount of information not easily digested.

This Special Product 'Dyes and tannins' is a first step to make the information in PROTA 3 better accessible to the key players in the sector by drawing conclusions and making recommendations.

Impact on the end-users (farmers, forest communities, cottage entrepreneurs) is the ultimate aim of the PROTA knowledge synthesis. However, this impact has to be realized through intermediate target groups. The conclusions and recommendations are aimed at the following 6 target groups:

- Rural development agencies (including the Extension Services providers) have to be made aware of 'Candidate technologies' that are ready to be tested or applied in farmer's fields.
- Vocational training centres need to incorporate 'Candidate technologies' in their training programmes.
- Private enterprises have an important role to play in overcoming the numerous 'Development gaps'.
- Researchers are provided with an overview of 'Research gaps' to be tackled and are made aware of instances where diversity is endangered and conservation needs exist.
- Students in institutions of Higher Education can make a meaningful contribution to the dyes and tannins sub-sector through their 'Thesis research'.
- Policy makers have to address 'Policy issues' in order to provide an enabling environment for all the above topics to be implemented properly.

1.2 Methodology

Following publication of PROTA 3: 'Dyes and tannins', a general overview of details related to botany, geography, ecology, cultivation and utilization was made (Chapter 2). The individual reference data are presented in Annex 1.

Subsequently about 55 stakeholders were asked to read carefully through the book and to fill a matrix '73 species × 6 key issues' with ideas and suggestions on:

- candidate technologies
- development gaps
- research gaps
- thesis subjects
- conservation needs
- policy issues.

The complete matrix is presented as Annex 2.

About 25 of the 55 stakeholders were invited to a Brainstorm Workshop (Nairobi, 2–5 April 2006) to finalize the conclusions and recommendations. These are briefly highlighted in Chapters 3–8 that indicate what the various target groups can do with regard to specific dye and tannin producing plant species, groups of dye and tannin producing plants or the sub-sector as a whole. During the Workshop a number of species were designated as most important either because they already play an important role or because of their potential. These species are listed in the Tables in boldface. Locally, other species may be or become important.

This Special Product will be followed up by a number of small 'grassroots' projects to realize impact on the end-users (farmers, forest communities, village entrepreneurs).

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2. General overview

This overview subdivides the African dye and tannin producing plants in a number of broad categories related to botany, geography, ecology, cultivation and utilization. The data per species (Annex 1) are intended to serve as a quick reference guide.

2.1 Primary Use dyes and tannins

The majority (56) of the 73 species are exclusively used as a dye. Only 2 are exclusively used as tannin and 15 have both dyeing and tanning properties.

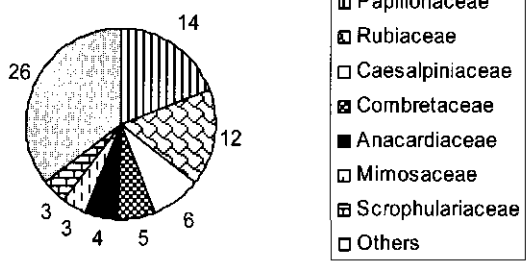
It is important to realize that PROTA 3: 'Dyes and tannins' only deals with the 116 Primary Use dyes and tannins, or better the 73 Primary Use dyes and tannins described in individual review articles (43 Primary Use dyes and tannins are only briefly mentioned in articles of more important related species, because hardly any information is available on them).

The c. 600 Secondary Use dyes and tannins listed in the PROTA 3 handbook are not discussed here, which is certainly an important limitation. For example, a species like paprika (*Capsicum annuum*), an important colourant in the international trade, is not included here. The discussion of the Secondary Use dyes and tannins is referred to the relevant Commodity groups, in order to avoid duplication.

2.2 Botanical families

The 73 dye and tannin producing plants belong to 28 different botanical families showing their occurrence throughout the plant kingdom, out of which 7 families account together for more than 60% of the species: *Papilionaceae* (14), *Rubiaceae* (12), *Caesalpiniaceae* (6), *Combretaceae* (5), *Anacardiaceae* (4), *Mimosaceae* (3) and *Scrophulariaceae* (3).

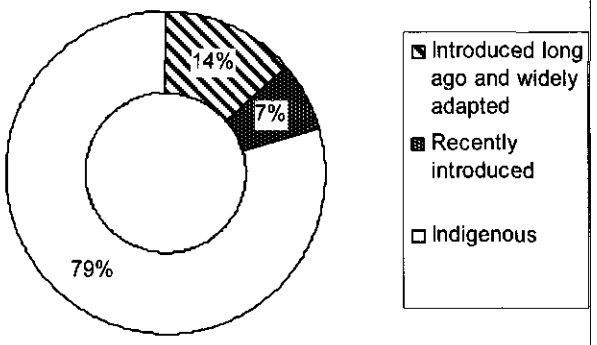
Figure 1. Number of dye/tannin species by botanical family



2.3 Origin

Out of the 73 dyes and tannins, 58 are indigenous to Africa and 15 are introduced. Among the latter, 10 were introduced long ago and have become 'adapted' (local cultivars or ecotypes have developed in the course of time), the remaining 5 are 'exotic' (cultivation depends on foreign cultivars).

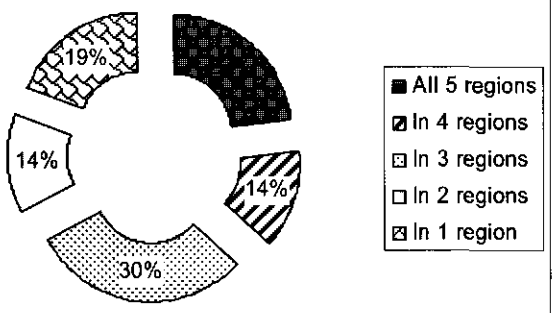
Figure 2. African dyes and tannins by origin



2.4 Distribution in tropical Africa

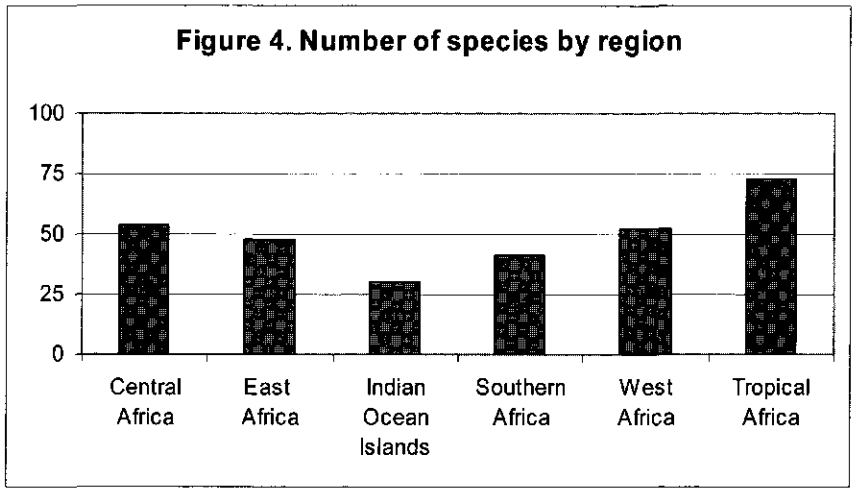
The regional occurrence of species (Figure 3) is important in formulating recommendations for the national, regional or continental level. It appears that 27 out of 73 species are more or less panafrican, occurring in all five (17) or in four (10) of the regions (Central, East, Indian Ocean Islands, Southern, West). 24 Species are rather regional, occurring in only one (14) or two (10) regions.

Figure 3. Species distribution by number of regions



The number of endemics is the largest (6) in the Indian Ocean Islands and the lowest (1) in Southern Africa.

The number of species by region varies considerably as shown in Figure 4. Of the 73 dyes and tannins species 54 occur in Central Africa and 30 in the Indian Ocean Islands.



2.5 Cultivation status

Of the 73 species, more than 60% (45) are only collected from the wild, 18 are collected from the wild but are also cultivated, and 10 are only cultivated.

2.6 Plant parts used

Out of the 73 species, the bark is used in 30 species, followed by 25 species of which the leaves or leafy twigs are used and 18 of which the underground parts are used (roots, tubers or rhizomes). Minor categories include fruits (13), flowers (8), wood (6) and seeds (6). The plant part used is important for sustainability of use. Fruits and leaves can usually be harvested on a regular, sustainable basis whereas harvesting of underground parts, wood and bark often kills the plant.
Dye and tannin species are often multipurpose with respect to plant parts used. In 44% of the species more than 1 plant part is used.

2.7 Secondary uses

The Primary Use dyes and tannins are often multipurpose and have on average 4 Secondary Uses. Most important are the Commodity groups 'Medicinal plants' (66), 'Timbers' (27), 'Fuel plants' (27) and 'Fibres' (27). The secondary use 'Medicinal' is

often based on the same chemical compounds that are responsible for the dyeing and tanning properties. Especially tannins have apart from their tanning also dyeing and medicinal properties.

2.8 Growth form

Many of the 73 dye and tannin producing plants are shrubs or trees (48), the remainder being made up of herbs (18) and lianas (7).

2.9 Life cycle

Most dye and tannin producing plants are perennial (60) and only 10 are annual herbs. 3 *Indigofera* species can behave as annuals or perennials depending on environmental conditions or cultivation practices.

2.10 Altitude

The ecological information is often not sufficient to subdivide the dye and tannin producing plants clearly into Lowland and Highland species. An attempt has been made, taking occurrence mainly above or mainly below 1000 m a.s.l. as criterion. Typical lowland dye and tannin plants are 14 species, many of which are mangrove species. For many wild species the ecological preference is not evident from the review articles. No dye and tannin producing plants are restricted to the highlands although black wattle (*Acacia mearnsii*) is grown in East Africa exclusively at higher altitudes.

2.11 International trade

Reliable trade figures are hard to obtain. The most important vegetable tannin in the international trade is mimosa extract from black wattle (*Acacia mearnsii*). The amount of extract traded is about 55,000 t/year.
The estimated amounts of dyes for the other species, most of them food colourants, entering in the international trade are given in Table 1 by plant species.

Table 1. Estimated amounts of dyes traded annually in the international market

Species	Tonnes
Paprika (*Capsicum annuum*)	45,000
Turmeric (*Curcuma longa*)	15–20,000
Annatto (*Bixa orellana*)	10,000
Henna (*Lawsonia inermis*)	> 9000
Aztec marigold (*Tagetes erecta*)	6000
Logwood (*Haematoxylum campechianum*)	600
Indigo (*Indigofera* spp.)	50

The annual growth of the colourant market in Europe is around 1% but the growth of the food colourant market is estimated at 10–15%. This increase is largely due to a shift in consumer-driven demand for naturally derived colourants. As this market is very dynamic it is useful to try to stay up-to-date. A website that keeps track of recent developments is http://www.foodnavigator.com/news-by-product/.

2.12 Conclusion

Botanical, geographical, ecological, agronomic and utilization aspects have to be taken into account in making recommendations for the dye and tannin sector in tropical Africa. Annex 1 gives a number of these characteristics at the species level.

3. Candidate technologies

3.1 Cultivation and management guides

A need is felt for up-to-date cultivation guides for a number of dye and tannin producing species and for different countries or regions. Specific mention was made by respondents of such guides for:

- turmeric (*Curcuma longa*),
- Natal indigo and Indian indigo (resp. *Indigofera arrecta* and *Indigofera tinctoria*) and
- henna (*Lawsonia inermis*).

On several other species sufficient information on cultivation is available but guides will become relevant once infrastructure for marketing and processing is in place, e.g. for:

- black wattle (*Acacia mearnsii*),
- annatto (*Bixa orellana*) and
- Aztec marigold (*Tagetes erecta*).

Especially for the mangrove species, management guides could be produced on sustainable management and optimal utilization.
Relevant parts of the PROTA reviews can be combined with information relevant for the local situation to produce these guides.

3.2 Improved harvesting techniques and post harvest handling

Sustainability is important especially for species of which the bark is harvested for use. For n'galama (*Anogeissus leiocarpa*) and barringtonia (*Barringtonia racemosa*) techniques of partial debarking will allow regrowth and bark can be harvested again after regeneration. In Burkina Faso, the harvesting of n'galama bark is regulated.
In most species of which the bark is used, the wood is used as well. Black wattle (*Acacia mearnsii*), black mangrove (*Bruguiera gymnorhiza*), and yellow mangrove (*Ceriops tagal*) are therefore usually harvested by felling. *Lannea* species (especially *Lannea microcarpa*) are felled for their bark and the recent increase in demand would make planting beneficial, all the more so as the young leaves are used as a vegetable.
The coppicing ability of a number of woody species allows re-growth after harvesting bark and wood or for combining its use as a dye or tannin with that of a life fence. Some of the species with good coppicing ability are:

- sappanwood (*Caesalpinia sappan*),
- *Combretum glutinosum*,
- magic gwarri (*Euclea divinorum*),
- *Lannea barteri*,
- emblic myrobalan (*Phyllanthus emblica*) and
- avaram (*Senna auriculata*).

3.3 Improved extraction methods

For a number of species traditional processing technologies are available in West Africa, for example for African grape (*Lannea microcarpa*) and dye-cultivars of sorghum (*Sorghum bicolor*). Especially in Burkina Faso traditional technology has been documented and research has produced notable modifications that improve the efficiency of extraction. These technologies are unknown beyond West Africa.

3.4 Introduction of improved cultivars and technologies

For several dyes and tannin producing species improved cultivars from outside tropical Africa can be introduced and promoted after on-farm testing. In many cases, apart from introduction of improved cultivars, the technology developed elsewhere may be relevant as well, e.g. the Asian technology for growing Indian indigofera (*Indigofera tinctoria*). For annatto (*Bixa orellana*) Central America could yield improved cultivars and management techniques. For Aztec marigold (*Tagetes erecta*) Zambia, South Africa and India are possible sources for cultivars and technologies.

3.5 Introduction of species from other regions in Africa

Adoption of a few new species is likely to be beneficial. Black wattle (*Acacia mearnsii*) is a candidate for introduction outside the countries where it is already found, although a cool season is required for acceptable tannin content of the bark. On the equator the minimum altitude for cultivation is 1800 m. Magic gwarri (*Euclea divinorum*) is absent from West Africa and could be introduced there for tanning, although its tendency to become a weed in grasslands would advocate against introduction.

3.6 Domestication

Domestication of wild species or local wild forms is an option for farmers in a number of cases, especially where harvesting for traditional uses becomes difficult because of scarcity of the species or through regulation of the harvesting. Obvious examples are:

- African rock fig (*Ficus glumosa*),
- n'galama (*Anogeissus leiocarpa*),
- zebra leaf aloe (*Aloe zebrina*),
- *Combretum glutinosum*,
- *Flemingia grahamiana*,
- African grape (*Lannea microcarpa*) and
- cannonball mangrove (*Xylocarpus granatum*).

3.7 Multipurpose species

Most dye and tannin producing plant species have secondary uses. Importance of the uses may be different by region. The use with highest priority will dictate the mode of utilization. In many cases the wood of perennial species, either used for fuel or timber, is the most valued product. Tannin-rich bark may be an important by-product in many of the woody mangrove species. In the case of African bloodwood (*Pterocarpus angolensis*) the wood yields a valuable timber as well as a valuable dye. When primarily used for timber, the by-products like offcuts and sawdust can be used for the extraction of the dye.
The dye containing sawdust, a by-product of processing of the wood is a valuable commodity in a species like camwood (*Baphia nitida*). In many cases however the by-products are discarded as farmers lack knowledge on their potential usefulness and value. In order to allow farmers to make correct decisions, information on the miscellaneous uses should be passed on.

3.8 Auxiliary plants

Many dye and tannin producing plants can play an auxiliary role in farming. Such species include:

- black wattle (*Acacia mearnsii*); soil rehabilitation,
- babul acacia (*Acacia nilotica*); soil rehabilitation,
- sappanwood (*Caesalpinia sappan*); live fence,
- *Craterispermum* spp.; live fence,
- African rock fig (*Ficus glumosa*); live fence,
- indigo (*Indigofera* spp.); cover crop, green manure,
- African padauk (*Pterocarpus soyauxii*); agroforestry,
- kantuffa (*Pterolobium stellatum*); control of *Opuntia* sp.

3.9 Commercial cultivation and international trade

There are few vegetable dyes/colourants that enter the international trade but there are some good opportunities for African farmers. Turmeric (*Curcuma longa*) is probably the best known but no exports from tropical Africa are known to exist. Exports of turmeric from tropical Africa would have to compete with well-established export chains from Asia to Europe and the US.
Annatto (*Bixa orellana*) is widespread in tropical Africa, but Kenya is the only country in the continent that exports annatto.
Trade in bark of n'galama (*Anogeissus leiocarpa*) has only recently started with exports from Burkina Faso to France for the cosmetic industry. This trade may well expand considerably in the near future although it probably faces competition from *Anogeissus latifolia* from India.
Henna (*Lawsonia inermis*) is not yet grown in tropical Africa on a commercial scale. There certainly is room for expansion.
Black wattle (*Acacia mearnsii*) will remain an important vegetable tannin in the world market.

Table 2. Candidate technologies by species

Species name	English name	Candidate technologies
Acacia mearnsii	Black wattle	Soil rehabilitation Multipurpose (tannin, timber, fuel, paper pulp) Alternative for paper pulp of *Eucalyptus globulus* Vegetative propagation techniques
Acacia nilotica	Babul acacia	Soil rehabilitation Multipurpose (drier areas) Optimal harvesting & extraction Renewable resource (fruits)
Adenorandia kalbreyeri	–	Ornamental
Aloe zebrina	Zebra leaf aloe	Domestication (ornamental/ confectionery)
Anogeissus leiocarpa	N'galama	Management wild trees Domestication Optimal harvesting & extraction techniques
Baphia nitida	Camwood	Multipurpose Use of by-product (sawdust)
Barringtonia racemosa	Barringtonia	Sustainable harvesting of bark
Bixa orellana	Annatto	Commercial production ? Colorant dairy products Hedgerow systems Ornamental Harvest & post-harvest techniques for improved quality
Bruguiera gymnorhiza	Black mangrove	Sustainable (commercial) use (leaves and small branches)
Caesalpinia coriaria	Divi-divi	Promote use (dry areas; for dye & ink & tannin) Renewable resource (fruits)
Caesalpinia sappan	Sappanwood	Multipurpose (timber, fuel, tannin, dye, live fence, ornamental)
Ceriops tagal	Yellow mangrove	Sustainable use Multipurpose harvesting
Cochlospermum tinctorium	–	Commercial production Ornamental
Combretum glutinosum	–	Cultivation/ domestication Optimal harvesting & extraction techniques
Cosmos sulphureus	Orange cosmos	Ornamental

Table 2. Candidate technologies by species (Continued)

Species name	English name	Candidate technologies
Craterispermum laurinum	–	Life fence (fire resistant)
Craterispermum schweinfurthii	–	Life fence (fire resistant) Bee forage, dental care
Curcuma longa	Turmeric	Management (mixed cropping) Local market: expansion Cultivation guide Introduce where not yet grown
Danais ligustrifolia	–	Promotion (on-going) in Madagascar for commercial & local use
Diospyros loureiriana	Dye diospyros	Use in basket weaving craft
Euclea divinorum	Magic gwarri	Management & replanting Renewable resource (powerful coppicing)
Ficus glumosa	African rock fig	Multipurpose (vegetable, fruit, firewood, live fence, medicinal) Domestication
Flemingia grahamiana	–	Promote use and cultivation Renewable resource (dye from fruits)
Impatiens tinctoria	Balsamine	Ornamental
Indigofera arrecta	Natal indigo	Promote as multipurpose (fodder, covercrop, green manure, dye) Cultivation guide
Indigofera longiracemosa	Indigo	Green manure
Indigofera tinctoria	Indian indigo	Commercial production Multipurpose Cultivation guide Introduction of Asian cultivars
Laguncularia racemosa	White mangrove	Planting for fuel
Lannea microcarpa (& *Lannea barteri* & *Lannea velutina*)	African grape	Multipurpose (fruit, medicinal, dye, vegetable) Popularize extraction techniques from Burkina
Lawsonia inermis	Henna	Cultivation guide Quality Introduce: commercial crop
Morinda lucida	Brimstone tree	Multipurpose
Philenoptera laxiflora	Gambian indigo	Ornamental

Table 2. Candidate technologies by species (Continued)

Species name	English name	Candidate technologies
Phyllanthus emblica	Emblic myrobalan	Fruit cultivars from India Renewable resource (coppicing, fruits) Revive (Madagascar)
Pterocarpus angolensis	African bloodwood	Promote planting (multipurpose, sustainable) Use of bark (by-product of timber)
Pterocarpus soyauxii	African padauk	Use as agroforestry species (multipurpose)
Pterolobium stellatum	Kantuffa	Living fence, ornamental, dye For control of *Opuntia*
Rhus tomentosa	Wild currant	Ornamental
Rothmannia longiflora	–	Multipurpose
Rothmannia whitfieldii	–	Multipurpose
Senna auriculata	Avaram	Multipurpose: promote Renewable resource (flowers, leaves) Post-harvest techniques
Sorghum bicolor	Sorghum	Cultivars and extraction technology from elsewhere Commercial production Collection (chain)
Syzygium rowlandii	–	Bee forage
Tagetes erecta	Aztec marigold	Husbandry techniques (Zambian & South African experience) Processing Cottage industry
Terminalia chebula	Chebulic myrobalan	Introduce & promote (multipurpose, commercial cultivation) Renewable resource (fruits)
Xylocarpus granatum	Cannonball mangrove	Domestication Sustainable use By-product of timber

4. Development gaps

4.1 Candidate species for selection and breeding

For dye and tannin producing species, selection would be a first step to improve yields. Selection offers the best opportunities for improvements in perennial species. Breeding may offer opportunities for quick improvement in annual and short-lived perennial species.
Many dye and tannin species have other uses apart from their dye or tannin use. Selection or breeding for one use may not be compatible with its other uses. For example emblic myrobalan (*Phyllanthus emblica*) is used as a fruit tree and for dye, tannin and medicinal use. Selection for more and better fruits is not compatible with higher tannin content but breeding for higher tannin content may also increase its value as a medicinal.
Some obvious candidates for selection in the group of perennials are:

- black wattle (*Acacia mearnsii*): adaptation to tropical lowland conditions would allow for production in countries that are presently importing black wattle extract (e.g. Burkina Faso); increased tannin content and bark quality; stemshape, wood yield,
- babul acacia (*Acacia nilotica*): high yield of pods, early maturity, pest (bruchid) resistance, content of dye, tannin and gum,
- n'galama (*Anogeissus leiocarpa*): high tannin content,
- annatto (*Bixa orellana*): high seed yield and bixin/norbixin content,
- logwood (*Haematoxylum campechianum*): high dye content, growth and adaptation,
- nato (*Labourdonnaisia madagascariensis*): yield,
- henna (*Lawsonia inermis*): high yield and quality; adaptation,
- gara (*Philenoptera cyanescens*): high yield and quality; adaptation,
- emblic myrobalan (*Phyllanthus emblica*): edible fruit; medicinal-dye.

The annual, short-lived perennials of the genus *Indigofera* have good prospects for fruitful breeding work. Especially Natal indigo (*Indigofera arrecta*) and Indian indigo (*Indigofera tinctoria*) have promise as fieldcrops. The aim of breeding is high yield and adaptation to local conditions. The perennial herb Indian madder (*Rubia cordifolia*) harbours a lot of variation. Breeding and selection probably can use this variation to make quick progress. Breeding in the annual herb Aztec marigold (*Tagetes erecta*) would aim at increasing the lutein content and is already underway in India. Breeding programmes of sorghum (*Sorghum bicolor*) do not comprise dye cultivars. It should however be relatively simple to use techniques and parent material from these programmes to make quick progress in breeding improved dye cultivars with improved resistance to pests and diseases and higher yield.

4.2 Genitors

The use of wild relatives as genitors in breeding is possible in many genera. They may be a welcome source of resistance and adaptation. Many more species, both cultivated and wild, could be used in breeding notably in the genera *Acacia*,

Caesalpinia, *Indigofera*, *Pterocarpus* and *Rubia*.
Psilanthus ebractiolatus is an interesting genitor for coffee breeding but holds no promise as a dye-plant.

4.3 Extraction

For some of the commercial crops raw material is exported. An example is annatto (*Bixa orellana*), a commercially grown dye crop in Kenya in which the seed is only dried and packed before exportation. Another example is the black wattle (*Acacia mearnsii*) where exports take place as bark chips or as extracts.

Adding value to the produce by extraction before export is thus the most preferred method for ensuring these products compete better in the international markets. Processing of the produce will not only reduce transport cost but will also provide employment. Because the international market sets high standards, especially for products that are meant for the food industry, sophisticated processing is a must to arrive at a product with constant quality.

Extraction facilities need a reliable supply of raw products. Therefore either large-scale plantations or a solid system with out-growers is needed. In tropical Africa the production of black wattle is still largely confined to large-scale plantations while annatto is mainly grown by out-growers. The establishment of a network with small-scale producers, well trained extension workers, reliable collection mechanism, an appropriate processing facility and secure outlets to the international market, is a must to allow for a viable industry. In Southern Africa (Malawi, Zambia, Zimbabwe) paprika (*Capsicum annuum*) is a crop where such an approach has been successfully implemented and paprika oleoresin is exported. Similar approaches could be applied to turmeric (*Curcuma longa*) and Aztec marigold (*Tagetes erecta*).

4.4 Novel products

Especially in the field of vegetable food colourants and cosmetics, prospects for new products are good. A combination of public and private enterprise seems to have the best prospects to develop and produce new products based on material of plant origin. In the case of n'galama (*Anogeissus leiocarpa*) this seems already well on track with a French cosmetic firm teaming up with a local community in Burkina Faso. Arabian primrose (*Arnebia hispidissima*), camwood (*Baphia nitida*), *Flemingia grahamiana* and balsamine (*Impatiens tinctoria*) all have traditional uses as cosmetics. Arabian primrose also holds promise as a food colourant. These species are therefore candidates to be developed into commercial crops with a prerequisite that a fair benefit sharing agreement is reached between the parties involved.

Table 3. Development gaps by species

Species name	English name	Development gaps
Acacia mearnsii	Black wattle	Selection/breeding for vigour, bark quality, stem shape, timber, tannin content & adaptation
Acacia nilotica	Babul acacia	Selection/breeding for dye, tannin & gum content, pest (bruchid) resistance and early maturity
Acridocarpus excelsus	Mavoravo	Selection
Anogeissus leiocarpa	N'galama	Selection/breeding for tannin content (Seed & seedling production ??) Diversified use in fashion industry
Arnebia hispidissima	Arabian primrose	Commercial food colorant & cosmetic
Baphia nitida	Camwood	Dye extraction in Africa (added value) Local cosmetics
Bixa orellana	Annatto	Selection and breeding for yield and bixin/ norbixin content Trade of extracts rather then seeds Increased competition (in Kenya a single factory)
Crocus sativus	Saffron	Commercial production in dry highlands
Curcuma longa	Turmeric	Breeding & selection Appropriate cultivars
Euclea divinorum	Magic gwarri	Alternative to *Acacia mearnsii*
Flemingia grahamiana	–	Waras' cosmetics Selection
Haematoxylum campechianum	Logwood	Breeding & selection
Impatiens tinctoria	Balsamine	Cosmetic in Ethiopia
Indigofera arrecta	Natal indigo	Selection for yield and adaptation
Indigofera coerulea	Indigo	(Selection)
Indigofera longiracemosa	Indigo	(Selection)
Indigofera tinctoria	Indian indigo	Selection
Labourdonnaisia madagascariensis	Nato	Selection & breeding ??
Lannea microcarpa *(& Lannea barteri & Lannea velutina)*	African grape	Adapt existing technology to larger scale food & textile industry

Table 3. Development gaps by species (Continued)

Species name	English name	Development gaps
Lawsonia inermis	Henna	Breeding for yield, quality and adaptation
Philenoptera cyanescens	Gara	Breeding for yield, quality and adaptation
Phyllanthus emblica	Emblic myro-balan	Breeding (medicinal-dye or edible fruits) Phytotherapeuticals
Psilanthus ebractiolatus	–	Genitor for coffee
Pterocarpus angolensis	African bloodwood	Methods of sustainable harvest of timber
Rubia cordifolia	Indian madder	Selection & breeding for dye content
Sorghum bicolor	Sorghum	Breeding (resistance, yield, protein, ..)
Tagetes erecta	Aztec marigold	Breeding & selection for lutein content

5. Research gaps

5.1 Candidate species for research

Research should concentrate on the important and potentially important species of dye and tannin producing plants. National and regional policies will decide which species to concentrate on. Of the tannin producing species, black wattle (*Acacia mearnsii*) is the most important and useful at present. For the production of high value vegetable tannin in warm tropical climates breeding of black wattle is a possibility. An alternative is the use of mixtures of bark extracts of babul acacia (*Acacia nilotica*) and gum-arabic acacia (*Acacia senegal*). Magic gwarri (*Euclea divinorum*) could also be exploited as the tannins give results comparable to those of black wattle. Careful management of trees in natural stands and in pasture land that is invaded by magic gwarri can give a sustainable production or result in more productive grassland. In the Philippines Madras thorn (*Pithecellobium dulce*) is considered a good alternative for black wattle. This South American exotic is widely introduced in Africa but like black wattle and magic gwarri can easily get out of control and become an invasive weed if not properly managed.
The importance of some of the dye producing species is strongly linked to local traditional uses and depends on developments in the international markets. It is therefore advisable for researchers to keep a close look at new international developments in the dyes and tannins sub-sector.

5.2 Sustainable use

The vast majority of dye and tannin producing species is exclusively harvested from the wild. In cases where the plant parts harvested are leaves or fruits, e.g. n'galama (*Anogeissus leiocarpa*) and babul acacia (*Acacia nilotica*) respectively, little damage is done and the plants will recover. Often the bark is harvested as well. Research should work on management techniques that optimize the use of the different plant parts. In species like n'galama and babul acacia options for sustainable use are to harvest only leaves or to harvest leaves and debark the tree partially to allow for regrowth of the bark. The unsustainable alternative is to cut the tree and use the bark for tannin and the wood for construction or for firewood. These choices apply for many of the perennial species and notably for the management of mangrove species.

5.3 Agronomy

For most species of dye and tannin producing plants little has been done on the possibilities of cultivation. Many indigenous species have been neglected in this respect. There are several bottlenecks that need to be solved to be able to grow some of the dye and tannin producing species efficiently. Propagation is a problem in many species. Vegetative propagation is a good option in black wattle (*Acacia*

mearnsii) and annatto (*Bixa orellana*) to avoid the variation in seedlings. Methods to increase the viability of the seeds of n'galama (*Anogeissus leiocarpa*) are badly needed. Many aspects of cultivation and management need to be worked out for species like:

- *Combretum glutinosum*,
- turmeric (*Curcuma longa*),
- *Danais ligustrifolia*,
- African rock fig (*Ficus glumosa*),
- Natal indigo (*Indigofera arrecta*),
- Indian indigo (*Indigofera tinctoria*),
- African grape (*Lannea microcarpa*),
- African bloodwood (*Pterocarpus angolensis*) and
- kantuffa (*Pterolobium stellatum*).

5.4 Diseases and pests

Diseases and pests are not important in dye and tannin producing plants. As most are exclusively collected from the wild, diseases and pests are hardly considered a bottleneck. For only a few of these wild species, mention is made of diseases or pests and hence causes and solutions need further research:

- 'mukwa' dieback in African bloodwood (*Pterocarpus angolensis*),
- spider mites and aphids in balsamine (*Impatiens tinctoria*).

Not surprisingly pests and diseases are most important in the commercially grown species and these include:

- fungal diseases in black wattle (*Acacia mearnsii*),
- fungal diseases, insect pests in annatto (*Bixa orellana*),
- leafspot, rhizome rot in turmeric (*Curcuma longa*),
- fungal diseases, insect pests, parasitic weeds, birds in sorghum (*Sorghum bicolor*),
- blight, mould, leaf spot, rootknot nematodes in Aztec marigold (*Tagetes erecta*).

Although control measures are known for most of these problems in the annual crops, appropriate Integrated Pest Management (IPM) packages need to be developed and all the more so as the international market demand for organically grown product increases. Resistant lines, timely planting and rotation are some of the common approaches used to reduce disease and pest related yield losses.

5.5 Trade and marketing statistics

Trade, marketing and production data per species should be available on a regional scale to be able to assess the relative importance of the different species. Apart from the commonly commercialized species, statistics should also be made available for other species such as *Combretum glutinosum* that is exported from Ghana but otherwise is little documented.

5.6 Processing technology

With an upsurge in interest of natural dyes, renewed attention goes to extraction technology. In recent years progress has been made in Europe with the extraction and purefication of indigo (from woad – *Isatis tinctoria*) and anthraquinones (alizarin and purpurin from madder (*Rubia tinctoria*)). The technology is probably relevant for other indigo producing species and other *Rubia* species (notably Indian madder (*Rubia cordifolia*)) respectively. However the information on these technologies is not yet necessarily in the public domain and thus researchers intending to embark on work in this field should try to compile as much information as possible beforehand.

5.7 Dye properties

For many dye producing species the exact nature of the chemical compounds responsible for the colour is unknown. Furthermore properties of a number of dyes like colour fastness, appropriate mordants etc. are still incompletely researched. The growing consumer demand for natural and healthy foodstuffs forces manufacturers to use natural food colourants. Food manufacturers have increasingly been looking for alternatives to artificial food colourants. The quest is for natural water-soluble colours, especially with little flavour, to replace synthetic colours. Examples of species that are used for extraction of such natural colorants are carrot (*Daucus carota*) and garden beet (*Beta vulgaris*) while the fruits of several species of the genus *Opuntia* are also of interest.

5.8 Pharmacological and medicinal research

A large number of dye and tannin producing plants have medicinal uses. Over 90% of the dye and tannin species have a documented medicinal use but only the minority has been tested scientifically. About 11 species out of the 73 treated in PROTA 3 have documented use as a treatment for malaria. Out of these, only 4 species have been tested for antiplasmodial activity.

Table 4. Research gaps by species

Species name	English name	Research gaps
Acacia mearnsii	Black wattle	Pests and diseases Vegetative propagation
Acacia nilotica	Babul acacia	Management for soil rehabilitation
Acridocarpus excelsus	Mavoravo	Domestication Medicinal properties
Adenorandia kalbreyeri	–	Phytochemistry Industrial processing
Alectra sessiliflora	–	Medicinal properties Chemistry
Aloe zebrina	Zebra leaf aloe	Chemical properties
Anogeissus leiocarpa	N'galama	Medicinal properties, chemical & cosmetic Dying efficiency Propagation Management Increased seed viability
Arnebia Hispidissima	Arabian primrose	Medicinal properties Domestication Chemistry
Baphia nitida	Camwood	Medicinal properties Domestication
Barringtonia racemosa	Barringtonia	Medicinal, insecticidal & nutritional properties
Bertiera spicata	–	Dye properties
Bixa orellana	Annatto	Medicinal properties, pharmacology Pests and diseases In vitro transformation of lycopene into bixin Vegetative propagation
Bruguiera gymnorhiza	Black mangrove	Sustainable use Management Natural regeneration/ artificial propagation Growth & development Ecology of mangroves
Buchnera hispida	–	Medicinal properties
Caesalpinia coriaria	Divi-divi	Pharmacology Propagation & management for commercial use
Caesalpinia sappan	Sappanwood	Medicinal properties use, pharmacology Propagation & management for commercial use

Table 4. Research gaps by species (Continued)

Species name	English name	Research gaps
Ceriops tagal	Yellow mangrove	Sustainable use Management (regeneration) Medicinal properties
Cochlospermum tinctorium	–	Medicinal value (esp. malaria & yellow fever) Propagation
Combretum glutinosum	–	Medicinal properties, pharmacology Case study Ghana (dye export) Establishment of plantations
Craterispermum laurinum	–	Medicinal properties
Craterispermum schweinfurthii	–	Medicinal properties
Cremaspora triflora	–	Medicinal properties Ornamental
Cryptolepis sanguinolenta	–	Medicinal properties, pharmacology
Curcuma longa	Turmeric	Agronomy Medicinal properties IPM (Integrated Pest Management)
Danais ligustrifolia	–	Chemistry Domestication
Diospyros loureiriana	Dye diospyros	Medicinal properties Use as histological colorant
Elephantorrhiza elephantina	Elephant root	Potential as dye, tannin and medicine Domestication
Euclea divinorum	Magic gwarri	Domestication Tannin properties Use for rehabilitation of degraded land, dye & tannin
Ficus glumosa	African rock fig	Medicinal properties Dye & tannin properties Husbandry
Flemingia grahamiana	–	Medicinal properties Value as cover crop
Griffonia physocarpa	–	Properties (dye & medicinal)
Haematoxylum campechianum	Logwood	Agroforestry Commercial cultivation
Impatiens tinctoria	Balsamine	Pharmacology Pests & diseases

Table 4. Research gaps by species (Continued)

Species name	English name	Research gaps
Indigofera arrecta	Natal indigo	Medicinal properties Husbandry (sowing & harvesting) Colour fastness
Indigofera coerulea	Indigo	Husbandry (sowing & harvesting) Colour fastness
Indigofera longiracemosa	Indigo	Husbandry (sowing & harvesting) Colour fastness
Indigofera tinctoria	Indian indigo	Medicinal properties Husbandry (sowing & harvesting) Colour fastness
Labourdonnaisia madagascariensis	Nato	Dye extraction method
Laguncularia racemosa	White mangrove	Management Pharmacology
Lannea barteri	–	Husbandry Properties (medicinal, dye, tannin)
Lannea microcarpa	African grape	Husbandry (sustainable use) Properties (medicinal, dye, tannin, pharmacology) Use of fruit as food colorant Pests & diseases
Lannea velutina	–	Husbandry Properties (medicinal, dye, tannin)
Lawsonia inermis	Henna	Medicinal properties, chemistry
Ludwigia leptocarpa	Anglestem primrose willow	Properties (dye, tannin, medicinal)
Morinda lucida	Brimstone tree	Cultivation Properties (dye, medicinal)
Mucuna flagellipes	–	Application in cosmetics Properties (dye, medicinal)
Mucuna poggei	Buffalo bean	Properties (dye, tannin, medicinal)
Mucuna sloanei	Horse-eye bean	Properties (dye, food, medicinal) Application in cosmetics
Pauridiantha rubens	–	Husbandry Phytochemistry
Philenoptera cyanescens	Gara	Cultivation Properties (indigo precursors, medicinal)
Philenoptera laxiflora	Gambian indigo	Cultivation Properties (indigo precursors, medicinal)

Table 4. Research gaps by species (Continued)

Species name	English name	Research gaps
Phyllanthus bojerianus	–	Properties (dye) Husbandry
Phyllanthus emblica	Emblic myrobalan	Propagation Husbandry
Psilanthus ebractiolatus	–	Medicinal properties
Psychotria psychotrioides	–	Properties (dye, medicinal)
Pterocarpus angolensis	African bloodwood	Use of by-products of timber Cultivation (commercial) 'Mukwa' dieback Dye composition Medicinal properties
Pterocarpus soyauxii	African padauk	Use of by-products of timber Cultivation (commercial)
Pterolobium stellatum	Kantuffa	Properties (medicinal, tannin) Commercial exploitation
Rothmannia longiflora	–	Dye, medicinal, ornamental properties of all *Rothmannia* species
Rothmannia whitfieldii	–	Dye, medicinal, ornamental properties of all *Rothmannia* species
Rubia cordifolia	Indian madder	Pharmacology Medicinal properties Commercial cultivation
Senna auriculata	Avaram	Potential for cultivation on large scale Supplement for *Acacia* tannins
Sorghum bicolor	Sorghum	Pests, diseases (IPM) Role of *Bipolaris maydis* in apigeninidin production Extraction, processing technology
Striga gesnerioides	Witchweed	Control (weed)
Syzygium rowlandii	–	Properties (wood & bark)
Tagetes erecta	Aztec marigold	Husbandry, adaptability, production & marketing Pests & diseases (IPM)
Terminalia chebula	Chebulic myrobalan	Medicinal properties
Xylocarpus granatum	Cannonball mangrove	Husbandry

6. Thesis subjects

There is considerable overlap between Research gaps and Thesis subjects. Relatively simple research questions could be taken up by students as part of their thesis work. Extensive problems would have to be taken on by researchers or teams that could devote more time to solving the problem.

6.1 Taxonomy

Taxonomical questions of comparatively simple nature can be tackled by students. Especially for the species used for dye and tannin in Madagascar the taxonomy needs to be studied further. In a number of cases uses are documented but the identity of the species is linked to a local name only. An example is 'nato' that may apply to *Labourdonnaisia madagascariensis*, to all species in the genus or even to all species of the *Sapotaceae* family. 'Mavoravo' is the local name of *Acridocarpus excelsus*. This species, which has a wide distribution in Madagascar in the different climatic zones, has been subdivided in subspecies and varieties. It would be worthwhile to verify the subdivision and to relate use(s) to the infraspecific taxa. Confusion of species by farmers, extension workers and researchers occurs in several genera. Notably in *Indigofera* it might be helpful to make simple keys for determination of the locally cultivated and collected species. This would require fieldwork that could be combined with ethnobotanical studies.
In a number of species variation is poorly understood. Study of the intraspecific variation over the whole range of distribution would be desired, but also local studies on variation in characteristics such as productivity, deserve attention. Examples are:

- babul acacia (*Acacia nilotica*),
- dye diospyros (*Diospyros loureiriana*),
- avaram (*Senna auriculata* especially the Tanzanian 'wild' population) and
- Indian madder (*Rubia cordifolia*).

6.2 Ethnobotany

Documenting specific uses, extraction methods, modes of application etc. is long overdue for a large number of species. For many widely distributed species the ethnobotany is documented for only a single or a few sites. Regional ethnobotanic studies can reveal different uses for specific plants. A few of the promising species of which use is locally important are particularly data-deficient, such as:

- camwood (*Baphia nitida*),
- dye diospyros (*Diospyros loureiriana*) and
- *Pauridiantha rubens*.

Of many of the dye plants from Madagascar the methods of dying fibres are well-known but otherwise little is known.

6.3 Chemistry

A wide range of subjects in the field of chemistry are worthwhile to be tackled by students. Characterisation of the compounds responsible for colouring should be a priority for quite a number of dye producing species. The safety of use of plant-based specific colourants in food and as ingredients in cosmetic applications needs to be determined. This would be covered by toxicity studies.
Optimal extraction methods for both dye and tannin producing species are worth researching as only traditional methods are currently used for many species. Comparative studies on the tannin producing bark and dye yielding fruits of different species in the genus *Lannea* could provide leads for optimal utilization of these species. Similarly the indigo precursor containing species in the genera *Indigofera* and *Philenoptera* could be compared.
Traditional extraction techniques are probably not the most efficient and they do not extract the chemicals exhaustively. Another problem with the traditional extraction techniques is the formation of by-products. This is a major problem in the production of indigo and removal of these by-products by purification is costly. The best approach is to look into ways of extraction that avoid the formation of by-products.

6.4 Markets: demand and supply

For many species it is unclear what the national market demand is, what prices are paid and what quantities are traded. Local or national studies could provide insight in existing or potential opportunities for farmers. BSc and MSc research could provide basic statistical data and series of such studies could indicate developments that justify further study. Changes over time in intensity of use of a species could indicate a need for conservation measures. The exploitation of a vegetation type like mangrove with useful products such as tannins, construction wood, firewood, charcoal and its effect on fisheries could be subject of multidisciplinary studies leading to recommendations for sustainable use.

6.5 Production and ecology

For most species the influence of external factors on dye or tannin content are poorly understood. Tannins have a function in the defence mechanism of plants. For a number of trees it is known that the tannin content of the leaves starts to increase as soon as they our browsed. Manipulation of plants to induce higher tannin content could have practical value for achieving higher tannin yields.

Dye and tannin content are also affected by rainfall and plant nutrition are factors that influence dye and tannin content as well. In non-leguminous indigo producing plants nitrogen fertilization was found to increase both the yield and the content of indigo precursors. These processes are insufficiently understood and quantified, hence could be fruitfully investigated.

Table 5. Thesis subjects by species

Species name	English name	Thesis subjects
Acacia mearnsii	Black wattle	Tannin production related to morphology & ecology
Acacia nilotica	Babul acacia	Taxonomy (variation) Propagation techniques Requirements international market
Acridocarpus excelsus	Mavoravo	Market survey Diversity
Adenorandia kalbreyeri	–	Value & safety in cosmetics
Aloe zebrina	Zebra leaf aloe	Taxonomy
Anogeissus leiocarpa	N'galama	Non-toxic tannins Commercialization Cosmetic value of anogelline
Arnebia hispidissima	Arabian primrose	Prospects as food colorant (effects on nutrient availability; toxicity) & cosmetic
Baphia nitida	Camwood	Ethnobotany Extraction of colorants
Bertiera spicata	–	Dye prospects
Bixa orellana	Annatto	Production and market statistics Post-harvest handling
Bruguiera gymnorhiza	Black mangrove	Production and market statistics for individual mangrove species
Buchnera hispida	–	Phytochemistry
Caesalpinia sappan	Sappanwood	Dye potential (market & trade statistics)
Ceriops tagal	Yellow mangrove	Production and market statistics for individual mangrove species
Combretum glutinosum	–	Tannin production related to ecology
Craterispermum laurinum	–	Phytochemistry
Craterispermum schweinfurthii	–	Phytochemistry
Cremaspora triflora	–	Phytochemistry (dye)
Curcuma longa	Turmeric	Breeding methodology
Danais ligustrifolia	–	Ethnobotany Taxonomy genus
Diospyros loureiriana	Dye diospyros	Ethnobotany Taxonomy genus

Table 5. Thesis subjects by species (Continued)

Species name	English name	Thesis subjects
Euclea divinorum	Magic gwarri	Market
Flemingia grahamiana	–	Market survey
Indigofera arrecta	Natal indigo	Comparison indigo sources Taxonomy
Indigofera coerulea	Indigo	Comparison indigo sources Taxonomy
Indigofera longiracemosa	Indigo	Comparison indigo sources Taxonomy
Indigofera tinctoria	Indian indigo	Dye yield (cultivars & ecology) Comparison indigo sources Taxonomy
Labourdonnaisia madagascariensis	Nato	Distribution, numbers, taxonomy of genus
Laguncularia racemosa	White mangrove	Characterization of dye & tannin Production and market statistics
Lannea barteri	–	Characterization of dye & tannin Comparison *Lannea* sources
Lannea microcarpa	African grape	Characterization of dye & tannin Comparison *Lannea* sources Appropriate technology
Lannea velutina	–	Characterization of dye & tannin Comparison *Lannea* sources
Lawsonia inermis	Henna	Market potential Production statistics
Mucuna sloanei	Horse-eye bean	Commercial interest as vegetable
Pauridiantha rubens	–	Document cultivation, ethnobotany Characterization of dye
Philenoptera cyanescens	Gara	Market & production statistics
Philenoptera laxiflora	Gambian indigo	Market & production statistics
Phyllanthus emblica	Emblic myrobalan	Market
Pterocarpus angolensis	African bloodwood	Propagation Extraction techniques
Pterocarpus soyauxii	African padauk	Extraction techniques
Rubia cordifolia	Indian madder	Variability (taxonomy) Market study

Table 5. Thesis subjects by species (Continued)

Species name	English name	Thesis subjects
Senna auriculata	Avaram	Ethnobotany
Sorghum bicolor	Sorghum	Use of dye as functional food colorant Dye characteristics by cultivar
Tagetes erecta	Aztec marigold	Quantity & quality of dye

7. Conservation needs

The main purpose of conservation of germplasm is to maintain the genetic variation. This variation can be used in breeding or to re-establish the species where it has become extinct. Gene banks have an important task in conservation, exploration, collection, characterization, evaluation and documentation of germplasm.

7.1 Species threatened by overexploitation

Overexploitation is an important reason why species become scarce or threatened. Examples of dye and tannin producing species that have become scarce (or) locally extinct due to overexploitation are:

- n'galama (*Anogeissus leiocarpa*),
- *Combretum glutinosum*.

Many of the endemic species of the Indian Ocean islands that are used for dye or tannin have become rare. Limited knowledge on their status, their identity and on their use makes it difficult to evaluate their status.
Sudden increase in use of a species harvested from the wild is likely to decrease its population and monitoring of such species is imperative.

7.2 Species threatened by habitat destruction

Many dye and tannin species occur in mangrove vegetation and are exploited not only for their use as dye or tannin but also for other uses, notably of their wood for construction and firewood.
Habitat loss as the cause for eradication is of concern in the Indian Ocean Islands with examples such as nato (*Labourdonnaisia madagascariensis*), a rare and much sought after forest species, and *Pyranthus tullearensis*, a species of wooded grassland that is threatened by recurrent bush fires.

7.3 Threatened landraces

An important category for germplasm collection and conservation are the landraces of traditionally grown crops. These landraces are adapted to the local conditions and may harbour interesting characteristics such as disease resistance and heat tolerance.
Only few of the dye and tannin producing species are cultivated. Dye producing cultivars of sorghum (*Sorghum bicolor*) are restricted to western Africa and Sudan. Only recently interest of scientists was revived and several named landraces have possibly disappeared. Although there are large germplasm collections of sorghum it is not clear if these collections contain dye cultivars. A regional attempt should be made to collect and conserve the dye producing landraces.
For black wattle (*Acacia mearnsii*) breeders in Southern Africa tend to optimize for wood yield and the tannin content of the bark takes a less dominant role. The older

cultivars with high tannin content may disappear because of the increased value of the wood. The closure of a Kenyan factory which used to extract tannin from black wattle and consequently the breaking up of black wattle plantations may also lead to the loss of landraces.

7.4 Management and coverage of collections

Most dye and tannin producing plant species are not represented in germplasm collections. For the species that are represented, the numbers of samples are too small and only cover a part of the diversity present in the species. For a number of species that are present in germplasm collections, not the whole geographic range has been covered and hence only part of the variation within the species is captured. An exception to this is the babul acacia (*Acacia nilotica*). Of these species, collections have been made covering the whole geographic range but evaluation of this material is time-consuming and still underway.
A number of potentially important species have their centre of origin outside tropical Africa. Indian indigo (*Indigofera tinctoria*) and henna (*Lawsonia inermis*) are species with an Asian origin while black wattle (*Acacia mearnsii*) is native to Australia. In case breeding or selection for such species would be considered, collection in the area of origin and evaluation of these provenances would be a first step.

7.5 Access to information and germplasm

One of the major problem that breeders and researchers often experience is to figure out what germplasm is available because documentation is incomplete or inaccessible. A database maintained by IPGRI (International Plant Genetic Resources Institute)
http://www.ipgri.cgiar.org/system/page.asp?frame=germplasm/dbases.htm is the best source to information about germplasm collections.
Another important problem is access to or availability of the germplasm. The International Treaty on Plant Genetic Resources for Food and Agriculture, (http://www.fao.org/ag/cgrfa/itpgr.htm), signed in 2004 and ratified by the majority of Food & Agricultural Organisation (FAO) member states, has made provisions through a 'Multilateral System of Access and Benefit-sharing' for a number of species. Although none of the dye and tannin producing plant species reviewed in PROTA 3 is on the list, the principle of benefit-sharing should equally apply. Where the issue of Intellectual Property Rights (IPR) is applicable, it should be respected as it is recognized by signatories of the FAO treaty.

Table 6. Conservation needs by species

Species name	English name	Conservation needs
Acacia mearnsii	Black wattle	Germplasm collection and characterization
Acacia nilotica	Babul acacia	Germplasm collection and characterization
Acridocarpus excelsus	Mavoravo	Germplasm collection
Aloe zebrina	Zebra leaf aloe	Ex-situ (CITES)
Anogeissus leiocarpa	N'galama	Germplasm collection and evaluation
Barringtonia racemosa	Barringtonia	Germplasm collection
Caesalpinia coriaria	Divi-divi	Germplasm collection
Ceriops tagal	Yellow mangrove	Habitat conservation
Combretum glutinosum	–	Germplasm collection
Elephantorrhiza elephantina	Elephant root	Germplasm collection
Impatiens tinctoria	Balsamine	Germplasm collection
Labourdonnaisia madagascariensis	Nato	Conservation in- & ex-situ
Laguncularia racemosa	White mangrove	Habitat conservation
Lawsonia inermis	Henna	Germplasm collection (India)
Pterocarpus angolensis	African bloodwood	Conserve in-situ
Pterocarpus soyauxii	African padauk	Conserve in-situ
Pyranthus tullearensis	–	Germplasm collection
Rothmannia whitfieldii	–	Germplasm collection
Sorghum bicolor	Sorghum	Germplasm collection & characterisation of dye-cultivars Market survey (local & international)
Terminalia scutifera	–	Vulnerable for genetic erosion (habitat, small distribution area)

8. Policy measures

8.1 Trends in production and demand

Policy makers should be well aware of international trends in production and demand. The present general trend for increased demand for natural products and for substitution of synthetic substances will probably become stronger. Plant-derived products are likely to take a larger share in the international markets, particularly for products produced biologically.

For tannins the international demand for plant derived materials is still considerable. This is largely due to the failure to produce synthetic tannins with exactly the same characteristics as the natural products. Especially for black wattle (*Acacia mearnsii*) demand remains high as it produces light-coloured and better quality leather. Concerns over environmental damage that synthetic tanning like chrome-tanning can cause, reinforces the increased use of natural tannins.

Natural dyes have lost their important role in international trade around the start of the 20th century after it became possible to produce synthetic dyes on an industrial scale. These synthetic dyes were cheaper than the natural products. Furthermore they were purer and more constant in quality resulting in more uniform products. Indigo (*Indigofera* spp.), formerly an important commodity in the international trade, was reduced to a dye that was only produced on a small scale in Asia and Africa for local use. Revival of interest in plant-derived dyes will result in an increased demand. Selection and breeding for uniformity and improved extraction techniques will help to produce dyes with a constant quality that will also contribute to increased popularity of natural dyes. In the European Union 8000 tonnes of synthetic indigo are used annually. Attempts are made to produce indigo by extraction from woad (*Isatis tinctoria*). The SPINDIGO (Sustainable Production of Plant-derived Indigo) project (www.spindigo.net) has bred new strains, developed mobile extractors, attempted to find feasible ways for purification etc. Outcomes of this project, even if only partially successful, will provide important information and lessons and other sources of natural indigo will probably benefit from the findings.

The international market for natural food colourants is even more affected by consumer requirements than the markets for tannins and for dyes used to colour textiles. The quest for safer, natural food translates into high demand for plant-derived colourants for use in both human nutrition and animal feeds. Some of the better known food colourants in international trade are those from annatto (*Bixa orellana*), turmeric (*Curcuma longa*) and saffron (*Crocus sativus*). Safflower (*Carthamus tinctorius*) and paprika (*Capsicum annuum*), although primarily of interest as an oil crop and vegetable respectively, play an increasing role in the food colourant trade. Arabian primrose (*Arnebia hispidissima*) and sorghum (*Sorghum bicolor*) are some of the species that could play an important role as producers of food colourants in the near future. Aztec marigold (*Tagetes erecta*) produces the colorant lutein that is allowed in the USA only for use in animal feeds and pet food. Lutein is registered in the European Union as a permitted food colour under the

code E161b. Carrot (*Daucus carota*) and garden beet (*Beta vulgaris*) are also used as food colourants. The fruits of several species of the genus *Opuntia* are also of interest as a source of colourants.

The use of plant derived dyes in cosmetic products is likely to increase as well. Use of species like henna (*Lawsonia inermis*) and sorghum (*Sorghum bicolor*) in hair dyes is well-established, respectively starting to gain momentum. Arabian primrose (*Arnebia hispidissima*) and n'galama (*Anogeissus leiocarpa*) are also of interest for the cosmetic industry. Lycopene, the red colourant of the tomato (*Lycopersicon esculentum*), is increasingly used in skin-care preparations.

8.2 Cultural heritage

The use of natural dyes in traditional production of textiles in tropical Africa is well-documented in a number of cases:

- Adinkra clothes in Ghana (*Lannea barteri*),
- Basilan textiles in the Sahel esp. Mali (*Anogeissus leiocarpa, Lannea* spp.),
- Bogolan textiles in Mali (*Anogeissus leiocarpa, Lannea microcarpa, Combretum glutinosum, Ficus glumosa*),
- Bara siti cloth in Gambia (*Philenoptera laxiflora*),
- Hile, sampak and siole textiles of Cameroon (*Acacia nilotica*),
- Langtang weaving of Nigeria (*Acacia nilotica*),
- Kobene clothes in Ghana (*Morinda lucida*),
- Madagascar textiles (*Phyllanthus bojerianus, Labourdourdonnaisia madagascariensis*),
- Adire cloth in Nigeria (*Philenoptera cyanescens*),
- Gara cloth in Sierra Leone (*Philenoptera cyanescens*),
- Raffia ikats in Madagascar (*Danais ligustrifolia, Indigofera arrecta* & *Indigofera tinctoria*),
- Lamba mena textiles in Madagascar (*Danais ligustrifolia*),
- Abata and Ifala cloth in Nigeria (*Sorghum bicolor*).

Many of these textiles still play a role in cultural events like circumcision, burial ceremonies etc. Some of the traditional textiles have been 'discovered' by international fashion designers, have become popular in the Western world and as a result are now important export products. Preserving the traditional techniques is important for the cultural identity of people but can also become an important source of income and foreign currency.

8.3 Conservation measures

With regards to conservation, policy makers should formulate and enforce laws and take responsibility for national germplasm conservation (botanical gardens, herbaria, gene banks). Few dye and tannin producing plant species are found in germplasm collections. Only *Acacia* spp., *Aloe* spp., *Indigofera* spp. and sorghum (*Sorghum bicolor*) are well presented in African collections. In the case of sorghum

the absence of dye cultivars is apparent. Germplasm collection of the indigenous species is needed, mostly not because of direct threats, but to capture the variation in these species.
Regional (e.g. the Southern African Development Community (SADC)), panafrican (e.g. the Forum for Agricultural Research in Africa (FARA)) and international institutions (e.g. the International Plant Genetic Resources Institute (IPGRI)) should be involved in coordinating efforts, increasing efficiency and avoiding duplication. Availability of germplasm to breeders, including private seed companies, should be facilitated. In cases where Intellectual Property Rights (IPR) issues play a role, policy makers have a duty to ensure that correct procedures are followed.
Mangrove vegetation harbours a large number of dye and tannin producing plant species and deserve protection measures. Legislation is an important factor in securing sustainable harvest. Promoting cultivation can help to relieve wild populations.
Deliberate importation of alien species can threaten the indigenous biodiversity. In the group of dye and tannin producing plants, black wattle (*Acacia mearnsii*) has a reputation of invading natural vegetation. Magic gwarri (*Euclea divinorum*), still absent from Western Africa, also has the potential of becoming dominant in pasture land.
Control of agricultural imports, especially seeds, are needed to avoid importation of potentially invasive weeds. Several species traditionally used for dyeing are notorious weeds, e.g. *Alectra sessiliflora*, *Buchnera hispida*, anglestem primrose willow (*Ludwigia leptocarpa*) and witchweed (*Striga gesneroides*). All these species already have a very wide distribution so the risk of introducing them in new areas is limited.

8.4 Import substitution

Import substitution is of only limited relevance for dye and tannin production. Notably synthetic tannins are imported in tropical Africa. These imports could to some extent be replaced by producing natural tannins locally. The same applies to black wattle (*Acacia mearnsii*) extract that is imported in many African countries. Of the food colourants turmeric (*Curcuma longa*) is probably the only one that is imported into tropical Africa in considerable quantities. Substituting synthetic dyes with natural ones in tropical Africa will probably become a possibility once research has yielded the parameters for production at some larger scale and at lower prices.

8.5 Quality standards and control

Policy should take measures to protect the export trade by setting and enforcing quality standards. Especially in food colourants importing countries have tight controls for unadmissable contamination. Poor quality export products will result in decerasing marketing possibilities. The presence of aflatoxins is another problem of

plant products that have not had a proper post-harvest treatment. Another risk to consumers' health is microbiological contamination with e.g. salmonella and *Escherichia coli*. If a country intends to expand exports of dyes, a tight system of controls including laboratory testing should be put in place. A credible certification system for organically grown products will help to get a larger share in the western markets.

8.6 Capacity building

Capacity building is to be supported as a shortage of dye and tannin experts is felt in many if not all countries of tropical Africa. Of more concern is that few plant breeders are active in the dye and tannin sector. In general agricultural extension workers have insufficient knowledge of dye and tannin production.

8.7 Extension and promotion

Governments have great influence on how extension services are structured and how extension messages are delivered. The Training & Visit (T&V) system is still used in many countries while other countries have changed to Farmer Field Schools (FFS) systems. Policy makers should make sure that the most appropriate and efficient extension approach is used.

When starting production of a novel crop for the export market, policy makers together with other stakeholders have a contribution to make as this can only succeed with concerted efforts. An example is the production of paprika for food-colourant uses in Zambia. The government provided subsidies for fertiliser, irrigation and pre-shipment finance. Development agencies provided funding, and foreign experts have contributed to technical assistance and training. This has resulted in first instance in exports of 400 tonnes a year, most of it in its raw form, to South African manufacturers. Irrigation of the crop allows for three flushes a year, which increases the critical mass needed to produce value-added products. A processing plant to manufacture oleoresin, a food colourant, is operational and the processed product is exported.

Table 7. Policy measures by species

Species name	English name	Policy measures
Acacia mearnsii	Black wattle	Substitute for synthetic (imported) tannins Export of wood chips, export facilities & quality control Substitute for *Eucalyptus*
Acacia nilotica	Babul acacia	Promote use Substitute import tannins Role in tradition, cultural value
Alectra sessiliflora	–	Control (parasitic weed)
Anogeissus leiocarpa	N'galama	Legislation for sustainable use Promote plantations Export ?? Role in tradition, cultural value
Arnebia hispidissima	Arabian primrose	Sustainable use - cultivation
Baphia nitida	Camwood	Local extraction of dye (before use as fuel) Use for reforestation
Barringtonia racemosa	Barringtonia	Legislation for sustainable use Habitat conservation
Bixa orellana	Annatto	Export trade Quality certification
Bruguiera gymnorhiza	Black mangrove	Legislation for sustainable use Habitat conservation Reforestation
Buchnera hispida	–	Control (parasitic weed)
Ceriops tagal	Yellow mangrove	Management policy & pollution reduction Mangrove protection
Combretum glutinosum	–	Avoid over-exploitation Role in tradition, cultural value
Curcuma longa	Turmeric	Import substitution (any import into Africa?) Quality certification
Danais ligustrifolia	–	Role in tradition, cultural value Habitat protection
Elephantorrhiza elephantina	Elephant root	Harvest control
Euclea divinorum	Magic gwarri	Harvest control Invasive in pastures
Ficus glumosa	African rock fig	Role in tradition, cultural value Harvest control
Flemingia grahamiana	–	Quality certification

Table 7. Policy measures by species (Continued)

Species name	English name	Policy measures
Indigofera arrecta	Natal indigo	Role in tradition, cultural value
Indigofera tinctoria	Indian indigo	Role in tradition, cultural value
Labourdonnaisia madagascariensis	Nato	Protection measures (endemic Madagascar)
Laguncularia racemosa	White mangrove	Mangrove policies
Lannea barteri	–	Role in tradition, cultural value
Lannea microcarpa	African grape	Monitor (over-) exploitation Role in tradition, cultural value
Lannea velutina	–	Role in tradition, cultural value
Lawsonia inermis	Henna	Promote commercial production Role in tradition, cultural value Quality certification
Ludwigia leptocarpa	Anglestem primrose willow	Potential weed
Morinda lucida	Brimstone tree	Role in tradition, cultural value
Philenoptera cyanescens	Gara	Monitor (over-) exploitation Role in tradition, cultural value
Philenoptera laxiflora	Gambian indigo	Role in tradition, cultural value
Phyllanthus bojerianus	–	Role in tradition, cultural value
Pterocarpus angolensis	African bloodwood	Sustainable use (regulation) Enforce replanting
Pterocarpus soyauxii	African padauk	Sustainable use Enforce replanting
Pyranthus tullearensis	–	Protection measures
Rothmannia whitfieldii	–	Protection
Sorghum bicolor	Sorghum	Stimulate production & export (handcraft, fabric & food colorant) Role in tradition, cultural value
Striga gesnerioides	Witchweed	Control (parasitic weed)
Tagetes erecta	Aztec marigold	International approval for use as food colorant Quality certification

Table 7. Policy measures by species (Continued)

Species name	English name	Policy measures
Terminalia Scutifera	–	Mangrove protection
Xylocarpus granatum	Cannonball mangrove	Habitat protection Control cutting Mangrove policies

Annex 1: Comparative data on 73 species of dye & tannin producing plants

Key to the table columns

Origin:
- Indigenous, i.e. of African origin
- Adapted, i.e. introduced but long ago (local cultivars or eco-types have developed)
- Exotic, i.e. introduced; cultivation depends on foreign cultivars

Distribution Distribution in tropical Africa (see PROTA map on inner backcover):
- C: Central Africa
- E: East Africa
- I: Indian Ocean Islands
- S: Southern Africa
- W: West Africa

Status: Cultivation status:
- Wild
- Cult. (cultivated)
- Both

SU: Secondary Uses (Primary use = 3: Dyes and tannins)

1. Cereals and pulses	10. Fuel plants
2. Vegetables	11. Medicinal plants
4. Ornamentals	12. Spices and condiments
5. Forages	13. Essential oils and exudates
6. Fruits	14. Vegetable oils
7. Timbers	15. Stimulants
8. Carbohydrates	16. Fibres
9. Auxiliary plants	

Cycle: Life cycle:
- Annual
- Perennial
- Both

Min – Max Alt.: Minimum and maximum altitude (in m above sea-level)

Prop.: Propagation:
- G: Generative
- V: Vegetative

Species	English name	Family	Origin	Distribution	Status	Use	Plant part used	SU	Cycle	Growth	Min–Max Alt.	Prop.
Acacia mearnsii	Black wattle	Mimosaceae	adapted (from Australia)	C E I S W	cult.	T	bark	4, 5, 7, 9, 10, 11, 16	perennial	tree	1500 - 2500	G
Acacia nilotica	Babul acacia	Mimosaceae	indigenous	C E I S W	wild	D & T	fruits, bark	2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16	perennial	tree	0 - >2000	G
Acridocarpus excelsus	Mavoravo	Malpighiaceae	indigenous	_ _ I _ _	wild	D	bark	11	perennial	shrub / tree	0 - 1250	G
Adenorandia kalbreyeri	–	Rubiaceae	indigenous	C _ _ _ W	wild	D	fruit	4	perennial	shrub / liana	? - ?	G
Alectra sessiliflora	–	Scrophulariaceae	indigenous	C E I S W	wild	D	flowers, roots	11	annual	herb	0 - 2500	G
Aloe zebrina	Zebra leaf aloe	Asphodelaceae	indigenous	_ _ _ S _	wild	D	roots	2, 4, 11	perennial	herb	? - ?	G, V
Anogeissus leiocarpa	N'galama	Combretaceae	indigenous	C E _ _ W	both	D & T	leaves, bark, roots	4, 5, 7, 9, 10, 11, 13, 16	perennial	shrub / tree	0 - 1900	G
Arnebia hispidissima	Arabian primrose	Boraginaceae	indigenous	C E _ _ W	wild	D	roots	5, 11	annual	herb	? - ?	G
Baphia nitida	Camwood	Papillonaceae	indigenous	C _ _ _ W	both	D	wood, roots, bark	1, 4, 5, 7, 9, 11, 16	perennial	shrub / tree	0 - 600	G, V
Barringtonia racemosa	Barringtonia	Lecythidaceae	indigenous	_ E I S _	wild	D & T	bark	2, 4, 7, 10, 11, 16	perennial	tree	0 - 900	G, V
Bertiera spicata	–	Rubiaceae	indigenous	_ _ _ _ W	wild	D	bark	–	perennial	shrub	0 - ?	G
Bixa orellana	Annatto	Bixaceae	adapted (from America)	C E I S W	both	D	seeds	4, 5, 10, 11, 12, 16	perennial	shrub / tree	0 - 2000	G, V
Bruguiera gymnorhiza	Black mangrove	Rhizophoraceae	indigenous	_ E I S _	wild	D & T	bark	2, 7, 9, 10, 11, 12, 13, 16	perennial	tree	0 - 50	G
Buchnera hispida	–	Scrophulariaceae	indigenous	C E I S W	wild	D	plant	11	annual	herb	0 - 1800	G
Caesalpinia coriaria	Divi-divi	Caesalpiniaceae	adapted (from America)	C E I S W	cult.	D & T	fruits, wood	4, 9, 11	perennial	tree	0 - ?	G
Caesalpinia sappan	Sappanwood	Caesalpiniaceae	adapted (from Asia)	C E I _ W	cult.	D	wood, fruits	4, 7, 9, 10, 11, 12	perennial	tree	0 - ?	G
Ceriops tagal	Yellow mangrove	Rhizophoraceae	indigenous	_ E I S _	wild	D & T	bark	7, 10, 11, 13, 16	perennial	shrub / tree	0 - 50	G
Cochlospermum tinctorium	–	Cochlospermaceae	indigenous	C E _ _ W	wild	D	rhizome	6, 11, 16	perennial	shrub	300 - 1500	G
Combretum glutinosum	–	Combretaceae	indigenous	C E _ _ W	wild	D	leaves, bark	2, 5, 7, 10, 11, 13	perennial	shrub / tree	? - ?	G
Cosmos sulphureus	Orange cosmos	Asteraceae	exotic (from America)	C E I S W	cult.	D	flowers	4	annual	herb	? - ?	G
Craterispermum laurinum	–	Rubiaceae	indigenous	_ _ _ _ W	wild	D	bark, leaves	9, 11, 16	perennial	shrub / tree	? - ?	G, V

Species	English name	Family	Origin	Distribution	Status	Use	Plant part used	SU	Cycle	Growth	Min–Max Alt.	Prop.
Craterispermum schweinfurthii	–	Rubiaceae	indigenous	C E _ S W	wild	D	bark, leaves, wood	7, 8, 9, 10, 11, 16	perennial	shrub / tree	0 - 1500	G, V
Cremaspora triflora	–	Rubiaceae	indigenous	C E I S W	wild	D	fruits, seeds	4, 6, 7, 10, 11	perennial	shrub / tree	0 - 2000	G
Crocus sativus	Saffron	Iridaceae	exotic (from Eurasia)	_ _ _ _ W	cult.	D	styles, stigmas	4, 11, 12	annual	herb	? - ?	V
Cryptolepis sanguinolenta	–	Asclepiadaceae	indigenous	C E _ S W	wild	D	roots	2, 11	perennial	shrub	? - ?	G
Curcuma longa	Turmeric	Zingiberaceae	adapted (from Asia)	C E I S W	cult.	D	rhizome	2, 11, 12, 13	perennial	herb	0 - 1200	V
Danais ligustrifolia	–	Rubiaceae	indigenous	_ _ I _ _	wild	D	roots	11	perennial	shrub / liana	0 - 1000	G
Diospyros loureiriana	Dye diospyros	Ebenaceae	indigenous	_ E _ S _	wild	D	roots, bark	6, 7, 10, 11	perennial	shrub / tree	0 - 750	G
Elephantorrhiza elephantina	Elephant root	Mimosaceae	indigenous	_ _ _ S _	wild	D & T	rhizome	5, 11, 15	perennial	shrub	0 - ?	G
Euclea divinorum	Magic gwarri	Ebenaceae	indigenous	C E _ S _	wild	D & T	bark, roots, fruits	4, 6, 7, 10, 11, 12, 16	perennial	shrub / tree	0 - 2700	G, V
Ficus glumosa	African rock fig	Moracecae	indigenous	C E _ S W	wild	D & T	bark	2, 5, 6, 9, 10, 11, 13, 16	perennial	shrub / tree	0 - 2000	G, V
Flemingia grahamiana	–	Papilionaceae	indigenous	C E _ S W	both	D	fruit-hairs	8, 9, 11	perennial	herb / shrub	0 - 2100	G
Griffonia physocarpa	–	Caesalpiniaceae	indigenous	C _ _ _ W	wild	D	leaves, roots	11, 16	perennial	shrub / liana	0 - ?	G
Haematoxylum campechianum	Logwood	Caesalpiniaceae	adapted (from America)	C E I S W	cult.	D	wood	4, 7, 8, 9, 11	perennial	shrub / tree	0 - ?	G, V
Impatiens tinctoria	Balsamine	Balsaminaceae	indigenous	C E _ S _	both	D	tubers, roots	4, 5, 11	perennial	herb	700 - 3600	G, V
Indigofera arrecta	Natal indigo	Papilionaceae	indigenous	C E I S W	both	D	leafy twigs	2, 5, 9, 11	both	herb / shrub	200 - 2700	G
Indigofera coerulea	Indigo	Papilionaceae	indigenous	C E I _ W	both	D	leafy twigs	11	annual	herb	200 - 1250	G
Indigofera longiracemosa	Indigo	Papilionaceae	indigenous	_ E I _ _	both	D	leafy twigs	9, 11	both	herb / shrub	0 - 200	G
Indigofera tinctoria	Indian indigo	Papilionaceae	adapted (from Asia)	C E I S W	both	D	leafy twigs	5, 9, 11	both	herb / shrub	0 - 1250	G
Labourdonnaisia madagascariensis	Nato	Sapotaceae	indigenous	_ _ I _ _	wild	D & T	bark	7, 10, 11	perennial	tree	0 - ?	G
Laguncularia racemosa	White mangrove	Combretaceae	indigenous	C _ _ S W	wild	D & T	bark, leaves	5, 6, 7, 8, 10, 11	perennial	shrub / tree	0 - 50	G, V
Lannea barteri	–	Anacardiaceae	indigenous	C E _ _ W	wild	D	bark	6, 7, 8, 9, 10, 11, 16	perennial	tree	500 - 1600	G, V

Species	English name	Family	Origin	Distribution	Status	Use	Plant part used	SU	Cycle	Growth	Min–Max Alt.	Prop.
Lannea microcarpa	African grape	Anacardiaceae	indigenous	C _ _ _ W	wild	D	bark	2, 5, 6, 7, 10, 11, 13, 16	perennial	tree	? - ?	G
Lannea velutina	–	Anacardiaceae	indigenous	C _ _ _ W	wild	D	bark	5, 6, 7, 10, 11, 13, 16	perennial	tree	? - ?	G
Lawsonia inermis	Henna	Lythraceae	adapted (from Asia)	C E I S W	both	D	leaves	4, 7, 10, 11, 13, 16	perennial	shrub / tree	0 - 1350	G, V
Ludwigia leptocarpa	Anglestem primrose willow	Onagraceae	adapted (from America)	C E I S W	wild	D	leaves	11, 12	annual	herb	0 - 1900	G, V
Morinda lucida	Brimstone tree	Rubiaceae	indigenous	C E _ S W	both	D	wood, root, leaves	7, 10, 11, 12, 16	perennial	shrub / tree	0 - 1300	G, V
Mucuna flagellipes	–	Papilionaceae	indigenous	C _ _ S W	wild	D	stems, leaves	11, 13, 16	perennial	liana	0 - 1400	G
Mucuna poggei	Buffalo bean	Papilionaceae	indigenous	C E _ S W	wild	D	stems, leaves	1, 5, 11, 16	perennial	liana	0 - 2000	G
Mucuna sloanei	Horse-eye bean	Papilionaceae	indigenous	C _ _ S W	both	D	plant	1, 2, 11, 14	perennial	liana	? - ?	G
Pauridiantha rubens	–	Rubiaceae	indigenous	C _ _ _ _	both	D	leaves	–	perennial	shrub / tree	0 - 500	G
Philenoptera cyanescens	Gara	Papilionaceae	indigenous	C _ _ _ W	both	D	leafy twigs	11, 12	perennial	liana / shrub	0 - 400	G
Philenoptera laxiflora	Gambian indigo	Papilionaceae	indigenous	C E _ _ W	wild	D	leafy twigs	2, 5, 6, 7, 10, 11, 12	perennial	tree	0 - 2100	G
Phyllanthus bojerianus	–	Euphorbiaceae	indigenous	_ _ I _ _	wild	D	leafy twigs	–	perennial	shrub	0 - 1600	G
Phyllanthus emblica	Emblic myrobalan	Euphorbiaceae	exotic (from Asia)	_ _ I _ _	cult.	D & T	leaves, fruits, bark	2, 5, 6, 7, 9, 10, 11	perennial	tree	0 - 1500	G, V
Psilanthus ebractiolatus	–	Rubiaceae	indigenous	C _ _ _ W	wild	D	fruits, seeds	11, 15, 16	perennial	shrub / tree	0 - ?	G
Psychotria psychotrioides	–	Rubiaceae	indigenous	C E _ _ W	wild	D	bark, leaves	11	perennial	shrub	0 - 1200	G
Pterocarpus angolensis	African bloodwood	Papilionaceae	indigenous	C E _ S _	both	D	roots, wood, bark	4, 5, 8, 9, 10, 11, 13, 16	perennial	tree	0 - 1800	G, V
Pterocarpus soyauxii	African padauk	Papilionaceae	indigenous	C E _ _ W	wild	D	wood, roots, bark	2, 10, 11	perennial	tree	0 - 500	G, V
Pterolobium stellatum	Kantuffa	Caesalpiniaceae	indigenous	C E _ S _	both	D & T	bark, leaves	4, 5, 9, 10, 11	perennial	shrub	500 - 2500	G, V
Pyranthus tullearensis	–	Papilionaceae	indigenous	_ _ I _ _	wild	D	bark	–	perennial	shrub / tree	500 - 1100	G
Rhus tomentosa	Wild currant	Anacardiaceae	indigenous	_ _ _ S _	wild	T	wood, bark, leaves	4, 6, 10, 16	perennial	shrub / tree	0 - 2500	G

Species	English name	Family	Origin	Distribution	Status	Use	Plant part used	SQ	Cycle	Growth	Min-Max Alt.	Prop.
Rothmannia longiflora	–	Rubiaceae	indigenous	C E _ S W	wild	D	fruits, leaves, seeds, flowers	4, 6, 7, 11, 16	perennial	shrub / tree	0 - 1700	G
Rothmannia whitfieldii	–	Rubiaceae	indigenous	C E _ S W	wild	D	fruits, seeds	7, 11, 15	perennial	shrub / tree	0 - 1700	G
Rubia cordifolia	Indian madder	Rubiaceae	indigenous	C E _ S _	wild	D	roots, fruits	2, 4, 6, 11, 12	perennial	herb	0 - 2600	G, V
Senna auriculata	Avaram	Caesalpiniaceae	adapted (from Asia)	C E _ _ W	both	D & T	bark, flowers, seeds	2, 4, 7, 9, 11, 15, 16	perennial	shrub / tree	0 - 600	G, V
Sorghum bicolor	Sorghum	Poaceae	indigenous	C E I S W	both	D	leaf sheaths, grains	5, 8, 10, 11, 16	annual	herb	0 - 2300	G
Striga gesnerioides	Witchweed	Scrophulariaceae	indigenous	C E I S W	wild	D	plant juice, roots, flowers	5, 11, 16	annual	herb	? - ?	G
Syzygium rowlandii	–	Myrtaceae	indigenous	C _ _ _ W	wild	D	bark	7, 11	perennial	tree	500 - 2400	G
Tagetes erecta	Aztec marigold	Asteraceae	exotic (from America)	C E I S W	cult.	D	flowers	4, 11, 12, 13	annual	herb	0 - 2000	G
Terminalia chebula	Chebulic myrobalan	Combretaceae	exotic (from Asia)	C E _ _ W	cult.	D & T	fruits, flowers	6, 7, 11	perennial	tree	0 - 2000	G, V
Terminalia scutifera	–	Combretaceae	indigenous	_ _ _ _ W	wild	D	bark	7, 11	perennial	tree	0 - 50	G
Xylocarpus granatum	Cannonball mangrove	Meliaceae	indigenous	_ E I S _	wild	D & T	bark	7, 10, 11, 14	perennial	tree	0 - 50	G

Annex 2: Matrix '73 species × 6 key issues'

Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Acacia mearnsii	Soil rehabilitation Multipurpose (tannin, timber, fuel, paper pulp) Alternative for paper pulp of *Eucalyptus globulus* Vegetative propagation techniques	Selection/breeding for vigour, bark quality, stem shape, timber, tannin content & adaptation	Pests and diseases Vegetative propagation	Tannin production related to morphology & ecology	Germplasm collection and characterization	Substitute for synthetic (imported) tannins Export of wood chips, export facilities & quality control Substitute for *Eucalyptus*
Acacia nilotica	Soil rehabilitation Multipurpose (drier areas) Optimal harvesting & extraction Renewable resource (fruits)	Selection/breeding for dye, tannin & gum content, pest (bruchid) resistance and early maturity	Management for soil rehabilitation	Taxonomy (variation) Propagation techniques Requirements international market	Germplasm collection and characterization	Role in tradition, cultural value (Hile, sampak & siole textiles of Cameroon; Lang-tang weaving of Nigeria) Promote use Substitute import tannins
Acridocarpus excelsus		Selection	Domestication Medicinal properties	Market survey Diversity	Germplasm collection	
Adenorandia kalbreyeri	Ornamental		Phytochemistry Industrial processing	Value & safety in cosmetics		
Alectra sessiliflora			Medicinal properties Chemistry			Control (parasitic weed)
Aloe zebrina	Domestication (orna-mental/ confectionery)		Chemical properties	Taxonomy	Ex-situ (CITES)	
Anogeissus leiocarpa	Management wild trees Domestication Optimal harvesting & extraction techniques	Selection/breeding for tannin content (Seed & seedling production ??) Diversified use in fashion industry	Medicinal, chemical & cosmetic properties Dying efficiency Propagation Management Increased seed viability	Non-toxic tannins Commercialization Cosmetic value of anogelline	Germplasm collection and evaluation	Legislation for sustainable use Promote plantations Export ?? Role in tradition, cultural value (Basilan & bogolan textiles of Sahel (esp. Mali))
Arnebia hispidissima		Commercial food colorant & cosmetic	Medicinal properties Domestication Chemistry	Prospects as food colorant (effects on nutrient avail-ability; toxicity) & cosmetic		Sustainable use - cultivation
Baphia nitida	Multipurpose Use of by-product (sawdust)	Dye extraction in Africa (added value) Local cosmetics	Medicinal properties Domestication	Ethnobotany Extraction of colorants		Local extraction of dye (before use as fuel) Use for reforestation
Barringtonia racemosa	Sustainable harvesting of bark		Medicinal, iInsecticidal & nutritional properties		Germplasm collection	Legislation for sustainable use Habitat conservation
Bertiera spicata			Dye properties	Dye prospects		
Bixa orellana	Commercial production ? Colorant dairy products Hedgerow systems Ornamental Harvest & post-harvest techniques for improved quality	Selection and breeding for yield and bixin/ norbixin content Trade of extracts rather then seeds Increased competition (in Kenya a single factory)	Medicinal properties, pharmacology Pests and diseases In vitro transformation of lycopene into bixin Vegetative propagation	Production and market statistics Post-harvest handling		Export trade Quality certification

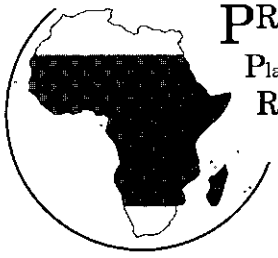
Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Bruguiera gymnorhiza	Sustainable (commercial) use (leaves and small branches)		Sustainable use Management Natural regeneration/ artificial propagation Growth & development Ecology of mangroves	Production and market statistics for individual mangrove species		Legislation for sustainable use Habitat conservation Reforestation
Buchnera hispida			Medicinal properties	Phytochemistry		Control (parasitic weed)
Caesalpinia coriaria	Promote use (dry areas; for dye & ink & tannin) Renewable resource (fruits)		Pharmacology Propagation & management for commercial use		Germplasm collection	
Caesalpinia sappan	Multipurpose (timber, fuel, tannin, dye, live fence, ornamental)		Medicinal use, pharmacology Propagation & management for commercial use	Dye potential (market & trade statistics)		
Ceriops tagal	Sustainable use Multipurpose harvesting		Sustainable use Management (regeneration) Medicinal properties	Production and market statistics for individual mangrove species	Habitat conservation	Management policy & pollution reduction Mangrove protection
Cochlospermum tinctorium	Commercial production Ornamental		Medicinal value (esp. malaria & yellow fever) Propagation			
Combretum glutinosum	Cultivation/ domestication Optimal harvesting & extraction techniques		Medicinal properties, pharmacology Case study Ghana (dye export) Establishment of plantations	Tannin production related to ecology	Germplasm collection	Avoid over-exploitation Role in tradition, cultural value (Bogolan textiles in Mali)
Cosmos sulphureus	Ornamental					
Craterispermum laurinum	Life fence (fire resistant)		Medicinal properties	Phytochemistry		
Craterispermum schweinfurthii	Life fence (fire resistant) Bee forage, dental care		Medicinal properties	Phytochemistry		
Cremaspora triflora			Medicinal properties Ornamental	Phytochemistry (dye)		
Crocus sativus		Commercial production in dry highlands				
Cryptolepis sanguinolenta			Medicinal properties, pharmacology			
Curcuma longa	Management (mixed cropping) Local market: expansion Cultivation guide Introduce where not yet grown	Breeding & selection Appropriate cultivars	Agronomy Medicinal properties IPM (Integrated Pest Management)	Breeding methodology		Import substitution (any import into Africa ?) Quality certification

Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Danais ligustrifolia	Promotion (on-going) in Madagascar for commercial & local use		Chemistry Domestication	Ethnobotany Taxonomy genus		Role in tradition, cultural value (Raffia ikats & lamba mena textiles in Madagas-car) Habitat protection
Diospyros Loureiriana	Use in basket weaving craft		Medicinal properties Use as histological colorant	Ethnobotany Taxonomy genus		
Elephantorrhiza elephantina			Potential as dye, tannin and medicine Domestication		Germplasm collection	Harvest control
Euclea divinorum	Management & replanting Renewable resource (powerful coppicing)	Alternative to *Acacia mearnsii*	Domestication Tannin properties Use for rehabilitation of degraded land, dye & tannin	Market		Harvest control Invasive in pastures
Ficus glumosa	Multipurpose (vegetable, fruit, firewood, live fence, medicinal) Domesticate		Medicinal properties Dye & tannin properties Husbandry			Role in tradition, cultural value (Bogolan textiles in Mali) Harvest control
Flemingia grahamiana	Promote use and cultivation Renewable resource (dye from fruits)	Waras' cosmetics Selection	Medicinal properties Value as cover crop	Market survey		Quality certification
Griffonia physocarpa			Properties (dye & medicinal)			
Haematoxylum campechianum		Breeding & selection	Agroforestry Commercial cultivation			
Impatiens tinctoria	Ornamental	Cosmetic in Ethiopia	Pharmacology Pests & diseases		Collection of germplasm	
Indigofera arrecta	Promote as multipurpose (fodder, covercrop, green manure, dye) Cultivation guide	Selection for yield and adaptation	Medicinal properties Husbandry (sowing & harvesting) Colour fastness	Comparison indigo sources Taxonomy		Role in tradition, cultural value (Raffia ikat Madagascar a.o.)
Indigofera coerulea		(Selection)	Husbandry (sowing & harvesting) Colour fastness	Comparison indigo sources Taxonomy		
Indigofera longiracemosa	Green manure	(Selection)	Husbandry (sowing & harvesting) Colour fastness	Comparison indigo sources Taxonomy		
Indigofera tinctoria	Commercial production Multipurpose Cultivation guide Introduction of Asian cultivars	Selection	Medicinal properties Husbandry (sowing & harvesting) Colour fastness	Dye yield (cultivars & ecology) Comparison indigo sources Taxonomy		Role in tradition, cultural value (Raffia ikat Madagascar a.o.)
Labourdonnaisia madagascariensis		Selection & breeding ??	Dye extraction method	Distribution, numbers, taxonomy of genus	Conservation in- & ex-situ	Protection measures (endemic Madagascar)

Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Laguncularia racemosa	Planting for fuel		Management Pharmacology	Characterization of dye & tannin	Habitat conservation	Mangrove policies
Lannea barteri			Husbandry Properties (medicinal, dye, tannin)	Characterization of dye & tannin Comparison *Lannea* sources		Role in tradition, cultural value (Adinkra clothes in Ghana)
Lannea microcarpa	Multipurpose (fruit, medicinal, dye, vegetable) Popularize extraction techniques from Burkina	Adapt existing technology to larger scale food & textile industry	Husbandry (sustainable use) Properties (medicinal, dye, tannin, pharmacology) Use of fruit as food colorant Pests & diseases	Characterization of dye & tannin Comparison *Lannea* sources Appropriate technology		Monitor (over-) exploitation Basilan & bogolan textiles of Sahel (esp. Mali) Role in tradition, cultural value
Lannea velutina			Husbandry Properties (medicinal, dye, tannin)	Characterization of dye & tannin Comparison *Lannea* sources		Role in tradition, cultural value (Basilan & bogolan textiles of Sahel (esp. Mali))
Lawsonia inermis	Cultivation guide Quality Introduce: commercial crop	Breeding for yield, quality and adaptation	Medicinal properties & chemistry	Market potential Production statistics	Germplasm collection (India)	Promote commercial production Role in tradition, cultural value Quality certification
Ludwigia leptocarpa			Properties (dye, tannin, medicinal)			Potential weed
Morinda lucida	Multipurpose		Cultivation Properties (dye, medicinal)			Role in tradition, cultural value (Kobene clothes in Ghana)
Mucuna flagellipes			Application in cosmetics Properties (dye, medicinal)			
Mucuna poggei			Properties (dye, tannin, medicinal)			
Mucuna sloanei			Properties (dye, food, medicinal) Application in cosmetics	Commercial interest as vegetable		
Pauridiantha rubens			Husbandry Phytochemistry	Document cultivation, ethnobotany Characterization of dye		
Philenoptera cyanescens		Breeding for yield, quality and adaptation	Cultivation Properties (indigo precursors, medicinal)	Market & production statistics		Monitor (over-) exploitation Role in tradition, cultural value (Adire cloth in Nigeria; Gara cloth in Sierra Leone)
Philenoptera laxiflora	Ornamental		Cultivation Properties (indigo precursors, medicinal)	Market & production statistics		Role in tradition, cultural value (Bara siti cloth in Gambia)
Phyllanthus bojerianus			Properties (dye) Husbandry			Role in tradition, cultural value (Madagascar textiles)

Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Phyllanthus emblica	Fruit cultivars from India Renewable resource (coppicing, fruits) Revive (Madagascar)	Breeding (medicinal-dye or edible fruits) Phytotherapeuticals	Propagation Husbandry	Market		
Psilanthus ebractiolatus		Genitor for coffee	Medicinal properties			
Psychotria psychotrioides			Properties (dye, medicinal)			
Pterocarpus angolensis	Promote planting (multipurpose, sustainable) Use of bark (by-product of timber)	Methods of sustainable harvest of timber	Use of by-products of timber Cultivation (commercial) 'Mukwa' dieback Dye composition Medicinal properties	Propagation Extraction techniques	Conserve in-situ	Sustainable use (regulation) Enforce replanting
Pterocarpus soyauxii	Use as agroforestry species (multipurpose)		Use of by-products of timber Cultivation (commercial)	Extraction techniques	Conserve in-situ	Sustainable use Enforce replanting
Pterolobium stellatum	Living fence, ornamental, dye For control of *Opuntia*		Properties (medicinal, tannin) Commercial exploitation			
Pyranthus tullearensis					Germplasm collection	Protection measures
Rhus tomentosa	Ornamental					
Rothmannia longiflora	Multipurpose		Dye, medicinal, ornamental properties of all *R.* species			
Rothmannia whitfieldii	Multipurpose		Dye, medicinal, ornamental properties of all *R.* species		Germplasm collection	Protection
Rubia cordifolia		Selection & breeding for dye content	Pharmacology Medicinal properties Commercial cultivation	Variabilty (taxonomy) Market study		
Senna auriculata	Multipurpose: promote Renewable resource (flowers, leaves) Post-harvest techniques		Potential for cultivation on large scale Supplement for *Acacia* tannins	Ethnobotany		
Sorghum bicolor	Cultivars and extraction technology from elsewhere Commercial production Collection (chain)	Breeding (resistance, yield, protein, ..)	Pests, diseases Role of *Bipolaris maydis* in apigeninidin production Extraction, processing technology	Use of dye as functional food colorant Dye characteristics by cultivar	Germplasm collection & characterisation of dye-cultivars Market survey (local & international)	Stimulate production & export (handcraft, fabric & food colorant) Role in tradition, cultural value (Abata/ Ifala cloth in Nigeria)
Striga gesnerioides			Control (weed)			Control (parasitic weed)
Syzygium rowlandii	Bee forage		Properties (wood & bark)			

Species name	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Tagetes erecta	Husbandry techniques (Zambian & South African experience) Processing Cottage industry	Breeding & selection for lutein content	Husbandry, adaptability, production & marketing	Quantity & quality of dye		International approval for use as food colorant Quality certification
Terminalia chebula	Introduce & promote (multipurpose, commercial cultivation) Renewable resource (fruits)		Medicinal properties			
Terminalia scutifera					Vulnerable for genetic erosion (habitat, small distribution area)	Mangrove protection
Xylocarpus granatum	Domestication Sustainable use By-product of timber		Husbandry			Habitat protection Control cutting Mangrove policies



PROTA
Plant Resources of Tropical Africa
Ressources végétales de l'Afrique tropicale

PROTA in short

The Plant Resources of Tropical Africa (PROTA) programme was initiated in 2000 and developed into an international partnership of 11 institutions in 11 countries during the Preparatory Phase 2000–2003. Since 19 February 2003, PROTA operates as an international foundation domiciled in Wageningen, Netherlands.

PROTA is a major 'information brokerage and knowledge repatriation' programme. The objectives are to bring the 'world literature' on the useful plants of Tropical Africa, now accessible only to the resourceful happy few, into the (African) public domain, and contribute to greater awareness and sustained use of the plants, with due respect for traditional knowledge and intellectual property rights. PROTA will describe the estimated 7,000 useful plants during the Implementation Phase 2003-2015. The information carriers will be freely accessible Web databases (www.prota.org), a low-price Handbook and CD-Rom series featuring 16 Commodity groups, and Special Products per commodity group for rural development, education, research and policy actors (all in English and French).

PROTA 1: Cereals and pulses (2006)
PROTA 2: Vegetables (2004)
PROTA 3: Dyes and tannins (2005)
PROTA 4: Ornamentals
PROTA 5: Forages
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