ISSN 1020-3370

NON-WOOD FOREST PRODUCTS

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Natural colourants and dyestuffs

Food and Agriculture Organization of the United Nations

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Natural colourants and dyestuffs

A review of production, markets and development potential

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1995

Reprinted 2003

ISBN 92-5-103747-7

FOREWORD

Natural colourants and dyestuffs are an important group of non-wood forest products. They can be of plant or insect origin. These products have various end uses. Natural colourants are employed to impart colour to food products, and natural dyestuffs are used to impart colour to textiles and other non-food products.

The number of colourants and dyestuffs found in nature are enormous. While some of them are fairly well-known, many of them are not commercially important. To provide a comprehensive coverage of all the plants and animals providing colourants and dyestuffs is a very difficult task. This publication attempts to provide only a representative selection of plants and insects yielding colourants and dyestuffs. Its purpose is to give an indication of the wide-ranging sources of natural colourants and dyestuffs and to encourage further research and studies relating to this group of products.

The draft of this document was prepared by C.L. Green of UK-ODA Natural Resources Institute (NRI). Formatting of the text and proofreading was done by Elisa Rubini. The preparation and publication of this document was guided and supervised by C. Chandrasekharan, Chief of the Non-Wood Products and Energy Branch. I record my sincere thanks to them.

It is my fervent hope that this publication will help to enhance the interest of forest resource managers to pay due attention to the development of non-wood forest products.

Karl-Hermann Schmincke
Director
Forest Products Division

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GLOSSARY OF TERMS

*agroforestry system	a mixed cropping system — involving trees, other plants and often animals — which has been created within or on the verge of a natural forest or artificially as an agricultural innovation
colour, natural	a colouring material for foodstuffs, derived from a natural source, or, of synthetic origins but identical chemically to a naturally occurring compound
colour, nature identical	a synthetically produced chemical compound which is identical in all respects to the compound found as a colour component of a natural source
*colourant, natural	the dried part of a plant or animal (or an extract thereof) which is employed to impart a colour to foodstuffs
dye	a chemical compound of natural or synthetic origin which is soluble in the medium used to impart a colour to textiles and other non-food products
*dyestuff, natural	a dye obtained from a natural source (plant or animal)
E number	the code number assigned by the European Community to approved food additives of natural or synthetic origin
extract, natural	the product obtained by extraction of natural (vegetable) materials with water, vegetable oils or organic solvents
fastness/fast colour	the ability of a dye to withstand colour fading in the dyed material on repeated exposure to light or washing
lake	a chemical complex formed by the treatment of certain colourants and dyestuffs with metal salts
mordant	a metallic salt which combines both with the dye and the fibre being dyed and improves colour fastness
*non-wood forest product (NWFP)	a natural product, other than wood, derived from a tree or other plants or animals in a forest system
oleoresin, spice	the product obtained by extraction of a spice with an organic solvent and which contains the soluble non-volatile and volatile substances originally present in the raw material
*pigment, natural	the specific chemical compounds which are responsible for the visible colour in live plants
synthetic	a material produced by chemical synthesis

* denotes a definition used for the specific purpose of this review; in other texts, these terms may be defined differently.

INTRODUCTION

This review deals with natural products which find use as colourants for foodstuffs or as dyes for textiles and other non-food materials including cosmetics.

The terminology employed for these products is not uniform in commerce or in the published literature and for the purpose of this review the following **definitions** are used:

natural colourants	*natural products which are incorporated in foodstuffs to provide a specific colour in the final edible product;*
natural dyes/ dyestuffs	*natural products which are used to impart a desired colour to non-food materials (textiles, wood, leather, etc.) by a process known as "dyeing";*
natural pigments	*the specific chemical compounds which are responsible for the visible colour in live plant parts.*

(Other important terms used in the main text of this review are defined in the glossary.)

SCOPE AND PURPOSE OF THE REVIEW

The review focuses on natural colourants and dyestuffs which are obtained from trees, shrubs, other plant forms and insects present in forestry and agroforestry systems of the tropics and sub-tropics, i.e., non-wood forest products (NWFPs). In view of the enormous number of colourants and dyestuffs found in nature as NWFPs, an exhaustive coverage was not possible and the approach taken was to provide a representative selection of product types. Examples are given of those which enjoy a current major usage and of some others which were formerly important but have suffered from technological or socio-economic developments.

The main purpose of the review, therefore, is to provide information — through the selected examples — which will assist an appraisal of the future developmental opportunities or constraints for the product group. In order to furnish a wider perspective, the review also includes some examples of major natural colourants and dyestuffs which now are mainly produced in horticultural systems; both as an indicator of comparative market demand and production economics and since some are suitable for adaptation within agroforestry systems.

The review does not cover the subject of vegetable tannins because this group of natural products are employed primarily as preserving and softening agents for leather and natural fibres rather than as dyestuffs. Moreover, tannins are an extensive and complex subject area which deserve the attention of a separate review.

FORMAT OF THE REVIEW

The main sections of the review sequentially deal with:

(a) the major natural colourants and dyestuffs which enter international trade;

(b) other natural colourants and dyestuffs which have a significant producer country or regional demand but are minor items of international trade;

(c) some minor natural colourants and dyestuffs;

(d) dyes derived from lichens;

(e) colourants and dyestuffs obtained from insect parasites of forest trees; and

(f) selected, natural colourants and dyestuffs which are obtained mainly from horticultural systems or by harvesting of wild (non-forest) plants.

For each commodity, information is provided on: the botanical source; global production and trade in the primary and processed products of added-value (where reliable data are available); prospects for expansion of production, processing and trade; cultivation, processing and exporting requirements. In addition, a selected bibliography is given for each commodity.

Developmental prospects are considered in relation to the local and international markets since demand and competition are the deciding factors for the success of any new commercial venture. The ability to produce in itself is only one element in a developmental appraisal. Competition from synthetic alternatives in particular must be examined for the international market and it is frequently of considerable importance on local markets.

AN OVERVIEW OF THE GLOBAL MARKETPLACE: COMPETITION BETWEEN NATURAL AND SYNTHETIC PRODUCTS AND LEGISLATION ON FOOD COLOURANTS

Up to the latter part of the nineteenth century, the plant and animal kingdoms provided all the colouring materials for dyeing textiles, the preparation of cosmetics and paints, and for making foodstuffs more visually attractive. Cultivation of plants and rearing of animals or gathering the wild resource, together with processing and trading was of enormous socio-economic importance for many communities worldwide. This pattern commenced to change very rapidly following the discovery by chemists of means of synthesising dyestuffs. The initial impact was felt in the textiles sector and major natural dyes, such as indigo, lost most of their market by 1900. Progressively, a wider range of synthetic dyes was manufactured and these displaced many other natural materials in foods and cosmetics. The success achieved by synthetics resulted from a combination of factors: comparative cheapness, reliability of supply, consistency of quality and special quality attributes — greater colour fastness with textiles and superior stability in food media.

A few natural dyes have retained a significant position in the textile sector owing to their unique qualities but it must be accepted that the dominance of synthetic dyes is irreversible in the global textile industry.

The food sector, however, is now experiencing a trend back towards natural colourants. This change has not been driven by the food industry but by consumers in developed countries who are concerned over possible health risks associated with synthetic food additives. The new situation presents welcome opportunities in the natural resource sector but also it must be appreciated that there are constraints which relate to legislation on food ingredients.

A discussion of the finer details of legislation on food colourants is not attempted here but interested readers may refer to the specialist texts listed in the bibliography. However, the main points may be summarised as follows. The range of colours of natural origin permitted for use in foods is not extensive in the three major markets, the European Community (which is a different and distinct legal entity to the European Union), USA and Japan; moreover, the three lists are not identical (see Tables 1 to 3). A naturally-derived colour may be a traditional food ingredient which is generally regarded as safe in one of these markets but it can be regarded as new in another. Today, "new" food colours are required by the regulatory authorities to undergo the identical stringent toxicological testing as new synthetics and this is a very expensive process. Some case examples in the European Community are presented in the following main section of this review. Finally, it should be noted that developments in food colour legislation are a continuing process and it is wise for both researchers and exporters to periodically gather an up-date on changes since these can profoundly influence markets.

Table 1: Natural colours (and colours of natural origin) permitted in food and drinks in the USA by the Food and Drug Administration (FDA) and exempt from certification

Annatto extract
β-apo-8'-carotenal[a]
β-Carotene[a]
Beet powder
Canthaxanthin[a]
Caramel
Carrot oil
Cochineal/carmine
Cottonseed flour, toasted
Fruit juice
Grape colour extract
Grape skin extract
Paprika and paprika oleoresin
Riboflavin (NI)
Saffron
Turmeric and turmeric oleoresin

[a] Nature-identical forms only (i.e., synthetically produced material which is chemically identical in all respects to the naturally occurring compound).

Table 2: Natural colours/colours of natural origin listed as permitted for foods by the European Community

E100	Curcumin	
E101	Riboflavin	
E120	Cochineal/carminic acid/carmines	
E140	Chlorophyll	
E141	Copper complexes of chlorophyll and chlorophyllins	
E150	Caramel	
E153	Vegetable carbon	
E160	(a)	α-, β-, γ-carotene
	(b)	Annatto extracts, bixin, nor-bixin
	(c)	Paprika extract, capsanthin, capsorubin
	(d)	Lycopene
	(e)	β-apo-8'-carotenal (C30)
E161	(a)	Flavoxanthin
	(b)	Lutein
	(c)	Cryptoxanthin
	(d)	Rubixanthin
	(e)	Violaxanthin
	(f)	Rhodoxanthin
	(g)	Canthaxanthin
E162	Beetroot red, betanin	
E163	Anthocyanins	

Table 3: Recognised ingredient classification in the European Community for natural materials and extracts with a colouring power but not presently approved for the "E" list of natural colours

Product	Category
Santalin (red sandal) Spice extract blends	Spice extracts
Alfalfa Marigold Crocin Saffron Safflower Hibiscus	natural (vegetable) extracts

MAJOR COLOURANTS AND DYESTUFFS ENTERING INTERNATIONAL TRADE 1

ANNATTO SEED AND ITS EXTRACTS

SUMMARY OF BASIC INFORMATION

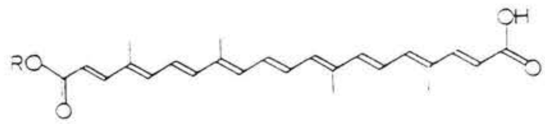
Usage:	(a) As ground seed for food colouring or as a condiment in many growing countries; and (b) mainly in the form of soluble extracts for food colouring in developed countries.
Common names for product and botanical source:	Annatto or bixa seed (English); urucum (Portuguese); achiote (Spanish).
Raw material source:	Seeds harvested from wild and cultivated trees.
Botanical source:	*Bixa orellana* L. (family: Bixaceae); a small tree, native to tropical Central and South America but now widely distributed throughout the tropics.
Form traded internationally:	Seeds and, increasingly, as the added-value extracts.
World production:	(estimated) 10,000 tonnes annually.
International trade:	(estimated) 7,000 tonnes annually in seed equivalents.
Major exporters:	Peru and Kenya.
Major importers:	USA, Western Europe and Japan.
Availability of reliable published information:	Fair to good.

DESCRIPTION AND COLOURANT USES

Annatto of commerce is the dried seed of *Bixa orellana* L., an evergreen shrub or small tree which is indigenous to Central and tropical South America. The tree has been introduced widely throughout the tropics as an ornamental or for commercial production of seed and it has become naturalised in many countries of Africa and Asia.

The seed is valued as a source of pigments which impart a red or orange hue, dependent upon the form of usage. In growing countries, the seed is employed directly as a condiment and as a food colourant, especially for cereals in Latin America, and prior to the introduction of fast, synthetic dyestuffs it was used also as a dye for textiles. Export-oriented production is aimed at developed country markets where annatto extracts are employed as natural colourants by the food industries and to a lesser extent in other products, such as cosmetics.

The pigments occur in the coat of the seed which displays a deep red colour. The principal pigment is bixin, the *cis*-form of the mono-methyl ether of a carotenoid carboxylic acid. The total pigment content of seeds (expressed as bixin) can vary widely, both between and within production areas; the best quality seeds on the market contain over 3% bixin but supplies from several major sources often have only about 2%.



R = CH_3 .... bixin
R = H .... nor-bixin

International trade has historically been conducted with seeds. However, the past decade has seen the successful development of exports in added-value extracts by the two major supply sources, Peru and Kenya.

FORMS OF USAGE IN DEVELOPED COUNTRY MARKETS

The predominant usage of annatto in developed country markets is in the form of extracts by the food industries. The traditional major colouring applications have been in hard cheeses, butter, other dairy products and in margarine. Fish products, salad dressings, confectionery, bakery products, ice-creams, beverages and snack-foods largely account for the remainder of demand.

Annatto (*Bixa orellana L.*)

The particular type of extract employed is dependent on the food product and the need for the pigment to be oil- or water-soluble.

Water-soluble extracts are employed in bi-phasic or water-based food products such as hard cheeses, bakery products, soups, sauces, pickles, smoked fish, sugar and flour confectionery. The extracts contain a mixture of the sodium or potassium salts of the *cis*- and *trans*-isomers of nor-bixin, transformation products of natural bixin which are created by the extraction procedure (described later). Imports are made of aqueous pastes and of the dried, powdered product; the latter may be spray-dried on to an inert carrier. Sales to end-users are made with spray-dried material on a carrier or, more commonly, as aqueous solutions (of which the weakest contain 0.1% of bixin).

Oil-soluble extracts are used in margarine, salad oils and other foodstuffs possessing a high fat content. The oil soluble products may contain bixin or nor-bixin or a combination of both, in the free-acid form. They are sold in the dried state or as ready-to-use solutions or suspensions in edible vegetable oils. Solid products may contain up to 99% bixin while vegetable oil solutions may be as low as 0.1% (described later).

Bixa orellana tree. (Photo: G. Blaak)

Bixa orellana in flower. (Photo: G. Blaak)

Bixa orellana with fruits. (Photo: G. Blaak)

Close-up of *Bixa orellana* fruits with exposed seeds. (Photo: NRI)

Dosage levels of bixin/nor-bixin in food products usually range between 0.01 to 0.5%. The main competitor for annatto extracts in certain food applications is synthetic beta-carotene.

WORLD DEMAND AND SUPPLY TRENDS

International Trade

Accurate computation of the **scale of world trade** is made difficult by the fact that trade is conducted both in seeds and in extracts; the latter being in various forms and possessing differing pigment concentrations. A conservative estimate for total world trade is 7,000 tonnes, calculated in seed equivalents. (Other researchers put the figure as high as 9,000 tonnes.)

Table 4: Major importers of annatto seed and its extracts

	Annual imports of seed plus extracts, expressed as seed equivalents (tonnes)	Annual imports of extracts, expressed as percentage of total seed equivalent usage
USA and Canada	2,500	10%
Western Europe	2,500	25%
Japan	1,500	80%

Source: Natural Resources Institute (NRI) estimates (based on published trade statistics and interviews with traders).

The acceptance and growth in imports of extracts produced at source into these three major markets is recent, dating from the early 1980s; previously all imports were of seed. The most important extract traded in terms of volume is the water-soluble (nor-bixin) type, followed by vegetable oil extracts and with solvent-extracted bixin in the last place.

Demand for annatto as a colourant by the food industries in developed countries displayed growth during the 1980s in response to either the banning of certain synthetic pigments or from consumer preference for natural products. Non-traditional uses of annatto have developed recently in many countries; for example, in bakery products.

The **Japanese market** in particular has grown considerably in recent years since all synthetic or "nature-identical" colourings are banned in food products. Japan mainly sources annatto seed and extracts from Kenya where it has a strong involvement in the industry.

The **USA** is the largest single market for annatto. It sources over 60% of its requirements from Peru and the bulk of the remainder from the Caribbean region. Penetration of this market by extracts produced at source have been small when compared to those of Western Europe and Japan.

In **Western Europe**, the UK and the Netherlands are the largest importers of annatto seed and extracts, mainly sourced from Peru, and they jointly took the equivalent of 700 tonnes of seed in 1990. Most of the Dutch imports are re-exported to other countries in the European Community. The major consumers in Western Europe are the UK and France and they account for approximately 40% and 30%, respectively, of the total European Community demand. In both countries, annatto is predominantly used in the water-soluble (nor-bixin) form as a colouring for hard cheeses. Usage in margarine is another important outlet in the UK.

Imports by the rest of the world are estimated as up to 1,000 tonnes in seed equivalents, of which Eastern Europe accounted for over half prior to 1990. Within Latin America, there is a substantial volume of regional trade where annatto is employed in various food applications, including use as a condiment.

The **market trend** in developed countries has been for a progressive increase in imports of extracts and for more stringent quality requirements (bixin content) for imported seed. Modest rather than dramatic growth in consumption may be expected in Japan and North America. In Western Europe, however, the future is dependent upon whether or not the European Community's regulatory authorities demand that very costly toxicological testing be undertaken on bixin and nor-bixin.

Production and Exports

Annatto has been traditionally grown in many Latin American and Caribbean countries, and over the past century it has achieved significance as a crop in a large number of African and Asian countries. However, there are only three **major producers**: Peru and Kenya, which are the major world exporters; and Brazil which is a net importer. **Small volume producers and exporters** include the Dominican Republic, Colombia, Ecuador, Jamaica, Costa Rica and Guatemala in the Western Hemisphere; Côte d'Ivoire and Angola in Africa; and India, Sri Lanka, Thailand and the Philippines in Asia.

Table 5: Approximate volumes of recent annual world exports

	tonnes, in seed equivalents
Peru	4,000
Kenya	1,500
All others	1,500

Source: Natural Resources Institute (NRI) estimates.

In **Peru**, production of annatto is export-oriented and is very heavily dependent upon the harvesting of wild trees. Annual crop levels vary considerably, partly because the annatto harvest overlaps with that of coffee and also from price responsiveness. Extraction prior to export commenced on a small scale around 1980 and had developed by the early 1990s to take in over half the annual crop. Several multinational companies, based in the USA and Western Europe — Peru's traditional major markets — have established processing factories in Lima and the production and marketing are closely integrated.

Annatto is a low input, cultivated crop in some of the coastal districts of **Kenya**. All seed is purchased by a parastatal and the bulk is then resold to the sole extractor firm which exports to Japan under long-term contract arrangements. Owing to low farm-gate prices in recent years, seed production has fallen below the processing requirement.

By contrast, the large production of **Brazil** is to meet the local market demand which consumes several thousand tonnes annually. Supplies are mainly dependent upon small farmers; many large farmers were encouraged to enter into production in the mid- to late 1980s on the expectation of a major growth in world demand but withdrew upon failing to reach price expectations.

Qualities and Prices

There are no published standard specifications for annatto seed or its extract, other than the cleanliness requirements of the American Spice Trade Association (ASTA). Quality, therefore, is defined by the purchaser against in-house standards.

For seed, the content of moisture (maximum acceptable, 10%) and of extraneous matter is a quality consideration. However, the most important quality criterion is the content of bixin and the price fetched is broadly related to this pigment figure. A typical figure for "total bixinoids", expressed as bixin, is 2% on an "as received" basis — anything greater than this is regarded as better than average and anything less as being inferior quality. Values of 2.5 to 3.5% probably represent the upper range of bixin content in traded seed. Where purchases of seed are made on a spot basis there is usually no adjustment in price made to take account of differences between sample and consignment values for bixin content. If a producer can show the ability to offer consistently good seed in terms of bixin content, then this will undoubtedly work in his favour in negotiating a price.

While some intrinsic differences in bixin content according to the origin of the seed are likely, there is an absence of documented data and it is not possible to rank producing countries in terms of the quality of their seed. Trade opinion is contradictory with regard to Peruvian *vs* Kenyan seed quality. However, the view seems to be shared that Indian seed is of relatively poor quality.

Table 6: Prices of Peruvian annatto seed, together with the export volumes, 1984-90

	1984	1985	1986	1987	1988	1989	1990
Quantity (tonnes)	1,500	1,300	1,200	650	1,450	1,650	1,500
Unit value (US$/tonne, FOB)	750	800	1,900	2,300	1,300	900	600

Source: Peruvian Government export statistics.

Shortages of Peruvian seed in 1985 and 1986, brought about by a combination of poor harvests and increasing local demand by extract manufacturers, led to sharply increased prices of seed in 1986 and 1987. World prices declined subsequently as supplies of seed improved. There has been an upward movement in seed prices in the more recent period, partly as a result of the poor Kenyan crop. A landed UK price of US$ 800-1,000 per tonne of seed was quoted by one trade source in mid-1992 for a bixin content of 3% (i.e., top quality).

Annatto extracts entering trade consist of crude extracts in the form of water-soluble powders or pastes (of nor-bixin, containing 20-40% pigments), oil solutions, or bixin concentrates or more highly purified forms of bixin. Bixin crystals — essentially pure bixin — are available from Peru. Reliable price data for extracts are not readily available but as a guide to relative values, in 1988, when seed fetched *ca* US$ 1,500/tonne, bixin powder was valued at *ca* US$ 1,000/tonne/1% bixin, i.e., US$ 30,000/tonne for a 30% extract. Bixin crystals were valued at US$ 107,000/tonne.

Marketing Structures and Procedures

Annatto seed is mainly purchased direct from source by the major processors in the consumer centres. Very little trade is conducted through intermediate brokers or dealers. Shipments are made in containers packed entirely with the seed; a 6-m container will take about 18 tonnes. Since the pigment content of the seed deteriorates on multiple handling and from prolonged storage, shipments normally are made immediately after the harvest season ends.

Export of annatto extracts is mainly made directly to the major users but there is some trade with smaller companies which make up formulations for further onward sale. In Peru, several multinational companies have bought local processing operations and their exports are shipped to their food factories.

Prospects for New Suppliers

While there is some uncertainty over trends in usage levels of annatto in the European Community, world demand is expected to remain substantial. This, combined with recent supply problems in Kenya, suggests that prospects exist in the medium term for sales of modest quantities of seed by new sources, provided that its quality is consistent and sufficiently high (preferably a minimum of 2.4% bixin content).

In the longer term, the scale of imports by the major consumer countries of annatto seed is expected to decline further in favour of extracts. Seed producers without domestic extraction industries might then be faced with the decision of investment in processing facilities or of export to other growing countries which have established factories and a seed supply problem.

Consumption might increase in the longer term within some of the more populous developing countries which are expanding their processed food industries. If this materialises, it would provide an alternative to the developed country markets.

CULTIVATION, HARVESTING AND PRIMARY PROCESSING

Climate and Soil Requirements

Bixa orellana can adapt to a wide range of conditions in the tropics and in the frost-free sub-tropics. It thrives best at temperatures between 20-26°C in areas with an annual rainfall of 1,250-2,000 mm, preferably well distributed but with a dry season for seed ripening. Nutritional requirements are not high and the tree can be grown on a variety of soil types, provided that drainage is good.

Production Systems

In Peru, the bulk of the crop is obtained from harvesting wild trees, while Kenya, the other major export-oriented producer, has an extensive system of informal cultivation. Elsewhere, both mixed cropping (with other cash crops and food staples) and intensive, mono-crop plantation systems are practised. The latter involves spacings of 3 m x 3 m or 4 m x 4 m, the choice being dependent on soil conditions and the intrinsic growth characteristics of the planting stock. Intercropping can be carried out on plantations in the first year and this assists suppression of weeds.

Annatto fits well into an agroforestry system, provided that it is not shaded by other large trees; an open sunny position is necessary for good performance.

Propagation

Cuttings may be employed for propagation and this approach is preferable for initial multiplication if elite material, possessing a good combination of high seed yields and seed pigment contents, is available. Propagation is more commonly undertaken with seed, either sown directly in the field or raised in a nursery, but this can result in high variability between plants.

Husbandry

Artificial fertiliser application is not necessary on soils of medium fertility and, other than weed control in the first year, husbandry requirements are not demanding. The most important operation is pruning in order to produce a canopy which is easy to harvest (some varieties can grow untended to over 5 m in height) and to prevent disease entering broken branches. Shaping is practised at the end of the first year and pruning of branch ends is done after every harvest.

Harvesting

Under favourable conditions, the first harvest is obtained 18 months after field planting. Seed capsules appear 30 days after flowering and ripen over a further 1-2 months; their colour varies from green to deep red. Seed capsule production and harvesting patterns vary according to local climatic conditions. Hot, dry conditions compress the season, while in Kenya harvesting occurs over 7 months with two peak bearing periods.

Seed capsules should be harvested when they commence to split open but before there is a risk of rain or sunlight damage to the seeds and loss by natural dispersal. The cluster of ripe capsules at the end of a branch is removed with a knife or secateurs by cutting above the first node.

Seed Yields

Seed yields reach their peak when the trees are 4 to 5 years of age and a decline usually does not become evident until around 12 years. Productivity can continue for up to 20 years.

Considerable variability is encountered in seed yields and this is influenced by spacing, growing conditions, management practices and the variety (which also has a marked effect on the pigment content). Yields of dried seed are reported to range from 500 kg to

2,500 kg/ha/year for established plantations with 900 to 1,500 kg/ha/year being the most common. For individual trees, the dried seed yield may vary between 0.5 to 4 kg per year.

Post-Harvest Treatment of Seeds on Farm

Seed capsules must be dried as quickly as possible to prevent mould formation and seed germination. This should aim at giving a seed moisture content of 7 to 10%; overdrying results in a loss of the pigment. Over-mature, mouldy and insect-damaged capsules are removed prior to commencing the drying operation.

Traditional sun-drying of the capsules takes 3 to 10 days. Mats or concrete barbecues should be used, with frequent turning and protection from dew at night. Artificial driers, either solar or solid fuel types, have been introduced in some producing areas to speed the process and to reduce spoilage at peak harvest or during wet periods. Temperatures of 55-60°C are recommended for artificial drying and over-drying should be avoided.

The traditional method of obtaining the seed is to beat the dried capsule with a stick on the ground or in a bag. Each capsule may contain, according to the variety, between 10 to 50 seeds which are distributed between two valves. Extraneous matter is therefore removed by sieving and winnowing but care must be taken to avoid abrasion and loss of the valuable pigmented seed coat.

Various designs of machines have been developed to achieve capsule breaking, sieving and winnowing in large-scale operations.

Immediately on completion of the cleaning step, seeds must be bagged to prevent inadvertent contamination and pigment degradation by exposure to light. Sale of the crop should be made as soon as possible since the pigments deteriorate on storage.

Exporter Handling of Seeds

Exporter operations with seed involve redrying, when necessary, and mechanical cleaning (sieving and aspiration) and bagging. At all stages care must be taken to avoid abrasion damage to the seed and the period between purchase and shipment is kept as short as possible to prevent deterioration in the pigment content.

Clean double jute or hessian bags (50-70 kg capacity) are employed for export, and ocean shipment is carried out in containers which are preferably ventilated types.

ADDED-VALUE PROCESSING TO EXTRACTS

Water-Soluble Products

The most commonly employed process for the production of water-soluble products involves direct extraction of the seed with aqueous alkali (usually sodium or potassium hydroxide) as the first step. Typically, seed is soaked or stirred in dilute aqueous alkali in a stainless steel vessel for about 10 minutes at a temperature not greater than 70°C. This operation transforms the natural bixin in the seed coat to a simple water-soluble derivative, the salt of nor-bixin. The extract is run off from the vessel and the extraction process may be repeated on the seeds to ensure maximum pigment recovery. The alkaline extract(s) is filtered and then acidified with dilute mineral acid (usually sulphuric or hydrochloric acids) to precipitate free nor-bixin. The precipitate is partially de-watered in a filter press to obtain a weak paste. This may be concentrated by evaporation of water for sale as a paste or be subjected to full dehydration, followed by milling to obtain a dried, powdered product. The latter is expected to possess a pigment content of 30% or more.

The alternative process for water-soluble annatto production is the treatment with alkali of bixin obtained by extraction of seeds with vegetable oil or organic solvents (described below). The resulting aqueous solution of nor-bixin salt may be sold directly or be processed further to obtain free nor-bixin.

Oil-Soluble Products

A very crude product, in the form of a water suspension, may be prepared by first steeping seeds in hot water and then filtering and concentrating the extract to a paste.

However, oil-soluble annatto is normally produced by direct extraction of the seed with food-grade vegetable oils. The extraction is carried out below 70°C and is aided by mechanical abrasion ("raspelling"). This initial extract is subjected to blending to give the requisite standardised product which is a suspension of *cis*- and *trans*-bixin in vegetable oil. If a colour more yellow than normal is required, the initial extract is either produced at a high temperature (over 100°C) or it is subsequently heat-treated.

Bixin crystals are produced by a process similar to that employed for spice oleoresins. The seeds may be extracted with an organic solvent — hexane, methylene chloride, acetone or alcohol — and, after concentration, crude crystals are obtained. There are a number of variants for the production of 99% pure bixin crystals; one uses methylene chloride as the initial extraction solvent and hexane and acetone are employed successively as washes to remove fats and resinous materials. Crude and pure crystals are sold directly or are employed to prepare vegetable oil suspensions or for conversion to the water-soluble nor-bixin salt.

Extraction by supercritical carbon dioxide has been reported in the literature but has not been adopted commercially as yet.

DEVELOPMENTAL POTENTIAL

Research

The agronomy and processing of annatto has been fairly well researched and published since the late 1970s, notably in Latin America and especially in Brazil. This reported work includes examination of variability in relation to physical form, yields and quality of seed, plus low-technology processing methods.

Further research needs are more country-specific and adaptive, relating to improvement of planting stock through selection and breeding, the economics of seed and extract production for the international market and, where appropriate, the potential for usage within domestic food industries.

Commercial Production

The earlier discussion on markets concluded that scope exists for the export of seeds in modest quantities by new sources and for the development of added-value processing industries by larger-scale producers. It must be stressed, however, that success with both activities will be dependent on production of good quality material. Selection of planting stock with a high intrinsic pigment content in the seed is of critical importance for competitiveness. Also, the adoption of handling methods which avoid post-harvest deterioration must be considered as an integral part of the operation.

OTHER USES

The bark of the tree has been employed in the past as a source of fibres for cordage and for the extraction of a water-soluble gum. Neither of these products appear to have any significant future developmental potential owing to the availability of superior alternatives.

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HENNA

SUMMARY OF BASIC INFORMATION

Usage:	Principally as aqueous extracts for hair and skin dyeing.
Raw material source:	Leaf of cultivated plants.
Botanical source:	*Lawsonia inermis* L. (syn. *L. spinosa* L.; *L. alba* Lamk) a shrub or small tree which is indigenous across a tract from Iran to Western India but now widely introduced throughout the tropics and sub-tropics.
Form traded internationally:	Dried, whole or powdered leaves.
World production:	Data unavailable but substantially greater than international trade.
World trade:	At least 9,000 tonnes annually.
Major exporters:	India, Pakistan, Iran, Sudan and Egypt.
Major importers:	Middle East and North Africa, Western Europe and North America.
Availability of reliable published information:	Poor.

DESCRIPTION AND DYESTUFF USES

Henna of commerce is the dried leaf of *Lawsonia inermis* L., a shrub or small tree which is indigenous to the area between Iran and northern India. The plant has been introduced widely throughout the tropics and sub-tropics as an ornamental (frequently as a fragrant hedge), for home use as a dyestuff and elsewhere as a commercial crop, notably in several North African countries.

Aqueous extraction of the dried leaf provides a dye which can range in colour from black, to red through to blonde (neutral). From ancient times, henna has been employed as a cosmetic dye for hair, skin and nails and it has acquired a particular significance in Islamic culture. More recently, there has been an increase in its usage as a hair dye in Western Europe and North America.

Prior to the widespread availability of synthetic dyestuffs, henna was employed also as a dye for textiles and leather.

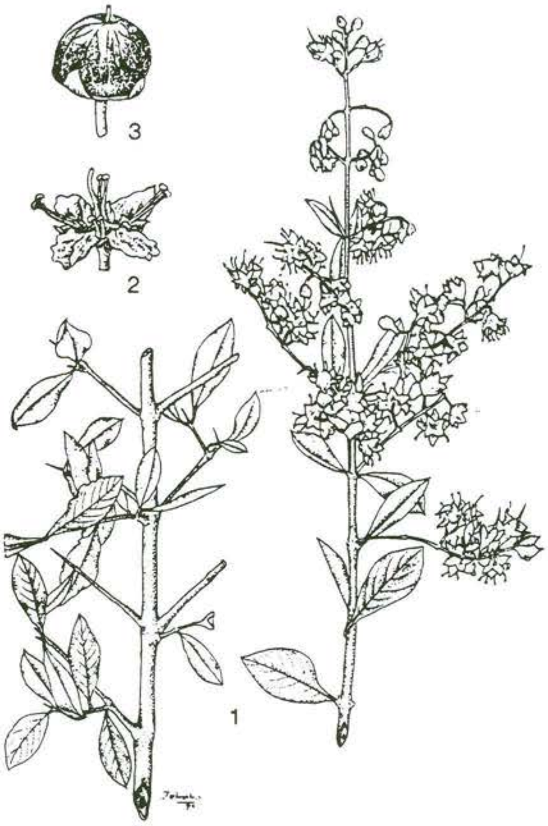
The major pigment in henna leaf is lawsone (2-hydroxy-1,4-napthaquinone). This fixes strongly to protein and, consequently, it has fast-dyeing properties. Considerable variability can exist between lots of dried henna leaf in the pigment content (which normally ranges between 1 and 2%) and, more importantly in cosmetic applications, in the colour tone.

International trade is conducted in whole or powdered leaf.

WORLD DEMAND AND SUPPLY TRENDS

International Trade

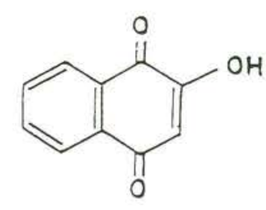
Henna is included within a general category for imports/exports in many countries and it is not possible to make a precise estimate of the **scale of world trade**. However, examination of both import and export statistics suggests an annual trade of at least 9,000 tonnes of dried leaf between the major exporters and the major markets.



Lawsonia inermis. 1) lower and upper part of flowering branch; 2) flower; 3) fruit. From: *Prosea*, No. 3 "Dye and tanning-producing plants".

The major importers are the Islamic countries of the Middle East and North Africa. Europe and North America are significant but much smaller markets.

Many countries in **the Middle East and North Africa** have a domestic production of henna but require supplementation by imports. The largest individual importer in this region is Saudi Arabia (approximately 3,000 tonnes), with Algeria, Syria and Turkey as other substantial outlets. Dubai acts as entrepot in the Gulf with annual imports of approximately 900 tonnes. The main suppliers to the Middle East market are India and Pakistan with Sudan, Iran and Egypt in the second rank. Some smaller producers have traditional links; for example, Yemen with Saudi Arabia and Niger with Algeria. Black henna for skin dyeing has the greatest demand in these markets but there is a substantial consumption also of red henna for hair dyeing. Retail sales are virtually all of whole or powdered leaf in these countries.



lawsone

In **Western Europe**, France is the biggest importer (250 tonnes) and it engages in re-exports. The United Kingdom and Germany import approximately 100 tonnes annually, while demand in other Western European countries appears to be at a smaller level.

Imports by the **USA** are less clearly quantified from import statistics but are of the order of several hundred tonnes annually.

Usage in Western Europe and North America lies predominantly in hair dyeing. End-users purchase both compounded formulations for immediate use and the powdered leaf for home formulation.

Eastern European imports were substantial during the 1970s and 1980s and at around 500 tonnes per annum.

Singapore acts as an entrepot, serving many markets worldwide.

The overall **international market trend** appears to be a plateauing of demand or at best a very modest long-term growth. In the major Middle East market, consumption is expected to remain substantial but with usage in some countries, notably Saudi Arabia, being mainly confined to the older generation and rural populations; the young and middle-class favour more modern cosmetics. In Western Europe and the USA, a growth in usage was experienced over the 1970s and 1980s along with a trend towards natural products, but this now appears to have stabilised and any future changes in demand are likely to be at the margin, following fashion trends with cosmetics. Eastern Europe may offer a potential for increased sales in the longer term, following economic recovery, but equally the greater availability of Western-type cosmetics may act as a counterbalance.

Any future major growth in global consumption is likely to occur in Asian countries with a strong Islamic culture and growing populations. This new demand could be met in several cases by increased domestic production.

Production and Exports

World production of henna is substantially greater than the volume of international trade, owing to the high level of domestic usage in many growing countries. No reliable figures are available on the scale of world production.

The **major exporters** are in approximate order of importance: India, Pakistan, Iran, Sudan and Egypt. Other smaller-scale exporters include Niger and Yemen. India's exports fluctuated between 4,500 and 7,600 tonnes annually over 1988-93, while Sudan's exports declined from just over 1,000 tonnes to 750 tonnes between 1990 and 1993.

Production in India and Pakistan is extensive rather than intensive and there is a high demand for henna on the domestic markets. The situation in Iran is similar. In several North African countries, intensive production systems are practised.

Although fluctuations in global supply levels have occurred on occasion, there has been no extended period of shortages to the international market.

Qualities and Prices

Apart from India, there are no published standard specifications for henna. Although a method exists for the quantitative assay of the major pigment (lawsone) content, this is rarely used even in developed country markets. In all markets, the colour tone (black, red or neutral) is of greater importance than the pigment strength. Colour quality assessments are made by buyers on a qualitative basis and this can involve a hair or a wool dyeing test against a set of in-house reference standards.

Consignments are offered on the basis of recognized trade categories or grades, and samples are evaluated by buyers for quality within the expectations for the type.

In developed country markets, additional quality tests may be made for the presence of adulterants, such as castor bean leaf, and for the microbial load, especially the presence of *Salmonella*.

Prices for henna reflect international supply levels and differentials between grades. In the Gulf market, black henna generally commands twice the price of red henna and during 1992 prices ranged from approximately US$ 700/tonne for top grades of Indian and Pakistani black henna to US$ 250/tonne for the lowest grades. During this period Iranian powdered henna fetched approximately US$ 300/tonne and the best Sudanese henna was regarded as too highly priced by comparison with Indian material. Over the period 1987-91, the unit value of henna imports to the Gulf fell by 20-30%.

The unit value of Sudanese exports fell in line with the overall market price movement from US$ 1,500/tonne to US$ 500/tonne between 1990 and 1993.

Marketing Structures and Procedures

In the Middle East market, most imports are made direct from source but Dubai and Singapore play a significant role as entrepots for some countries. Trading is undertaken by numerous, often small companies in the region. In recent years there has been a marked move towards import of pre-packaged material (100 to 500 g sachets in 25-50 kg cartons) for direct retail sale.

Western Europe predominantly imports leaf in packages of 50 kg. The minimum shipment size is 5 tonnes but 10 to 20 tonne lots in containers are more usual. Some of the larger users import direct but trade is more commonly conducted by a number of specialist dealers and broker firms.

Prospects for New Suppliers

While no rapid growth is expected in demand for henna, the market is sufficiently large for the entry on a modest scale of new suppliers. However, success will be dependent upon the ability to supply regularly a consistently good quality product at competitive prices. Additionally, attention would have to be devoted to gaining a sound understanding of the different requirements for quality and packaging in each of the major geographical markets and of their trading structures.

CULTIVATION, HARVESTING AND PRIMARY PROCESSING

The published literature on henna is scanty, with the majority of articles pre-dating 1950. However, it is unlikely that agricultural practices and productivity in most countries have changed radically from the summary given below since it is predominantly a small-holder crop which has not ranked high in the priority lists for agricultural programmes.

Climate and Soil Requirements

The henna plant has proven to be adaptable to a wide range of conditions in the tropics and the frost-free sub-tropics. It is tolerant of drought and sandy-stony soils but thrives best in fertile, water-retentive soils. Under ideal conditions for rain-fed cultivation, the rainfall should be well-distributed but with two dry periods a year in order to facilitate post-harvest leaf-drying.

Production Systems

Henna is normally planted in rows with individuals as close as 15 cm within a row, which takes on the appearance of a low hedge when mature. The distance between rows varies greatly according to the producing area, from a dense monoculture (up to 200,000 plants per ha) to a mixed system with annual food crops. (Although not normally considered within the context of agroforestry systems, henna fits the requirements provided that overshadowing by large trees is avoided.)

Input levels similarly vary enormously from one producing area to another from no irrigation to irrigation with heavy applications of fertilizer or farmyard manure (in order to replace the soil nutrient depletion arising from frequent leaf harvesting).

The economic lifetime of plants is between 4 to 6 years with intensive cultivation but many producers do not replace their crop for 12 years or more.

Propagation and Field Establishment

Seed and cuttings are employed for multiplication in nurseries. Presoaking in water or chitting assists germination of seeds which possess a tough outer coat. Prior to field establishment, the young plants are clipped back to around 20 cm in order to promote bushy growth. The planting site should be prepared by ploughing and ideally have compost or manure incorporated.

Husbandry

Weed control is necessary in the first year of field growths and following harvesting in subsequent years. When established as a monoculture with moderate row spacing, annual food crops may be grown in the first year and this assists weed control; legume crops are particularly useful.

Application of fertilizer or manure, if available, over the lifetime of the plot promotes vigorous growth/regeneration after harvesting. Similarly, irrigation is of benefit in low rainfall areas.

Harvesting

The first harvest is taken 12 months after field planting by cutting the plant about 10-15 cm above ground level. Subsequently, two harvests are taken a year under rainfed conditions (spring and autumn in the sub-tropics) and three harvests may be possible with irrigation.

Harvesting should be carried out in a rain-free period and, preferably, under low humidity conditions in order to aid rapid leaf drying and to avoid spoilage.

Leaf Yields

The yield of dried leaf is highly variable and is dependent upon a number of factors: the germplasm characteristics, the soil nutrition level, water availability and the age of the plantation. The first year's crop is low and maximum productivity is achieved in the second and third years. Performance thereafter is highly dependent upon soil nutrition. Under rainfed conditions, the yield from the first (spring) harvest is about 30% of the annual total for the two crops.

Published information on crop yields suggests that under rainfed conditions for dense planting the dried leaf yield in the first year may be around 200 kg/ha while over the second, third and fourth years the yields normally range between 1,000-1,500 kg/ha. With irrigation and heavy fertilizer treatment, plus three croppings a year, yields in excess of 2,000 kg/ha can be obtained in the peak productivity years.

Post-Harvest Operations on Farm

After cutting, the leaf is allowed to dry while still attached to the stem and this may be done by leaving the crop in the field. Retention of a desirable attractive green colour is assisted by drying in the shade but this can be impractical with very large crops and in the absence of suitable facilities.

Most of the dried leaf can be simply detached by beating the stem on the ground. This should be done on a clean surface to avoid soil contamination and the inclusion of extraneous matter. Sale in clean bags should be made as soon as possible after the harvest to avoid deterioration during storage.

Exporter Operations

Material entering the exporter's premises should be checked for moisture content and, if necessary, be redried in the sun to 10%. Lots should then be graded on the basis of visual appearance and testing for colour tone of aqueous extracts.

For export of leaf, packaging of the graded material should be made in jute or hessian sacks which hold 50 kg. Ocean shipment is now predominantly by means of container vessels and ventilated containers should be selected when available.

ADDED-VALUE PROCESSING

For general trade, added-value processing options are restricted to preparation of the powder by simple mechanical comminution and for certain Middle East and Asian markets the powder may be packaged in plastic bags (containing 100-500 g) for retail sale. Precise requirements for the size and labelling of retail packs must be determined from the buyer.

DEVELOPMENTAL POTENTIAL AND RESEARCH NEEDS

Considerable scope exists for improvement of henna productivity and product quality/value in the majority of growing countries. Germplasm selection for both biomass and pigment content enhancement would be a useful area for research.

Re-examination is merited also of field management systems, particularly for mixed cropping and of means of maintaining post-harvest quality; the latter should include the potential for the use of simple, inexpensive driers in humid climates. However, the most important immediate need is a thorough study of the future market demand, particularly in the Middle East and the more populous Asian countries, in order that national agricultural planning bodies can formulate an appropriate strategy on production.

Other Uses

The wood of the henna plant is employed as fuel and for carpentry products in some countries.

Leaf and bark have been used in traditional medicine in several countries for various ailments, including treatment of jaundice. The antifungal, antibacterial and nemacidal properties of extracts have received some scientific examination in recent years but their effectiveness and economic competitiveness have not yet been established.

The flowers possess a pleasant aroma and crude perfumes are produced in some major growing areas by preparing a suspension of comminuted flowers in vegetable oil. There is no recorded international trade in henna flower essential oil.

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LOGWOOD AND ITS EXTRACTS

SUMMARY OF BASIC INFORMATION

Synonyms: (a) Wood: campeachy wood (English); bois bleu (French).
(b) Extracts: haematoxylin; haematein.

Usage: (a) Principally as the haematin extract for dyeing textiles black and blue shades; and
(b) limited usage of the haematoxylin extract in histology.

Botanical source: *Haematoxylum campechianum* L. (family Leguminosae); a small tree indigenous to Central and tropical South America but now widely distributed in the tropics.

Raw material source: Harvesting of the trunkwood of wild and cultivated trees.

Form traded internationally: Mainly as powdered extracts, known as crystals.

World production and international trade: Estimated at 600 tonnes annually.

Major exporters: Jamaica, Haiti and Dominican Republic.

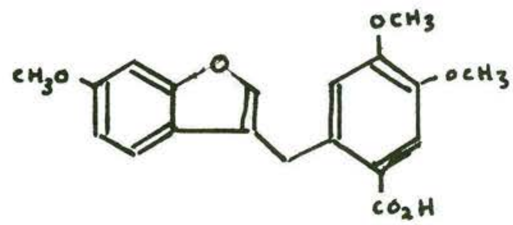
Major importers: Western Europe, USA and Japan.

Availability of reliable published information: Very limited and mostly outdated.

DESCRIPTION AND DYESTUFF USES

Logwood (*Haematoxylum campechianum* L.) is a small tree (up to 12 m tall) which is native to Central America and the northern tropical region of South America. Its dyestuff value was recognised at an early stage by the Conquistadors who then promoted cultivation on the major Caribbean islands. During the nineteenth century, logwood was introduced to South and Southeast Asia but this region did not develop as a significant commercial source.

The heartwood contains about 10% of a colourless compound, haematoxylin, which on oxidation transforms to a violet-blue substance, haematoxein (commercial synonym, haematein). Young trunkwood is white to pale yellow while older trees display pigmented streaks arising from the natural oxidation of haematoxylin. The pigment can be produced by deliberate oxidation in the commercial aqueous extraction process of young trunkwood.

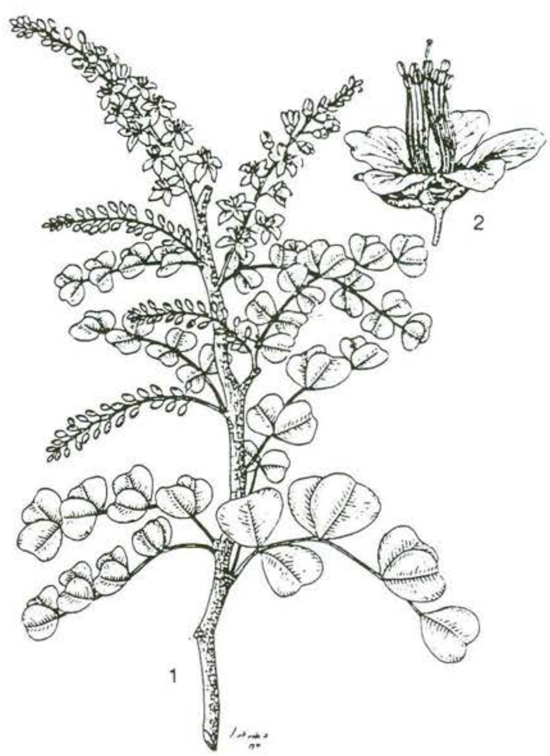


haematoxylin

Haematein has resisted total substitution by synthetic dyes owing to its special properties. It has a fair degree of fastness, good penetration and by selection of different mordants subtle colour tones ranging through grey, brown, blue to black can be produced. The black colour is especially important since few synthetic dyes can compare it in tone. Major applications lie in the dyeing of natural and synthetic fabrics and other uses include dyeing of leather, fur, feathers, paper, wood and incorporation in inks.

Haematoxylin is employed in comparatively small quantities as a histological staining agent by pathology laboratories. In this application, it has successfully resisted challenges from alternatives.

Only a minor international trade is conducted in trunkwood. The bulk of the wood is extracted immediately after tree felling and the product is powdered for export.



Haematoxylum campechianum L. 1) flowering branch; 2) flower. From *Prosea* No. 3 "Dye and tanning-producing plants".

WORLD DEMAND AND SUPPLY TRENDS

International Trade

As is the case with many similar products, the true **scale of current world trade** is difficult to quantify owing to the shortcomings in classification within import and export statistics. The best possible estimate is 600 tonnes of extracts per year (which corresponds very roughly to 2,500 tonnes of logwood feedstock).

The **major importers** are Western Europe, North America and Japan. France is the largest individual importer in Western Europe and engages in a substantial re-export trade with other countries in the European Community and further afield.

Periodic supply problems and, consequently, price rises have been encountered over the past twenty years and this has resulted in a **trend** towards increased substitution by synthetics in major dyeing applications. However, the special qualities of haematin and haematoxylin remain highly regarded and the threat of complete substitution by synthetics is not yet evident.

Production and Exports

Export of logwood played an important role in the economy and development of a number of countries in Central America and the Caribbean, and it was a significant element in the decision to colonize British Honduras (now Belize). The trade peaked in the late nineteenth century at around 100,000 tonnes of wood per annum, with Haiti accounting for 90% at some stages and British Honduras shipping between 4,000-13,000 tonnes.

During the twentieth century, demand progressively declined and also exports moved from logs to extracts.

The **major commercial sources** of logwood extracts in recent years have been the larger Caribbean islands (Jamaica, Haiti and the Dominican Republic).

Other producers include several Central American countries and Brazil.

Trees are cultivated in Jamaica and some of the other islands but elsewhere in the region the industry is heavily dependent upon wild trees.

Qualities

Dried extracts, often called crystals, are distinguished as haematoxylin or haematein; the latter is graded according to the degree of oxidation of haematoxylin to haematein, typically over the range of 15 to 100%. An 80% grade, for example, contains haematein:haematoxylin in the ratio of 80:20.

Marketing Structures and Procedures

Direct purchases from source are made by a large number of specialist firms, some of which are end-users. In Western Europe, France performs a major function as the principal importer and distributor to other countries.

Prospects for New Suppliers

Demand in the major developed country markets is not expected to grow but the periodic problems of supply shortages offer scope for market entry on a modest scale by new producers.

Any significant prospects for increased global usage probably lies with those countries in South America and Asia which are experiencing population growth and an emergent middle-class with sophisticated tastes in the quality and range of dyed manufactured products.

CULTIVATION, HARVESTING AND PROCESSING

Climate and Soil Requirements

The tree is adaptable in the lowland tropics to a range of soils. In Central America, it is frequently found on marshes which are prone to periodic flooding. In Jamaica, the tree thrives best in moist interior valleys and coves at the foot of hills and tolerates chalky soil.

Production Systems

The tree may be established on an intensive (plantation) or extensive basis. While not reported as being used in an agroforestry context, logwood would appear well suited for this purpose. Annuals or short-lived perennial shrubs probably could be cultivated as lower storey crops in the early years of a plantation.

Propagation

Cuttings and seed are both used for propagation.

Husbandry

Apart for weed control during the early phase of establishment, logwood requires minimal attention.

Harvesting

Trees are felled while relatively young since this ensures a high haematoxylin recovery. The age at which this size is attained is dependent upon the variety and the site's soil and climatic characteristics.

Extraction

Bark and sapwood are first removed from the trunkwood. The heartwood then is mechanically reduced to chips for extraction which is carried out in hot water, sometimes in an autoclave under pressure. When hot, the extract is orange-red in colour and this changes to yellow on cooling.

Dehydration of the extract under vacuum provides haematoxylin crystals. For the production of haematin, the extract is aerated or treated with an oxidising agent prior to dehydration.

Yields of Heartwood and Extracts

No reliable published data are available on heartwood or extract yields.

Developmental Potential and Research Needs

The scope for further development of the logwood industry is dependent on future supply and demand levels. The primary requirement, therefore, is for a thorough market study of both traditional (developed country) and prospective new (Asian and Latin American) areas.

If the findings of the market study were positive, research would be merited on the following topics:

(a) selection of elite germplasm for propagation since there are clearly significant provenance differences amongst the cultivated and wild stock in pigment content, growth performance and eco-climatic adaptation;

(b) utilisation of the species as a component of agroforestry systems; and

(c) the potential for improvement of yields and quality control in the processing operations.

Other Uses

The wood can be employed as building and carpentry timber but has some limitations in the latter application owing to its uneven and brittle characteristics. It is also an acceptable fuelwood.

Extracts have been employed in traditional medicine in the past as an astringent, anti-inflammatory agent and for gastrinal disorders.

The tree produces fragrant flowers and this has led to its use as an ornamental hedge and as a food source for honeybees.

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RED SANDALWOOD

Summary of Basic Information

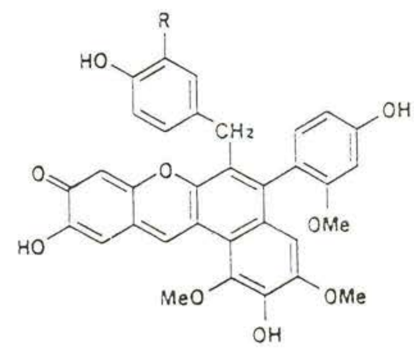
Usage:	As a spice and as an orange-red food colourant.
Product synonyms:	Santalin; sandalwood extract.
Raw material source:	Heartwood of a tree; mainly harvesting of wild resource.
Botanical source:	*Pterocarpus santalinus* L. (Papilionaceae sub-family; Leguminosae).
Common synonyms for botanical source:	Red sandalwood; red sanders; sanderswood; lalchandan, errachandan, rakta chandan.
Distribution:	Confined to a specific area of India.
Product traded internationally:	The powdered heartwood.
World production and trade:	Around 50 tonnes a year of heartwood.
Exporter:	India.
Major importers:	Western Europe, Japan and China (Taiwan province).
Availability of reliable published information:	Poor.

Description and Colourant Uses

"Red sandalwood" or "red sanders" (*Pterocarpus santalinus* L.) is a deciduous medium-sized tree (up to 11 m), which is indigenous to a restricted area of Andhra Pradesh and Madras States in India. It is a member of the "insoluble redwoods", i.e., red dyestuff sources which are not extractable by water (e.g., *Pterocarpus indica* of South and Southeast Asia and *Pterocarpus* species of Africa).

Red sandalwood and some of the other "insoluble redwoods" were employed in the past for dyeing wool, cotton and leather and for wood staining. Today, usage of red sandal appears restricted to foods where it imparts a sweet-spicy flavour and orange-red shades. For the food industries, the extract is normally sold in the alcohol-soluble form, either as liquids or powders but water-soluble forms (salts) are also available. Red sandal has been traditionally used with fish products in Europe and more recent applications include the colouring of seafood sauces, meat products, snackfoods, breadcrumbs and alcoholic drinks. Dosage levels range from 0.1 to 1% (weight for weight).

The principal red pigments in red sandal heartwood are santalin A and B, and these are soluble in organic solvents and alkalis but not in water. A yellow isoflavone pigment, santal is present also. The santalins together with other related pigments are found in some other *Pterocarpus* and *Baphia* species.



RH = OH ... santalin A
R = OMe ... santalin B

WORLD DEMAND AND SUPPLY TRENDS

Exports of red sandalwood from India to Europe commenced in the seventeenth century, primarily for textile dyeing but there was some demand also for the timber. Around 1880, exports averaged 3,000 tonnes per annum with the UK as the major importer. By 1900, exports and usage of red sandal as a textile dye had effectively ceased owing to the competition from synthetics.

In the 1930s, Japan commenced to import Indian red sandalwood for the manufacture of the traditional "shamishen" musical instrument and this market remains important today at a level of several hundred tonnes per annum. Demand by Japan for "wavey grain" quality timber resulted in significant illegal and destructive exploitation of the wild resource in the 1950s and 1960s and controls were imposed on trading.

In Europe, red sandalwood extract has a long history of use as a red colourant for fish processing, e.g., in pickled herrings. More recently, interest has been shown by the food industry to expand the range of applications. In the European Community, red sandalwood extract is presently classified as a "spice extract" and thorough toxicological testing may be demanded by the regulatory authorities before reclassification to food colourant status with an E number.

Exports of red sandal powder from India averaged 50 tonnes annually between 1988-1993. The major importers have been Japan, China (Taiwan province) and Western Europe.

SILVICULTURE AND COLOURANT PROCESSING

Climate and Soil Requirements

The natural habitat of *P. santalinus* in India is characterised by a hot, dry climate with around 100 mm of rain in each of the two annual monsoons. The trees are found in dry, hill areas, often on rocky ground, and at altitudes ranging from 150-900 m.

Propagation and Management

Natural regeneration occurs by seed. Artificial propagation can be achieved with seeds and cuttings. Saplings are field planted when one year old and at spacings of 3.5 to 4.5 m. Both waterlogged sites and overshading by other trees must be avoided.

The tree regenerates well from coppicing but growth is slow and a 40-year coppice rotation is practised in India.

Colourant Extraction

Only the heartwood is employed for extraction of the colourant. The process involves reduction of the wood to chips or powder and extraction with alcohol.

The extract may be simply concentrated or be stripped of solvent to give a solid product prior to sale. No reliable published information is available on commercial extraction yields.

For sale to end-users, specific formulations (as liquids, dispersed solids or water-soluble forms) are prepared at strengths appropriate for the food product.

OTHER USES

Red sandalwood has multipurpose uses. In India, it has played a traditional role in medicine as an astringent and for the treatment of gastric and skin disorders. During the nineteenth century when sustainable exploitation of the natural resource was not accorded a high priority, the wood was employed for railway sleepers and for boiler fuel.

Today, production of "wavey grain" timber for the export market is of some importance and there is usage on the domestic market for carving, furniture and charcoal. The leaves are employed as cattle fodder.

DEVELOPMENT AND RESEARCH NEEDS

In recent years, attention has been devoted in India to selection of elite germplasm for the production of "wavey grain" timber and to improved means of vegetative propagation. Relatively little systematic work has been reported on the utility of the species as a multipurpose tree or on food colourant aspects. With regard to the latter, the most pressing need is probably a thorough assessment of market demand trends and its relationship to raw material supply.

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COLOURANTS AND DYESTUFFS MAINLY OF LOCAL OR REGIONAL IMPORTANCE 2

CUTCH

SUMMARY OF BASIC INFORMATION

Usage:	(a) Cheap dyestuff for canvas, etc.; (b) as a tanning agent for leather, and as a viscosity modifier in oil well drilling.
Product synonyms:	Cutch black catechu) for unrefined khair) product
Product type and form traded:	Dried aqueous extract of tree heartwood.
Botanical source:	*Acacia catechu* Willd. (family: Leguminosae); both from wild and cultivated trees.
Synonyms for botanical source:	"Cutch" or "catechu" or "khair" tree in India; "sha" in Myanmar; "sa-che" or variants of "seesiat" in Thailand.
Distribution:	(a) Natural range is in an arc across southern Himalayas from Pakistan, through Nepal, India, Bangladesh, Myanmar to Thailand and, possibly, extending into Yunnan Province, China; (b) introduced to Indonesia.
World production:	Possibly between 6,000-9,000 tonnes per annum.
International trade:	Poorly quantified, possibly 1,500 tonnes per annum mainly in Asian region.
Major producers:	India (with smaller-scale production in Pakistan, Bangladesh, Myanmar and Thailand).
Major importer:	Pakistan.
Availability of reliable published information:	Fair.

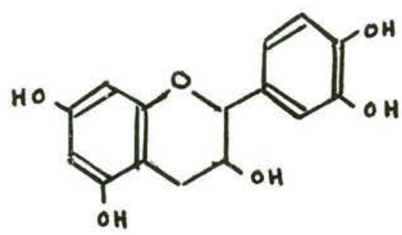
DESCRIPTION AND DYESTUFF USES

"Cutch" is the purified aqueous extract of the heartwood of the multipurpose tree, *Acacia catechu* Willd. This deciduous, thorny species grows up to 15 m high and is indigenous to the southern range of the Himalayas (extending in India as far south as Andhra Pradesh and Orissa), Myanmar and northern Thailand.

Processing involves three stages: production of a crude extract "black catechu"; isolation of "katha" and solidification of the residue, "cutch".

"Black catechu" has been traditionally employed in the producer countries for crude dyeing, leather tanning and in indigenous medicines.

The further processed "cutch" is employed as a cheap brown dye and preservative for canvas, fishing nets and similar items and also as a tanning agent for leather, particularly in India. In more recent times, cutch has found use as a viscosity modifier in oil well drilling. It is composed mainly of catechu-tannic acid with catechin, catechu red, quercetin and a gum as minor components.



catechin

"Katha" is a brown semi-crystalline substance which contains catechin and its isomers. It is used as an ingredient of "pan" and "pan marsala" chewing confectionery in India.

World Demand and Supply Trends

International Trade

"Black catechu" is included in several European pharmacopoeias but the current scale of usage, if any, is insignificant. There appear to be no imports of cutch into developed country markets for use as a dyestuff or as a tanning agent.

Trade in cutch appears restricted to the traditional usage areas of the Indian sub-continent and certain countries in Southeast Asia. Imports have been reported for Pakistan, Nepal, Bangladesh and Myanmar, which are not self-sufficient in domestic production, and by China. The scale of this trade cannot be precisely quantified but probably totals only slightly larger than India's exports, i.e., around 1,500 tonnes annually.

Acacia catechu. 1) flowering branch; 2) branchlet with fruits. From *Prosea* No. 3 "Dye and tanning-producing plants".

Production and Exports

The **major producer** of cutch and katha is India where production is based in the northern provinces on wild and cultivated trees and involves both cottage-scale and industrial-scale processing (with some factories having a throughput capacity of 1,000 tonnes of raw material per month). Up-to-date information is not available for India on output levels or on the breakdown in domestic usage of cutch between dyestuff, tanning and medicinal applications. However, factories have recently reported difficulties in operating at full capacity owing to raw material supply problems; the tree is valued as a fuelwood and for other purposes. During the mid-1970s, some 63,000 tonnes of wood were consumed annually by the katha/cutch industry and this is estimated crudely as providing around 5,000-6,000 tonnes of cutch. India recorded exports of 1,000-1,300 tonnes of cutch annually over 1988-1993 with Pakistan as the major destination.

Black catechu being sold by street vendor, Myanmar. (Photo: M. Kashio)

Minor producers of unrefined "black catechu" include Myanmar, Thailand, Bangladesh and Pakistan. Reliable data are available only for Thailand; current production is cottage-industry type, based on a limited natural resource with sales mainly to the domestic traditional medicine market but involving small exports to Pakistan, Nepal and Bangladesh.

The absence of reliable data makes it impossible to predict a **market trend** for cutch as a dyestuff or tanning agent. However, a continued substantial demand may be expected in the traditional regional market and this could possibly increase along with population growth, demand for manufactured goods and industrialization. The major perceived constraint lies with the availability of the wood raw material which is already under pressure from alternative uses, particularly as a fuelwood, in many countries.

Prices and Qualities

The following prices were reported in an FAO study for October 1992.

Table 7: Wood and cutch prices for India and Thailand, 1992

	India	Thailand
Wood	up to US$ 240/m^3	ca. US$ 13/m^3
Best quality katha	US$ 15/kg	-
Cutch	US$ 0.80/kg	-
Crude extract	-	US$ 0.80/kg

Source: Kashio, M. (1992).

Quality standards for cutch and katha have been published by the Indian Standards Institution.

Prospects for New Suppliers

Supply shortages for cutch could develop within the main traditional regional markets of Asia owing to the high demand for the raw material as fuelwood. This might offer the opportunity for entrance to the market by new sources, both for export on a modest scale and to supply any domestic demand. Prospective candidates include Nepal and Indonesia; the tree is indigenous in the former and it has been established as an exotic on plantations in the latter. However, the opportunities or constraints for new ventures require a thorough supply and demand study in the region, and this must also take into account trends in usage of alternative, inexpensive natural and synthetic dyestuffs and tannins.

SILVICULTURE, HARVESTING AND PROCESSING

Climate and Soil Requirements

A. catechu is found in moderate rainfall areas over its natural range from the Southern Himalayas down to northern Thailand. It has not proven suitable for the most dry or heavy rainfall areas in India. The altitude limit in the Himalayas is around 1,200 m. It is adaptable to a wide range of well-drained soils, even poor stony types which are unsuitable for many other trees.

Production Systems

In India, the tree is grown on large plantations and in smaller, communal lots (in which it is exploited for fuelwood and village-scale processing purposes).

Variability in Germplasm

Several varieties of *A. catechu* are recognised in India and they possess differing characteristics. The three main types are var. *catechu* in the Western Himalayas; var. *catechuoides* in the Eastern Himalayas; and var. *chundra* in the more southerly areas.

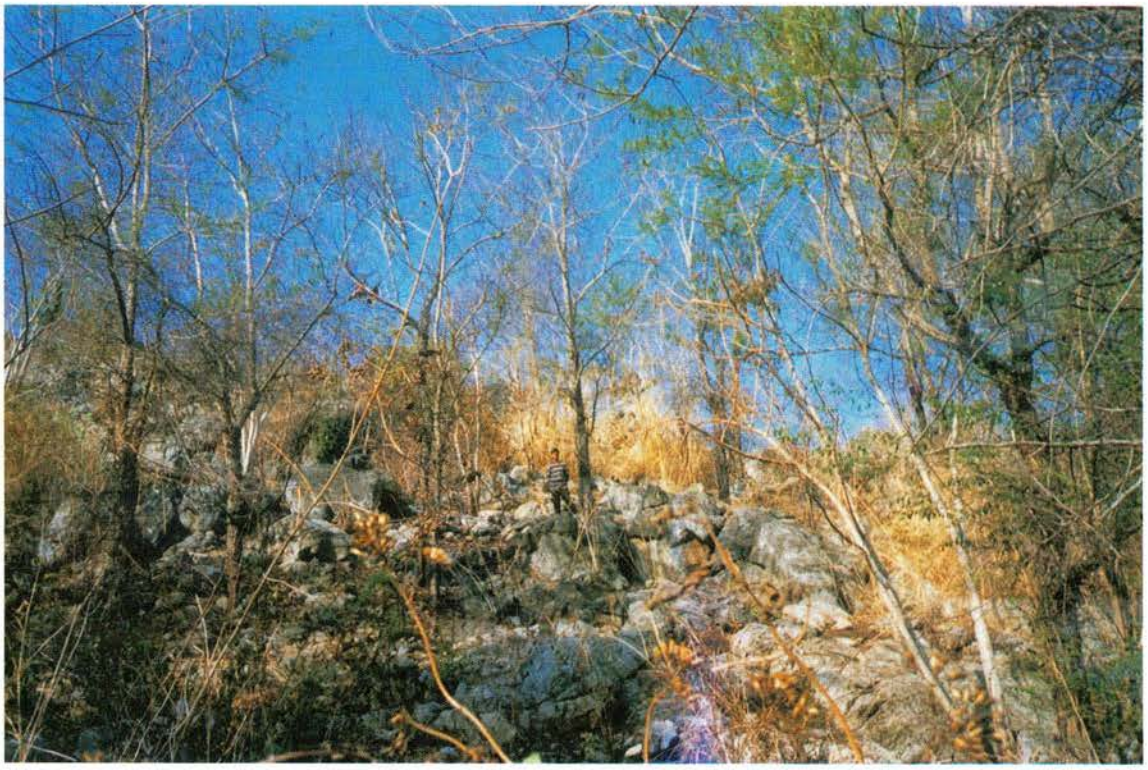
Propagation

Seeds are employed for propagation and germination is reported as improved by hot-water pre-treatment. Seedlings are raised in nurseries for about six months prior to field planting (at spacings of 2 m x 4 m or greater).

Husbandry and Management

Weeding is the most important action in the early years after establishment.

Rotation regimes depend upon the intended usage: for fuelwood production in India, felling is usually at 10-15 years of age; trunks with a diameter of 30-35 cm are considered the most economic for cutch extraction and this size may not be achieved for 30 years.



Wild growth of *Acacia catechu*, Thailand. (Photo: M. Kashio)

Heartwood of *Acacia catechu* being cut and chipped for extraction of cutch and katha. (Photo: M. Kashio)

Crude cutch ("black catechu") attaining consistency. (Photo: M. Kashio)

Katha, machine cut into pieces for sale. (Photo: M. Kashio)

Processing

The dark heartwood of the trunk and of branches greater than 2.5 cm diameter are employed for extraction. Freshly cut material should be employed to optimise extraction yields.

Modern village-scale processing in India involves a number of distinct operations. Heartwood is mechanically chipped prior to the first extraction which is undertaken in metal, open-topped pots of 40 litres capacity. Approximately 10 kg of chips, supported in a wire basket, are boiled with 25 litres of water for 2 hours. The extract is removed and the chips are subjected to a second extraction. The combined extracts are filtered and are then concentrated by boiling in the metal pots until the specific gravity attains approximately 1.05. Katha crystallizes out over a period of several days from the concentrate and this is removed with the aid of a filter press; final preparation of the katha prior to sale involves maceration in clean water, filtering, pressing and drying to around 10% moisture content. The filtrate obtained after removal of the katha is concentrated by evaporation to a viscous state and is then allowed to solidify as cutch.

Factory-scale processing is basically similar but on a larger scale (typically 2.5 tonnes of heartwood per batch extraction) with additional mechanical aids. The extraction may be carried out both at atmospheric pressure or in autoclaves at 100-110°C; the process is repeated on the chips six times with the complete operation taking about 12 hours per batch. The extracts are concentrated in a steam-heated vacuum evaporator and the product is then stored at 0°C for 12 days to crystallize out the katha. The cutch residue is subjected to vacuum concentration and is finally poured into wooden boxes (holding 25 kg) to solidify.

Cutch and katha may be cut into pieces for sale, if required by the buyer, and the katha is sometimes reduced to a powder.

Yields

Heartwood yields vary considerably according to the size of the trees at felling and the planting density.

Processing yields based on heartwood feedstock average 4% for katha and 8% for cutch.

Developmental Needs

Processing methods have been well defined in India and more recently have been re-examined in Thailand. Similarly, there is a substantial body of Indian silvicultural data on the species. Needs for future research on production relate mainly to definition of climatic limit constraints, particularly in the humid tropics.

The immediate developmental requirement is for a thorough market study which will define the opportunities or constraints for further expansion of production and trade.

Other Uses

As noted earlier, cutch is employed as a tanning agent for leather and in oil well drilling. Both crude and refined cutch and extracts of the tree bark have been traditionally used in medicine, usually as an astringent for treatment of sore throats and diarrhoea.

However, the primary demand for the tree in many growing sites is as a coppiceable fuelwood source. The timber is regarded highly, also, for furniture and implement manufacture.

The thorny branches are frequently employed for the construction of animal-proof hedges.

The tree is one of the hosts for lac insects.

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BRAZILIN FROM THE AMERICAN BRAZILWOODS AND EAST INDIAN SAPPANWOOD

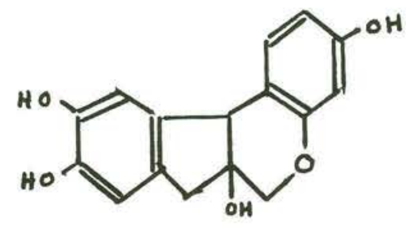
SUMMARY OF BASIC INFORMATION

	The American Brazilwoods	East Indian Sappanwood
Usage: **Product synonyms:**	Red dyestuff for textiles and paper.	Textile dyeing and wood staining (in Asia).
(a) Wood	Brazilwood; Nicaragua wood; brasilette; Lima wood; Pernambuco wood; Bahia wood.	Sappanwood; Indian redwood; kayu secang (Indonesia); sibukoa, sapang (the Philippines); sepang (Malaysia); teing-yet (Myanmar); faang (Thailand); vang nhuom (Viet Nam).
(b) Extract	Brazilin; brazilein.	
Raw material source:	Heartwood of wild trees.	Heartwood of wild and cultivated trees.
Botanical source:	*Haematoxylin brasiletto* Karst.; *Caesalpinia echinata* Lam.; *C. brasilensis* L. (all in Leguminosae family) and some other species native to Central and South America.	*Caesalpinia sappan* L. (syn. *Biancaea sappan* (L.) Todaro (Leguminosae family) with distribution from India through Southeast Asia.
Product traded internationally:	Heartwood.	Heartwood.
World production and trade:	Data unavailable; probably very small current trade.	
Availability of reliable published information:	Poor.	Fair.

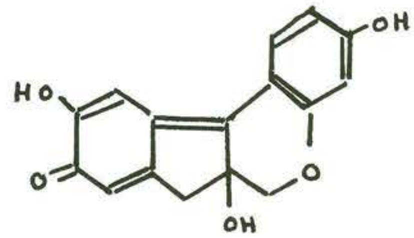
DESCRIPTION AND DYESTUFF USES

"Brazilwood" held the role as one of the most important red dyestuffs for textiles from the Middle Ages to the end of the nineteenth century. The name is derived from "fiery red" or "glowing coals". It was obtained originally from the heartwood of *Caesalpinia sappan* L., a small tree which occurs in India, across Southeast Asia and southern China. On the discovery of the Americas, several other tree species were found to provide a superior red dye and these rapidly displaced the East Indian product in trade, usurping the name of "brazilwood". The country, Brazil, acquired its name through the abundance of its redwoods rather than *vice versa*.

The American brazilwoods have been sourced from a number of different countries and species over the years. Their precise botanical identities and relative importance in trade have been the subject of debate. Record and Hess (1943) state that at that time the major source was *Haematoxylon brasiletto* Karst from Nicaragua. This species is a small tree with a natural range from southern California to Colombia and Venezuela and it overlaps with logwood (*H. campechianum,* the source of the black-blue dye of commerce). The other main species frequently cited as major sources of brazilwood are *Caesalpinia echinata* Lam. [syn. *Guilandina echinata* (Lam.) Spreng] and *C. brasilensis* L. [syn. *Brasiletta violacea* (Mill.) Britt and Rose] but according to Record and Hess, these are native to Brazil and Haiti, respectively, and were never as important as *H. brasiletto*. Additional minor sources include *Caesalpinia platyloba* S. Wats [syn. *Brasiletta platyloba* (S. Wats) Britt and Rose], *C. bahamensis* Lam. and *C. andreana* Mich.



brazilin



brazilein

Summary of Basic Information

The American brazilwoods contain a water-soluble compound, brazilin, in their pale yellow heartwoods and this transforms on oxidation to the red dyestuff, brazilein. Shades of purple to bright red are obtained according to the mordant used in the dyeing process. East Indian sappanwood contains brazilin and another pigment, sappanin.

World Demand and Supply Trends

International demand for East Indian sappanwood as a dye source declined to insignificance by the end of the nineteenth century. Imports of "brazilwood" from Central and South America to the USA and Western Europe appear to have declined after the 1950s and the extent of current trade is not clear from trade statistics.

Production of sappanwood for dyestuff purposes in India and Southeast Asia is now minor and incidental to other uses, which include fuelwood.

There appears to be little prospect of resurrecting demand for brazilwood or sappanwood as dyestuffs, other than in small-scale, local artisanal activities.

Cultivation, Harvesting and Processing

Climate and Soil Requirements

The "brazilwoods" of Central and South America span a range of ecoclimatic conditions but the requirements for individual species are less than adequately documented owing to some confusion in their identities.

East Indian sappanwood occurs at low to medium altitudes in India and Southeast Asia with rainfall ranging from 700-4,300 mm and mean temperatures of 24-28°C. It is adaptable to clay soil and calcerous rocks but does not tolerate waterlogging.

Propagation, Husbandry and Harvesting

Little published information is available on the brazilwoods.

Sappanwood is propagated from seed, which benefits from immersion in boiling water. Cultivation is usually practised under the shade of other trees within the forest or on the forest verge and with a coppicing regime. For firewood use, coppicing is practised at intervals of 3-4 years while for dye production harvesting is carried out at 6-8 years when good heartwood formation has occurred.

Processing

For all species, the highest yields of dye are obtained by extraction of the heartwood. Heartwood is reduced to chips prior to sequential extraction in boiling water. With sappanwood, the raw material is often first reduced to a powder, moistened and is then allowed to ferment, thereby encouraging oxidation of the brazilin and the other natural pigments. The aqueous extract is concentrated prior to use as a dye. The yield of sappanwood dye has been reported as up to 20% of the heartwood on a moisture-free basis.

Other Uses

The American *Caesalpinia* species are described as hard and heavy timbers which are useful for construction work, pit props, etc., and find use in carpentry.

East Indian sappanwood is used in the Philippines as a fast growing coppiceable fuelwood. Elsewhere in Southeast Asia, it is frequently employed as a hedge while wood and bark are used in traditional medicine for the treatment of diarrhoea and a variety of other ailments. The fruits, like those of most *Caesalpinia* species, are rich in tannins and may be used for treatment of leather.

Developmental Potential and Research Needs

In view of the superiority, availability and price of competing synthetic dyestuffs, it is probable that brazilwood and sappanwood dye usage will be restricted to craftwork products in future.

With sappanwood, research is merited on its comparative value with other species as a fast growing fuelwood source and on some aspects of its silviculture. Its potential as a medicinal plant beyond existing, local traditional uses are questionable.

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KAMALA

Summary of Basic Information

Usage: Orange-yellow dye for textiles.

Product synonym: Kamala powder (English)
rottlière des teinturiers (French)
croton tinctoria (French)

Raw material source: Fruits of a tree; mainly harvested from the wild.

Botanical source: *Mallotus philippensis* (Lamk) Muell. Arg.; syn. *Croton philippense* Lamk. (Family: Euphorbiaceae).

Common synonyms for botanical source: Kamala or monkey face tree; kapasan (Indonesia); banato (the Philippines); hpawng-awn (Myanmar); kaai kat hin (Thailand); rum noa (Viet Nam).

Distribution: Western Himalayas, India, Southeast Asia, Southern China, through to Australia.

World production: Unknown.

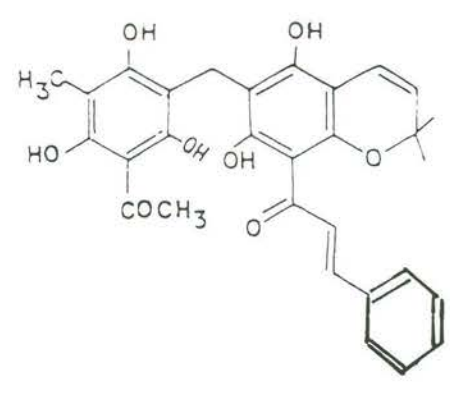
International trade: Insignificant.

Availability of reliable published information: Fair.

Description and Dyestuff Uses

The kamala tree (*Mallotus philippensis* Muell. Arg.) is an evergreen tree, growing up to 25 m which is indigenous to much of South and Southeast Asia and extends through the Pacific as far as Australia.

The fruit of the tree has a red glandular pubescence which, when detached and comminuted, is known as kamala powder. The pigments, present at about 10% by weight, are partially soluble in hot water and are fully soluble in organic solvents and alkalis. The principal red pigment is the chromene compound, rottlerin which is somewhat unstable. On dyeing textiles such as silk and wool, kamala powder produces an attractive bright orange colour but this gradually fades on exposure to the sun.



rottlerin

WORLD DEMAND AND SUPPLY TRENDS

Prior to the advent of colour-fast, synthetic dyes, kamala powder was used extensively in India and neighbouring Southeast Asian countries and enjoyed a small export trade. Today, usage has declined to a minor level within the region and demand can be met adequately from the harvesting of wild trees.

Some recent publications have suggested the possibility of employing kamala as a colourant and as an anti-oxidant additive for processed foods. However, the prospects are not good in such applications owing to a combination of factors: the known physiological action of rottlerin (see later), the costs of full toxicological testing and in the case of anti-oxidant applications, the effective dosage probably would be very high.

Mallotus philippensis (Lamk) Muell. Arg. 1) branch with female inflorescences; 2) fruiting branch. From *Prosea* No. 3 "Dye and tanning-producing plants".

SILVICULTURE, HARVESTING AND PROCESSING

Climate, Soil and Ecology

The kamala tree has a fairly wide adaptation range in the tropics and sub-tropics, displaying frost and drought resistance. In the wild state, it is most commonly found in evergreen forests but occurs also in scrub and on open rocky land. Kamala is frequently the pioneer tree in secondary forests in India where eventually sal (*Shorea robusta*) becomes dominant. It is shade tolerant.

Propagation

Multiplication can be achieved by the use of root suckers or from seed. The latter are viable for approximately six months but the germination rate can be poor.

Husbandry

The tree grows slowly and often does not attain a trunk diameter of 15 cm after 15 years in India. Weeding in the early years is an important activity.

Harvesting and Processing

In India, harvesting is carried out as the fruits ripen in February and March and processing follows immediately. The operation involves detachment of the pigmented glandular pubescence on the fruits. Beating the fruit, followed by manual sifting provides the crude powder. Alternatively, the fruits may be stirred in water and the kamala powder which settles at the base of the vessel is recovered and dried. The yield of powder ranges between

1.5 to 4% of the fresh fruit weight. Crystalline rottlerin may be prepared by organic solvent extraction and concentration.

Other Uses

Rottlerin, the major pigment of kamala powder, has anthelmintic activity and extracts have been employed in India for treatment of cattle. It is reported also to reduce fertility in mammals.

The fruit seeds contain about 20% of a "drying oil", similar in properties to tung oil (*Aleurites* spp.), which has kamolenic acid as its major component. In India, the oil is employed as a fixative for cosmetics and to treat parasite infections on the skin.

The wood is often used as a fuel and occasionally as timber, but in this application suffers from a tendency to shrinkage and from insect attacks.

The leaves of the tree can be used as animal fodder.

Developmental Prospects

The potential for greater utilization of the kamala tree does not appear high, particularly in the context of formal cultivation. Prospects of increased usage of kamala powder as a dyestuff or food colourant/antioxidant are slim for the reasons described earlier. In the case of the seed oil, it is necessary to study more thoroughly the economics of production and the comparative advantage in its properties against other fatty oils derived from faster growing species. It is possible that the kamala tree's economic role will remain as a small source of seasonal income from the management of wild forests.

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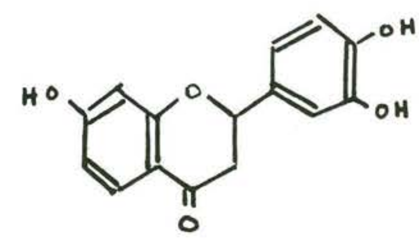
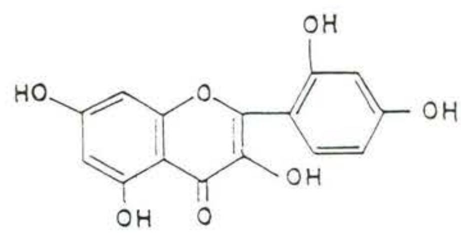
3 SOME MINOR DYESTUFFS FROM TROPICAL AND SUB-TROPICAL TREES

In addition to the examples described in some detail above, several other tropical and sub-tropical tree species were the sources of internationally traded dyestuffs prior to the advent of synthetic dyes at the end of the nineteenth century. Examples include: "fustic" or "dyer's mulberry" (ex. *Chlorophora tinctoria*) from the Americas and "Indian mulberry" (ex. *Morinda citrifolia*) of Asia, whose pigments are mixtures of flavones related in structure to fustin and morin.



fustin

In the past, a very large number of forest trees and large shrubs were employed for dyeing purposes at the local community level. Today, however, usage in developing countries of these natural forest dyestuffs has reduced substantially owing to competition from synthetics but it has not by any means disappeared. For the most part, the forest tree and shrub dyestuffs currently used are the co-products obtainable from exploiting the natural resource for another primary purpose, which may be fuelwood or tannin production.



morin

Tables 8 and 9 list some of the tree and large shrub species of the Americas and of Africa and Asia which have been employed as local minor dyestuffs in recent years. Interested readers can obtain information on a wider range of forest tree and shrub dyestuff-yielding species by reference to the texts listed in the Supplementary Selected Bibliography given in Appendix 1.

Table 8: Some other trees of the tropical and sub-tropical Americas, used locally as minor sources of dyestuffs

Family	Species	Common name	Distribution	Plant part used as dyestuff	Colour and usage
Juglandaceae	*Juglans neotropica* Diels	Peruvian walnut	Peru	leaves, fruit, bark	
Julianiaceae	*Julia adstringens* Schecht.	cuachalala	Mexico	bark	
Leguminosae	*Diphysia carthagenensis* Jacq.; *D. robinioides* Benth.	cascabellio; cuachepil	Central America	heartwood	yellow
	Pithecolobium dulce (Roxb.) Benth.	bixihui; jaguay; campeche marron	Central and northern South America	bark	yellow
	Pterogyne nitens Tul.	ibiraro; palo amargo	Argentina, Paraguay, Brazil	wood	purple
	Russellodendron cacalaco (H.& B.) Britt and Rose	cacalaco	Mexico	pods	
	Tara spinosa (Mol.) Britt and Rose	divi-divi; guarango	Andes, Bolivia	pods	black (used for textiles and ink)
	Vachellia farnesia (L.) Wight and Arn	aroma; cassie; cashia	Central and South America	bark, fruit	black (used for textiles and ink)
Lythraceae	*Lafoensia glyptocarpa* Hoehne	ariana; cabeca; pau terra	Brazil	bark	yellow
Moraceae	*Chlorophora tinctoria* (L.) Gand	fustic; dyer's mulberry; bois jaune; borassa; mora	Central and northern South America, Caribbean	heartwood	yellow; formerly exported as "fustic" for dyeing textiles khaki
Papaveraceae	*Bocconia arborea* S. Wats *B. frutescens* L.	palo amarillo; pau cimmaron; celandine	} Mexico, Central } America, Central } and northern } South America, } Caribbean	fruit capsules	yellow
Rubiaceae	*Genipa americana* L.	jagua; genipapeiro	Central and northern South America and Caribbean	fruits	used as a black skin dye by Indians in Brazil
	Sickingia rubra (Mart.) K. Schum	arariba vermelha	Brazil	bark	red
Symplocaceae	*Symplocos* spp.	amarellinho; caa apoam	Brazil	bark and leaves	yellow

Table 9: Some other trees and large shrubs of tropical and sub-tropical Asia and Africa, used locally as minor sources of dyestuffs

Family	Species	Common name	Distribution	Plant part used as dyestuff	Colour and usage
Aselepiadaceae	*Marsdenia tinctoria* R. Br.	tarum akar (Indonesia); payangit (the Philippines)	Himalayas to China; India to Southeast Asia	leaves	blue dye
Combretaceae	*Terminalia bellirica* (Gaertner) Roxb.	beleric myrobalan, bedda nut tree; jaha kebo (Indonesia); jelawai (Malaysia)	Himalayas, India to Southeast Asia	fruits	black dye for matting and ink
	Terminalia catappa L.	Indian almond; ketapang (Indonesia and Malaysia); talisai (the Philippines)	Southeast Asia	bark, leaves	black dye
	Terminalia chebula Retz.	chebulic myrobalan; black myrobalan; manja (Malaysia); maa-nae (Thailand)	Himalayas, India to Southeast Asia	fruits	yellow to black dyes (but much less important than as a tradeable tannin)
Ebenaceae	*Diospyros malabrica* L.	Malabar ebony; kledung (Indonesia); tako Thai (Thailand)	India; Southeast Asia	fruits	black dye
Euphorbiaceae	*Aprosa frutescens* Blume	kruen (Thailand); kayu malam (Indonesian); mesekam (Malaysia)	Southeast Asia	bark	black dye
	Exocaria indica (Willd.) Muell. Arg.	mock-willow; gurah (Indonesia); buta-buta (Malaysia); krahut (Thailand)	India; Southeast Asia	leaves	green-yellow to black dye
	Macaranga tanarius (L.) Muell. Arg.	tutup ancar (Indonesia); kundoh (Malaysia); ka-lo (Thailand); binunga (the Philippines)	Southeast Asia, China	leaves	black dye
	Omalanthus populneus (Geisler) Pax.	mouse deer's poplar; tutup (Indonesia); malabinunga (the Philippines)	Thailand, Malaysia	bark, leaves	black dye
	Phyllanthus emblica L.	emblic myrobalan, Indian gooseberry; kimalaka (Indonesia); nelli (the Philippines); ma-khaam pom (Thailand)	Himalayas, India, Southeast Asia	leaves	brown dye
	Phylanthus reticulatus Poiret	wawulutan (Indonesia); malantinta (the Philippines)	India to southern China and Southeast Asia	ripe fruits stems/leaves root	black for ink black for cotton red dye
Guttiferae	*Garcinia hanburyi* Hook. f.	gamboge tree; rong (Thailand)	Southeast Asia	sap	gold-yellow dye for varnishes, lacquer, etc.

Table 9 (continued):

Family	Species	Common name	Distribution	Plant part used as dyestuff	Colour and usage
Leguminosae	*Acacia nilotica* (L.) Willd. ex Del	babul, Egyptian thorn	Africa to India	pods	black/brown dye; used in inks
	Albizia lebbekoides (D.C.) Benth.	taris (Indonesia); siris (Malaysia); haluganit (the Philippines)	Southeast Asia	bark	red dye
	Butea monosperma (Lamk) Taubert	dhak, palas (India); palasa (Indonesia)	India to Southeast Asia	flowers	yellow-red dye
	Caesalpina coriaria (Jacq.) Willd. *C. digyna* Rottler	)) divi-divi)	south and Southeast Asia	pods	blue-black dye; used in inks
	Peltophorum pterocarpum (D.C.) Backer ex. K. Heyne	yellow flame, copper pod; soga (Indonesia); non-see (Thailand); siar (the Philippines)	Sri Lanka, Southeast Asia	bark	brown dye, component of Indonesian "soga" dye for batik
	Sophora japonica L.	Japanese pagoda tree; sari kuning (Indonesia)	China and Korean peninsular	flower buds	yellow to grey dye; formerly item of regional trade
Menispermaceae	*Fibraurea tinctoria* Lour.	peron (Indonesia); sekunyit (Malaysia); kam-phaeng (Thailand)	India, Southeast Asia, China	stem	yellow dye
Moraceae	*Maclura cochinchinensis* (Lour.) Corner	kayu kuning (Indonesia); kederang (Malaysia); kokom pusa (the Philippines)	Himalayas to Japan; India, Southeast Asia	heartwood	yellow dye for batik
Oleaceae	*Nyctanthes arbor-tristis* L.	night-jasmine; srigading (Indonesia)	Himalayas to Southeast Asia	flowers	saffron-yellow dye
Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Savigny	Black mangrove	East and south Africa; south and Southeast Asia	bark	dark brown dye
	Ceriops decandra (Griffith) Ding Hou	tengar (Indonesia; Malaysia); malatangal (the Philippines)	Southeast Asia	bark and sap	black dye (used for batiks)
	Ceriops tagal (Perr.) C.B. Robinson	tengar (Indonesia; Malaysia), tangal (the Philippines)	East Africa to India and Southeast Asia	bark sap	red dye black dye for batik
Rubiaceae	*Morinda citrifolia* L.	Indian mulberry; morinde (French); mengkudu besa (Indonesia); tumbong-aso (the Philippines)	Southeast Asia, Pacific	rootbark	red dye; formerly of commercial importance
Symplocaceae	*Symplocos cochinchinensis* Lour. S. Moore ssp. *cochinchinensis*	jirak (Indonesia); pokok api-api (Malaysia)	Southeast Asia	inner bark	yellow dye; most frequently mixed with *Morinda* spp for reds

LICHEN DYES 4

SUMMARY OF BASIC INFORMATION

Usage:	(a) Dyestuff for wool and silk; (b) production of litmus; and (c) food colouring (limited).
Common names of dyes:	Orchil, archil, orseille (French) and cudbear; generic terms used for red/purple/violet dyes obtained by treatment of certain lichen species with ammonia.
Raw material source:	Collection of wild growing material from trees and rocks.
Common names of lichen sources:	(a) Orchil/cudbear generally for orchil dye types (b) crottle/crottal for some individuals, especially those on rocks.
Botanical sources:	(a) Orchil/cudbear types: *Rocella tinctoria, Ochrolechia tartarea* (syn. *Lecanora tartarea*), *Evarina prunastri* (Stag's horn), plus some species of *Parmelia, Umbilicaria* and *Lasallia*. (b) Non-orchil types include certain species of *Parmelia*, *Hypogymnia*, *Lobaria*, *Peltigaria*, *Sticta* and *Xanthoria*.
Distribution:	Worldwide; certain orchil types common in coastal sub-tropics and tropics.
World production and international trade:	Unknown.
Availability of reliable published information:	Poor.

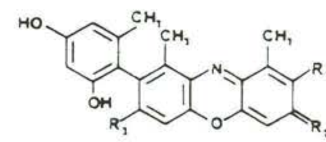
DESCRIPTION AND USES

Lichens are a unique group of plant organisms in which there is a symbiotic association between an alga and a fungus. They are very slow growing, occur on rocks and trees and are remarkable in their geographical distribution which spans the tropics to the Arctic tundra. Approximately 15,000 different types of lichens have been recognized, of which the majority occur in habitats which are too austere for other plants.

Man has employed certain types of lichens from ancient times for purposes which include food, animal fodder, medicinal preparations, perfumery and as dyestuffs.

With wool and silk, the lichen dyes can be employed without a mordant and produce subtle, muted colours which range from yellow, brown, red, purple to violet. Certain species, known as the orchils, provide purple to red-violet dyes on treatment with ammonia. This same group is employed also to produce the acid-base indicator, litmus.

The chemistry of the lichen pigments is complex, involving a diversity of oxygen ring compounds which are generically, if inaccurately, termed the "lichen acids". Orchil type dyes and litmus contain a mixture of derivatives of the natural depside pigments, produced by the action of the ammoniacal liquor. The process involves conversion of depsides to orcinol and then to orcein; the latter being a mixture of oxy- and amino-phenoxazon or phenoxazin.



orcein

WORLD PRODUCTION AND TRADE

The purple orchils have been the most important group of lichen dyes in historical trade and during the classical Greek and Roman period production was probably based on *Rocella tinctoria* which is native to the Mediterranean area. During the seventeenth century, a growth in usage of orchils developed with the discovery of the ammonia treatment process. Shortages of supplies developed in the Mediterranean and new sources were developed first in the Canary Islands and on Cape Verde. During the nineteenth century, India and Ceylon (Sri Lanka) assumed importance with processing mainly being done in the United Kingdom. Later, supplementation of supplies developed in Northern Europe and in the USA.

During the twentieth century, usage of lichen dyes of all types has declined in the face of competition from lower cost and progressively improving synthetic dyestuffs. However, lichen dyes resisted supplantation for a much longer period than most other natural dyestuffs, especially in materials such as Scottish and Irish tweeds.

In recent years, there has been a revival in usage in lichen dyes of local origin in the manufacture of specialist, craft textiles in Europe and North America where the subtlety of the colour is much appreciated. Nevertheless, no prospects are foreseen for any significant global improvement in the low level of international trade.

HARVESTING AND PROCESSING

Harvesting

This is a simple operation of collecting the appropriate species for particular applications, followed by drying and storage until required for processing.

Non-Orchil Dyestuff Preparation

The basic method for non-orchil dye preparation is to gently boil the lichen in soft water for several hours. Depending upon the lichen type and the desired colour, the pH may be altered by addition of vinegar or washing soda.

Orchil Dye Preparation

This process involves a slow aerobic fermentation of the lichen in aqueous ammonia over a period of a couple of weeks.

Litmus Production

A mixture of the most common orchil type lichens (*Rocella, Lecanora/Ochrolechia* species) are employed for litmus production. The process is a variation on the orchil dye method and involves addition of potash and lime to the aqueous ammonia medium.

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INSECT DYES 5

LAC

SUMMARY OF BASIC INFORMATION

Usage:	Textile dyeing.
Common name of product:	Lac dye.
Product type and form traded:	Concentrated extract.
Botanical source:	The lac insect, *Laccifer lacca* (super family: Coccoidea); a parasite of a large number of trees.
Synonyms for botanical source:	*Kerria lacca.*
Distribution:	Northern India, through Bangladesh, Myanmar, Thailand, Indochina and Yunnan Province of China.
World production:	Not quantifiable.
International trade:	Small; possibly 10 tonnes annually.
Major producers:	India and China.
Importers:	No clear regular buyers.
Availability of reliable published information:	Poor.

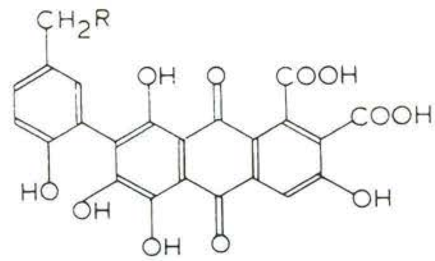
DESCRIPTION AND DYESTUFF USES

Lac dye is the scarlet pigment present in the live, pre-emergent insects (*Laccifer lacca*; syn. *Kerria lacca*) which develop in a resinous cocoon, known as "sticklac" on the twigs of over 160 host trees in an arc from northern India through to Indo-China. The dyestuff is obtained by aqueous extraction of sticklac; the resinous residue is further processed to "seedlac" and to the fully refined "shellac".

The water-soluble dyestuff, lac dye is composed of analogues of laccaic acid, mainly in the form of ammonium salts. These pigments are present at up to 10% in sticklac which has been harvested before adult insects depart their cocoon. Processed seedlac and shellac have a low content of laccaic acids but retain a yellow water-insoluble pigment, erythrolaccin.

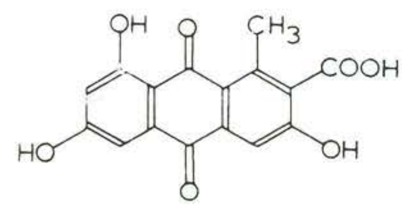
From ancient times, lac dye has been employed in India as a skin cosmetic and for the dyeing of wool and silk, while China has a tradition of usage for leather dyeing. The colour of the dye can be modified by the appropriate choice of mordant from violet to red and brown.

Seedlac and shellac, the major processed products of sticklac, are employed in varnishes, paints, printing inks, sealing wax, micanite compounds, as coatings for pharmaceutical and confectionery products.



laccaic acids

A: R = CH_2—NH—$COCH_3$
B: R = CH_2OH
C: R = $CH(NH_2)COOH$
E: R = CH_2-NH_2



laccaic acid D

World Demand and Supply Trends

International Trade

The history of substantial trade in sticklac derivatives commenced during the eighteenth century with the export of lac dye by India. Up to nearly the end of the nineteenth century the dye trade was buoyant and was still more important for India than exports of seedlac and shellac. However, the advent of cheaper and superior synthetic dyestuffs rapidly eroded demand for lac dye. Since the late 1940s, international trade in seedlac and shellac has declined also from competition by synthetic alternatives.

A minor trade in lac dye exists today but accurate quantification is difficult owing to deficiencies in the compilation of statistics by several potential exporters and importers. Only India clearly identifies lac dye in its export statistics and these reveal an irregular annual volume of shipments (0 to 15 tonnes annually over 1988-93) and of destinations.

Production and Exports

The **major producers** of sticklac and its derivatives today are India, Thailand and the People's Republic of China; the first two are also the major exporters of lac products and share almost equally the export market, while China's production is mainly consumed on the domestic market. Minor producers include Bangladesh, Myanmar, Viet Nam and Sri Lanka.

In **India**, lac dye usage is small and the bulk of the aqueous dye extract, obtained in the first step of processing of lac is allowed to run to waste. Processing of sticklac is oriented towards manufacture of seedlac and shellac, of which some 80% is exported, but this trade has declined also as a result of competition from Thailand and synthetic resins. India's annual production of sticklac was approximately 50,000 tonnes in the mid-1950s and reduced to around 12,000 tonnes by the late 1980s. Over the same period, India's exports of lac fell from 29,000 tonnes to around 7,000 tonnes per annum (predominantly of refined shellac) with the USA, Western Europe and (prior to 1990) Russia as the principal market outlets. The most recent statistics show a continuing downward trend in lac exports with a figure of 4,500 tonnes in 1992/93. While the scale of the industry has diminished in India, it remains of socio-economic importance to an estimated 3 million people, mainly tribal groups, in West Bengal, Bihar, Madhaya Pradesh, Orissa and Assam. Cultivation of sticklac is a spare-time agroforestry activity which fits in with production of staple food crops. Individual producers sell a few kilograms of sticklac which then passes through an intermediary marketing chain to processors. The majority of Indian exports are shipped from Calcutta.

Thailand's production and exports of lac commenced in the 1950s and progressively eroded India's share of the international market through keen pricing. Recent exports have been of the order of 7,000 tonnes annually, mainly of the partially refined seedlac. There is no reported export oriented production of lac dye in Thailand.

China's main cultivation area for sticklac is the province of Yunnan, where recent annual production volumes have been 4,000-5,000 tonnes of crude sticklac and 2,000-3,000 tonnes of processed shellac, together with an unspecified volume of lac dye. Production has been undertaken on a smaller scale in the province of Fujian since the mid-1950s. Exports of shellac are comparatively small at approximately 500 tonnes per annum with Japan as the principal buyer.

Prospects for New Suppliers

No upswing in demand for lac dye may be expected within developed country markets in textile applications but, new usage in food colouring is highly unlikely in view of the costs of testing for safety and the availability of established alternatives. Prospects for increased consumption within producer countries also appear slim in the textile and leather dyeing industries in the face of competition from synthetics which are in regular supply and of a more consistent quality.

Demand for lac in developed country markets appears stable but with no sign of growth prospects. Some potential may exist for increased consumption of lac within those larger developing countries with growing populations and industrial bases but on the evidence of lac's competitive status within India this may not be great.

CULTIVATION, HARVESTING AND PROCESSING

Climate and Host Trees

Lac insects can be cultured over a fairly wide range of the tropics and sub-tropics and on a large number of host trees (see Table 10).

Insect Species

The lac insects fall under the Laccaferinae sub-family of the Lacciferidae, and of the various species the most important for commercial production is *Laccifer lacca*. In India, two strains are cultivated, "kusiumi" and "rangeeni", which differ in their seasonal cycle and preferred host trees. Strains in other lac producing countries are less well defined.

Production Systems

Lac cultivation is a seasonal, part-time agroforestry activity which may be based on cultivated or wild host trees. In order to obtain maximum yields of sticklac, the insects are cultured, the host trees are managed and attention is given to control of parasites.

Husbandry

The first operation is pruning of the host tree in order to stimulate the growth of young shoots which provide sap as food for the insects. This is done four to six months prior to inoculation of the tree with "broodlac", a cocoon containing mature females at a stage just prior to emergence. Eggs laid on the host develop into larvae and form a resinous cocoon ("sticklac"). Harvesting is undertaken approximately six months later and the tree is subjected to a repeat treatment of pruning and inoculation.

Table 10: Some of the more important host trees

Country	Common name of host tree	Species	Family
India:			
(a) most common:	dhak/palas	*Butea monosperma* (Lamk) Taubert	Leguminosae
	ber	*Zizyphus mauritanea*	Rhamnaceae
	kusum	*Schleichera oleosa*	Sapindaceae
(b) others include:	khair/cutch	*Acacia catechu* Willd.	Leguminosae
	babul	*A. nilotica* Willd.	Leguminosae
	arhan	*Cajanus cajan*	Leguminosae
	sappan	*Caesalpinia sappan* L.	Leguminosae
	pipal	*Ficus religiosa* L.	Moraceae
	banyan	*F. bengalhensis*	Moraceae
Thailand - most common	rain tree	*Samanea saman*	Leguminosae
China - include		*Cajanus cajan* *Dalbergia balencea* *Hibiscus* spp.	Leguminosae Leguminosae Malvaceae

A coupe system of management, involving resting of the trees in alternate years, has been devised by the Indian Lac Research Institute. This involves variations according to the insect strain and the host tree.

Harvesting

Harvesting involves cutting off the twig with the attached sticklac. For lac dye production, this should be done before all of the insects escape since they contain, rather than the resin, the desired pigment. The insects are killed by exposing the sticklac to the sun. When the primary objective is seedlac and shellac production, most of the insects may be allowed to escape as the quality of the product is partly assessed on its colour; the paler the better.

Processing

Twigs and other extraneous matter are first removed from the sticklac by hand picking, winnowing and sieving. Processing is undertaken as quickly as possible thereafter in order to avoid deterioration.

Lac dye is isolated as the next step, both for its deliberate production and for its discarding if the primary purpose is seedlac/shellac production. The operation involves crushing the sticklac and extraction several times with water; insects and other debris are removed also at this stage. The dyestuff is obtained as a precipitate on acidification of the aqueous extract.

The washed resin obtained after dye removal is known as "seedlac". Conversion of seedlac to the fully refined product, "shellac", can be accomplished by several processes: simple melting and filtering under pressure; melting and extrusion under pressure; and solvent extraction. Bleaching is carried out to obtain the palest form of shellac.

Yields

Sticklac yields are dependent upon various factors: the insect strain, the host tree and the management system. Annual yields of sticklac per tree reported for Bihar in India are: 6–10 kg on kusum (*S. oleosa*); 1.5-6 kg on ber (*Z. mauritanea*); and 1-4 kg for palas (*B. monosperma*).

Pigment contents in sticklac can be as high as 10% but the yield of isolated lac dye can be below 1% with poor quality sticklac and inefficient extraction methods.

The yield of fully refined shellac is approximately 50% of the sticklac raw material.

DEVELOPMENTAL POTENTIAL

Lac cultivation and seedlac/shellac processing have been thoroughly researched in India. The main requirement on these topics is full implementation by producers and, where necessary, the devising of appropriate modifications in other countries (e.g., the most suitable host trees and coupe systems). Methods of improved control of lac parasites and of preventing the lac insect from developing as a pest on non-host species need further study.

Superior, more efficient means of producing lac dye certainly could be developed. But in the absence of clear evidence of the potential for a growth in market demand, investment in such research on lac dye would be difficult to justify.

Prospects for growth for international trade in seedlac/shellac are not promising. With these products, however, non-traditional producers might usefully assess demand trends within their domestic markets and the value of encouraging production — as an additional cash crop component within agroforestry systems — for import substitution purposes.

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KERMES

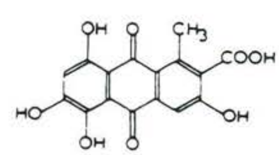
SUMMARY OF BASIC INFORMATION

Usage:	(Formerly) as a red dye for wool and silk.
Product synonyms:	Kermes (English, French and German); chermes (Italian); quermes (Spanish).
Botanical source:	Various species of *Kermes* scale insects, especially *Kermes ilicis* (syn. *Coccus ilicis* or *Kermococcus vermilis*) of the Coccoidea superfamily; colonizers of certain oak species, especially the kermes oak (*Quercus coccifera*).
Distribution:	Mediterranean and Middle East region.
World production and trade:	Unknown; certainly very small.
Availability of reliable published information:	Poor.

HISTORY AND USES

Kermes is red-crimson dye which is obtained from females of a number of species of *Kermes* scale insects, of which *Kermes ilicis* — a parasite of the kermes oak — has been the most important. It has a history dating back to ancient times in the Mediterranean and Middle East region when alternatives for dyeing wool and silk were unavailable. The colour descriptors, crimson in English and carmoisine in French, are derived from the word kermes.

The pigment present in the insects is kermesic acid and this requires a mordant in the dyeing process.



kermesic acid

Usage of kermes dye was considerable in Europe and the Middle East until the end of the sixteenth century when the cochineal insect was discovered and commercially developed in the Americas. Cochineal contains an analogue of kermesic acid as its pigment and provides a similar colour but more importantly the extractable yield of the dyestuff is very much greater from cochineal than with kermes insects. Cochineal rapidly superseded kermes in commercial dyeing.

Today, dyeing with kermes is effectively restricted to enthusiasts. Although research on kermes species (and related sources, such as "Armenian Red" from *Porphyrophora hamelii* and "Polish Cochineal" from *Margarodes polonicus*) as a dye or food colourant source has been reported periodically in the literature, there appears little realistic prospect of it regaining commercial significance owing to the high costs of collection.

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MAJOR COLOURANTS AND DYESTUFFS MAINLY PRODUCED IN HORTICULTURAL SYSTEMS 6

COCHINEAL AND CARMINE

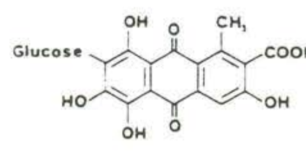
Summary of Basic Information

Usage:	(a) Primarily as a colourant for cosmetics and foods. (b) Very minor usage as a textile dyestuff.
Common names for products:	(a) The dried insects: cochineal (English); cochinilla or zacatillo (Spanish); cochenille (French); cocciniglia (Italian); cochenille or koschenille or Nopalschildaus (German). (b) The extract of the insect: carminic acid. (c) The aluminium lake of carminic acid: carmine.
Botanical source:	Pregnant females of *Dactylopius* spp. insects; principally *D. coccus* Costa (syn. *Coccus cacti* L. and *C. cacti coccinellifera*); Dactylopidae family; Coccidae superfamily.
Insect hosts:	Cacti of *Opuntia* spp. ("prickly pear") and *Nopalea* spp. ("torch thistles"), especially *N. cochenillifera*.
Distribution:	(a) Native to Mexico, Central America and western Andes countries of South America. (b) Widely introduced and naturalised elsewhere in the tropics and sub-tropics.
Products traded internationally:	The dried insects and the extracts; the latter predominating today.
World production and trade:	Approximately equivalent to 300-350 tonnes of dried insects per annum.
Exporters:	(a) Peru (90% plus of world supplies). (b) Canary Islands and some others in Central and South America.
Major importers:	USA, Western Europe, Japan.
Availability of reliable published information:	Fair to good.

Description and Colourant Uses

Cochineal is the name used to describe both the colour and the raw material source: the dried, pregnant females of tropical American *Dactylopius* species, especially *D. coccus* Costa. The main hosts of these scale insects are the aerial parts of "prickly pear" and "torch thistle" cacti (*Opuntia* and *Nopalea* species, respectively). Less important host plants in the tropical Americas include *Schinus molle*, *Acacia macarantha* and *Caesalpinia spinosa*.

The principal pigment in cochineal is a protein-bound glycoside of the anthraquinone, carminic acid. This is very soluble in water and its colour changes according to pH. An orange colour is obtained in an acidic media and a transformation from violet to red occurs with increasing pH number from 5 to 7. Carminic acid extracts display good stability to heat, light and oxygen.



carminic acid

Treatment of carminic acid with an aluminium salt produces a soluble aluminium lake, known as carmine, which may be precipitated by addition of a calcium salt. Carmine exhibits good resistance to heat, light and oxygen and provides a blue to red colour in alkaline solution. Reduction of the pH reduces the blue colour and below pH 3 carmine is insoluble. Precipitation of carmine with tin salts produces a vivid scarlet colour which was formerly important in textile dyeing.

The major usage of carminic acid and carmine today lies in non-textile applications. Carmine is an important colourant for cosmetics, especially those employed near the eye. Carminic acid and particularly carmine aluminium lake are permitted and widely used in the food industries in North America and Western Europe. Extensive toxicological screening in the European Community has resulted in the listing of cochineal and its derivatives as E120, "Natural Red" but individual European countries have their own regulations on the permitted range of food/beverage applications and on dosage levels. In Japan, carminic acid rather than carmine is employed by the food industry.

Carminic acid is usually supplied as an aqueous solution with a pigment content of less than 5% and at this low colouring power its range of applications are limited. Spray dried forms are available also.

Carmine is the main product employed for cosmetics, food and pharmaceutical colouring applications. It is most commonly traded as a powder with a carminic acid content of 40 to 60%. Liquid aqueous alkaline forms (and their spray dried derivatives) are also available with a carminic acid content of 2 to 7%; potassium hydroxide solutions have largely displaced the traditional ammonia medium. Carmine competes with beetroot red (betanin) and anthocyanins in food colouring and its main limitation is insolubility at low pH. Typical applications are in soft and alcoholic drinks, bakery products, dairy products, confectionery and pickles and at dosage levels ranging from 0.1 to 0.5%.

Current dyestuff usage is minor and limited to those who require special tones for luxury textiles or artists' paints.

World Demand and Supply Trends

The use of cochineal as a textile and paint dyestuff in Mexico and Peru dates back almost 3,000 years. The commercial potential was quickly recognized by the Spaniards on their conquest of the Aztec Empire of Mexico. Cochineal was introduced to Europe in the early years of the sixteenth century, achieving the status of a well-known item of trade within fifty years. Its superiority over kermes in textile dyeing was rapidly acknowledged and demand for the latter progressively eroded along with increased supplies of the New World material.

Cultivation of cochineal was actively promoted by Spain in its colonies in the Americas and the industry played a formative economic development role in some countries, notably in Guatemala.

By the early nineteenth century, the cochineal insect and its cactus host had been widely introduced by Spain and its colonial rivals to many parts of the Old World. A peak global production and trade of many thousands of tonnes per annum was attained in the mid-nineteenth century, with Mexico, Guatemala, Haiti, Java and the Canary Islands being prominent sources; exports from the last named were as high as 3,000 tonnes in 1875.

The development of synthetic, coal-tar based dyes in the latter part of the nineteenth century resulted in a progressive reduction of demand for cochineal in the textile industry. However, it held a share of the market for a much longer period than most natural dyestuffs and, for example, was used as the scarlet dye for the dress uniforms of the British Brigade of Guards until the mid-1950s.

Current major usage of cochineal and its derivatives lies exclusively in the cosmetics and food industries with Western Europe (notably France and the UK), the USA, Japan and Argentina as the principal markets (listed in descending order). Total demand in 1995 was estimated to be in excess of 300 tonnes of cochineal per annum. **Peru** has been the dominant exporter for several decades, accounting for 90% or greater of the export market. The only other significant supplier has been the **Canary Islands** with exports fluctuating between 10 and 30 tonnes per annum.

Prior to 1980, all **Peruvian exports** were in the form of raw cochineal. In the subsequent period, an extraction industry has developed in Peru and today over 50% of the annual crop is processed to carmine prior to export. A small quantity of carminic acid is produced also. The major buyer of carmine is Western Europe, followed by the USA. Japan predominantly imports cochineal for local processing. The volume and value of Peruvian exports in the recent period are given in the following table:

Table 11: Peruvian production and exports, 1986-1993

	Cochineal			Carmine	
Year	**Production (tonnes)**	**Exports (tonnes)**	**Value (US$ millions)**	**Exports (tonnes)**	**Value (US$ millions)**
1986	266	139	6.1	19.2	4.6
1987	320	118	6.4	31.7	7.9
1988	319	141	5.9	30.4	7.0
1989	355	177	5.3	47.8	6.9
1990	383	189	5.7	46.7	7.1
1991	399	160	2.7	59.8	6.9
1992	493	193	3.1	74.9	7.7
1993	500	NA	NA	NA	NA

NA = not available
Source: Peruvian Government exports statistics.

These figures show a considerable improvement on raw material production as compared to the latter half of the 1970s and early 1980s when the average annual output fluctuated around 180 tonnes. Supply problems and associated high prices (reaching around US$ 100/kg, fob for cochineal) were particularly acute in some years in the early 1980s owing to a combination of factors. Peru is largely dependent upon harvesting wild material and the major source is the Ayacucho area (with approximately 35,000 ha of wild cacti) which was subject to terrorist disturbance in the early 1980s. Simultaneously, the new extraction industry posed competition to the traditional exporters for the limited supplies and this was exploited by middlemen in the marketing chain. Subsequently, the Peruvian Government imposed a quota system on division of the crop between the two export channels and this, together with other general improvements, has led to greater stability. Cultivation has been adopted also since the mid-1980s and the size of individual plantations range from 1 to 20 ha.

Increased availability of raw material has led to a progressive reduction in **fob export prices** from around US$ 50/kg and US$ 250/kg for cochineal and carmine, respectively, to US$ 17/kg and US$ 100/kg in the recent period. The recent price levels are of a similar order of magnitude to those prevailing in the mid-1970s.

Exports of cochineal from the Canary Islands have been mainly destined for Western Europe and historically have been higher-priced than Peruvian material.

The **consumption** of cochineal and carmine in the major markets has increased substantially along with supplies, price stability and the trend towards natural colours in foodstuffs. Prospects for significant further expansion in these traditional markets is uncertain but globally a modest growth is likely.

Several countries — where the insect and its host cactus are indigenous or have naturalised — have expressed interest in resuscitating or newly developing cochineal production. Their prospects for success will depend on local production costs as compared to Peru and, also, on the output levels achieved by the latter if formal cultivation is widely adopted.

CULTIVATION AND PRIMARY PROCESSING

The insects and their host cacti are adapted to arid areas of the tropics and sub-tropics and in many areas of introduction the cacti have achieved the status of a weed.

When cultivated, a host plant is inoculated with a brood of the insects which are readily collected since they mass together. The females mature over a period of 90-110 days and, thus, under favourable weather conditions up to four harvests can be taken a year.

Harvesting involves brushing the white-grey, powdery mass of females off the plant immediately prior to egg laying. Primary processing involves killing and drying the females, during which their weight reduces by 70%. Simple sun-drying of the insects provides "silver cochineal" which includes the brood powder and is regarded as of inferior quality. Accelerated, artificial killing and drying gives the more highly regarded "black cochineal"; several variants have been employed and in Peru a brief immersion in hot water, followed by sun-drying is the commonest method.

Cleaning and grading is normally undertaken by exporters. This involves removal of extraneous matter by manual sifting and sieving and redrying, if necessary, to 12% moisture content.

Between 80 and 100 thousand insects are required to produce 1 kg of cochineal. Yields from cultivation in Peru have been reported to range from 120-240 kg/ha/year.

Some reports in the literature state that in Mexico and Central America a distinction was made between cultivated and wild strains of insects, the former were larger and contain double the pigment content (up to 22%). While precise species/strain identification can be difficult over a wide geographic range, wild insects in Peru regularly contain at least 16% carminic acid and have frequently attained 20%. It is possible that the low pigment content of some wild material results from premature harvesting, especially in years of high prices.

ADDED-VALUE PROCESSING

Carminic acid has a good solubility in water and cochineal has been traditionally extracted with water or aqueous alcohol at 90-100°C by a batch or continuous process. For sale of carminic acid, the extracts are concentrated to provide solutions of between 2 and 5% (maximum) pigment content. Use of protolytic enzymes has been reported to improve extraction yields considerably.

Carmine for the food and cosmetics industries is prepared from the carminic acid extract by treatment with an aluminium salt and aluminium hydroxide substrate. Addition of ethanol to the complex provides soluble carmine while treatment with a calcium salt results in precipitation. Between 4-5 kg of cochineal are required to produce 1 kg of the carmine lake. In the solid form, the carminic acid content of carmine is usually a minimum of 50% but rarely exceeds 60%. Treatment of carmine with aqueous ammonia provides the traditional soluble red form of the colourant.

Production of dyers scarlet involves a similar process but aluminium is substituted by tin salts.

OTHER USES

Cochineal found use in European medicine up to the mid-nineteenth century and, possibly, was employed in Aztec and Inca traditional medicine.

The main new interest in the insect lies in its use as a biological control agent in areas where *Opuntia* cacti pose problems as weeds. In some countries, development of cochineal production has been proposed as a spin-off from the cacti control operation.

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CROCIN FROM SAFFRON AND *GARDENIA JASMINOIDES*

SUMMARY OF BASIC INFORMATION

	Saffron	**Gardenia jasminoides**
Usage:	For flavouring and imparting a yellow colour to foods.	Yellow food colourant.
Common name for processed product:	Saffron extract or crocin extract.	Crocin extract; gardenia extract.
Raw material source:	Stigmas of a crocus; mainly cultivated.	Fruits of a shrub; mainly cultivated.
Botanical source:	*Crocus sativus* L. (Family: Iridaceae).	*Gardenia jasminoides* Ellis (Family: Rubiaceae).
Synonyms for botanical source:		*Gardenia florida* L; *Gardenia grandiflora* Lour; *Gardenia augusta* (L) Merr.
Common names for botanical source:	Saffron (English); safran (French and German); azafran (Spanish); fan-hung-hua (Chinese); saufuran (Japanese); Za'faran (Arabic).	Cape Jasmine, garden gardenia; bunga cina (Malaysia); ceplok piring (Indonesia); rosal (the Philippines); phut cheen (Thailand).
Distribution:	Indigenous to Greece, Turkey and Iran; now widely cultivated across temperature zones from Europe to China and in the Americas.	Indigenous to southern China and Japan; widely cultivated elsewhere, especially in Southeast Asia.
Form traded internationally:	As dried stigmas.	
World production of raw material:	Unknown.	Unknown but much greater than international trade.
International Trade:	Possibly 50 tonnes/annum of saffron.	Unquantified but small.
Major exporters:	Spain, Iran in the first rank. India in second rank.	China.
Major importers:	Gulf and Middle East states.	Far East and Southeast Asian countries.
Availability of reliable published information:	Good.	Poor.

DESCRIPTION AND COLOURANT USES

Crocin extract is the trade term for the yellow, water-soluble food colourant obtained from cape jasmine (*Gardenia jasminoides* L.) and from saffron (*Crocus sativus* L.). However, the extracts are not used interchangeably in all applications since saffron is valued as much for its aroma and flavour as for its colouring properties and, moreover, it is the world's most expensive spice/colourant.

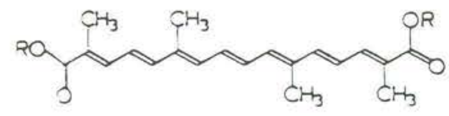
Saffron is the dried stigma of a crocus which originated in Greece and Asia Minor but which is now widely cultivated in a band from Western Europe through temperate and sub-tropical Asia to China. Saffron has been used as a spice from ancient times in the Mediterranean and from the Middle Ages it achieved great popularity throughout Europe with commercial cultivation being undertaken in several northern Europe countries until the eighteenth century. The spice is an essential ingredient for the preparation of many southern European regional dishes, such as paella (rice, meat, fish and vegetables) and arroz con pollo (rice and chicken) in Spain and bouillabaisse (fish and shellfish stew) in France. Other traditional applications for saffron in Europe include bakery products and sugar confectionery. Saffron extract is widely used in the food industry today for top-of-the-range products at typical dosage levels of 0.1 to 0.2% (weight for weight) to impart a characteristic flavour, along with a water soluble and heat stable yellow colour. In the European Community, saffron extract does not have an "E number" and falls into the category of "natural extracts".

Gardenia jasminoides. 1) flowering branch; 2) fruiting branch.

Cape jasmine (*Gardenia jasminoides* Ellis) is an evergreen shrub which originates from southern China and Japan. It is now widely cultivated in the tropics and sub-tropics, particularly in Southeast Asia both as a garden ornamental and as a source of a yellow food colourant. The pigments are contained in the fruit, which is used in the Far East either directly or after drying in a wide range of dishes and as a tea infusion. In recent years, usage of the extract has developed in the processed food industries in Western Europe as a less expensive colourant substitute for saffron in applications where the latter's flavour is not required. It is usually sold under the name of "crocin extract". Typical dosage levels of the extract in confectionery and bakery products range from 0.05 to 0.1%, while fish products in brine may contain up to 1.5%. In the European Community, the extract of cape jasmine fruit is described as a "natural colour" and it does not have an "E number".

Crocus sativus. From *Prosea* No. 3 "Dye and tanning-producing plants".

The major yellow pigment present in both saffron stigmas and cape jasmine fruits is crocin, the gentiobiose form of the carotenoid crocetin. In addition to the **crocins**, cape jasmine fruits contain iridoid and **flavanoid** pigments. The aroma of saffron arises **from a** volatile aldehyde, safranal, which is produced **during** processing from picrocrocin; the latter is responsible for the bitter taste of saffron.



R = gentiobiose ... crocin
R = H ... crocetin

WORLD DEMAND AND SUPPLY TRENDS

The international market for saffron was dominated by Spain up until the recent period owing to the volume and quality of its production. Today, Spain retains its position as the supplier of the best quality material but the high costs for the labour-intensive harvesting have reduced annual output from around 60 tonnes in 1970 to below 20 tonnes in the early 1990s. The main beneficiary has been Iran while smaller volumes are exported regularly by India (around 10 tonnes), some Mediterranean and South American countries.

Quantification of the international trade in saffron is made difficult by the shortcomings in the statistics of many countries. Total annual trade is perhaps 50 tonnes, with Western Europe, North America and the Gulf States as the major markets. Japan and South American countries are also significant, if smaller, consumers. The principal supplier to all markets, excepting the Gulf States, is Spain but it also imports Iranian and Indian material which, presumably, re-enters trade under a Spanish label. Annual import levels for individual countries fluctuate in response to availability and prices; the USA, for example, took 3 tonnes in 1992 and this level rose to 8.3 tonnes in 1994.

Prices for saffron undergo significant swings and over the period 1980 to 1994 the New York spot market price for Spanish material moved between US$ 574 to 1,304 per kg; peaks were in 1980 and 1988-90 and troughs occurred in 1985 and 1994. Iranian and Indian material is highly discounted in price, reflecting the poorer quality when compared to that of Spanish saffron.

No detailed information is available on the breakdown of usage of saffron between direct incorporation in foods and in the form of its extract in the individual developed country markets. However, extract usage can be expected to be higher in countries such as the United Kingdom and the USA than in France and Spain.

It is likely that saffron cultivation will decline further in Spain along with the adoption of more remunerative crops and the drift of labour away from rural areas. This might provide an opportunity for the entrance to the market of new, low cost producers, provided that attention is paid to product quality.

No reliable production data are available on **cape jasmin fruits** but the volume is believed to be substantial in Southeast Asia and the Far East. Interest in the extract as a colourant by the Western European food industry has grown in recent years since it is one-tenth of the cost of saffron and does not have a strong flavour. However, current consumption is small. The extract is mainly sourced from China.

The level of usage of saffron and its extract in traditional saffron dishes in Western Europe and North America is expected to remain stable and perhaps to grow modestly along with the processed food industry. The future growth prospects for cape jasmin fruit extract in these markets will depend to a large extent upon trends in food legislation. As a non-traditional food additive, it is possible that cape jasmine extract may need to undergo costly toxicological testing before receiving approval as a natural colour for use in foods.

CULTIVATION AND PROCESSING

Saffron

Crocus sativus L. is a perennial which resembles the purple spring crocus but blooms in the autumn. It is adaptable to a wide range of climates from the temperate to the sub-tropical and on soils varying from sandy to well-drained clay loams. Most commercial production areas may be described as dry and in Spain the rainfall rarely exceeds 400 mm per year. Two heavy rainfalls are sufficient, one in the spring and the other in the autumn.

Propagation is by means of corms; these are produced annually by the mother corm which withers away and feeds the young cormlets. A plot of saffron is usually cultivated for four years before replanting with selected, disease-free corms. Planting is undertaken in the late spring on well-cultivated land which has been treated with compost and, where necessary, adequately limed. Typical spacing distances are 10-25 cm in double rows in trenches.

Cultivation in the first year is restricted to weeding and turning the top soil between rows in September before the plants sprout. After the harvest in October, the soil between rows is dug again and manuring may be repeated. The leaves are removed in the following April or May and these are often dried for use as winter fodder for animals.

Harvesting spans four to six weeks in the autumn. Each plant only flowers for about fifteen days and harvesting, therefore, must be timely. Intact flowers are picked and this is done early in the morning to prevent withering. On the same day the stigmas must be removed from the harvested flowers and drying be initiated.

Fresh stigmas are odourless and the characteristic aroma develops only after stimulation of enzymatic action during the drying operation. Slow, sun-drying invariably results in a product of poor flavour quality and appearance. Careful artificial drying provides a superior product and in Spain various techniques are employed, including revolving drum driers.

Yields of flowers vary considerably according to local site conditions. On average, however, about one hectare yields one million blooms, weighing approximately 800 kg, which provide 50 kg of fresh stigmas and 10 kg of dried saffron.

Grading involves classifying dried stigmas by length, colour, aroma and freedom from extraneous matter. Spanish saffron grades range from "very select" with stigma lengths of over 30 mm and a style of 23-24 mm to "ordinary" with a stigma length of 20-24 mm.

Saffron extract is usually prepared by treatment with aqueous alcohol, followed by careful concentration. Approximately 140,000 stigmas are required to produce 1 kg of extract.

Cape Jasmine

Gardenia jasminoides Ellis originates from temperate areas but grows well in the tropics at altitudes above 400 m. It requires an open sunny position on well-drained soils and prefers a soil pH of 6 to 7.

Propagation is usually undertaken with cuttings or by marcotting. Flowering may commence one year after field establishment.

For manufacture of the extract, fruits are first dried and are then extracted with aqueous alcohol. Crocin yields of up to 10% have been reported for dried fruit.

Patents have been published on extraction methodology and subsequent treatment with proteases or beta-glycosides to produce a range of colours.

OTHER USES

Saffron was employed as a textile dye prior to the advent of coal tar based synthetics. Additionally, it plays a role in traditional Indian medicine and, formerly, was used in Europe for treatment of various disorders.

Cape jasmine fruit are employed on a small-scale for craft-dyeing in the Far East and several parts of the plant are employed in traditional medicine. The plant is widely grown as an ornamental.

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INDIGO

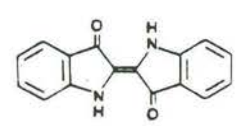
SUMMARY OF BASIC INFORMATION

Usage:	Blue dyestuff for textiles.
Common name for product:	(Natural) indigo dye; Indian indigo.
Raw material source:	Leaf and stems of cultivated perennial shrubs.
Botanical source:	*Indigofera* spp. (family: Leguminosae), especially *I. arrecta* Hochst. and *I. tinctoria* L.
Common name for botanical source:	*I. arrecta* - Natal indigo; *I. tinctoria* - Indian indigo.
Distribution:	Widespread through Asia, Africa and the Americas.
Form traded internationally:	Solid or powdered extract.
World production:	Data unavailable.
World trade:	Small, possibly 50 tonnes/year.
Exporters:	India and possibly some others.
Importers:	Western Europe, North America, Japan.
Availability of reliable published information:	Fair.

DESCRIPTION AND DYESTUFF USES

Indigo is one of the most ancient blue dyes used by man for textiles. The pigment is present in the leaves of a number of *Indigofera* species, of which the Asian *I. tinctoria* and the African *I. arrecta* have been the most important for commercial production.

The major pigment, indigo, obtained from *Indigofera* species is identical to that of woad (*Isatis tinctoria*), the body-paint of the Ancient Britons. The indigo dyestuff is not present in the living plants but is formed post-harvest by hydrolysis of indican glucoside to indoxyl which is then subjected to oxidation. It is one of the few natural dyestuffs whose fastness properties are not improved by mordanting.



indigo

WORLD DEMAND AND SUPPLY TRENDS

Indian indigo (from *I. tinctoria*) became available in Europe in the twelfth century but encountered major opposition from the woad growers of England, France and Germany until the sixteenth century. Thereafter, indigo achieved dominance over woad owing to the combination of its higher dyestuff content, lower cost, the opening of the sea route to India and, somewhat later, by the development of plantations in the Americas.

Prior to the manufacture of synthetic indigo at the end of the nineteenth century, natural indigo was probably the most widely used natural dyestuff in the textile industry and had particular importance for wool. However, the market share of the natural product fell to 4% by 1914. For India, the cultivated area and annual dye production in the 1890s were around 0.6 million ha and 3,000 tonnes, respectively, while the figures in the 1950s were 4,000 ha and 50 tonnes.

Today, indigo is still cultivated in India, parts of Southeast Asia and Africa. It is employed locally in craft dyeing (batik production, etc.) and there is a small export trade. Some recent resurgence of interest in natural indigo has been shown in the West European and North American markets for use with denim fabrics where the "faded look" is fashionable. As yet, however, this has not resulted in any clear upturn in international trade; for example, India's exports over 1988-93 show an erratic fluctuation between 2 and 20 tonnes rather than a steady growth.

There have been reports, also, of the development in the USA of a bio-technological method for the production of "natural indigo" from bacteria but its impact on the market is not yet clear.

CULTIVATION AND PROCESSING

Soil and Climate

Most of the commercial *Indigofera* species are adaptable to a range of climates in the tropics and warmer areas of the sub-tropics but display differing performance. Growth is best on permeable soils which are rich in organic matter.

Propagation and Husbandry

Multiplication is usually by means of seed and pre-soaking in water can assist germination. Field spacing of plants is dependent upon the species and its growth characteristics, but 50-60 cm spacing is common.

Indigofera tinctoria. Flowering branch. From *Prosea* No. 3 "Dye and tanning-producing plants".

Husbandry involves little more than irrigation of young plants, when necessary, and weed control between planting and harvest(s).

While *Indigofera* species are perennial shrubs, the economic lifetime varies between 1 and 3 years according to the species and local conditions. The first harvest is taken at three or four months from sowing and this involves cutting the stems 10-20 cm above ground level. Under favourable conditions, three crops may be obtained per year.

There is a paucity of reliable information in the literature on crop yields for the various species. However, *I. arrecta* is regarded as much superior to *I. tinctoria* and the former has largely supplanted the latter in India. *I. arrecta* is reported to provide between 130 to 325 kg/ha year of indigo extract.

Processing

Freshly cut leaf, usually with stem attached, is subjected to extraction as soon as possible after harvesting. The operation involves soaking the fresh material in water for 10-15 hours during which fermentation of the indican glucoside occurs. The liquid is then run off and is aerated to achieve oxidation. After a settling period, the sludge of indigo is separated and is then dried into a cake.

Dyeing is carried out in vats containing alkali as a solubilising agent and with a reducing agent present. The textile is dipped into the vat and is then dried in the air; the blue colour of the textile develops during the final stage.

OTHER USES

Parts of *Indigofera* species have been used throughout the tropics in traditional medicine and some attention has been given in recent years to their potential in modern medicine.

In some areas, the plants are used as a cover crop and a green manure.

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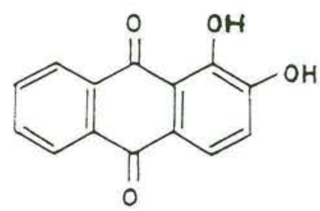
MADDER

SUMMARY OF BASIC INFORMATION

Usage:	Red dye for textiles.
Common name for product:	Madder.
Raw material source:	Roots of a cultivated perennial, climbing herb.
Botanical source:	*Rubia tinctoria* L. (family: Rubiaceae).
Common name for botanical source:	European madder.
Distribution:	Indigenous to Europe and Asia Minor. Introduced to India and elsewhere.
World production and trade:	Undocumented; certainly small.
Availability of reliable published information:	Fair.

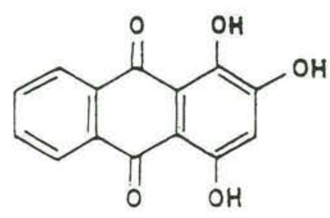
DESCRIPTION AND DYESTUFF USES

The madders are perennial, climbing herbs with a wide geographic distribution and the roots of certain species have been exploited as the source of a red dyestuff for textiles since ancient times. Amongst the Asian species, Indian madder (*R. cordifolia* L.) has a long history but European madder (*R. tinctoria* L.) was the most important for commercial production and this was introduced to India as a superior dyestuff source.



alizarin

The major pigments obtained from European madder are the anthraquinones alizarin and purpurin, but isolation requires the prior hydrolysis of the glucoside precursor in the roots. Indian madder mainly yields purpurin.



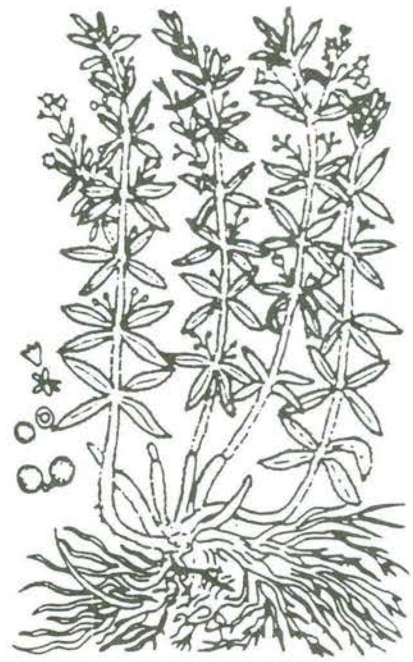
purpurin

Alizarin gives an intense red colour on conversion to an insoluble lake by the addition of alum and alkali. Depending on the mordant used, the colour shade can be modified through red, pink, orange, lilac and brown. The importance of madder as a red dyestuff for textiles, especially with cotton and linen, expanded upon the adoption of the "Turkey red" process in which calcium is incorporated in the pigment complex. However, alizarin was amongst the first dyes to be synthesised in the second half of the nineteenth century and the natural material was rapidly displaced from the market.

World Demand and Supply Trends

Small-scale production of European madder is still carried out in Kashmir in India and, possibly, elsewhere. In India, the natural dyestuff is employed for craft dyeing and there is a very minor demand for craft dyeing and artists' paints in Western Europe and North America.

No significant resurgence in usage is foreseen since synthetic alizarin in most applications is superior and cheaper than madder.



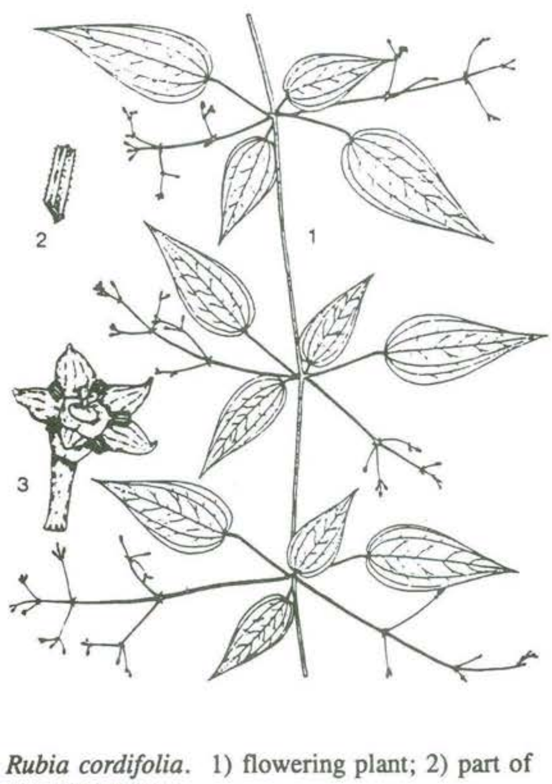
Madder (*Rubia tinctoria*).

Cultivation and Processing

R. tinctorium is adaptable to temperate and sub-tropical climates and prefers moist, limey soils. Propagation is usually by means of buds or sets from the rootstock at about 1,400 kg/ha. Alternatively, it may be grown from seed, using about 60 kg/ha.

Husbandry involves weeding and providing support for the climbing aerial parts. Harvesting of the roots is undertaken at an age of two or three years and this is normally done around the flowering period when the pigment content reaches a maximum.

After harvesting the roots are washed and dried. The pigment glucoside content ranges from 2 to 3.5% in the dried roots. Soaking the roots in water promotes release of the dye by hydrolytic fermentation.



Rubia cordifolia. 1) flowering plant; 2) part of stem; 3) flower.

Other Uses

Rubia species play a role in traditional medicine in Asia and may be used as a cattle fodder. In the latter application, however, the pigmented species can cause discolouration of the animal's milk.

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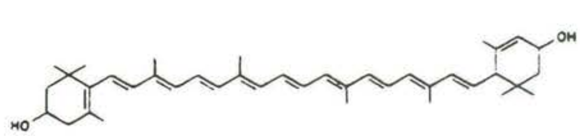
MARIGOLD (TAGETES)

SUMMARY OF BASIC INFORMATION

Usage:	(a) Major - yellow colourant additive to poultry feed; (b) minor - colourant for human foodstuffs.
Common names for products:	(a) "Marigold meal" and "Aztec marigold" for the dried, powdered flowers; and (b) "marigold extract" for the solvent extract of the flowers.
Raw material source:	Flowers of an annual herb.
Botanical source:	*Tagetes erecta* L. (family: Compositae).
Common name for botanical source:	"Aztec marigold" in the Americas; "khaki bush" in Africa.
Distribution:	Indigenous to Mexico, Central America and the Western Andes of South America. Widely introduced elsewhere in the world.
Form traded internationally:	(a) The dried flowers (marigold meal), (b) organic solvent extracts, usually suspended in vegetable oils.
World production and trade:	Unquantified; perhaps equivalent to 6,000 tonnes of meal.
Major exporters:	Mexico and Peru.
Major importers:	Mexico, Western Europe (especially Spain) and North America.
Availability of reliable published information:	Moderate to fair.

DESCRIPTION AND COLOURANT USES

The common term "marigold" embraces a diversity of plants with golden flowers, including the *Tagetes* species of the Americas. The latter have been widely introduced throughout the world, some purely for decorative purposes and others for industrial use. For example, *T. glandulifera* Schrank and *T. minuta* L. are cultivated in southern Africa and India — in addition to South America — for the production of "Tagetes oil", an essential oil employed by the international perfumery industry; world demand for this oil is about 10 tonnes annually.



lutein

Another species, *T. erecta* L. or "Aztec marigold" provides an important yellow colourant from its flowers. This is produced on a significant scale only in the Americas. The principal pigment in the flowers is the xanthophyll, lutein, which is present in the form of esters of palmitic and myristic acids.

The principal use of Aztec marigold is as an additive, either in the form of the dried flower meal or as a solvent extract, to poultry feed in order to enhance the yellow colour of the flesh and the yolks of eggs.

There is a minor usage of the extract as a food colourant in Western Europe in products where a yellow colour is required, together with stability to heat, oxidation and SO_2. Typical applications include: salad dressings, ice cream, dairy products and other foodstuffs with a high fat content, soft drinks, bakery products, jams and confectionery. The pigment is usually supplied as a liquid extract on an edible vegetable oil carrier at a concentration of 5 to 12% lutein and recommended dosage levels range from 0.05 to 0.8% (weight for weight) according to the application. Dispersed, powdered forms of the extract are also available. Although naturally derived lutein is embraced within the E161 classification in the European Community, marigold extract has not been assigned an "E number" and is traded as a "vegetable extract". It competes with lutein extracted from alfalfa grass.

Marigold extract is not currently approved for use as an additive to human foods in the USA.

World Demand and Supply Trends

Marigold meal is produced principally in Mexico, Peru, Ecuador, Argentina and Venezuela. More recently, smaller-scale producers include South Africa and Zambia. Apart from Peru, statistics on production and international trade in the meal and its extract are scanty and unreliable. However, total trade is probably equivalent to many thousand tonnes of meal annually. Peruvian exports alone were up to 3,000 tonnes of meal a year in the mid- to late 1980s.

There is a large trade within Latin America itself where marigold is widely employed in poultry feed. Mexico imports substantial quantities in order to supplement its domestic production and the needs of its extraction industry.

Other principal importers are North America and Western Europe, both in the form of meal and extract. The usage in the USA and in the major European importing countries, Spain and Portugal, lies in poultry feed. Elsewhere in Europe, the preference is for white chicken meat and yellow colour enhancement of egg yolks is most frequently achieved by incorporation of permitted synthetic dyestuffs in the feed.

The principal producer of the extract is Mexico with smaller-scale processing in Peru and some of the major import markets. South Africa and Zambia plan to produce the extract for the export market in the near future.

Usage of marigold extract as a colourant for human foodstuffs in Western Europe is presently very small. Total consumption by this sector of lutein pigments from all sources (marigold and alfalfa) has been recently estimated as less than 1 tonne a year. Any growth of food usage in developed countries will depend on trends in legislation and, specifically, a requirement for costly toxicological testing before being approved as a natural colour. Also, marigold's quality/price competitiveness with other natural lutein sources will be a significant factor in future usage.

CULTIVATION AND PROCESSING

Cultivation

T. erecta is an annual herb which prefers a warm, low humidity climate and grows well up to 500 m in the tropical Andes. Propagation is by means of seed and plant spacings are typically 20 cm x 90 cm.

Flowering commences 90 to 100 days from field establishment and harvesting of fully developed flowers is carried out regularly throughout the season.

Harvested flowers are sun- or shade-dried, depending upon facilities available and are then reduced to a powder prior to packaging for sale. Yields of meal in Peru have been reported as 1,000-1,200 kg/ha.

Extraction

Hexane is the most commonly used solvent for extraction. Prior to sale, the concentrate of the extract is either mixed with an edible vegetable oil or, when destined for poultry feed, it may be mixed with soya or corn meal. Anti-oxidants may be added to these products; the choice being dependent upon the end-use and permitted list in the end-market.

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PAPRIKA

SUMMARY OF BASIC INFORMATION

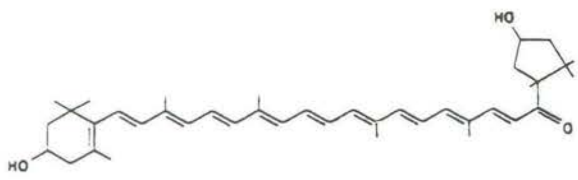
Usage:	(a) As a spice; (b) as an orange-red food colourant.
Common names of products:	(a) Sweet paprika; the powdered dry spices; (b) paprika oleoresin; the concentrated, solvent extract of the colour and flavour.
Raw material source:	The fruits of an annual herbaceous plant.
Botanical source:	Specific varieties of *Capsicum annuum* L. which have large, fleshy, intensely red coloured fruit and possess no pungency.
Common name for botanical source:	Paprika; sweet red pepper.
Distribution:	Widely cultivated throughout the world.
World production:	(a) Paprika - 45,000 tonnes (estimate) (b) paprika oleoresin - 1,000 tonnes (estimate).
World trade:	(a) Paprika - 30,000 tonnes (estimate) (b) paprika oleoresin - 700 tonnes (estimate).
Major exporters:	Spain, Hungary and Morocco.
Major importers:	Western Europe, North America, Eastern Europe and Japan.
Availability of reliable published information:	Good.

DESCRIPTION AND FOOD COLOURANT USES

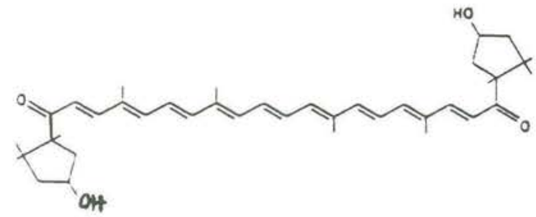
Paprika is obtained from the fruits of selectively bred varieties of "sweet peppers", *Capsicum annuum* L. The fruits are large, fleshy with an intense red colour and are devoid of, or contain very little of, the pungent ("hot") capsaicinoid compounds which characterise most other species and varieties of *Capsicum*. In commerce, paprika is always a dried, ground product but a small international trade between growers and grinders does exist in dried, unmilled fruit pods. Products termed "hot paprika" are marketed but these are strictly variants of the UK's "chili powder" and the "red pepper" of the USA in which a high colouring power is combined with a mild pungency.

While being a source of red-orange colouring in culinary applications, sweet paprika also possesses a distinctive, much appreciated aroma and flavour and it is classified as a spice. Paprika plays an important role in the cuisine of Spain and Hungary (e.g., Hungarian goulash); the two European countries where production of the variety developed on a major scale following the introduction of *Capsicum* species from the Americas in the sixteenth century.

The pigments present in paprika are a mixture of carotenoids, in which capsanthin and capsorubin dominate. These are oil-soluble, stable to heat and pH variation but deteriorate in light.



capsanthin



capsorubin

Extraction of paprika with organic solvents provides paprika oleoresin which is a concentrated form of the pigments and the flavour. The oleoresin is employed as an alternative to the spice in the industrial preparation of sausages, meats, soups and pickles and in other savoury products, such as snack foods and breadcrumbs. The presence of the flavour in most commercial oleoresins restricts the scope of application as a food colour in a number of other products, e.g., confectionery and desserts. The colour imparted by the oleoresin ranges from red to orange, depending upon the concentration used. Commercial oleoresins are available in strengths ranging from 40,000 to 100,000 ASTA (American Spice Trade Association) colour units; the strongest type has a pigment content of approximately 10%. The oleoresins are oil-soluble and normally are sold as solutions in edible vegetable oil. Water-miscible forms of the oleoresin are also available and these incorporate polysorbates or are emulsions with gum arabic.

Paprika extract/oleoresin is listed by the European Community as a natural colour which is permitted for use in foods and it has been assigned the number E160(c). In the USA, paprika oleoresin is also included in the Food and Drug Administration's list of approved natural colours for incorporation in foods and beverages.

WORLD DEMAND AND SUPPLY TRENDS

Paprika is a spice with very specific geographical markets, namely Eastern and Western Europe, the Mediterranean, North America, Argentina and Chile. Elsewhere in the world, demand is for the pungent or "hot" types of capsicums (i.e., chillies).

Accurate assessment of the world production and trade in both paprika and its oleoresin is plagued by problems of the classification systems employed in official statistics. In the case of the spice, paprika, it is usually combined in export and import statistics together with pungent capsicums (chillies), frequently with allspice/pimento, and occasionally with pepper. Paprika oleoresin is similarly combined with other spice oleoresins in published trade statistics for many countries. It is only in the USA import data that paprika and its oleoresin are distinctly identified.

The size of the international trade in paprika in the late 1970s was estimated as somewhat in excess of 30,000 tonnes per annum with Spain and Hungary as the major exporters and Bulgaria, Yugoslavia and Morocco as significant secondary sources. Western Europe was the largest market, accounting for around 50% of world imports. At that time, USA imports were of the order of 4,000-5,000 tonnes annually which was much less than its domestic production of paprika. Additionally, world paprika oleoresin production was estimated as between 400-500 tonnes annually, of which the bulk was manufactured within the major paprika growing countries (Spain, USA and Hungary). Total world production of paprika in the late 1970s, therefore, was probably around 40,000 tonnes per annum.

In the subsequent period, there has been a global growth in the consumption of both paprika and its oleoresin, together with an increase in the number of suppliers. Western Europe remains the largest import market with a demand for paprika approaching 20,000 tonnes annually in the early 1990s. Notably also, Spain has commenced to import significant volumes of paprika from diverse sources to supplement its domestic production and to maintain its dominant role in the global trade. Imports of paprika by the USA in the same period were around 4,000 tonnes annually with Spain and Morocco as its major suppliers. Total paprika consumption in the USA now appears greater than that of Western Europe on summing imports and domestic production. Other significant scale markets for paprika include Japan and a number of Eastern European and North African countries.

The USA is a major producer of paprika oleoresin but also has imported 300-400 tonnes annually in the first half of the 1990s, sourcing mainly from Spain and Morocco. Western European consumption of paprika oleoresin is difficult to quantify but is very substantial. The best possible educated guess at global demand for paprika oleoresin in the mid-1990s is 1,000 tonnes or more annually.

The past decade has seen the development of production of paprika and its oleoresin outside the "traditional" areas of Europe, the USA and North Africa. New suppliers to the market include Mexico, Chile, Argentina, Peru, Ethiopia, South Africa, Zimbabwe, Zambia, Malawi, Israel and India.

Production of paprika in Southern Africa averaged 20,000 tonnes annually over 1992-1994 and the installed processing capacity in the region in 1995 was around 250 tonnes of oleoresin per annum.

While the market has expanded and there have been some recent production problems in Spain and Hungary, it is possible that the future will see a period of increasing competition between producers and perhaps a significant change in the relative importance of individual sources.

Paprika prices displayed a growth trend during the 1970s. Spanish material on the New York market moved from US$ 0.8/kg to US$ 1.8/kg (cif) and stabilised at the latter price for a couple of years. The more recent period has seen rather greater price swings with average annual New York prices (cif) for imported paprika declining from US$ 2.0/kg to US$ 1.45/kg over the three years 1992-1994. The average annual unit value (US$/kg) of imported paprika oleoresin on the New York market over 1992-1994 fluctuated from 41.5 to 36.1 and then up to 47.4. For both paprika and its oleoresin, there is a significant differential in price according to its quality as judged primarily on its colouring power and tone.

CULTIVATION AND PROCESSING

Climate and Soils

Traditionally, paprika is a summer, annual crop of continental temperate and sub-tropical, and Mediterranean climates. However, some varieties may be grown in tropical climates.

Temperatures of 15-24°C are preferred, together with limey, well-drained, loam soils. It is usually a rainfed crop in areas with 60 to 1,250 mm of rainfall per year.

Propagation, Husbandry and Harvesting

Plants are raised from selected seed and care must be taken in the choice of the appropriate cultivar, both for end-product quality and field performance. Most European cultivars do not translate well to tropical conditions. Additionally, seed propagation nurseries in the tropics must be sited well away from any cultivation of pungent chillies since *Capsicum* species readily cross-pollinate. If this occurs, the new generation paprika strain would deteriorate in quality by acquiring pungency and losing colour power.

Field spacing is commonly 0.5 m x 1 m and weeding is an important activity in the early phase of husbandry. The interval between sowing and the first fruit setting is usually three months and harvesting can span 3 months.

Fruits are picked individually when they reach maturity, i.e., fully coloured and either still succulent or just beginning to wither. They are then dried either in the sun or by artificial methods. For sun-drying, the fresh fruits are usually cut open prior to spreading on a clean surface or to hanging in string bags. Achievement of the dry state (10-12% moisture content) can take between 8 to 15 days in the sun. Artificial drying is performed at 60-65°C on sectioned or diced fruits.

Yields of dried pods range from 2.5 tonnes/ha under rainfed conditions to 6 tonnes/ha or more with irrigation and careful management.

Exporters of unprocessed paprika first separate the seed, calices and peduncles from the dried pods. The pods are then compressed and bagged for shipment in containers.

Production of Paprika Powder

Only the pericarps and seeds are used to produce the paprika of commerce; placental tissue, calices and peduncles are discarded. The pericarp and seed are separated and each are washed since this assists removal of any pungent capsaicin which has migrated from the placental tissue.

Colour of the end-product is influenced by the content of seed mixed with the pericarp prior to grinding. "Select", bright red qualities of paprika contain no more than 10% seed while "ordinary" qualities contain up to 30% seed and possess a brick-red colour.

The paprika is sold by grade quality, as judged visually and objectively on the American Spice Trade Association (ASTA) colour scale. Shipment is in cardboard drums, lined with a polythene bag.

Oleoresin Processing

Extraction of paprika is undertaken with conventional spice oleoresin equipment, either on a batchwise or a continuous process, and employing an organic solvent (normally hexane). Extracts are concentrated and yields range considerably from about 5 to 12%, depending on the raw material quality and the solvent used.

Extracts are blended prior to sale to provide a standardized colouring power on the ASTA American Spice and Trade Association) scale.

A unique process is employed in Ethiopia as a matter of expediency since the raw material feedstock is not sweet paprika but an indigenous, highly pigmented but pungent capsicum. The extract is subjected to countercurrent treatment between apolar and polar solvents and the pigments separate into the former while the capsaicinoids are taken up by the latter.

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SAFFLOWER

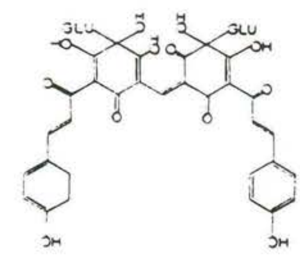
SUMMARY OF BASIC INFORMATION

Usage:	(a) Formerly as a red dyestuff for textiles; and (b) currently as a minor colourant by the food industry.
Common name for product:	Safflower; dyer's saffron.
Raw material source:	The florets of a cultivated, annual herb.
Botanical source:	*Carthamus tinctorius* L. (family: Asteraceae).
Common names for botanical source:	Safflower; bastard saffron; false saffron; dyer's saffron; distaff thistle; dyer's thistle.
Distribution:	Widespread through tropics and sub-tropics.
Form traded internationally:	Dried florets.
World production and trade:	Small, unquantified.
Major exporters:	India, Pakistan and China.
Major importers:	West European countries.
Availability of reliable published information:	Limited on the dyestuff/colourant; good on the seed and its oil.

DESCRIPTION AND DYESTUFF/COLOURANT USES

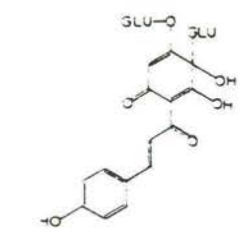
Safflower (*Carthamus tinctorius* L.) is an annual herb which is well adapted to semi-arid conditions in the tropics and sub-tropics. It is a thistle-like plant with a deep taproot, growing up to 120 cm high, with a branched stem and a flower head at the end of each branch.

The florets contain three major pigments, all of which are present as chalcone glucosides: the water-insoluble scarlet-red carthamin and the water-soluble "safflor yellow" A and B. The latter pigments are deliberately removed by water washing in the traditional primary processing of the florets in order to provide the desired, red raw material for dyeing/colourant usage.



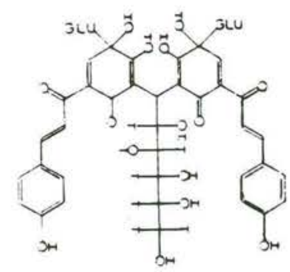
carthamin

Safflower was formerly employed, as its synonym "dyer's saffron" implies, as an inexpensive substitute for saffron in textile dyeing. The term "red tape" originates from the use of safflower to impart a pink-red colour to the tape employed to bind legal documents. The colour tone can be varied according to the mordant used through pink, red, rose, crimson to scarlet.



safflor yellow A

Today, dyestuff usage of safflower is limited to traditional applications in countries such as India. It is offered as a food colourant in some developed countries under the description of a "natural vegetable extract". Toxicological clearance has not yet been secured in the European Community for assignment of an "E number" as an approved natural colourant; nor is it listed under the US Food and Drug Administration's permitted list of natural colours for foods and beverages.



safflor yellow B

The major purpose of cultivating safflower globally is for the production of its seed and further processing to its edible fatty oil. The latter is a highly regarded, polyunsaturated type and receives a premium on the world market.

WORLD DEMAND AND SUPPLY TRENDS

Safflower is widely grown through the tropics and sub-tropics as an oilseed crop and production of seed is estimated to range between 0.8 and 1.0 million tonnes annually. The major oilseed producers in descending order of importance are Mexico, India and the USA. International exports of safflower seed oil are dominated by the USA and Australia. Literature on this subject abounds.

By comparison with the oilseed product, cultivation for the florets as a dyestuff/colourant raw material today is a very minor activity which is poorly documented. India is probably the main source but its export statistics reveal annual shipments of no more than 15 tonnes between 1988-93.

As with a number of other natural colourants, interest in safflower has been expressed by some sectors of the food industries in developed countries in recent years. However, the extent of future usage will depend on the ultimate, legislative requirements for safety clearance of new food additives, especially as a food colour where high dosage may be necessary to achieve the desired colour. The perceived comparative advantage of safflower over competing materials in specific applications will be a factor also. Any growth in demand probably could be readily served by existing producers in Asia.

Safflower (*Carthamus tinctorius*).

Cultivation and Processing

Cultivation Requirements

Safflower can be grown in a wide range of ecological conditions between 30-45° north and 15-35° north. However, it is generally regarded as a semi-arid region crop and is often grown in rotation with wheat or cotton in the winter-spring period. Growth performance is best on neutral to alkaline soils which are well-drained and fertile. Rainfed culture is common but irrigation provides the highest yields.

Propagation is by means of seeds. In rainfed arid environments, seeding rates are 8-10 kg/ha while 15-20 kg/ha may be used under irrigated conditions. Weeding is important to ensure high yields.

There are many varieties of safflower and in India a distinction is made between those with spinous leaves and the comparatively spineless. The latter type are considered superior for dyestuff/colourant production.

The first florets are removed immediately after their appearance in order to encourage branching and the formation of additional florets. Harvesting of the florets must be carried out regularly, usually every second or third day, in order to obtain fully opened flowers but before withering and seed formation occurs. Drying is undertaken in the shade to prevent light degradation of the pigments. Dried floret yields in India have been reported as 50 to 75 kg/ha.

Processing of the Dyestuff

The traditional Indian method of processing the dried florets commences with removal of the water-soluble yellow pigments. This involves repeated washing in acidulated water over several days. The water-washed florets are dried, often being compressed into a cake prior to sale. For dyeing or colourant use, this material is treated with aqueous sodium carbonate and the extract is acidified to yield a precipitate which is sold as a paste. The content of carthamin in Indian safflower florets has been reported to range from 0.3 to 0.6%.

Improved methods for extraction of carthamin from safflower and of alternative production by tissue culture have been reported in recent years, mainly by Japanese researchers.

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TURMERIC

SUMMARY OF BASIC INFORMATION

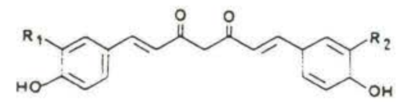
Usage:	(a) As a spice; (b) as a yellow colourant for foodstuffs.
Common names for the products:	(a) Turmeric or curcuma for the spice; (b) turmeric oleoresin for the concentrated extract; (c) "pure curcumin" for the refined oleoresin, free of volatile oil.
Raw material source:	The rhizomes, particularly the "finger" side-growths of a perennial herbaceous herb.
Botanical source:	*Curcuma domestica* Val. (syn. *C. longa* Koenig *non* L.; family: Zingiberaceae).
Common names for botanical source:	Turmeric; curcuma.
Distribution:	Widespread throughout the tropics.
Product forms traded internationally:	Whole and powdered spice; the oleoresin and "pure curcumin".
World production:	Not quantified for the spice but possibly tenfold or greater than international trade.
International trade:	(a) 15,000-20,000 tonnes per annum for the spice (b) 100-150 tonnes for the oleoresin.
Exporters:	India (dominant), China and numerous smaller suppliers in Asia, Latin America and some in Africa.
Major importers:	Iran, North America, Western Europe and Japan.

DESCRIPTION AND COLOURANT USES

Turmeric is a small perennial herbaceous plant with a tuber, bearing many rhizomes or "fingers" which are aromatic and pigmented yellow orange-red. The plant originates from the Indian sub-continent and possibly neighbouring areas of Southeast Asia but it is now widely grown throughout the tropics as an annual. The usage today is as a spice and a food colourant but it was formerly employed also as a yellow dyestuff for textiles.

The turmeric of commerce consists of the dried finger rhizomes and these vary in size from 2.5 to 7.5 cm in length and possess a diameter of approximately 1 cm. Breaking the dried fingers reveals a pigmented interior which can range in colour from yellow to reddish-orange, depending upon the pigment content (2 to 7% in commercial material). The rhizomes contain also a volatile oil with a characteristic aroma and flavour which varies in abundance according to the cultivar. Good commercial turmeric has a 1:1 ratio of oil to pigment (weight for weight).

Three principal pigments are present in the rhizomes: curcumin, desmethoxycurcumin and bis-desmethoxycurcumin; these are collectively known as curcuminoids. They are found also in other *Curcuma* species.



R1	R2
OCH_3	OCH_3 ... curcumin
OCH_3	H ... desmethoxycurcumin
H	H ... bis-desmethoxycurcumin

As a spice, turmeric is valued for the combination of flavour and yellow colouring power. It is an essential ingredient of many curry recipes and it is in this application that usage is greatest on a global basis. Colouring of rice, usually as an inexpensive alternative to saffron is another widespread use.

In Western Europe and North America, turmeric is employed for a range of food colouring purposes, notably in mustard. Today, food manufacturers employ the oleoresin of turmeric, the concentrate of the solvent extract, to a greater extent than the powdered spice. The volatile oil content can be reduced in the processing of the oleoresin and this reduces the aroma impact in applications where the primary objective is colouring. "Pure curcumin" (95% curcuminoid content) is also available but this is less frequently used. Applications of the oleoresin and curcumin range from sugar confectionery, ice cream, dry mixes for puddings and drinks and pickles. Colours range from lemon in acidic media to orange in alkalis.

The oleoresin is oil-soluble, while pure curcumin is less oil-soluble and both are insoluble in water. Incorporation of a food grade solvent and emulsifier, usually polysorbate, in the oleoresin provides a water-soluble product.

Turmeric, its oleoresin and curcumin are universally permitted as food additives. In the European Community, curcumin from turmeric is included in the natural colour list as E100 while turmeric and its oleoresin are on the US Food and Drug Administration's approved natural colour list for foods and beverages.

World Demand and Supply Trends

Turmeric is grown widely throughout the tropics and it is not possible to accurately quantify world production since the bulk is consumed domestically rather than entering international trade. In the case of the world's largest grower, India, annual production fluctuates widely but has averaged 390,000 tonnes in the recent period, of which no more than 5% is exported (between 8,000 and 20,000 tonnes from year to year) and this represents the surplus over domestic demand.

The scale of annual world trade for the turmeric spice is estimated as between 15,000-20,000 tonnes while the demand for turmeric oleoresin and pure curcumin is perhaps 150 tonnes. India is the dominant exporter of both the spice and of the oleoresin, supplying 60% or more of the two markets in most years. In the case of the oleoresin, India has effectively captured the market in Western Europe from former domestic processors of the imported spice and only the USA still manufactures a substantial proportion of its oleoresin requirement.

Nevertheless, the USA is India's major market for the oleoresin and takes about 90 tonnes annually.

China is second in the world league as a supplier of the spice while in the third rank there are a number of other countries in the Indian sub-continent, Southeast Asia, the Caribbean and Latin America. None of these are of significance as oleoresin suppliers.

The major world markets for the spice are Iran, Western Europe (especially the UK and Germany), North America and Japan. Numerous other countries are smaller-scale importers.

All of the major markets are characterised by distinct preferences for quality characteristics of the spice. Most prefer the "Madras" type which is yellow coloured and moderately pigmented, containing up to 3.5% of curcuminoid pigments. The best quality of Madras is exported by India, where the name originated, although the Chinese equivalent has gained a high regard in recent years. A second type, known as "Alleppey" turmeric after the port of export of this material in India, is highly pigmented, containing between 4.5 and 6.5% curcuminoid pigments. This is the type of choice for oleoresin extraction and has always been preferred in the USA, where it accounts for 90% of the average annual spice import of 2,000 tonnes. India again is the dominant supplier of the Alleppey type of turmeric, both in terms of volume and the highest quality. Thailand supplies a fair quality Alleppey type material, while highly pigmented but poor colour-tone material is exported by several countries in the Caribbean and South America, notably Jamaica, Haiti and Peru. Japan now imports principally a special Indian quality known as "Rajpuri".

International market prices for turmeric are set by the size of India's crop and the volume available for export. Indian Alleppey turmeric commands a premium over the Indian Madras type in most years and the differential is often a factor of two. On the major market for Alleppey turmeric, i.e., the USA, price differentials are paid also according to the curcumin content over its range from 4.5 to 6.0%. Between 1985 and 1994, New York annual average spot market prices for Indian Alleppey turmeric with a 5.5-6.0% curcumin content fluctuated between US$ 1.2-2.5/kg. In the same period, Thai turmeric of comparable curcumin content was usually discounted by 15% and the discount on Peruvian material was on average 30%. For Madras type turmeric, China has in most years priced well below India in order to increase its market share.

Future market trends are expected to differ according to their geographical location. Demand for turmeric in developed countries is likely to grow only modestly. By contrast, a continual increase in consumption is expected in Asia along with population growth. This could lead to shortages, particularly of high quality material, owing to the present high dependence upon India. While many countries have the potential to expand production to meet any emergent supply gap, the present quality of their products is very mediocre and this is primarily the consequence of intrinsic deficiencies in their planting stock. Success on the market will be dependent first on the introduction of superior cultivars, either Madras or Alleppey types; the former presents the greater market opportunity in terms of scale of demand.

The prospects for new producers of turmeric oleoresins are not great in the medium term in view of the existing competitiveness of the market and the established, dominant position of India. Profitability could be ensured only by operating the equipment at close to maximum capacity by production of a range of spice oleoresins, using high quality raw materials.

Turmeric (*Curcuma domestica*) cultivation, Solomon Islands. (Photo: NRI)

Turmeric "fingers". (Photo: NRI)

Cultivation and Processing

Climate and Soil Requirements

Turmeric thrives in a hot, moist tropical climate with rainfall of 1,000-2,000 mm. It prefers a rich well-drained loam soil. Cultivation is possible from sea level up to about 1,500 m.

Cultivation

Propagation is by means of pieces of the lateral rhizomes which are detached from a plant at harvest time. They are stored under leaves or soil for two to three months until the commencement of the planting season.

Planting is often made on ridges to aid subsequent harvesting and spacing is usually 20–40 cm.

Harvesting is undertaken when the leaves wither and this varies from 9-12 months of age, depending on the cultivar and the site.

The rhizomes are lifted, detached from the stems and then washed. The secondary lateral shoots' "fingers" are then separated from the bulbous material; the latter is either rejected or used to prepare low grade spice for the local market.

Primary Processing

This involves boiling the fingers in water, followed by drying in the sun. The boiling step is advantageous in uniformly dispersing the pigment and, also, gelatinising the starch, which facilitates rapid drying and provides a protection against insect attack during storage. Boiling is carried out for 1 to 4 hours and sun-drying may take up to fifteen days.

Moderately pigmented cultivars — the Madras type — by tradition have the outer fibrous skin removed prior to sale. This "polishing" operation can be accomplished by abrasion in a simple rotating drum. The highly pigmented, "Alleppey" types are not normally polished.

Dried spice yields vary according to cultivar and site from about 0.4 to 1.7 tonnes/ha.

Oleoresin and Curcumin Production

The oleoresin may be prepared by the standard procedure for spices of sequential extraction of the ground material in an organic solvent, followed by solvent stripping. Yields of 8 to 12% have been reported.

"Pure curcumin" is obtained by crystallization from the oleoresin, followed by sequential recrystallization to remove volatile oil and other plant extractives.

Other Uses

Turmeric has played a traditional role as a crude dyestuff and cosmetic in many societies but these applications are now minor. Usage in traditional medicine continues in Asia and interest has been expressed by some researchers in the potential within modern medicine. In particular, some attention has been given to the antimicrobial and antifungal activity of turmeric oil which is a by-product of oleoresin processing in India and has a very limited market demand at present. Prospects for commercial success in this area are probably slight.

Research and Development Needs

For the majority of countries which wish to develop production and exports of turmeric, the priority must be planting stock quality improvement. Selection must be made of cultivars with the appropriate curcumin content and colour tone for either the Madras or the Alleppey markets while avoiding an excessive volatile oil content; the latter is a common problem in many countries. Where insufficient variability is present in the indigenous resource, introductions of superior cultivars from elsewhere will be necessary.

A second area of recommended research for some countries is an appraisal of the potential of turmeric within agroforestry systems. The plant originated on the forest verge and has a degree of shade tolerance which lends it to incorporation in a mixed cropping system with shrubs and young trees.

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APPENDIX 1

SUPPLEMENTARY SELECTED BIBLIOGRAPHY

The following list provides suggestions on additional reading on natural dyestuffs and food colourants. Some of the items have been cited earlier in individual product reviews and are repeated here since they furnish a wider and valuable perspective on a range of topics. Other texts in the list below cover minor, non-commercial plant sources.

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Natural colourants and dyestuffs are an important group of non-wood forest products which find use in industries producing confectionery, other food products, textiles, cosmetics, medicines, leather, fur, paper, paint, ink, etc. This document reviews the production, markets and development potential of these products and provides information that will help resource managers appraise the future opportunities and constraints for their development.

ISBN 92-5-103747-7 ISSN 1020-3370

TC/M/V8879E/2/11.03/300