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NON-WOOD FOREST PRODUCTS

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Flavours and fragrances of plant origin

Food and Agriculture Organization of the United Nations

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by

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FOREWORD

Non-wood forest products are extremely heterogenous. They play a vital role in the life and welfare of the people. A large number of items of our everyday use contain a varying proportion of non-wood forest products.

Sustainable utilisation and development of non-wood forest products are highly demanding on scientific knowledge and information relating to their resource distribution and management, chemical and biological properties, uses, supply-demand situation and so on. However, the information base of non-wood forest products is still weak. Sources of existing information are dispersed. There is a lack of an adequate system of compiling and disseminating available information. These exert a negative influence on the development of non-wood forest products.

In order to remedy this deficiency, the FAO Forest Products Division has initiated publication of a new series on non-wood forest products. The present publication on flavours and fragrances of plant origin is the first of the series.

The material for this publication was prepared by John Coppen of the UK-ODA Natural Resources Institute under the advice and general guidance of C. Chandrasekharan, Chief of the FAO Non-Wood Forest Products and Energy Branch.

We hope that this publication will serve as a useful reference for all concerned with non-wood forest products.

Karl-Hermann Schmincke
Director
Forest Products Division

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ABBREVIATIONS

CENARGEN	Centro Nacional de Recursos Genéticos e Biotecnologia (Brazil)
C & F	Cost and freight
CIF	Cost, insurance, freight
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazil)
EC	European Community
EOA	Essential Oil Association of USA
FAO	Food and Agriculture Organization of the United Nations
FCAP	Faculdade de Ciências Agrárias do Pará (Brazil)
FMA	Fragrance Materials Association of USA
FOB	Free on board
FOT	Free on tanker
INPA	Instituto Nacional de Pesquisas da Amazônia (Brazil)
ISO	International Standardization Organization
ITE	Institute of Terrestrial Ecology (UK)
NRI	Natural Resources Institute (UK)
ODA	Overseas Development Administration (UK)
OFI	Oxford Forestry Institute (UK)
pa	per annum

In all Tables:

-	indicates nil
~	indicates < 0.5 tonnes (except Table 1, < 0.05 tonnes)
na	indicates not available
ne	indicates not estimated

CHAPTER 1

FLAVOURS AND FRAGRANCES OF PLANT ORIGIN

INTRODUCTION

Taste and smell are the two most sensitive human senses. The nose can often detect and distinguish odours at a level which even modern instrumentation is hard pressed to achieve. The natural world - especially that of higher plants - provides a multitude of flavours and fragrances, either directly or indirectly, which impinge upon these senses. Over the course of time, and with the benefit of many thousands of species of plants from which to produce them, countless numbers of such flavours and fragrances have found their way via essential oils into everyday life: into foods and drinks and confectionery items; into products for personal use such as perfumes, deodorants, shampoos, bath lotions, toilet soaps, toothpastes and mouth washes; into pharmaceutical preparations where flavours are added to make the product more appealing or to mask the taste of less agreeable ones; into items used about the house or office or in industry such as air fresheners, laundry soaps, detergents, cleaning agents and the like; into tobacco products; the list is endless.

In 1985, LAWRENCE estimated total world production of essential oils to be approximately 36,500 tonnes. (This figure excludes turpentine, which in 1985 would have been around 250,000 tonnes; see TURPENTINE, this report.) Levels of production were given for 168 individual oils; a further 62 oils were listed for which estimates could not be provided. Production ranged from the large-volume orange oil (ca 12,000 tonnes) to those with less than one tonne.

More recently, the same author (LAWRENCE, 1993) listed the world's top 20 essential oils in volume terms (again, excluding turpentine). Orange oil production was estimated at 26,000 tonnes (valued at US$58.5 million). Cornmint (*Mentha arvensis*) and eucalyptus oil (cineole-type) were placed second and third, respectively, with around 4,000 tonnes each. Patchouli was 20th, with just under 600 tonnes production. In total, the top 20 oils amounted to almost 56,000 tonnes valued at US$340 million.

VERLET (1993) has given a slightly lower estimate of world production of "volatile oils": approximately 45,000 tonnes. Of this, about 65 percent is estimated to come from perennial woody plants. About 55 percent of world production (in value terms) comes from 25 developing countries, the most important of which are the People's Republic of China, Brazil, Indonesia and India.

Such figures are quoted to give an indication of the scale and scope of the industry. The number of plant species which are involved is impossible to estimate accurately but must reach several hundreds for those oils which are traded and many more for those which are produced and used locally. They are distributed amongst numerous botanical families and encompass higher and lower plants, gymnosperms and angiosperms, mono- and di-cotyledons, annuals and perennials, wild and cultivated sources. Thousands more species have yielded volatile oils in the course of searching for new oils but, for one reason or another, (poor yields, poor quality, unfavourable economics, poor markets) have never reached the point of commercial exploitation.

Before the advent of synthetics and the production of certain flavours and fragrances from petrochemicals, virtually all such materials were obtained from plant sources. A few were obtained from animals. Even today, the building blocks of many synthetic compounds are derived from plants. Turpentine obtained from pine trees is the prime example of this: alpha- and beta-pinene have no direct flavour and fragrance use themselves, but are isolated from suitable species of Pinus and converted into derivatives with a wide range of flavour and fragrance applications.

Other plants, too, yield essential oils which are used as sources of chemical isolates for derivative manufacture. Chinese and Brazilian sassafras oils from *Cinnamomum camphora* and *Ocotea pretiosa*, respectively, are both sources of safrole, which is used to manufacture heliotropin, a valuable flavour and fragrance compound. *C. camphora* is also a source of natural camphor.

Rosewood oil was once an important source of linalool, an aroma chemical in its own right but also a precursor for other fragrance compounds. Although cheaper sources of linalool are now utilized (still of plant origin), rosewood still finds favour as a whole oil for perfumery use. Sandalwood oil, too, is prized in perfumery and the whole oil gives an aroma which synthetic substitutes cannot match. Lemon-like citral is obtained from *Litsea cubeba*.

Eucalyptus oils are used in whole form for perfumery use; in refined form as flavour and fragrance products; or as raw materials for the isolation of cineole or citrinellal (depending on the species of *Eucalyptus* which is utilized). Cedarwood oils are also used both in whole form and as sources of aroma chemicals.

Some odoriferous materials are obtained, and used, in a form other than an oil. The best grades of olibanum (frankincense) are chewed for their pleasant flavour, while others are burnt and employed as incense in religious ceremonies or about the house.

All of the oils or resins referred to above are employed today as flavour or fragrance materials and form the basis of this report. They all have established markets but offer potential for increased or improved production, sometimes from plant sources which are alternatives to existing ones. They are chosen to illustrate the diversity of natural flavours and fragrances and the sorts of opportunities (and constraints) which exist. Many others might have been used.

Some, such as frankincense and myrrh, have been used for thousands of years. Others such as *Litsea cubeba* and *Cedrus deodara* oils have become articles of commerce more recently, in the last forty years. The plants from which they are obtained come from a variety of ecological zones: the moist rainforests of South America; the semi-arid regions of Africa; the more temperate areas of North America; the mountainous regions of Asia; and many others. They range from the slow-growing sandal tree to the fast-growing eucalypts.

Basic data on the plants described in this report are given below:

Genus	Family	Main producing regions	Main applications
Cinnamomum	Lauraceae	Asia	Flavours Fragrances Chemical isolates
Ocotea	Lauraceae	Latin America	Fragrances Chemical isolates
Aniba	Lauraceae	Latin America	Fragrances
Litsea	Lauraceae	Asia	Fragrances Chemical isolates
Piper	Piperaceae	Latin America	Chemical isolates
Eucalyptus	Myrtaceae	Worldwide	Flavours Fragrances Chemical isolates Medicinal
Santalum	Santalaceae	Asia, Pacific	Fragrances
Boswellia	Burseraceae	Africa, Asia	Flavours Fragrances
Commiphora	Burseraceae	Africa, Asia	Flavours Fragrances
Pinus	Pinaceae	Worldwide	Flavours Fragrances (both via chemical isolates) Others
Cedrus	Pinaceae	Africa, Asia	Fragrances Chemical isolates
Cupressus	Cupressaceae	Asia	Fragrances Chemical isolates
Juniperus	Cupressaceae	North America, Africa	Fragrances Chemical isolates

FORMAT OF THE REPORT

The format within which each oil or resin is discussed is structured so as to highlight a number of points:

- its uses;
- present (and, where possible, predicted) supply and demand, including national and international quality criteria and prices;
- plant sources, including the variability in oil yields and quality that may occur within natural populations, and the effects, possibly harmful, that oil production may have had on the resource;
- the type of harvesting and primary processing methods employed;
- the nature of any value-added processing;
- other uses to which the plant is, or could be, put;
- and the developmental potential of the oil, with an indication of some of the research needs necessary to maximize the social and economic benefits which are sought.

A selected bibliography is appended for each oil/resin to enable those who wish to explore the subject in more detail to do so.

REQUIREMENTS FOR THE SUCCESSFUL DEVELOPMENT OF NEW OR IMPROVED SOURCES OF FLAVOURS AND FRAGRANCES

Some importance has been attached in the report to providing an indication of markets for the oils or resins and past and present supply sources. It is a mistake, often made by researchers and others, to have no thought for which market the product of one's endeavour is most likely to succeed in or the opportunities or constraints that may exist for its development. If such considerations are given, they are usually relegated to second place while technical matters are attended to.

Essential oil production is no different from any other agricultural-based industry. Sustainable production is dependent upon it being remunerative to the producer and at least as attractive as other options that are open to him. This means that there needs to be a reasonable market for the product. Development will not follow spontaneously from the enthusiasm of researchers, no matter how well-intentioned this is (COPPEN and GREEN, 1993).

One misconception is that there are particular opportunities for new perfumery oils, previously unknown in trade. The reality is that the generally conservative nature of the essential oils industry and the uncertainties in supply of such oils from origin (both in terms of quantity and quality) make the production of completely new oils something that has only a small chance of success.

Of more likely success is the production of:

(a) established oils for which there is known demand and fair prospects for a new producer; or

(b) large-volume oils to serve as alternative sources of chemical isolates to existing ones.

One example of the latter approach (which is discussed in this report) is the potential use of previously unexploited *Piper* spp. as sources of safrole. Success in such a venture will bring with it environmental benefits as well as the provision of income-earning opportunities to those who take it up.

Over the past decade, as has been remarked elsewhere (GREEN and HONE, 1992), there have been many initiatives within developing countries to establish new essential oil industries. Unfortunately, the number of failures has exceeded the successes. The former have frequently arisen from basic mistakes: hasty, inappropriate selection of planting stock; misreading of markets and prospects in the face of the known competition; miscalculation of returns against alternative crop options in the investment area; and poor marketing of the product.

An important factor in those developments which have succeeded is the degree of local commitment to the venture which has been made by the primary raw material producers. The attitudes and motivations of the prospective farmers to essential oil production need to be understood and modified if necessary to assist in the development. Where harvesting of wild trees or plants is practised which threatens the survival of the species or the maintenance of biodiversity, then alternative, sustainable options must be put forward to the people whose livelihoods may depend on it. Enforced regulation by legislation is not the answer.

Having established that there is a market for a particular flavour or fragrance (whether domestic or international) and an opportunity for new or improved production, what action is necessary to put these ideas into practice? One approach to the problem in some parts of the world is the development of agroforestry systems, involving trees and a mix of food and cash crops. The cash crops might be essential oil-bearing plants but must be carefully selected on the basis of known demand rather than on fanciful ideas of exotic natural oils inevitably finding a market in the environmentally-conscious world.

Selection of tree crops such as *Cinnamomum*, *Piper* and *Eucalyptus*, which can be harvested under a coppice system of management, offers opportunities for development. Some or all of the research needs enumerated in the section on *Piper hispidinervium* in Chapter 3 are applicable to other tree crops and the sequence of events which are needed to develop them. In the case of *Eucalyptus* it is possible to grow it as a multipurpose crop from which fuelwood or poles can be produced as well as oil. Slower-growing trees such as rosewood and sandal are more difficult to bring under cultivation but the possibility of utilizing sustainably harvested rosewood leaf, rather than wood, as a source of essential oil might be possible; and the successful cultivation of sandal in India in areas of natural stands not susceptible to spike disease may yet be achieved.

Harvesting of wild forest trees or shrubs is conceptually attractive, particularly if it involves non-destructive harvesting of aerial parts such as leaves or terminal branches which quickly regrow. However, the problems of collecting material that may be scattered over wide areas, perhaps of difficult terrain, are great. The supply of raw material for distillation would be unpredictable and probably too small to meet market demand, and the variability and uncertainty of the oil quality from widely sourced biomass would create further problems.

Bringing trees under cultivation has advantages insofar as both inputs and outputs are well-defined and can be controlled and adjusted as the needs demand. Selection and improvement of planting stock as a means of improving oil quality and productivity - which are not options when utilising wild trees - also become possible. Provision of sustainably harvested plant material for distillation can be undertaken in several ways: on a smallholder basis, with farmers owning individual distillation units; by some form of cooperative in which individual outgrowers contribute raw material to a single distillery; or through an estate feeding a central distillery.

Whatever the fashions of the day, flavours and fragrances of plant origin will continue to be in demand. And whatever form of exploitation is best suited to forest and man - natural stands, monocultures or mixed cropping systems - the opportunities for developing countries will remain.

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CHAPTER 2

CINNAMOMUM OILS (INCLUDING CINNAMON AND CASSIA)

Cinnamomum is a large genus, many species of which yield a volatile oil on distillation. The composition of the oil, and therefore its value and the use to which it is put, depends very much on the species that is distilled as well as the part of the plant which is utilized. The most important *Cinnamomum* oils in world trade are those from *C. verum* (cinnamon bark and leaf oils), *C. cassia* (cassia oil) and *C. camphora* (sassafras and Ho leaf oils). The latter species provides oils which are utilized as sources of chemical isolates.

However, a number of other *Cinnamomum* species are distilled on a much smaller scale and the oils used either locally or exported to regional markets. Given the large number of *Cinnamomum* species that exist, their widespread distribution in Asia, and the number still not characterised in terms of essential oil content and composition, the genus has much potential for providing new tree crops in developing countries.

The spice oils cinnamon and cassia are discussed first. An indication is then given of the types of oil found in other *Cinnamomum* species, including *C. camphora*, and those with the greatest perceived potential for future use.

DESCRIPTION AND USES

Cinnamon bark oil possesses the delicate aroma of the spice and a sweet and pungent taste. Its major constituent is cinnamaldehyde but other, minor components impart the characteristic odour and flavour. It is employed mainly in the flavouring industry where it is used in meat and fast food seasonings, sauces and pickles, baked goods, confectionery, cola-type drinks, tobacco flavours and in dental and pharmaceutical preparations. Perfumery applications are far fewer than in flavours because the oil has some skin-sensitizing properties, but it has limited use in some perfumes.

Cinnamon leaf oil has a warm, spicy, but rather harsh odour, lacking the rich body of the bark oil. Its major constituent is eugenol rather than cinnamaldehyde. It is used as a flavouring agent for seasonings and savory snacks. As a cheap fragrance it is added to soaps and insecticides. The oil's high eugenol content also makes it valuable as a source of this chemical for subsequent conversion into iso-eugenol, another flavouring agent.

Cassia oil is distilled from a mixture of leaves, twigs and fragments of bark. Cinnamaldehyde is the major constituent and it is used mainly for flavouring cola-type drinks, with smaller amounts used in bakery products, sauces, confectionery and liqueurs. Like cinnamon bark oil, its use as a fragrance is limited by its skin sensitizing properties.

WORLD SUPPLY AND DEMAND TRENDS

Markets

Cinnamon bark oil is a high-value essential oil but the volumes traded are very low. In the ten years since 1983 exports from Sri Lanka, virtually the only supplier of the oil, have never been more than 2.8 tonnes. Exports from Sri lanka for the six years 1987-92, together with their destinations, are shown in Table 1.

The major market is the EC, within which France is the biggest importer. In recent years the United States has emerged as the second largest importing country.

World demand for **cinnamon leaf** oil has been around 120-150 tonnes pa in recent years, met almost entirely by Sri Lanka. Sri Lankan exports (Table 2) have averaged about 120 tonnes pa for the period 1987-92, but this includes an exceptionally low output in 1990.

The United States and Western Europe are the largest markets for cinnamon leaf oil. Imports into France and the UK have fallen in the last few years, as they have slightly for India. Hong Kong is a significant importer although most of the oil is re-exported.

The ready availability of eugenol ex clove leaf oil has led to some loss in markets for cinnamon leaf oil. When eugenol is required for further conversion into iso-eugenol, that produced from cinnamon leaf oil possesses a more desirable aroma and flavour than when derived from clove leaf oil. For most other purposes, however, the cheaper eugenol ex clove leaf oil is preferred.

Estimation of world demand for cassia oil is complicated by the fact that export data are not available from the People's Republic of China, the major producer. Furthermore, the oil is only separately specified in import statistics of the USA and Japan, although these are known to be the major markets.

The levels of imports of cassia oil into the USA are shown in Table 3 for the period 1987-93.

Imports into the USA have risen in recent years and, with a soft drinks market which shows no sign of weakening, demand for cassia oil is expected to remain strong. Imports from Japan and Hong Kong are almost entirely re-exports of Chinese oil.

Japanese imports of cassia oil have averaged 60 tonnes pa for the six years 1988-93, virtually all of it coming directly from the People's Republic of China. A significant proportion of the imports are re-exported (to the USA, for example, above).

Supply sources

Sri Lanka is the only regular supplier of **cinnamon bark** and **leaf oils**. With the exception of 1990, when both oils were in short supply, production (as reflected in exports) has remained very constant for bark oil, with a slight downward trend for leaf oil. Internal consumption is small so that production levels are not much greater than exports.

Madagascar and the Seychelles have been intermittent suppliers of leaf oil on a very minor scale in the past. India produces very small amounts of leaf oil for domestic use.

Most cassia oil in international trade is of Chinese origin. There is believed to be significant domestic consumption so total annual production may be in excess of 500 tonnes.

Small quantities of cassia oil are produced in Indonesia, Viet Nam, India and Nepal but these are obtained from species of *Cinnamomum* other than *C. cassia* (see PLANT SOURCES) and are much less widely traded than Chinese oil.

Quality and prices

There is no international standard for **cinnamon bark oil** although batches containing cinnamaldehyde at the higher end of the range fetch the higher price. In the United States, an EOA standard specifies an aldehyde content of 55-78 percent.

International (ISO) standards exist for cinnamon leaf and cassia oils. For **cinnamon leaf oil**, ranges between which the major constituent, eugenol, should fall are specified in terms of total phenol content for oils of different origin. Oil from the Seychelles used to be preferred because of its high eugenol content (*ca* 90 percent). In practice, Sri Lanka now accounts for almost all of the oil in international trade and the standard specifies a 75-85 percent phenol content. Another constituent of the oil which contributes to its aromatic character is cinnamaldehyde and for Sri Lankan oil a maximum level of 5 percent is specified. Physico-chemical requirements are also given.

In the United States an FMA monograph, which replaces the old EOA standard, specifies the eugenol content of cinnamon leaf oil in terms of its solubility in potassium hydroxide (80-88 percent).

For **cassia oil**, cinnamaldehyde is the major constituent and a minimum content of 80 percent is specified in the ISO standard. Again, physico-chemical data are provided.

Cinnamon bark oil is considerably more expensive than the leaf oil and probably the most highly priced of all essential oils. During 1992 it was being offered at around US$385/kg, largely reflecting the high raw material cost. In 1993 and early 1994 dealers in London were only quoting prices on request.

Cinnamon leaf oil, in contrast, has been in the range US$6.50-7.50/kg for most of the last three years. Its price fell gradually from about US$7.50 in early 1991 to US$6.50 in mid-1993. In late 1993 it had risen again to US$7.30/kg and in early 1994 it was US$8.25/kg. Although it is a comparatively low-priced oil it is still more expensive than clove leaf oil as a source of eugenol (which was approximately US$2.70/kg in early 1994).

Cassia oil, too, has remained fairly level in price over the last few years. In the period early 1991 to mid-1993 it fetched US$33-35/kg. It then fell slightly and in early 1994 it was about US$29/kg. These prices are significantly lower than those which prevailed in the early and mid-1980s, when there was a shortage of cassia bark in the People's Republic of China. Any appreciable rise in price above the US$30-35/kg level is likely to encourage end-users to blend cheaply available synthetic cinnamaldehyde with natural cassia oil.

PLANT SOURCES

Botanical/common names

Family Lauraceae:

Cinnamomum verum Presl (syn. *C. zeylanicum* Nees)	True or Ceylon cinnamon
C. cassia Presl	Cassia, Chinese cinnamon, "Cassia lignea"
C. burmannii Blume	Indonesian cassia
C. loureirii Nees	Vietnamese cassia
C. tamala (Buch.-Ham.) Nees & Eberm.	Indian cassia

Description and distribution

The genus *Cinnamomum* comprises several hundred species which occur naturally in Asia and Australia. They are evergreen trees and shrubs and most species are aromatic. *C. verum*, the source of cinnamon bark and leaf oils, is a tree indigenous to Sri Lanka, although most oil now comes from cultivated areas. Smaller areas of wild trees are found in southwestern parts of India. *C. cassia*, the source of internationally traded cassia oil, occurs wild as a bush in the mountains of southern China but is now cultivated for oil production, mainly in the provinces of Kwangsi and Kwangtung.

The other cassias occur wild on the islands of Sumatra and Java, Indonesia (*C. burmannii*); in Viet Nam (*C. loureirii*); and India and Nepal (*C. tamala*). In all cases the trees are also cultivated.

Effects of oil production on the natural resource

Most of the above oils are now derived almost entirely from cultivated sources and there is no longer pressure on the wild resource.

HARVESTING/PRIMARY PROCESSING

Cinnamomum usually coppices well and commercial production of the bark spices entails cutting the stems low down after an initial establishment period and harvesting the bushy re-growth stems at regular intervals thereafter. In Sri Lanka, a first harvest may be obtained after 3-4 years, although both quality and yields improve with subsequent cutting. The stems are cut during the rainy season to facilitate peeling of the bark. Details of harvesting practice differ slightly from country to country but the basic principles are the same. Strips of bark are then formed into the familiar compound quills (cinnamon) or hollow quills (cassia) of the spices.

In Sri Lanka, **cinnamon bark** oil is produced by distillation of chips and variable amounts of featherings (pieces of inner bark from twigs and twisted shoots) and quillings (broken fragments of quills). In many cases the older form of hydro-distillation is used in which chips and water are placed together in the distillation vessel which is heated by direct fire. The oil distils over in two fractions, one lighter and one heavier than water, and a form of cohobation is used to recover residual oil from the distillation waters. More modern methods involve steam distillation.

The leaves left after trimming the cut stems, as well as those obtained from pruning operations, provide the raw material for production of **cinnamon leaf oil**. They are usually allowed to dry for a few days before distillation. Traditional stills in Sri Lanka are large wooden vessels capable of holding up to 200 kg of leaves, on top of which is fitted a copper still head. Steam is introduced from a separate wood-fired boiler. In some cases, all-metal vessels are used and water-steam distillation is employed.

Chinese cassia oil is produced by hydro-distillation of leaves, twigs and fragments of bark.

Yields and quality variation

For cinnamon and cassia oils there is more potential than usual for variation in oil yields and quality and this makes it difficult to cite typical data. Not only is there the expected intrinsic variation due to different geographical origins of the source raw material, but the composition of the charge that is distilled is liable to vary, particularly in the case of cinnamon bark oil and cassia oil. The method of distillation used (steam vs water-steam vs hydro-distillation) and other differences in distillation practice give rise to further causes of variation.

VALUE-ADDED PROCESSING

Cinnamon and cassia oils are both normally rectified within the importing country before sale to end-users in order to give a cleaner product or to provide an oil with more uniform composition. Rectification is also required to produce feedstock eugenol for subsequent derivative manufacture.

PRODUCTS OTHER THAN OIL

The major incentive to cultivation of *C. verum* and *C. cassia* has been their value as spice crops, for which world demand is considerable (tens of thousands of tonnes of bark annually). Indonesian cassia (*C. burmanii*) is much more important as a spice than as a source of oil and enters international trade along with Chinese cassia. There is some production of oleoresin for flavouring purposes, chiefly in North America from the cheaper Indonesian cassia. Bark also finds local use medicinally, particularly in the People's Republic of China.

DEVELOPMENTAL POTENTIAL

For the cinnamon and cassia oils of international commerce, production of oil is secondary to the production of the spice. The establishment of new areas of these particular *Cinnamomum* species will depend upon demand for the spice and economic returns to the farmer. Whether "waste" material from spice production is then utilized for oil production is, again, dependent on demand, prevailing oil prices and economic returns. The close relationship between the two commodities makes it unlikely that production of oil will shift, geographically, from the traditional centres of spice production.

Research needs

Apart from improvements in distillation practice, the greatest advances in productivity and quality will come from breeding programmes aimed at producing superior germplasm for planting. Some progress has already been made in identifying mother plants which give high yields of oil and high cinnamaldehyde and eugenol contents in the bark and leaves (GURUSINGHE and KIRINDE, 1985) and this work needs to be continued.

OILS FROM OTHER CINNAMOMUM SPECIES

The diversity of *Cinnamomum* as a genus, although not as great as, say, *Eucalyptus*, has analogies with the latter in terms of the variety of chemical types of volatile oil that may be distilled from the plants. Like *Eucalyptus*, the same species of *Cinnamomum* can afford oils with quite different compositions according to the population being studied, i.e. it may exist as different chemotypes. *C. camphora* is a well-known example and the wood from different groups of trees may yield camphor, linalool, safrole or cineole as the major chemical upon distillation.

This diversity, coupled with the ability of most *Cinnamomum* to respond to coppicing (a system of management which enables it to be harvested on a sustainable basis), and a market that is always receptive to new, alternative sources of natural aroma chemicals, makes *Cinnamomum* one of the most promising areas for research. The increasing number of reports in the scientific literature describing the oil characteristics of *Cinnamomum* species is evidence of the attention they are receiving in screening programmes.

Table 4 gives some examples of *Cinnamomum* species which are, or might be, used as sources of commercially valuable chemical isolates.

Cinnamomum camphora

C. camphora was heavily exploited as a source of camphor in Japan and Taiwan until the Second World War. Trees were felled and logs, stumps and branches distilled to give crystalline camphor and camphor oil. The species was introduced into India during the 1950s. Although yields of camphor are greater for old trees, leaves and woody material can be harvested regularly from plants over five years of age which are kept in a bushy form by coppicing. This form of harvesting is carried out in the People's Republic of China. The availability of cheap synthetic camphor (ex turpentine), however, has meant that there is now only modest international demand for the natural form. This, combined with the availability of competitively priced Chinese camphor (US$3.65/kg in early 1994) does not make its production elsewhere particularly attractive.

The use of *C. camphora* as a source of Ho leaf oil, on the other hand, has expanded in recent years and it is now an important source of natural linalool (which is still preferred over the synthetic form for some fragrance applications). Chinese Ho oil has largely displaced the use of rosewood as a source of natural linalool.

Fractionation of the camphor-free oil obtained from *C. camphora* provides an oil rich in safrole. This is usually described as Chinese sassafras oil (see SASSAFRAS OIL).

Other *Cinnamomum* species

The ease with which essential oils can be obtained from plant material (and subsequently analyzed in the laboratory) makes them ideal candidates for study as potential cash crops. A screening programme currently underway at the Forest Research Institute of Malaysia focuses on essential oils of indigenous flora and has already examined several *Cinnamomum* species. Some are considered to have economic potential in providing raw materials for local industry and income to farmers who might grow them. *C. mollissimum* leaves, for example, contain an oil which is rich in benzyl benzoate and could find application in insecticidal preparations. The trunkwood could possibly be harvested for mucilage on a coppice system (for mosquito coil manufacture), in the same way as *C. iners* is already being grown in Malaysia.

Cinnamomum species other than *C. camphora* which contain safrole in their leaves have potential for utilization, providing oil yields and safrole content are high enough to make its recovery worthwhile from an economic point of view.

Leaves of *C. tamala* (tejpat) are widely used in northern India as a spice but also furnish an essential oil on distillation and this finds some local use. Several chemotypes exist, producing oils rich in cinnamaldehyde or eugenol, but the existence of cheap supplies of these chemicals from other sources (eugenol-rich clove leaf oil from Indonesia, for example) means that *C. tamala* oil is unlikely to find wider international use.

Similarly, cineole-rich oils from *Cinnamomum* cannot compete with *Eucalyptus* oils.

The oils of some other *Cinnamomum* species are employed in whole form for perfumery use although this is usually in a domestic, rather than international context (e.g. *C. porrectum* oil, which is rich in neral/geranial, is distilled in the People's Republic of China). Nevertheless, the existence of a local market may be sufficient to encourage small-scale production of such oils. *C. osmophloeum* is being studied in Taiwan as a possible substitute for cassia oil in the food industry.

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Table 1
Exports of cinnamon bark oil from Sri Lanka, and destinations, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	2.7	2.7	2.6	0.7	2.8	2.8
Of which to:						
France	0.6	0.6	0.7	0.2	1.1	1.1
USA	0.1	0.4	0.4	0.1	0.5	0.4
Italy	0.4	0.3	0.4	0.1	0.2	0.3
UK	0.5	0.4	0.2	~	0.3	0.2
Netherlands	0.5	0.2	0.3	0.1	0.3	0.1
W. Germany	0.2	0.4	0.2	0.1	0.2	0.2
Switzerland	0.2	0.4	0.2	~	~	0.2

Source: Sri Lankan national statistics

Table 2
Exports of cinnamon leaf oil from Sri Lanka, and destinations, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	133	132	162	46	107	119
Of which to:						
USA	38	54	78	13	46	54
UK	29	19	18	2	9	11
France	19	21	24	8	9	8
Hong Kong	11	13	16	14	17	20
India	8	5	7	1	2	5
Spain	5	4	6	4	6	3
Switzerland	5	3	5	1	5	7
W. Germany	5	2	3	-	3	5

Source: Sri Lankan national statistics

Table 3
Imports of cassia oil into the United States, and sources, 1987-93
(tonnes)

	1987	1988	1989	1990	1991	1992	1993
Total	221	308	197	333	385	493	445
Of which from:							
China, People's Rep. of	195	286	123	241	na	na	na
Japan	16	15	21	37	na	na	na
Hong Kong	7	4	50	44	na	na	na

Source: American national statistics

Table 4
***Cinnamomum* species with actual or potential use as sources of chemical isolates**

Species	Plant part	Major oil constituent	percent in oil
C. camphora	Wood	Camphor, linalool, safrole or cineole	
C. camphora var. *linaloolifera*	Leaves	Linalool	91
C. sulphuratum	Leaves	Linalool	93
C. petrophilum	Leaves	Safrole	97
C. mollissimum	Bark, wood	Safrole	93, 99
C. mollissimum	Leaves	Benzyl benzoate	78
C. pubescens	Bark	Eugenol	84
C. tamala	Leaves	Cinnamaldehyde or eugenol	

CHAPTER 3
SASSAFRAS OIL

DESCRIPTION AND USES

There are two important sassafras oils of commerce: Brazilian sassafras oil, obtained from the trunkwood of *Ocotea pretiosa*, and Chinese sassafras oil from *Cinnamomum camphora*. Both contain 80 percent or more of safrole.

True sassafras oil, from the roots of North American *Sassafras albidum*, is no longer produced commercially, although it was once the main flavour constituent of "root beer". Its use for such purposes, and in other foods and drinks, has been banned for some years because of fears of health risks associated with consumption of safrole.

Only Brazilian and Chinese oils are discussed here, together with oils from *Piper* species, which show considerable promise as alternative, sustainable sources of safrole.

Sassafras oil was formerly used in numerous household fragrance applications such as floor waxes, polishes, soaps, detergents and cleaning agents. Its ability to blend with other oils and its powerful masking properties made it valuable for such purposes.

However, the principal use today is as a raw material for the isolation of safrole. This is then converted by the chemical industry into two important derivatives: heliotropin, which is widely used as a fragrance and flavouring agent, and piperonal butoxide (PBO), a vital ingredient of pyrethroid insecticides. Natural pyrethrum in particular would not be an economical insecticide without the addition of PBO as a synergist and the future of the natural pyrethrum industry is linked to the continued availability of PBO.

WORLD SUPPLY AND DEMAND TRENDS

Markets

Excluding the People's Republic of China, for which consumption levels are not known, demand for sassafras oil is estimated to be around 2,000 tonnes annually. Most of this is destined for heliotropin and PBO manufacture, the two outlets taking approximately equal amounts of oil.

Exports of sassafras oil from Brazil for the period 1986-90 are given in Table 5, which also shows the destinations for the two years 1986 and 1987.

Japan, Italy and the United States are the most important markets for the oil (the latter being the largest market for applications other than derivative manufacture). These countries, along with some other minor manufacturers, then export the heliotropin and PBO worldwide. Brazil has some manufacturing capacity for both heliotropin and PBO (equivalent to about 500 tonnes of sassafras oil) although a shortage of domestically produced oil has led to it importing some Chinese oil.

The demand for sassafras oil is determined by the markets for heliotropin and PBO. Heliotropin consumption is increasing, particularly in Eastern Europe, Asia and some developing countries, and sassafras oil is the preferred raw material for its manufacture. If supplies of the oil become tight, however, or its price rises markedly, then synthetic heliotropin would become more attractive.

Demand for PBO, both in conventional pyrethroid insecticides and in other insecticidal outlets now being developed, is also increasing but, in this case, the possibility of utilizing synthetic PBO to make up any shortage of sassafras oil-derived PBO is less attractive economically. The overall prospects for a sassafras type of oil are therefore very good.

Supply sources

More than half the sassafras oil currently entering world trade originates from the People's Republic of China. While this is likely to remain the case in the near future, Chinese domestic requirements for the oil will increase as technology for the manufacture of PBO is acquired and added to that which already exists for heliotropin production. This, together with supply difficulties caused by the destructive nature of production from wild *C. camphora*, means that in the longer term there are likely to be increasing amounts of sassafras oil diverted from exports to internal use.

Up until the 1960s, Brazil was the major exporter of sassafras oil. Production has declined since then as a result of depletion of the natural resource from which it is obtained, wild *O. pretiosa* in the Mata Atlantica areas of southern Brazil. Restrictions imposed on the felling of the trees in the late 1980s have resulted in a further decline in production and this is illustrated by the falling level of Brazilian exports (Table 5).

Since 1990, Viet Nam has been exporting sassafras oil. Current exports are believed to be of the order of several hundred tonnes pa, but with reliance, again, on wild trees (*C. camphora*), it is expected that supplies from this source will be relatively short-lived.

The current dependence worldwide on unsustainable exploitation of wild forest trees means that supplies from these sources will progressively reduce.

Quality and prices

Brazilian sassafras oil is traditionally described in trade terms as containing 84 percent safrole, although it usually contains a few per cent more. Chinese oil has a higher specification, 90 percent safrole, as a result of its method of production. (It is obtained not as a whole oil but as a safrole-rich fraction from the crude oil distilled from *C. camphora*. The major fraction consists chiefly of camphor.)

For conversion into heliotropin or PBO a minimum safrole content of 86 percent is preferred. The abundance of chemically similar compounds in the oil, such as methyl eugenol, should be low.

For some time, prices of sassafras oil were of the order of US$4/kg. During a brief shortage of sassafras in 1991/92 (caused largely by speculative stock-piling in the Far East) prices of Chinese oil were around the US$6-7/kg level. When this shortage was remedied prices eased and in early 1994 Chinese sassafras oil was on offer from London dealers at under US$4/kg. Brazilian prices are usually higher than those for Chinese oil.

PLANT SOURCES

Botanical/common names

Family Lauraceae:

Ocotea pretiosa (Nees) Mez. (syn. *O. cymbarum*)	Brazilian sassafras
Cinnamomum camphora Nees	Chinese sassafras

Description and distribution

Ocotea pretiosa is a medium-sized tree which grows wild in many parts of southeastern Brazil as well as Columbia and Paraguay. It has only ever been exploited commercially for oil production, however, in the Brazilian state of Santa Catarina. It is only here that trees with a suitably high safrole content are found.

Cinnamomum camphora occurs throughout much of Southeast Asia but its exact distribution and abundance are not known with any certainty. Large areas of wild trees once grew in Japan and Taiwan but these have largely disappeared through over-exploitation for camphor production in the years up to the Second World War. The botanical status of *C. camphora* and its varieties is also complex and there are several different chemotypes (see CINNAMOMUM OILS).

Effects of oil production on the natural resource

In both Brazil and the People's Republic of China, loss of trees by felling for oil production has been considerable. As mentioned earlier, concern over this led the Brazilian government to introduce regulations limiting the cutting of *O. pretiosa*. In the early years of the Brazilian industry trees over fifty years of age were common and yielded large amounts of oil. Today, the resource is seriously depleted and tree diameters are comparatively small. No significant replanting has ever occurred. Expressions of concern over the depletion of *C. camphora* have also been voiced by Chinese researchers.

HARVESTING/PRIMARY PROCESSING

In Brazil, trees are felled and cut into suitably sized logs for transportation to the distillery. There they are chipped and reduced further in size before being placed in the distillation vessels. Steam is raised by burning waste and spent wood. Distilleries are a mix of family and larger-sized operations.

Little information is available on the details of processing *C. camphora* in the People's Republic of China or Viet Nam. The crude oil obtained by primary distillation of the chipped wood is fractionated to remove camphor and furnish a safrole-rich oil.

Yields and quality variation

In both *O. pretiosa* and *C. camphora* oil yields are variable and dependant upon the quality of the wood feedstock. Higher yields are obtained from trunkwood from older trees and branchwood gives lower yields than trunkwood. Yields and oil composition undoubtedly vary, both within and between natural populations of trees, but the extent of this variation has not been well documented. A chemotype of *O. pretiosa*, which yields an oil rich in methyl eugenol, is known to occur in Brazil although its geographical distribution is distant from the Santa Catarina harvesting areas. Information is not available on the yields of oil obtained from coppiced *C. camphora*; the multiplicity of compositional types for the species is referred to elsewhere (see CINNAMOMUM OILS).

VALUE-ADDED PROCESSING

A large part of the total production of Brazilian and Chinese sassafras oil is exported whole to those importing countries where conversion to heliotropin and PBO takes place. Some manufacture of both derivatives occurs in Brazil and in the People's Republic of China heliotropin is produced. The products in both countries are then used partly to meet domestic needs and partly to serve overseas customers.

PRODUCTS OTHER THAN OIL

The value of the trees for oil production means that they are rarely used for other purposes.

DEVELOPMENTAL POTENTIAL

In the case of *C. camphora*, there is the potential for regeneration after felling the tree due to its ability to coppice but no information is available on the practicality or economics of this. The possibility of utilizing other *Cinnamomum* species as sources of safrole, not only in the People's Republic of China but elsewhere in Southeast Asia, is discussed briefly in the section on CINNAMOMUM OILS.

For *O. pretiosa*, the prospects of bringing it into formal cultivation - a necessary measure, since the depleted natural resource is now incapable of sustaining high levels of utilization - are unknown but may prove uneconomic. Like *Aniba* (see ROSEWOOD OIL) much basic information is lacking and, while this could be acquired through a concerted research effort, a more satisfactory outcome is likely to be obtained from research into alternative sources of safrole. The potential of certain *Piper* species to provide such an alternative in Brazil is therefore discussed below.

PIPER SPECIES AS ALTERNATIVE SOURCES OF SAFROLE

Certain forest shrubs of the Piperaceae family, indigenous to the humid forests of Central America and Greater Amazonia, have been found to contain high levels of safrole in their leaves. With further research they offer good prospects as new, commercial sources of safrole. Their successful development would also bring other social and economic benefits, albeit on a modest scale, to a region which is at the centre of world attention on environmental issues.

Piper auritum occurs from Mexico to Panama and is one species which has attracted attention. The leaf oil contains around 70 percent safrole and pilot-scale cultivation and distillation trials were conducted for a brief period in Mexico in the 1980s at INIREB, Xalapa. There appears to be no current work being conducted on this species and its potential remains uncertain.

The Brazilian Amazon contains a wide variety of *Piper* species and since 1990 attention has been focused on two with high safrole content in their leaves, *P. hispidinervium* and *P. callosum*. This work has been funded by ODA and has been undertaken by the Museu Paraense Emilio Goeldi in Belem in collaboration with the Centre for Agroforestry Research (CPAF-EMBRAPA) in Acre and supported by technical assistance from NRI. Progress to the end of 1992 has been reported by MAIA et al. (1993). Subsequently, *P. collosum* has been relegated in the research work in favour of the more promising *P. hispidinervium*.

The discussion on *P. hispidinervium* which follows is intended to highlight the developmental potential of the species and the ways in which research are being directed. The same basic approach can be applied to many other situations where it is required to bring wild forest species into semi-formal cultivation.

P. hispidinervium as an example of a species suitable for agroforestry intervention

P. hispidinervium is most frequently found on degraded forest or farm land where it occurs as a colonizing "weed", either as a pure stand or along with other *Piper* species. Surveys have revealed that it occurs in the majority of settled areas throughout Acre state in Brazil and it is believed to extend into Amazonas state as well as Peru and Bolivia. On natural sites, plants develop initially into bushes and at an early stage they appear to inhibit growth of competing vegetation. As the plants age they become more tree-like and stands up to 10 m in height may be found.

Techniques for propagation have been developed and growing trials established at several sites in Brazil using both rooted cuttings and seedlings. The trials are designed to provide information on growth characteristics and biomass yields (leaf + stem) under various planting and management regimes. Pilot-scale distillations have been conducted to determine oil quality and yields and permit estimation of productivity on a "per hectare per year" basis. Only by such means, together with knowledge of prevailing and projected oil prices, can economic returns to the farmer be calculated. The safrole content of the oil in unselected stock is about 85 percent. Improvement to 90 percent appears possible through selection.

Results to date indicate that the most likely form of exploitation is one in which the plants are first harvested at 6-8 months, with subsequent harvests at 4-6 month intervals for at least 3 years. Harvesting entails simply cutting the primary or re-growth stems approximately 20 cm above ground level.

Mixed planting of *P. hispidinervium* with young cash crop trees is a practical possibility and would be economically attractive to a farmer. Harvesting of *P. hispidinervium* would permit an early cash return during the period before the first harvest of the tree crop.

Further research needs

Development of *P. hispidinervium* to a point where it can be recommended to farmers for planting requires further research and reappraisal and this is in hand. The following areas of study are included in this programme. They may be taken as a general guide to the approach necessary for the development of any other forest crop.

- Observation of the species in its natural habitat to learn more about its variability and ecological requirements.

- Identification of superior germplasm for planting purposes. A larger number of natural populations needs to be sampled and tested for oil yield, quality (safrole content) and growth characteristics (biomass production).

- Determination of the best method of propagation (vegetative or from seed) in terms of survival, vigour and growth of the plants and the speed and ease of mass multiplication.

- Assessment of growth performance and oil production of selected planting stock at more sites to determine optimum climatic and edaphic conditions and the adaptation range of the species. In due course, this should be extended to on-farm trials to determine probable production costs.

- The effects of spacing, fertilizer application and cropping interval on biomass and oil yields.

- Closer monitoring of the seasonality of oil production within the plant in order to better assess the optimum time for harvesting.

- Identification, through socio-economic studies, of farmers who would adopt and benefit from production.

- Determination of the optimum form of management of the combined cultivation/distillation operation (i.e. are the plants best grown and distilled on a family basis using small-scale field stills; on a cooperative system; or by outgrowers supplying a large, central distillery?).

- Specification of marketing systems (farmer to buyer).

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1. Wild *Piper hispidenervium* growing on forest verge, Acre state, Brazil [C. Green, NRI].

2. Field trials: Coppiced *Piper hispidenervium* awaiting its fourth harvest, Brazil [D. Baker, NRI].

Table 5
Exports of sassafras oil from Brazil, and destinations, 1986-90
(tonnes)

	1986	1987	1988	1989	1990
Total	1582	1302	970	394	280
Of which to:					
Japan	543	596	na	na	na
USA	274	359	na	na	na
Italy	281	292	na	na	na
China, People's Rep. of	154	-	na	na	na
UK	169	15	na	na	na
Spain	124	25	na	na	na
France	11	7	na	na	na

Source: Brazilian national statistics

CHAPTER 4
ROSEWOOD OIL

DESCRIPTION AND USES

Rosewood oil is obtained by felling wild, Amazonian species of *Aniba* and steam distilling the comminuted trunkwood.

The oil ("bois de rose") possesses a characteristic aroma and is a long-established ingredient in the more expensive perfumes. Although formerly it was used more widely as a fragrance, particularly in soaps, where the strong top-note could be used to advantage, its relatively high price now makes it uncompetitive with the cheaper, larger volume oils.

Rosewood oil is rich in linalool, a chemical which can be transformed into a number of derivatives of value to the flavour and fragrance industries, and up until the 1960s rosewood oil was an important source of natural linalool. With the advent of synthetic linalool this use largely disappeared. For those applications where natural linalool is preferred, rosewood oil has been displaced by cheaper alternatives (Chinese Ho oils from *Cinnamomum camphora*). There does remain, however, a very small niche market for the preparation of linalool derivatives possessing an "ex rosewood" character.

Use in aromatherapy formulations, a relatively recent application, has become less attractive as environmental concerns have grown over the destructive nature of rosewood oil production in Brazil.

WORLD SUPPLY AND DEMAND TRENDS

Markets

In the 1960s, exports of rosewood oil from Brazil alone were around 500 tonnes pa. Today, the world market for rosewood oil is about 100 tonnes pa, the decline in use arising largely from its displacement by synthetic linalool. Dem Demand is reported to be stable, those who moved away from using rosewood oil in their formulations having done so many years ago. However, any marked and prolonged upward move in the price of the oil above recent levels could adversely affect demand. Some of the top-of-the-market perfumery houses have expressed concern over the destructive manner of producing rosewood oil and a transition to sustainable production would be welcomed by such users.

Recent exports from Brazil, now the only supplier of rosewood oil, are shown in Table 6.

The United States is the principal importer, followed by Switzerland, France and a number of other EC countries. Regional demand is very small and in 1990 was limited to Argentina (0.4 tonnes).

The magnitude of rosewood oil consumption in Brazil is uncertain; 20-30 tonnes of oil are purchased annually by the fragrance sector, much of it by local branches of multinationals, but it is likely that a large proportion of this is exported, either as the crude oil or in formulations (which are not identifiable in trade statistics).

Supply sources

Production of rosewood oil in Peru, Colombia and the Guianas, where *Aniba* also grows, declined to negligible quantities after the advent of synthetic linalool in the 1960s. Brazil is now the only supplier to the world market.

Since the fall in production brought about by the loss of linalool markets and, more recently, by the use of cheaper Chinese Ho oils, production levels have been of the order of 100 tonnes pa. Annual fluctuations are mainly the result of differences in rainfall and river levels which determine accessibility to the wild resource. Harvesting of the trees is concentrated around a number of well-defined tributaries of the Amazon in northern Amazonas and southern Para states.

While it should be possible to maintain present production levels in the medium term, the disinclination of younger generations of producers and labourers to undertake the arduous tasks involved in harvesting wild trees, and the increasing costs of collection as wild stands become more remote, suggest that production in the longer term may decline. Attempts at cultivation of *Aniba* to date have not been successful but the lack of any direct alternatives to rosewood oil in established, top-of-the-range perfumery formulations makes it desirable to pursue such objectives (see below).

Quality and prices

All major importing countries have published standard specifications for Brazilian rosewood oil and there is also an international (ISO) standard. These specify the botanical source and physico-chemical requirements, including the alcohol content (usually in the range 84-93 percent determined as linalool). These standards are minimum trade requirements and for perfumery applications individual batches of oil must conform to the aroma expectations of the buyer.

Notwithstanding the above, there are two grades of Brazilian rosewood oil recognised in trade:

- "Manaus" oil, which is shipped from Manaus, the export centre for the industry, and generally conforms to the standards described above.

- "American" oil, which is stretched by addition of synthetic linalool to give a slightly lower priced oil.

FOB prices for Brazilian rosewood oil have been in the range US$18-32/kg over the period 1987-93. Prices in late 1993 were about US$23/kg; they are expected to rise slightly in 1994 as a result of temporary shortfalls in wood supplies (arising from low river levels).

PLANT SOURCES

Botanical/common names

Family Lauraceae:

Aniba rosaeodora Ducke
Aniba duckei Kostermans
(syn. *A. rosaeodora* var. *amazonica*)

Rosewood (En.), pau rosa (Br.), bois de rose femelle (Fr.).

There is some disagreement as to the exact botanical status of these species. In Brazil, where most of the research on *Aniba* has been carried out, some groups regard *A. rosaeodora* as a synonym of *A. duckei* while others take the reverse view. A third opinion holds that morphological differences that exist within the genus are insufficient to justify separation into two species. Oil producers themselves recognise two plant sources but make no attempt to keep the distilled oils separate.

A number of other *Aniba* species co-occur with *A. rosaeodora* (*A. duckei*) but are not exploited because the oil content is low or the composition/aroma is poor.

Description and distribution

A. rosaeodora (*A. duckei*) is a large, evergreen tree reaching up to 30 m in height. All parts of the tree are fragrant although only the trunkwood is traditionally harvested and distilled.

Aromatic *Aniba* species are indigenous to the northern and western areas of Greater Amazonia. In Brazil it is found in the States of Amazonas, Pará and Amapá. Elsewhere in the region it occurs in Peru, Colombia, Ecuador, Suriname and French Guiana.

Effects of oil production on the natural resource

The perceived threat to the species posed by the destructive nature of harvesting has led to increasingly tight controls on the industry in Brazil. Government regulations exist which are intended to minimise this threat although there are difficulties in enforcing them. The results of recent field surveys in Brazil by Faculdade de Ciências Agrárias do Pará (FCAP) based in Belem indicate, in fact, that the species is not presently faced with extinction. Substantial wild stands exist deep within forest areas which are unlikely to be exploited for logistical or economic reasons.

However, the older, more accessible areas which have been utilised by the rosewood oil industry are effectively devoid of mature trees and there is no significant natural regeneration. This, together with the general problem of deforestation caused by land clearance, has led to a loss of germplasm diversity and a narrowing of the genetic base on which future domestication of the species will depend.

HARVESTING/PRIMARY PROCESSING

Harvesting is carried out by teams of collectors under contract to the distillery owners. Exploration of new areas is led by someone experienced in identifying and distinguishing the different *Aniba* species by appearance and odour. Access trails are created as individual stands of suitable trees are located. Whereas, formerly, trees up to 2 m diameter were readily available, these are now only found in the less accessible areas and trees as small as 15 cm diameter are harvested in order to maintain the supply of wood to the distillery. Occasionally, branches over 4 cm thick may also be collected. More recently, species of *Aniba* other than *A. rosaeodora* (*A. duckei*) have been felled as an expedient to bulk distillation raw material.

After felling, trees are cut into one metre lengths and transported to the river bank (which may be up to 20 km from the collection site). Logs are stock-piled and when river levels are high enough (dependent on the season) they are shipped downstream to the distillery.

Most distilleries in Brazil are very basic and designed to be "mobile" so that they can be sited on the river bank and moved around by raft as conditions dictate or allow. In preparation for distillation the logs are cut up into small pieces and then mechanically reduced to chips. Distillation is carried out in mild or galvanised steel vessels which may vary in size from 200-1,000kg capacity (of chips). Steam generation is by boiler fuelled with spent chips.

Yields and quality variation

Yields of oil vary according to the quality of the wood feedstock (collection area and species mix) and its moisture content, but typically are around 1 percent (w/w).

Although there are known to be batch-to-batch differences in linalool content, no systematic studies have been undertaken to determine the intrinsic variability of oil composition within natural populations of *Aniba*. The need for this has become more urgent with the recent inclusion of non-traditional species in the feedstock and the attention now being given to cultivation as a means of achieving sustainable oil production.

VALUE-ADDED PROCESSING

No further processing of the oil is carried out either by the primary distiller or any intermediate before it is formulated for fragrance use by the end-user.

PRODUCTS OTHER THAN OIL

Indians use the wood of *Aniba* for making canoes but its value for rosewood oil production mitigates against its use for other purposes.

DEVELOPMENTAL POTENTIAL

For reasons given above, the consumption of rosewood oil is now determined more by supply and price factors than by other market forces. With the inevitable rise in costs of production consequent upon a labour-intensive operation and the need to go deeper into the forest to locate suitable trees, there is every inducement to consider cultivation as a means not only of ameliorating the loss of biodiversity of *Aniba* in the primary forest but of ensuring the survival of the rosewood oil industry itself in the longer term. Such a solution would also offer the prospect of increased sales of oil and cash-earning opportunities for some of the poorer rural communities, albeit at a very modest level and on a small scale. Reclamation of small areas of degraded land by rosewood cultivation would be an added environmental attraction.

Research needs

The problems to be overcome before domestication can be considered a realistic, economic option should not be underestimated. Unlike some other Amazonian species which have attracted attention because of their much larger potential market (as sources of fruits or oil seeds, for example), comparatively little research has been carried out on *Aniba*.

Prior to 1990, studies were carried out on distribution, botany, propagation and silviculture by various Brazilian institutions (including INPA, CENARGEN and EMBRAPA). In addition, some commercial distillers had conducted their own trials by planting seedlings within the natural forest. Growth performance with tunnel planting (in cleared strips) within the forest has been poor.

Since 1990, a new, systematic programme of research has been carried out by FCAP, with technical assistance from UK institutions (NRI, OFI and ITE) and funded by the UK's Overseas Development Administration (ODA). This has involved germplasm collections from threatened sites, research on improved propagation methods and establishment of field trials. Results indicate superior growth rates in open-field situations compared to forest tunnel planting. The longer-term aim of this work is to evaluate the techno-economic potential for formal cultivation, including the viability of producing a marketable leaf oil from non-destructive harvesting (coppicing or pollarding).

Specific needs identified by FCAP for future research on rosewood include the following:

- Development of an economic means of mass propagation of planting stock.

- Determination of the practicality and requirements for field establishment and the optimum management regimes for short-rotation harvesting of trunkwood and for frequent harvesting of leaf.

- Appraisal of the market for leaf oil (either as a direct substitute for traditional wood oil or as a new, alternative source of low-priced natural linalool).

- Determination of the economics of production of wood and leaf oils.

- Investigation of the options for formal cultivation (as a monoculture or in mixed cropping systems on under-utilized or abandoned land) and the socio-economic aspects of production.

- Identification and selection for propagation of elite germplasm.

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Rosewood logs (*Aniba rosaeodora*) being transported by river to the distillery, Brazil (FCAP).

3. Rosewood logs (*Aniba rosaeodora*) being transported by river to the distillery, Brazil [FCAP].

4. Propagation trials: Seedling of *Aniba rosaedora* growing in partial shade, Brazil [FCAP].

5. Propagation trials: Branch method of developing juvenile stems of *Aniba rosaeodora* for clonal propagation, Brazil [FCAP].

Table 6
Exports of rosewood oil from Brazil, and destinations, 1986-92
(tonnes)

	1986	1987	1988	1989	1990	1991	1992
Total	48	39	95	78	60	74	68
Of which to:							
USA	28	22	na	na	40	na	na
Switzerland	6	6	na	na	11	na	na
France	10	9	na	na	3	na	na
W. Germany	1	1	na	na	2	na	na
UK	1	1	na	na	1	na	na
Netherlands	-	-	na	na	1	na	na
Spain	-	1	na	na	1	na	na

Source: Brazilian national statistics

CHAPTER 5
EUCALYPTUS OIL

DESCRIPTION AND USES

Eucalyptus oils are obtained by distillation of the leaves of *Eucalyptus* and have aromas characteristic of the particular species used.

The oils are classified in the trade into three broad types according to their composition and main end-use: medicinal, perfumery and industrial. Of these, the most important in terms of volume of production and trade is the medicinal type, characterised by a high cineole content in the oil. This, and the perfumery type, are discussed below. The so-called industrial oil, produced from *E. dives*, now has a very small and diminishing market and is not discussed further.

The medicinal type of oil may be sold as such, neat, in pharmacies and other retail outlets or in the form of sprays, lozenges, cough sweets and ointments or in formulation with other oils. It is used as an inhalant or chest rub to ease breathing difficulties, as a mouthwash in water to refresh or ease the throat, and as a skin rub to provide relief from aches and pains. Anti-plaque solutions in dental hygiene are a recent application. Although employed for medicinal purposes, the pleasant flavour and fragrance properties of cineole-rich eucalyptus oils play an important role in their acceptance and utilization on such a large scale. Eucalyptus oil is also used as a general disinfectant, cleaner and deodorizer about the house.

Of the two principal perfumery oils, that from *Eucalyptus citriodora* is produced in the greatest volume. It differs from the medicinal oils in containing citrinellal, rather than cineole, as the major constituent. The oil is employed in whole form for fragrance purposes, usually in the lower cost soaps, perfumes and disinfectants, but also as a source of citrinellal for the chemical industry. The citrinellal obtained by fractionation of the crude oil may be used as such as an aroma chemical or converted to other derivatives intended for fragrance use.

The only other perfumery oil produced in any quantity is that from *E. staigeriana*. No single chemical predominates in the oil and it is used in whole form for perfumery purposes. It has a lemon-type character.

WORLD SUPPLY AND DEMAND TRENDS

Markets

World production and trade in eucalyptus oils is dominated by the People's Republic of China, which is the largest producer of both cineole-rich medicinal oils (about 70 percent of world output and trade) and perfumery oil (from *E. citriodora*). It is not possible to quantify accurately total world demand for eucalyptus oils. The weakness of production statistics and of domestic consumption statistics in the producing country markets, especially for such a large producer and consumer as the People's Republic of China, makes published trade statistics of limited value for analytical purposes. Furthermore, several importing countries such as

Portugal, Spain and Australia are also producers and processors of eucalyptus oils and re-export much of what they import.

Notwithstanding these difficulties, total world production of medicinal type eucalyptus oil in 1991 has been estimated at around 3000 tonnes, of which approximately 2000 tonnes were exported (COPPEN and HONE, 1992). Production and exports of *E. citriodora* oil, the main perfumery oil, for 1991 are estimated at about 1500 tonnes and 500 tonnes, respectively.

Globally, the European Community is the largest importer of eucalyptus oils and recorded imports for the period 1984-90 are shown in Table 7.

It should be noted that medicinal and perfumery oils are not distinguished in trade statistics.

Within Europe, France, Germany and the UK are the major markets for eucalyptus oil-based products. In 1990 their combined imports amounted to 1840 tonnes.

Imports into the United States, the largest single country market for eucalyptus oils (excluding the People's Republic of China and those countries which re-export much of their imports after further processing), are shown in Table 8.

Changes and disruptions in Chinese patterns of trade and domestic usage of eucalyptus oils since 1989 have caused a fall in domestic offtake and an expansion of exports, the latter driven by a desire to earn foreign exchange. Although increasing, the world market for eucalyptus oil is not growing rapidly, and with no major new uses for it which could absorb large volumes, opportunities for new producers are likely to rest mainly with meeting local or regional needs rather than trying to compete in the wider international market.

Supply sources

The main producers and suppliers of cineole-type (medicinal) eucalyptus oil to the world market are shown in Table 9, together with estimates of their production and exports in 1991.

Under intense price pressure from Chinese oil, primary production in Portugal and Spain has decreased in recent years although both countries remain significant exporters of eucalyptus oil products. The balance of the starting oil is imported, chiefly from the People's Republic of China.

Southern Africa is a major producing region for eucalyptus oil, most of it from South Africa but a significant proportion from Swaziland. In South America, Chile and Brazil are the major producers, with smaller amounts coming from Bolivia, Uruguay and Paraguay.

Australia, the home of *Eucalyptus* and eucalyptus oil production, has declined in importance since its heyday in the 1940s. However, in the face of increasing production elsewhere in the world, the introduction of mechanized harvesting (see below) has enabled the Australian industry to become more efficient and it remains an important supplier of refined and finished eucalyptus oil products (based partly on its own production and partly on imports of crude or partially refined oil).

Production of *E. citriodora* oil is also dominated by the People's Republic of China. In 1991 it is estimated that she accounted for approximately two thirds, 1000 tonnes, of total production, of which, perhaps, 400 tonnes were exported. Brazil (500 tonnes) and India (50 tonnes) are the only other producers of this type of oil, with Brazil exporting about half of her production. Brazil is the only supplier to the world market of *E. staigeriana* oil; production is of the order of 60 tonnes pa.

Quality and prices

The value of eucalyptus oil for medicinal purposes lies in its cineole content, which largely determines, also, the price that it fetches. National and international standards exist which specify the minimum cineole content expected of such oils and this is normally 70 percent (m/m). The intrinsic composition of the oil is largely determined by the species of *Eucalyptus* that is distilled and for a few species (such as *E. polybractea*) the crude oil from the primary distillation of the leaves easily exceeds this minimum requirement. For most eucalypts which are exploited, however, the crude oil has to be rectified to increase its cineole content. These oils then enter international trade. Chinese oil, for example, is commonly traded as "eucalyptus oil 80 percent", referring to the fact that it contains at least 80 percent cineole.

Cineole-rich oils used strictly for medicinal purposes must satisfy national or international pharmacopoeia and this may introduce further requirements for compliance, although this will be a task for the rectifier of the oil rather than the primary producer. Crude *E. smithii* oil, for example, suffers from the disadvantage of containing a few percent of isovaleraldehyde and this adversely affects its odour. In order to meet pharmacopoeia standards the aldehyde content must be reduced by rectification.

For the perfumery oils, aroma characteristics are important but it is left to the subjective assessment of the prospective buyer to decide whether the oil is acceptable in this respect. Published standards exist for *E. citriodora* oil and these usually specify that the aldehyde content calculated as citrinellal should not be less than 70 percent.

Price trends of both cineole-rich and perfumery oils have been greatly influenced by the ample supplies of Chinese oils on the market in recent years and the price at which they have been offered. In early 1994 the price of standard grade Chinese 80 percent eucalyptus oil had fallen below US$3/kg from the US$6/kg level in 1989. Prices for cineole-rich oil of Portuguese/Spanish origin are US$2-3 higher than Chinese prices because of the preference by end-users for these traditional sources. A new producer of eucalyptus oil, however, would need to compete, at least in the first instance, with Chinese oil.

It is possible that the next few years will see reduced Chinese exports and a slow recovery in demand and prices, though eucalyptus oil will remain one of the lower priced essential oils.

Until the recent fall in prices, Chinese *E. citriodora* oil was lower priced than cineole-rich oil of Chinese origin. The situation has now reversed and in early 1994 *E. citriodora* oil was being offered by London dealers at US$3.35/kg.

PLANT SOURCES

Several hundreds of species of *Eucalyptus* have been shown to contain volatile oil, though probably fewer than 20 of these have ever been exploited commercially for oil production. Today, fewer than a dozen species are utilized in different parts of the world, of which six account for the greater part of world production of eucalyptus oils.

Those species currently exploited, and the countries in which they are utilized, are listed below. (The use of parentheses indicates a minor producer.) Other species that have been used in the past include *E. cinerea* (medicinal), *E. cneorifolia* (medicinal) and *E. macarthurii* (perfumery).

Botanical/common names

Family Myrtaceae:

Medicinal

Eucalyptus globulus Labill. (Tasmanian blue gum)	People's Republic of China, Portugal, Spain, India, Brazil, Chile, (Bolivia, Uruguay, Paraguay)
E. smithii R. Baker (gully gum)	South Africa, Swaziland, (Zimbabwe)
E. polybractea R. Baker (syn. *E. fruticetorum* F. Muell. ex Miq.) (blue mallee)	Australia
E. exserta F. Muell. (Queensland peppermint)	People's Republic of China
E. radiata Sieber ex DC. (syn. *E. australiana*, *E. radiata* var. australiana) (narrow-leaved peppermint)	(South Africa, Australia)
E. dives Schauer (cineole variant) (broad-leaved peppermint)	(Australia)
E. camaldulensis Dehnh. (syn. *E. rostrata* Schldl.) (river red gum)	(Nepal)

Perfumery

E. citriodora Hook. (lemon-scented gum)	People's Republic of China, Brazil, India
E. staigeriana F. Muell. ex Bailey (lemon-scented ironbark)	Brazil

Description and distribution

Eucalypts vary in form from low shrubs and multi-stemmed trees less than 10 m in height ("mallees") to large single-stemmed trees more than 60 m tall. The production of lignotubers is a characteristic of many species and this generally makes them respond to coppicing. On the death of the plant stem, either through fire or by cutting, dormant vegetative buds which have been present in a tuberous mass at the base of the tree develop and produce new stems. The ability to grow *Eucalyptus* under a coppice system of management is central to the economic production of oil.

The genus *Eucalyptus* is native to Australia and some islands to the north of it and consists of over 500 species of trees. These grow under a wide range of climatic and edaphic conditions in their natural habitat and is one reason for the successful introduction of *Eucalyptus* into so many other countries in the world. Together with *Pinus*, the two genera account for the larger part of exotic plantations in the Americas, Europe, Africa and Asia.

Like pines, eucalypts are grown for timber or pulp but their fast-growing nature also makes them ideally suited as a fuelwood crop. In some cases the favoured species for wood production (such as *E. saligna* and *E. grandis*, or *E. tereticornis* in India) are not suitable for oil. In other instances they are, and leaf oil may be obtained as a secondary product from the plantings (as is the case for *E. globulus* planted for pulp in Portugal, *E. citriodora* grown for charcoal production in Brazil and *E. smithii* utilized for mining timber in South Africa).

Species selection for oil production

When leaf oil is to be a product of new eucalypt plantings the choice of species will depend on the particular environmental conditions that prevail at the intended site. Although most species of *Eucalyptus* provide an oil on distillation, its economic recovery requires the oil to be of good quality (at least 60-65 percent cineole in the case of a medicinal-type oil) and produced in high yields. In practical terms, therefore, the choice is likely to fall on one of the species already utilized (and listed above).

In Swaziland and South Africa, *E. smithii* has been found to grow particularly well under local conditions, producing large amounts of leaf biomass, and this has led to it being preferred for oil production over other species. In the same region *E. radiata*, although it yields less biomass, gives a similar recovery of oil on a per hectare basis as *E. smithii*. Its better aroma characteristics, however, make it a species with much potential and it may in the future be more widely planted than it is at present.

Effects of oil production on the natural resource

In Australia, the reduced level of oil production compared with 50 years ago is a result of the inevitable rise in labour costs associated with such production rather than a loss of the trees themselves. In any case, as has been indicated, most eucalypts respond to coppicing and cutting back of the natural stands is soon followed by the emergence of coppice regrowth.

HARVESTING/PRIMARY PROCESSING

Eucalyptus leaf destined for oil production is obtained commercially by one of three methods:

- recovery of "waste" leaf from felled trees which have been grown primarily for their wood;

- short-rotation harvesting of plantations established specifically for oil production. Under such a system of coppicing, plants are allowed to grow for no more than about 20 months before cutting;

- regular harvesting of wild stands (peculiar to Australia).

Utilization of "waste" leaf

In most cases, the branches trimmed from the stems of eucalypts that are felled for timber, pulp or fuelwood production are left in the field as waste or burnt; this also includes the shoots and side stems derived from pruning operations. Those countries which possess large areas of an oil-yielding species are able to make use of this "waste" resource to produce oil. This is the case for the People's Republic of China, Portugal and Spain which recover oil from *E. globulus*. The foliage should not be left on the ground too long before transportation to the distillery or there is a risk of losing volatile oil.

Although the raw material itself (the foliage) may have very little cost associated with it, any prospective producer of eucalyptus oil who is contemplating the utilization of "waste" leaf should ensure that the logistics of collection are adequately considered. Labour and transport costs are not insignificant.

Coppice management specifically for oil production

Those species of *Eucalyptus* which respond well to coppicing may be grown specifically for oil on a short-rotation cycle. In Swaziland, where oil is obtained from *E. smithii*, the first cut is made 20-24 months after planting. Subsequent cuts of the coppice regrowth are made at approximately 16-month intervals, at which time the plants are 5-6 m tall. Harvesting may continue for many years and in Swaziland some areas of *E. smithii* are still being harvested after 20 years or more.

In Brazil, one producer of oils from *E. citriodora, E. globulus* and *E. staigeriana* adopts a slightly different system of harvesting. Eighteen months after planting, the smaller branches are cut from the stem. This process is repeated every 6 months or so until the branches are too high to be reached (a period of about 3 years). The stem is then cut at about knee height and two or three stems are allowed to grow over a period of about 12 months, when the harvesting cycle is repeated.

The distillery is usually located within a reasonable distance of where the eucalypts are growing and foliage from the harvesting operation is distilled either the same day or the following day.

Mechanical harvesting of *E. polybractea* in Australia

The multi-stemmed, shrubby nature of coppiced *E. polybractea* offers an alternative means of leaf collection that is not labour intensive: mechanical harvesting. This system of harvesting was developed in Australia as a means of reducing labour costs and is used to harvest natural stands of *E. polybractea*. The frequency of harvesting is between 18 months and 24 months, at which time the shrubs are about 1 m high.

On a more limited scale in Australia, *E. polybractea* has been planted as a crop for oil production. The first harvest is usually made after 3 years with subsequent harvesting at 18-month intervals.

An additional advantage of the mechanical harvesting system is that the mobile "bin" into which the cut foliage is blown functions not only as a means of transporting it back to the distillery, but as a distillation vessel. By such means, double handling by way of unloading and reloading of the leaf into a separate vessel is avoided. A steam line is simply connected to the bottom of the bin, and a cover with a hole in the centre which allows exit of the oil/water vapours during distillation is placed over the top. The vapours are led away through a flexible hose and then condensed and separated in the normal manner.

Yields and quality variation

Yields of oil from leaf vary somewhat between species but on a commercial scale are of the order of 1 percent on a "fresh" basis. (Note that "leaf" in this context includes the woody material of the branches which contains little or no oil.) Of more relevance to the economics of production is the yield of oil per hectare and this is dependent on the biomass production as well as the oil yield from the leaf. Production from *E. smithii* in Swaziland yields approximately 15 tonnes/ha of leaf, corresponding to about 150 litres/ha of oil.

The dependence of oil quality on species has already been referred to. There may also be marked differences in oil yield and quality within a species according to the provenance origin of the seed. *E. camaldulensis*, for example, has a very wide distribution in Australia, but only certain northern Queensland provenances (Petford, in particular) yield an oil which makes the species attractive as a source of medicinal oil. In extreme cases in their natural habitat, even trees within the same provenance may produce oils which are quite different to each other. *E. dives* is a well-known example and it is possible to obtain seed from cineole and piperitone variants.

Further small yield and compositional differences may arise from the use of juvenile rather than adult leaf for distillation, though it is not generally practicable to attempt to separate different types of leaf in a commercial operation.

VALUE-ADDED PROCESSING

The enhancement of cineole content of the crude oil by a process of rectification entails carrying out a fractional distillation under reduced pressure. Small producers of eucalyptus oils, for whom it is not economic to invest in the equipment needed to do this, sell their crude oil to other, larger producers or to rectifiers who are not, themselves, producers of crude oil. An annual oil production of the order of 40-50 tonnes is the minimum scale of operation that would make rectification a viable option for a producer.

Essentially pure cineole, termed "eucalyptol", is traded and used by some end-users, and commands a higher price than the lower grades, but it is necessary to prepare this in a second step after rectification. The cineole-rich fraction is frozen at -300°C to -400°C for up to 24 hours and the recovered mixture, which contains unfrozen impurities (principally limonene), is centrifuged. The liquid portion is thus removed and the frozen part warmed to furnish eucalyptol.

PRODUCTS OTHER THAN OIL

Apart from any primary utilization of the stem wood if the oil is produced from "waste" leaf, it is still possible to make use of both spent leaf (that is, the material remaining after distillation of the oil) and secondary biomass, even from operations involving short-rotation coppicing, and this aspect should always be considered by a prospective new producer of eucalyptus oil.

Small coppice stems from which the foliage is trimmed for distillation can be used as fuel, either for the boiler providing steam at the distillery or for sale to others. Spent leaf can also be used as a boiler fuel although only a portion of the total available will probably be consumed in this way. The remainder may be returned to the fields to serve as a fertilizer (or a mulch if conditions require it) or it may be converted to compost and sold to provide an additional source of income.

DEVELOPMENTAL POTENTIAL

Although present prices of eucalyptus oils are the lowest they have been in recent years, this is not atypical of the fluctuations that occur in the essential oil market and they may be expected, in due course, to recover. The advantage of *Eucalyptus* over most other essential oil-bearing tree crops is that it offers the possibility of genuine multipurpose utilization. Moreover, the trees can be grown on a large, plantation scale or on an individual or communal woodlot system. The rapid growth of the trees means that income can be derived from sales of the stems for poles, fuelwood or other purpose within a fairly short time (7-10 years) during which period leaf can also be harvested for oil production.

A number of socio-economic studies have been published describing the experiences of smallholder or cooperative groups who have included *Eucalyptus* species amongst the trees planted. In Africa, *E. camaldulensis* is often planted, either alone or with *Acacia, Gmelina* or some other species, usually as a source of poles and fuelwood, though they may also serve as shelterbelts and windbreaks. Utilization of waste leaf from Petford *E. camaldulensis* for simultaneous oil production is therefore an option but more research is needed to examine the likely economic returns to the farmer. In Kenya, and elsewhere, the supposed disadvantages of growing eucalypts (high water and nutrient consumption) have not been borne out in practice. Adverse effects of woodlots on neighbouring crops can be minimised by careful consideration of positioning.

Research needs

The intrinsic variability of *Eucalyptus* germplasm sources has already been discussed. The advantages to be gained from giving adequate attention to selection of seed for planting cannot be over-emphasized. Over-hasty planting of a species or provenance which is unsuited to local conditions, or does not produce an oil of acceptable quality or yield, will result in failure.

Despite the large store of knowledge that is available on the cultivation of eucalypts for wood and pulp, further research is needed to maximize the returns on eucalypts planted (solely or partly) for the production of oil:

- More extensive evaluation of the climatic and edaphic conditions under which the major oil-bearing species will grow in different parts of the world. As well as original research, collation of published (and unpublished) data which are presently scattered in the literature would be valuable. Armed with such information, more informed judgements could be made on which species are likely to be most suited to a particular site (though this would not eliminate the need to conduct field trials to verify this).

- Determination of biomass production. While information is often available on the yields of oil to be expected from the leaf of particular species of *Eucalyptus*, much less is known about the amount of leaf produced in the field, with which meaningful estimates can be made of productivity, i.e. oil yield per hectare per year. Specific areas requiring research include the effects of spacing, fertilizer application and frequency and height of coppicing on biomass/oil yields.

- Investigation of nutrient recycling. In cases where eucalypts are grown specifically for oil on a short rotation, the long-term effects of continued removal of biomass and possible nutrient depletion of the soil need to be studied.

- Socio-economic studies of the effects of including oil production in smallholder/cooperative ventures involving multipurpose eucalypts and woodlots. To date, most work has related to wood use only.

- Some species deserve particular attention. In Africa and Asia, *E. camaldulensis* has great potential as a source of fuelwood/poles and oil. In Africa, *E. smithii* and *E. radiata* are high oil yielders. In very dry areas *E. polybractea* may have potential although it would not be suitable for timber production.

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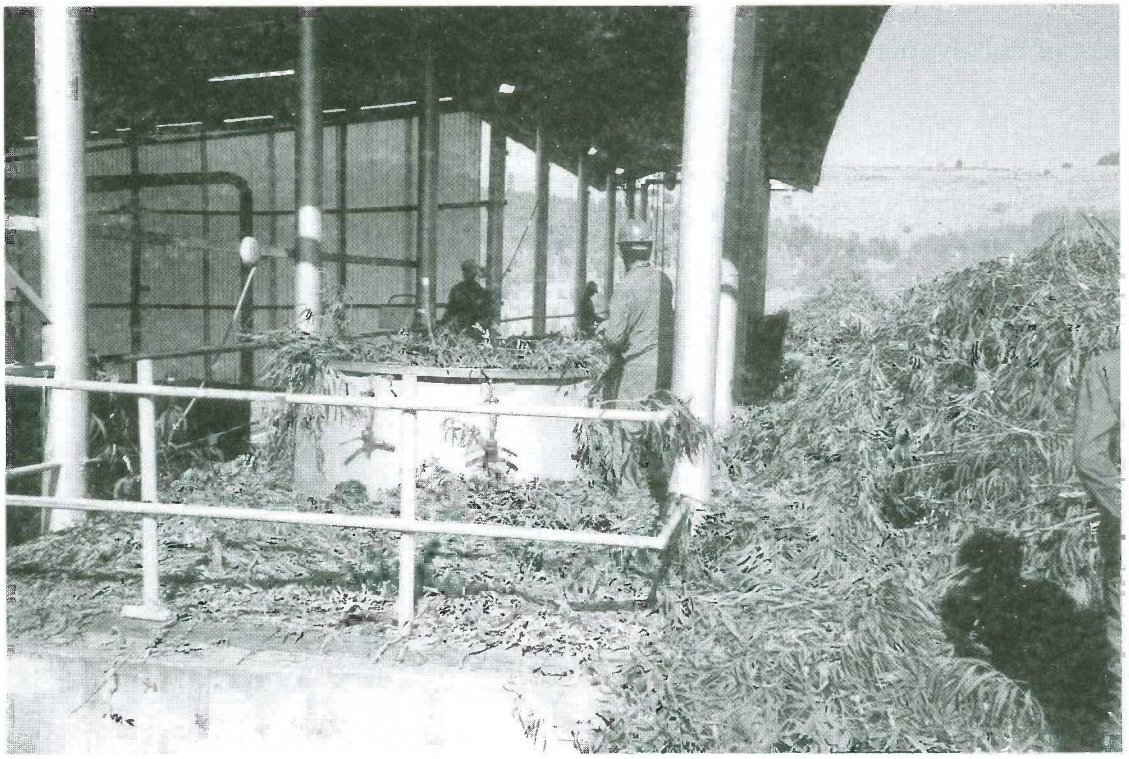
6. Eucalyptus leaves awaiting distillation. *Eucalyptus globulus*, showing juvenile and adult leaves, Portugal [J. Coppen, NRI].

7. Harvesting *Eucalyptus smithii*, Swaziland. First cut at about 24 months [J. Coppen, NRI].



8. Eucalyptus leaves being loaded into stills for distillation. *Eucalyptus smithii*, Swaziland [J. Coppen, NRI].

9. Regularly coppiced natural stands of *Eucalyptus polybractea* awaiting harvesting, Australia [J. Coppen, NRI].

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Table 7
Imports of eucalyptus oil into the European Community, and sources, 1984-90
(tonnes)

	1984	1985	1986	1987	1988	1989	1990
Total	1516	1194	1568	2025	1939	1987	2646
Of which from:							
China	807	460	771	1275	891	1139	1790
Portugal	229	204	156	172	164	171	117
Spain	132	182	172	146	131	144	175
Brazil	179	116	na	na	na	na	na
South Africa	68	80	na	na	na	146	164
Others	101	152	469	432	753	387	400

Source: NIMEXE; Eurostat (1989, 1990)

Table 8
Imports of eucalyptus oil into the United States, 1984-90
(tonnes)

	1984	1985	1986	1987	1988	1989	1990
Total	384	226	293	378	312	326	378

Source: Foreign Agricultural Circular, USDA

Table 9
World production and exports (excluding re-exports) of cineole-type eucalyptus oil estimated for 1991
(tonnes)

	Production	Exports
Total	2480-3130	1870-2070
Of which:		
China, People's Rep. of	1600-2000	1300-1500
Portugal	150- 200	150
India	150- 200	ne
South Africa	150- 180	120
Australia	120- 150	100
Swaziland	80- 100	80
Chile	80- 100	70
Spain	50- 100	50
Others	100	ne

Source: NRI and trade estimates

CHAPTER 6

SANDALWOOD OIL

DESCRIPTION AND USES

The term sandalwood has been applied at various times to oils from several different sources. Today, almost all the sandalwood oil traded internationally is so-called East Indian sandalwood oil distilled from the heartwood and roots of *Santalum album*. Australian sandalwood oil from *S. spicatum* and West Indian and African "sandalwood" oils are no longer produced. Unless otherwise stated the following discussion relates to the East Indian type from *S. album* (referred to, here, simply as sandalwood oil).

Sandalwood oil has a characteristic sweet, woody odour which is widely employed in the fragrance industry, but more particularly in the higher-priced perfumes. It has excellent blending properties and the presence of a large proportion of high-boiling constituents in the oil (about 90 percent santalols) also makes it valuable as a fixative for other fragrances. In India, where it is produced, it is used in this manner for the manufacture of traditional attars such as rose attar; the delicate floral oils are distilled directly into sandalwood oil.

WORLD SUPPLY AND DEMAND TRENDS

Markets

India and Indonesia are the two major producers and exporters of sandalwood oil but reliable production data are not available. Domestic consumption, which is certainly high in India and probably greater than the combined total for the rest of the world, is therefore also difficult to estimate. World production/consumption is probably of the order of several hundreds of tonnes annually.

Indian exports of sandalwood oil for the period 1987/88-1992/93, together with destinations, are shown in Table 10.

The United States and France are the two largest importers of Indian sandalwood oil. Imports into the former Soviet Union have fallen in the last two years and no early recovery of this market is expected. Imports into the Middle East have increased.

The USA is also the chief destination for Indonesian exports and thus represents the biggest market for sandalwood oil outside India.

Indonesian exports for 1987-92 are shown in Table 11.

Demand for sandalwood oil fell sharply in the 1970s as a result of very high prices and competition from synthetic substitutes. However, this largely affected the lower-priced formulations and the natural oil has retained its market in the top grade products. Demand now is influenced mostly by supply factors and the way in which this affects prices.

Supply sources

Indian exports over the last six years (Table 10) have averaged about 40 tonnes pa, with no distinct trend over the period. Production is based almost entirely on exploitation of wild trees. The lack of production or domestic consumption data make it impossible to judge the state of the supply base and whether this (and the level of exports) is likely to change in the future.

Indonesia is the only other supplier of East Indian-type sandalwood oil. Recorded annual exports over the six years 1987-92 (Table 11) averaged 15 tonnes.

Australian production of oil from *Santalum spicatum* ceased in 1971. Exports for the ten years to that date averaged less than 3 tonnes annually.

Quality and prices

There is an international (ISO) standard for sandalwood oil (ex *Santalum album*) which stipulates a minimum free alcohols (santalol) content of 90 percent (m/m). Ranges within which various physico-chemical properties must fall are also given. In the United States, an EOA standard specifies the same minimum santalol content. As a perfumery oil, the aroma characteristics are all-important and these are judged by the buyer to be acceptable or not for individual consignments.

Sandalwood oil is one of the most highly priced items in the essential oil trade, reflecting the nature of the raw material source and the tightness of supplies. In the late 1980s it was fetching almost US$200/kg. Throughout 1992 the price of oil of Indian origin offered by London dealers was about US$140-150/kg; Indonesian oil was about US$5 lower. In mid-1993 the price of Indian oil rose again to US$180/kg and this was still the price in early 1994.

PLANT SOURCES

Botanical/common name

Family Santalaceae:

Santalum album Linn.
(Sandalwood)

Other *Santalum* species occurring in Australia and islands of the Pacific have been, or are, harvested for their fragrant wood, although none (with the possible exceptions of very small quantities of *S. austrocaledonicum* and *S. yasi*) are currently used as sources of internationally traded oil. These include *S. spicatum* and *S. lanceolatum* (Australia), *S. ellipticum* (Hawaii), *S. yasi* (Fiji and Tonga), *S. macgregorii* (Papua New Guinea), *S. austrocaledonicum* (Vanuatu and New Caledonia) and *S. insulare* (French Polynesia).

Description and distribution

S. album is a small to medium-sized evergreen tree, sometimes reaching up to 18 m in height and 2.5 m in girth. It is a root parasite and successful regeneration (both natural and artificial) requires, amongst other things, suitable host plants.

S. album occurs naturally in India, Sri Lanka and the Malay Archipelago (Indonesia and surrounding islands). In India it is found in the drier regions in the south of the country, especially the states of Karnataka and Tamil Nadu, up to 1400 m. Formation of heartwood, from which the oil is obtained, is said to be best between 600 m and 900 m. Moderate rainfall (850-1200 mm) spread over several months and much sunshine are conducive to good growth. Sandal has become naturalized in parts of Rajasthan, Maharashtra, Madhya Pradesh and Uttar Pradesh and has been introduced into a number of other Indian states. The wood of trees outside their natural range, however, is very variable with respect to oil content and sometimes has little or no aroma.

In Indonesia, *S. album* occurs on the neighbouring islands of Timor, Sumba, Flores, Alor and Roti, although there is now only a significant population on Timor.

Effects of oil production on the natural resource

Cultivation of sandal in India has had limited success. While it might be expected that the destructive nature of sandalwood oil production, which entails the uprooting of mature trees, would put inexorable pressure on the wild resource there is little or no quantitative information available on which to judge the extent to which this might have occurred. Sandal trees freely produce seed and natural regeneration occurs both via seedlings and through root suckers which are produced when the tree has been felled and the stump extracted from the ground. The absence of heartwood in young trees provides little reason for felling trees less than 20-25 years old so they are allowed to grow to at least this age. The extent of heartwood formation is at its maximum at around 30-50 years.

The greatest threat to Indian sandal may be loss through spike disease rather than oil production. Trees of all ages and sizes are liable to be attacked and, if infected, succumb to the disease within about three years.

In Indonesia, continuous harvesting combined with very little regeneration (due to fires, shifting cultivation and uncontrolled cattle grazing) has led to a serious decline in the *S. album* population.

Elsewhere, too, the consequences of destructive harvesting (either for oil production or for sale of the log for incense production [see PRODUCTS OTHER THAN OIL]) are being increasingly recognized and some attempts have been made to quantify loss of the resource. In 1985 it was estimated that live *S. spicatum* stands in Western Australia were sufficient for a further 23 years harvesting before depletion, although favourable technical and economic changes could extend this period. Collection of dead wood (which forms an increasing proportion of the harvested logs) will contribute to a further extension.

HARVESTING/PRIMARY PROCESSING

In India, trees above 60 cm girth are harvested during the post-monsoon period. In areas affected by spike disease only dead and dying trees are harvested. After uprooting, the wood is cut into billets which are then transported to a central depot. The sapwood and heartwood parts of the trunk are clearly demarcated and sapwood is removed accordingly. Roots are primarily heartwood and require no initial division. The value of the wood and the high price that it fetches make smuggling something that the authorities have to contend with.

In preparation for distillation the billets of wood are chipped and then reduced to a powder. Most sandalwood oil is now produced by steam distillation of the powder. In former times direct water distillation, in which the raw material is immersed in water and distilled, was used. The high-boiling nature of the oil makes distillation rather slow and it takes many hours to complete.

Yields and quality variation

The yield of heartwood varies from locality to locality and the age of the tree. In India, trees of 100 cm girth have been reported to yield between 85 kg and 240 kg of heartwood according to the area from which they come.

The yield of oil is highest in the roots, about 10 percent (as received basis), and lowest in chips which are a mixture of heartwood and sapwood (1.5-2 percent). The oil content of the heartwood varies from tree to tree and is higher for older trees. In India, yields of about 0.9 percent have been reported from the heartwood of 10-year old trees, while mature trees of 30-50 years age have yielded 4 percent oil. The oil content also varies according to the colour of the heartwood. Light-coloured wood yields 3-6 percent oil, while dark brown wood yields about 2.5 percent oil.

Oil from the younger trees also has a slightly lower proportion of santalols than the mature trees (ca 80 percent cf 90 percent), another reason for not harvesting at too young an age.

VALUE-ADDED PROCESSING

No further processing of the oil is carried out until it is prepared for fragrance use by the end-user.

PRODUCTS OTHER THAN OIL

Sandalwood is much prized as a wood for carving and is used for making souvenirs and other items requiring fine workmanship. In India sapwood of sandal is used for wood turning, particularly toy making; the wood comes mainly from trimmings and immature trees killed by spike disease.

Sawdust from heartwood prepared for distillation is valuable enough to be collected and sold for use as an incense for religious purposes as well as for scenting clothes and cupboards.

Outside India, where exports of logs are prohibited, there is a thriving market for sandalwood as an incense in joss-stick manufacture. Australia supplies most of this market at present, mainly from *S. spicatum* which has a low oil content and which is, therefore, less attractive as a direct source of oil. Exports of logs from Western Australia were almost 2,000 tonnes in 1989, valued at A$11.5 million. Log exports from other sources have amounted to a few hundred tonnes or less from individual species.

The cotyledons and kernel of sandal seeds contain a fixed oil which has drying properties. Oil-free sandal seed meal is rich in protein and could be utilized as an animal feed if available in sufficient quantities.

DEVELOPMENTAL POTENTIAL

The nature of sandalwood oil and its origin in the heartwood of mature trees makes it an oil that although high in value is not attractive as a short or medium-term source of income for those who might consider cultivating the tree. In India, under natural conditions in the forest, sandal is slow-growing. Growth rate may be increased by improvement of soil fertility and other measures but vigorous growth leads to much reduced heartwood formation. Assuming that existing propagation and cultivation problems can be overcome, opportunities for utilizing sandal as anything other than a long-term cash crop are likely to depend on the identification of elite trees as a source of material for planting. This in turn requires the establishment of a wide-ranging screening programme to search for such trees, not only within *S. album* but amongst other species of *Santalum*. Production of oil from superior trees might then offer possibilities for commercial exploitation in the smaller island communities of the Pacific.

Research needs

Although sandal is highly valued, most research in India has focused on spike disease and little work has been done on the silvicultural and genetic aspects of sandal cultivation. Despite much effort, however, complete characterization of the mycoplasma-like organism believed to be responsible for the disease has still not been achieved. Research is still required to elucidate the precise cause of the disease and the best form of treatment if the risk of infection is not to make sandal cultivation for oil production an unacceptable investment risk.

Research needs include the following:

- Investigation of the intrinsic variability in oil yield and quality within natural populations of *S. album* at the provenance and individual tree level. Indonesia and other sources outside India (where most research to date has been undertaken) should be particularly targeted for sampling. It is known for other genera which occur naturally in Asia (*Pinus*, for example) that marked differences can occur between continental and insular populations of the same species.

- Correlation of heartwood and oil content of trees from natural populations of *S. album* outside India. Very little information is available on the growth characteristics of Indonesian trees and the rate at which they produce heartwood.

- Provenance trials to determine the relative performance of different *S. album* populations.

- Consolidation of tree improvement work already begun in India involving selection of plus trees for high oil content and resistance to spike disease.

- Investigation of oil yields and quality for species of *Santalum* other than *S. album*. The latter species appears to be richer in oil than most others but a systematic study of inter- and intra-species variability is needed to fill the gaps in the present state of knowledge. Where oil yields appear promising, quality assessment should be extended to end-user evaluation; chemical analysis alone is not sufficient to judge the commercial acceptability of oils intended for perfumery use.

- Development of improved propagation techniques and cultivation practices.

- Investigation of the suitability of other tree crops as hosts for cultivated sandal which might themselves serve as sources of income until the sandal is ready for harvesting.

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Table 10
Exports of sandalwood oil from India, and destinations, 1987/88-1992/93
(tonnes)

	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
Total	39	26	34	37	65	42
Of which to:						
France	11	8	14	10	8	9
USA	10	5	5	6	14	8
Soviet Union	7	2	4	7	2	-
Japan	3	2	2	2	4	2
UK	2	1	2	3	3	3
Switzerland	3	2	2	2	1	2
W. Germany	1	2	1	1	3	1
United Arab Emirates	1	~	2	4	5	3
Singapore	~	~	~	~	21	~
Oman	-	-	~	~	~	9

Source: Indian national statistics
Note: Year runs April to March

Table 11
Exports of sandalwood oil from Indonesia, and destinations, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	22	19	12	13	10	13
Of which to:						
USA	16	12	7	10	1	6
Netherlands	2	3	3	-	6	-
Singapore	~	2	-	-	3	3
Switzerland	1	-	-	-	-	3

Source: Indonesian national statistics

CHAPTER 7

LITSEA CUBEBA OIL

DESCRIPTION AND USES

Litsea cubeba oil is distilled from the small, pepperlike fruits of the tree of *Litsea cubeba*.

Oil of Chinese origin, the only source of internationally traded material, is rich in citral (about 70 percent) and has an intensely lemon-like, fresh, sweet odour. It competes to a limited extent with lemongrass, another citral-rich oil, in fragrance applications such as household sprays and fresheners although it is less suitable for use in soaps than lemongrass oil since it has less fixative power.

Its major use, however, both in the People's Republic of China and in international markets, is as a raw material source for the isolation of citral. This is used in its own right for flavour and fragrance purposes or converted by the chemical industry to a number of important derivatives such as ionones, which possess a violet-like fragrance, and vitamins.

WORLD SUPPLY AND DEMAND TRENDS

Markets

Although cheap synthetic citral (ex turpentine or petroleum hydrocarbons) is readily available, and has displaced much of the citral ex lemongrass previously used for derivative manufacture, there has remained a significant market for natural citral which low-priced *Litsea cubeba* oil has been able to meet. However, the oil is not separately specified in trade statistics and this, coupled with the lack of reliable data for Chinese production or exports, makes it difficult to quantify the demand and identify all the consumers. Countries with the capacity to fractionate essential oils and chemically convert isolates into products for the flavour and fragrance industries are the major importers of *Litsea cubeba* oil, i.e. the United States, countries of Western Europe and Japan. Total imports are probably of the order of several hundred tonnes annually, although trade in some years is estimated at up to 500 tonnes.

Supply sources

Chinese production of oil is impossible to quantify accurately. A report of the International Trade Centre in 1986 suggested a figure of 500-600 tonnes annually, but a recent Chinese source placed it much higher at 1500 tonnes pa. Social and economic changes in the People's Republic of China in recent years have led many people traditionally employed in the agricultural sector to turn to more remunerative activities for their livelihoods. One consequence of this has been a fluctuation in the level of harvesting *Litsea cubeba*. If Chinese domestic consumption of *Litsea cubeba* oil grows as expected, then quantities available for export are likely to decrease and opportunities will occur for new producers.

Small quantities of *Litsea cubeba* oil are produced on Java, Indonesia, but from the leaves rather than the fruits and it is not rich enough in citral to be suitable for export.

Quality and prices

Citral content is the most important indicator of oil quality and an international (ISO) standard specifies a minimum value of 74 percent. Both Chinese *Litsea cubeba* oil and Indian lemongrass oil, with which it competes, are described in trade terms as "75 percent", i.e. containing 75 percent citral.

The price of *Litsea cubeba* oil has been erratic as a result of competing economic forces in the People's Republic of China. It has fallen steadily in recent years and at the end of 1993 it was available in London at around US$3.40/kg (compared with US$7.75/kg in early 1991). In early 1994 it had risen slightly to US$4.30/kg. By comparison, lemongrass oil of Indian origin has remained at around US$9.75/kg for most of the last two years. In early 1994 it was US$9.10/kg. The longer term price trend is uncertain for *Litsea cubeba* but a firming is conceivable.

PLANT SOURCES

Botanical/common names

Family Lauraceae:

Litsea cubeba Pers.
(Litsea)

Description and distribution

Litsea cubeba is a small tree, 5-12 m high with a stem diameter of 6-20 cm. It is native to China, Indonesia and some other parts of Southeast Asia, where it occurs mainly in mountainous regions. In the People's Republic of China it occurs naturally in the south of the country but it has been successfully domesticated and large cultivated areas are found in central and eastern China south of the Yangtze River. In Indonesia the species grows wild in Java, Sumatra and Kalimantan from 700 m to 2300 m above sea level.

Effects of oil production on the natural resource

Information on this aspect, if it exists, is not readily accessible outside the People's Republic of China, but it is unlikely that harvesting the fruits for oil production can have seriously affected the state or size of the wild resource.

HARVESTING/PRIMARY PROCESSING

Details of the methods used for harvesting and the timing of it are not available in the more accessible literature. Nor is it known at what age the trees, in areas where they are cultivated, can furnish their first crop.

Standard methods of steam distillation are used to distil the fruits.

Yields and quality variation

Yields of oil distilled from the fruit are reported to be 3-5 percent. What this represents in terms of yield per tree is not known. Oil yield and composition undoubtedly vary according to the provenance origin of the trees but information on this is not well documented. "Krangean" and "trawas" oils from *L. cubeba* growing in West and Central Java, Indonesia, are different in composition, although they are both obtained from the leaves rather than fruits and are richer in cineole than citral.

VALUE-ADDED PROCESSING

Fractionation of the oil and recovery of citral takes place in the country of origin (for Chinese internal use) or the importing country. Chinese exports are of whole oil.

PRODUCTS OTHER THAN OIL

Although it is not a major timber species, the trunk wood of *L. cubeba* is sometimes used for making furniture and handicrafts. Parts of the tree have also been used for medicinal purposes.

DEVELOPMENTAL POTENTIAL

The Chinese monopoly of the market for citral-rich *Litsea cubeba* oil presents both constraints and opportunities for the potential new producer. End-users do not like to be dependent on a single source of supply of any oil and so would welcome alternative sources, providing quality (citral content) was assured and the price was attractive. Production of an oil with a higher citral content than Chinese oil might enable it to be priced at about the same or slightly higher than prevailing levels.

There may be particular potential in remote countries such as Bhutan where *L. cubeba* occurs, labour is available and new high value/low volume cash crops are imperative to social and economic development.

One obstacle to introducing the species into areas outside the People's Republic of China where it does not occur is that of acquiring seed for growing trials. Another is the lack of documented information relating to its cultivation which could be used as a basis for such trials.

Research needs

The following areas need to be researched if citral production is to be taken up by countries other than the People's Republic of China:

- Germplasm screening of *L. cubeba*. Sources of wild *Litsea* growing in Indonesia and elsewhere need to be screened for citral content and oil yield to try and identify suitable sources of planting stock.

- Economic viability of cultivating *L. cubeba*. This includes propagation studies and management trials.

- Germplasm screening of plants other than *L. cubeba*. Continued commercial interest in natural citral makes it worthwhile seeking alternative sources to *L. cubeba*. *Backhousia citriodora* is one plant which has aroused recent interest.

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CHAPTER 8

TURPENTINE FROM PINE RESIN

DESCRIPTION AND USES

Turpentine is the volatile oil distilled from pine resin, which itself is obtained by tapping trees of the genus *Pinus*. The solid material left behind after distillation is known as rosin. Both products are used in a wide variety of applications but only turpentine is discussed in detail here (rosin is briefly referred to in PRODUCTS OTHER THAN OIL, below).

Turpentine, rosin and derivatives of these which have been obtained via tapping of living pine trees (whether natural stands or plantations) are known collectively as gum naval stores (and the turpentine and rosin as gum turpentine and gum rosin, respectively). This distinguishes them from turpentine and rosin which have been recovered as by-products from chemical pulping of pines and which are referred to as sulphate naval stores; and wood naval stores, which are similar materials obtained from aged pine stumps. Neither sulphate nor wood naval stores are discussed further.

Traditionally, turpentine has been employed as a solvent or cleaning agent for paints and varnishes and this is still often the case today, particularly in those countries where the pine trees are tapped. There are also some specialized uses, in the pharmaceutical industry, for example.

Most turpentine nowadays, however, is used as a source of chemical isolates which are then converted into a wide range of products. Many of these, including the biggest single turpentine derivative, synthetic pine oil, are employed for fragrance and flavour use, although there are also many important non-aromatic applications such as polyterpene resins. Pine oil is used in disinfectants, cleaning agents and other products having a "pine" odour. Derivatives such as isobornyl acetate, camphor, citral, linalool, citrinellal, menthol and many others are used either in their own right or for the elaboration of other fragrance and flavour compounds. Many of the odours and flavours in use today, which are associated with naturally occurring oils, may well be derived, instead, from turpentine.

A few of the minor constituents of turpentine, such as anethole, are employed for fragrance or flavour use without the need for chemical modification.

WORLD SUPPLY AND DEMAND TRENDS

Markets

No more than some general comments and an indication of markets are given here. Trade statistics are complex and difficult to analyze in terms of gum turpentine alone: firstly, because it is not always disaggregated from sulphate turpentine and secondly, because there is considerable trade in turpentine derivatives, with a consequent loss of identity in terms of the type of turpentine used as feedstock.

GREENHALGH (1982) estimated world production of all types of turpentine to be approximately 250,000 tonnes in 1979. Of this, about 110,000 tonnes was gum turpentine, most of the remainder being sulphate turpentine. COPPEN (1993) estimated annual production of gum turpentine from the seven major producers at 140,000 tonnes based on 1987-89 data (Table 12). Most recently, DAWSON (1994) has estimated total world production of turpentine at 335,000 tonnes, of which around 100,000 tonnes is believed to be gum turpentine.

The USA and the People's Republic of China are the world's largest producers and consumers of turpentine. Most American requirements are met by domestic sulphate turpentine production but gum turpentine is also imported for fractionation and conversion into derivatives. Chinese requirements are met by her own production of gum turpentine.

Japan, Western Europe (particularly France, which imports Portuguese turpentine for fractionation), India and some Latin American countries (Mexico and Brazil, for example) are all major consumers of turpentine, but many other countries import or use domestically produced turpentine to a greater or lesser degree. Small producers such as Kenya and Thailand consume all their turpentine (a hundred tonnes or so each) locally. Others, such as Indonesia, which produces around 6,000 tonnes pa, export a major part of their production.

Recent export of gum turpentine from Indonesia, and their destinations, are shown in Table 13. There are a large number of importing countries but India is by far the biggest importer - over 4,000 tonnes in 1992 and making up for her own declining production.

Any new producer, therefore, or, indeed, an existing one who is able to expand production, is likely to find a ready market. Importers and end-users of turpentine (and rosin) are always anxious to widen their supply base. In addition, there is usually an ample domestic market.

Supply sources

The largest producer of gum turpentine in the world is the People's Republic of China (Table 12), although most is consumed domestically and does not enter international trade.

Portugal accounts for the greater part of world trade in gum turpentine but volumes have decreased in recent years as a result of falling resin production. The estimate of 16,000 tonnes for Portuguese turpentine production given in Table 12 (1987-89 data) needs to be revised downwards by a significant amount to reflect current levels. Only around 20,000 tonnes of resin was produced in 1993, equivalent to about 4,000 tonnes of turpentine, although this is forecast to rise to 25-30,000 tonnes of resin in the 1994 crop year.

The decline in resin production in Portugal has been brought about by increasing labour costs and a growing unwillingness of people to undertake the arduous task of tapping pine trees. Countries other than Portugal have experienced the problem and the USA, France, Spain and several others, which were formerly very significant producers of gum turpentine (and rosin) from tapping operations, now produce either none or very little. Production in Mexico and India has also suffered.

In many other countries, however, production has either commenced (where none previously existed) or increased in recent years. The prime example of this is Indonesia, where resin production has increased dramatically over the last decade and it is now one of the world's largest producers. Gum turpentine exports from Indonesia increased from around 3,400 tonnes in 1988 to 7,200 tonnes in 1992 (Table 13). Brazil is also now a significant producer although most of its production of turpentine is consumed domestically. Argentina is another South American producer of gum turpentine.

Some other producing countries are noted below (see PLANT SOURCES) although for most of the smaller ones (South Africa, Zimbabwe, Kenya, Thailand, Greece and Turkey) production is confined to meeting domestic needs rather than exports.

Quality and prices

An international (ISO) standard exists for "gum spirit of turpentine" but this is for turpentine intended for use in paints and varnishes.

Turpentine purchased by the chemical industry as a source of isolates for conversion to pine oil and fragrance and flavour compounds is assessed on the basis of its composition. The most versatile and widely used constituents of turpentine are alpha- and beta-pinene. Of these, the latter is the more valuable, although the former is usually more abundant. (The dependence of turpentine composition on the species of pine from which it is obtained is discussed in more detail below.)

A total pinene content of 90 percent or greater would be regarded as good, becoming excellent as the beta-pinene contribution increases above 30-40 percent. Portuguese, American and Brazilian turpentines are all high in pinenes. Anything much less than 70-80 percent pinene would be of limited value for derivative manufacture, at least if the turpentine were offered for sale on the international market. The presence of certain compounds in the turpentine lowers its value; the most common of these is 3-carene, which may comprise 50 percent or more of Indian turpentine.

Gum turpentine is traded in much higher volumes than other essential oils and is often imported direct from source by the end-user or fractionator. Prices are therefore subject to negotiation although they are very dependent on the quality (composition) of the turpentine: the greater the proportion of beta-pinene compared to alpha-pinene, the higher its value. The price of gum turpentine intended as a source of pinenes is also influenced by the price of sulphate turpentine and in the United States there has been an oversupply of this in the last year, leading to a softening of the market.

Where turpentine is intended for smaller, miscellaneous applications rather than fractionation, imports are usually made through dealers who specialize in naval stores. Prices are still dependent on the source and characteristics of the turpentine as well as the supply situation. A general shortage of turpentine in early 1989, for example, led to a sharp increase in the price of Portuguese turpentine (to about £580/tonne FOB Lisbon). The price had fallen to around £385/tonne FOT by mid-1991. In the last two years it has risen again to £480 (mid-1992) and £550/tonne FOB, early 1994 (= US$825 FOB or approximately US$920 CIF London).

By comparison, prices for Chinese and Indonesian turpentine in early 1994 were approximately US$640 and US$520 per tonne, respectively, on a CIF London basis. The higher price for Portuguese turpentine is due in part to its better quality, particularly the absence of 3-carene (which Indonesian turpentine contains), and part to the tightness of supplies following the fall in resin production in 1993. The price should ease somewhat if Portuguese resin production improves, as forecast, in 1994, although the longer-term trend is less certain.

PLANT SOURCES

While most pines yield resin of some sort upon tapping, the question of whether it is economic to do so depends on its quality and the quantities that are produced.

Those species of *Pinus* that are currently tapped, and the countries that are known to utilize them for this purpose, are listed below. Where tapping is solely or mainly carried out on natural stands, as distinct from plantations, this is indicated by (n).

Botanical/common names

Family Pinaceae:

Pinus elliottii Engelm. (slash pine)	USA, Brazil, South Africa, Zimbabwe, Kenya
P. pinaster Aiton (maritime pine)	Portugal (n)
P. massoniana D. Don (Masson pine)	People's Republic of China (n)
P. merkusii (Merkus pine)	Indonesia, Thailand (n)
P. caribaea Morelet (Caribbean pine)	South Africa, Kenya
P. roxburghii Sarg. (syn. *P. longifolia* Roxb. ex Lambert) (chir pine)	India (n), Pakistan (n)
P. oocarpa Schiede	Mexico (n), Honduras (n)
P. sylvestris L. (Scots pine)	Former Soviet Union (n)
P. radiata D. Don (Monterey pine)	Kenya
P. halepensis Miller (Alleppo pine)	Greece (n)
P. brutia Ten.	Turkey

Description and distribution

Pines are coniferous species, native to many parts of Central and North America, Europe and Asia, and small areas of North Africa. At one point their natural distribution extends south of the Equator (*P. merkusii* in Sumatra, Indonesia). In addition, they are widely planted for timber and pulpwood and there are extensive plantations in Africa and South America (as well as elsewhere). Those species which are tapped include temperate and tropical ones and they may grow near sea level or at altitudes of 1,000 m or more. In some parts of the world, such as Mexico and Central America, mixed stands are tapped.

Recent research in South Africa and Brazil has demonstrated that some *Pinus* hybrids which have been developed for improved wood production also give enhanced resin yields. Crosses of *P. elliottii* x *P. caribaea*, one of the most promising hybrids, may therefore be the trees of choice for tapping in the future.

Effects of resin production on the natural resource

If done properly, and using methods which involve removal of bark only, tapping trees causes no damage whatsoever to them and they may be (and are) tapped for up to twenty years or more.

The absence of any adverse effects caused by tapping is demonstrated by the fact that plantation pines are tapped in many parts of the world. No loss in quality of the log is observed after felling, whether it is destined for timber or pulp production, and although there is some loss of volume increment during the period of tapping this is more than compensated for by the revenue earned from resin production.

Even more traditional methods of tapping which involve some removal of wood from the tree (see below) may not be damaging to its survival, and trees can be seen in the wild which show evidence of very old tapping scars but which are otherwise quite healthy. The risk of damage, however, is undoubtedly heightened by use of these methods and if wood is removed too deeply from the tree, or over too wide an area, then it will suffer.

HARVESTING/PRIMARY PROCESSING

Unlike tapping *Boswellia* and *Commiphora* species, which results in discrete, hard "tears" forming on the exposed surface of the tree which are then removed by hand (see OLIBANUM, MYRRH AND OPOPANAX RESINS), pine resin is collected in a manner more akin to rubber tapping. A cup and gutter system is installed on the tree into which the resin flows, albeit more slowly than rubber latex.

Over the course of many years, and in different countries, several different systems of tapping have evolved. It is now recognized that tapping, however it is done, should be carried out carefully and in such a way as to avoid permanent damage to the tree, and the older methods in which deep cuts were made into the tree have generally given way to those which involve removal of bark alone ("bark chipping"). In the case of plantation pines, the use of a particular style of tapping is also influenced by the fact that the tree is to be felled for saw timber or pulpwood. In this case it is common to tap fairly intensively, using a wide face, for four years or so prior to felling.

Traditional forms of tapping (practised in Indonesia, Thailand and India, for example) entail removing a 10 cm-wide sliver of wood from the tree in a vertical direction using a specially designed tool. Exposure of the resin ducts causes resin to flow down the tree and it is directed into the receiver by a small metal gutter. After a while, the resin ducts become sealed and the tapper has to re-visit the tree every 3-4 days to repeat the operation, gradually moving up the tree with each removal of wood. The resin is collected from the trees at regular intervals (but not necessarily at each visit by the tapper) and placed in drums which, when full, are taken to the factory for distillation.

If tapping is continued for the whole year, then the tapped portion of the tree will extend upwards approximately 60 cm, less for a shorter season. The cup and gutter are removed at the end of each season and replaced just above the face in preparation for the new season. Tapping continues up the tree as far as the tapper can comfortably reach, at which point it can commence again near the base of the tree and to one side of the original face (keeping a short distance between the two faces). In this way a tree may be tapped for 20 years or more.

The preferred method of tapping to the one just described entails only removal of bark and is practised in most of the major (and many minor) producing countries. After installation of a suitable cup and gutter system near the bottom of the tree a horizontal strip of bark 2-2.5 cm high is removed, just above the gutter. (In Brazil, a specially designed plastic bag is tied flush to the face of the tree to hold the resin and this eliminates the need for a cup and gutter.) A chemical formulation, either a spray or a paste in which sulphuric acid is usually the "active" ingredient, is then applied along the top edge of the exposed tissue.

The combination of bark removal and acid treatment makes it unnecessary to cut into the wood to open the resin ducts. Equally important, the acid maintains resin flow for a longer period of time than is the case in traditional methods of tapping and the task need not be repeated until 2-3 weeks later, the removal of bark being made above and adjacent to the first one. Labour requirements are, therefore, much reduced compared to tapping methods which do not involve acid treatment.

One aspect of the bark chipping method which gives rise to two slightly different versions is the width of bark which is removed. In the United States, Brazil, Zimbabwe and several other countries where even-aged plantation trees are utilized, tapping is intensive and bark removal extends across the diameter of the tree. In some other countries (Portugal and South Africa, for example), where a long tapping life is preferred over higher short-term yields, a narrow face is used and bark removal is limited to a width of 10 cm. This also enables a simpler system of guttering to be used.

Once it has arrived at the factory, the resin is steam distilled to furnish two co-products, turpentine and rosin. In contrast to direct distillation of plant tissue for essential oils, resin has to be cleaned before it goes into the still. Typically, crude resin comprises 70-75 percent rosin, 15-20 percent turpentine and 10 percent foreign matter (pine needles, bark, insects, etc) and rain water. After dilution of the resin with turpentine (from a previous distillation) insoluble material is removed first by filtration. Ideally, although it does not always take place, water-soluble impurities are then removed by washing the resin with hot water. The cleaned resin then passes to the distillation vessel where the turpentine is recovered. At the end of the distillation the hot, molten rosin which remains in the still is drained into drums or other suitable containers and set aside to cool and solidify.

Yields and quality variation

As an approximate guide, mean annual yields of resin should not be much less than 2 kg per tree if tapping is to be economically viable. Around 3 kg per tree is probably a realistic maximum of what one can expect.

This means that for an operation aimed at producing 1,000 tonnes of resin per year, 0.3-0.5 million trees are required. Distillation of this quantity of resin will produce approximately 650-700 tonnes of rosin and 150 tonnes of turpentine.

Intrinsic quality and yields of resin from the tree are both determined by genetic factors and so the species of *Pinus* that is tapped is crucial to the viability of any tapping operation and the marketability of the turpentine.

P. patula, for example, although widely planted as an exotic species in Africa and elsewhere, does not give good yields of resin and the quality of the turpentine and rosin is extremely poor. As a consequence it is not tapped anywhere in the world. A species such as *P. elliottii* on the other hand, which is also quite widely planted for timber, is tapped because it gives good quality resin and in reasonable yields. In Thailand, where natural stands of both *P. merkusii* and *P. kesiya* exist, only the former is tapped; yields of resin from *P. kesiya* are too low.

Although one can make some generalizations about the relative merits of different species of pine for tapping, resin yields and turpentine quality (chemical composition) can sometimes vary markedly within a species, according to provenance origin. In natural stands, therefore, it may be advantageous to tap trees only in certain areas (although in practice, providing yields are not impossibly low, and if the turpentine is to be used ultimately in whole form rather than as a source of isolates, all trees are usually tapped). In plantations, however, where there may be large-scale planting of a particular provenance, these differences can be important.

In the case of *P. caribaea*, a species with much potential for tapping, there are some differences in turpentine composition between the three varieties (var. *caribaea*, var. *hondurensis* and var. *bahamensis*). Resin yields for this species are, on the whole, higher than for *P. elliottii*, the usual yardstick by which performance is judged, although again there are varietal and provenance differences.

There can also be significant differences in resin yield and turpentine composition between individual trees within a provenance and this can be taken advantage of in breeding programmes aimed at improving the long-term performance of a plantation resource base.

In addition to genetic factors, resin yields are also influenced by climatic conditions. High ambient temperatures are conducive to good resin flow, while prolonged periods of rainfall are not, and the extent of seasonal changes will largely determine the period during the year when it is profitable to tap the trees. Altitude is important insofar as it affects temperature, and it may be that where trees are growing over a range of elevations, only those at the lower, warmer sites can be tapped.

VALUE-ADDED PROCESSING

If the volumes of turpentine being produced are sufficiently high (at least several hundreds of tonnes annually, and preferably much more), and the pinene content is also high, then fractionation and production of value-added derivatives can be considered. In most cases, however, a new producer of naval stores would look first to selling whole turpentine to established end-users or fractionators.

PRODUCTS OTHER THAN TURPENTINE/RESIN

As explained earlier, rosin is always produced with the turpentine at the distillery and so plays a vital role in determining the overall viability of the gum naval stores operation. As with the turpentine, a new producer may be able to serve the domestic market or, if quality is acceptable, export it.

If plantation pines are tapped then the felled trees provide income from sale of the logs for timber or pulp.

Distillation of freshly cut foliage to yield pine needle oil is a possibility, although the market for this is rather specialized and its size is vastly smaller than for turpentine. It is not normally something that is undertaken at the same time as turpentine production.

DEVELOPMENTAL POTENTIAL

Rising labour costs and decreased supplies of gum naval stores from traditional producers mean that there are opportunities for those countries with a standing resource of pine trees, either natural stands or plantations, who do not presently produce turpentine and rosin. Apart from domestic use or exports of turpentine (and rosin), there may be opportunities for a new producer for regional trade in crude resin. Many existing producers of gum naval stores (in Africa, for example) cannot obtain enough resin from domestic resources and would welcome supplementary supplies. In the first instance, therefore, a tapping operation with no processing might be an option.

The production of resin (and from it turpentine and rosin) by tapping brings with it many social and economic benefits. It:

- provides employment and income opportunities for people in rural areas, including women;

- improves the profitability of primary forest activities (when plantation pines are tapped) by co-production of non-wood forest products;

- enables foreign exchange savings to be made through import substitution;

- and it may generate foreign exchange through exports.

Distillation of the resin, although necessarily conducted centrally (since small field stills of the type which might be used to distil plant material are not suitable) is still a technically simple operation and one that does not require sophisticated or hugely expensive equipment.

The technology of processing is therefore not something that need constrain a potential producer in a developing country.

Research needs

Apart from the problems of labour availability, the shortage of resin in many parts of the world is caused by: (a) low yields of resin from trees which are tapped and/or (b) a shortage of suitable trees. Solutions to these problems will not come easily but research aimed at solving them should include the following:

- Improved tapping methodology. More needs to be done to learn how to optimise such variables as streak height, tapping frequency and acid concentration to suit local conditions. Studies should include investigation of modified formulations for the stimulant that is applied to the tree during tapping; "ethrel" is one example of an additive which has been found to enhance resin yields when added to the standard formulation, but it has not yet been evaluated under a wide enough range of conditions. By increasing productivity it may be possible to tap in areas previously not possible (e.g. at higher, cooler elevations).

- Species/provenance trials. There is still insufficient knowledge about the relative performances of different species or provenances in producing resin. Where trials exist which were established to test growth and wood characteristics, and where they are old enough to support tapping (*ca* 15-17 years minimum age), small-scale tapping trials should be set up.

- Investigation of the variability of resin properties within natural populations of pines. Identification of superior provenances (or individual trees within a provenance) and establishment of seed orchards will enable the quality and productivity of plantation pines to be improved in the longer term.

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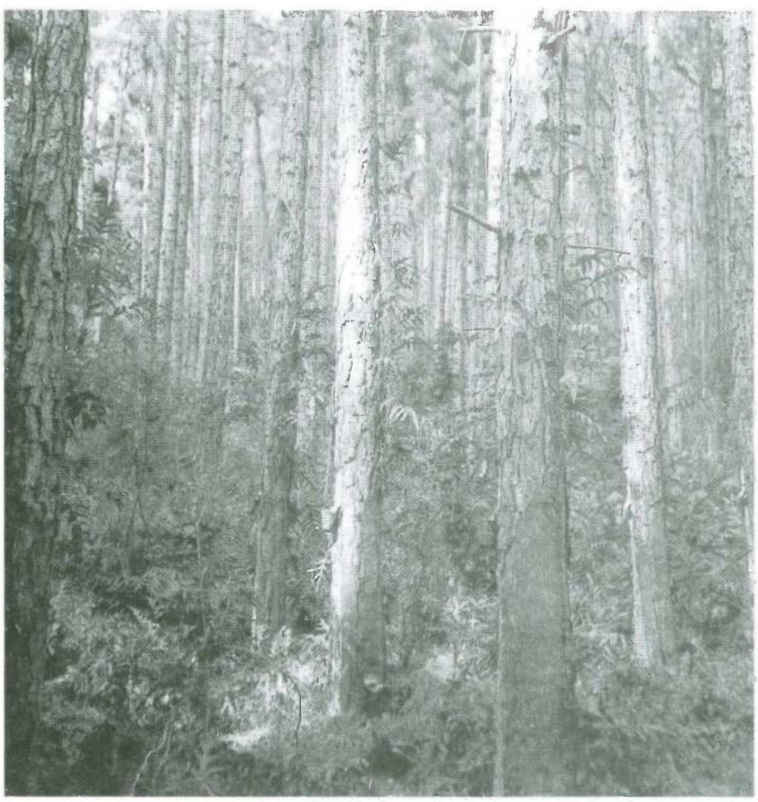
10. Traditional form of tapping practised in Indonesia, *Pinus merkusii* [J. Coppen, NRI].

11. Tapping *Pinus merkusii* in Thailand, which also involves removal of wood from the tree [J. Coppen, NRI].

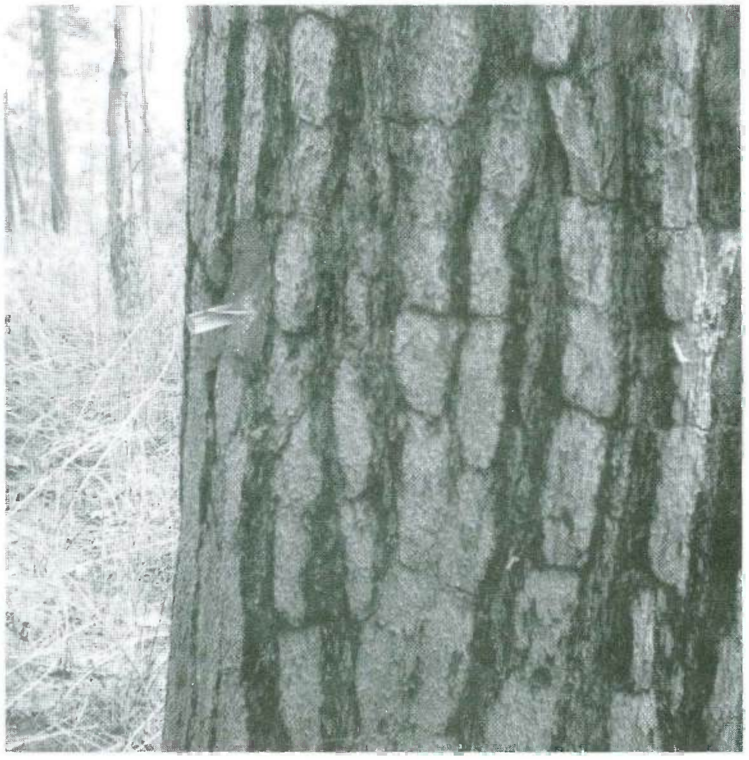
12. Tapped face of *Pinus elliottii* showing bark removal (wide face), South Africa [J. Coppen, NRI].

13. Tapped face of *Pinus elliottii* showing bark removal (narrow face), South Africa [J. Coppen, NRI].

14. Tapping *Pinus elliottii* in Brazil illustrating use of plastic bags for resin collection [J. Coppen, NRI].



15. *Pinus caribaea* in third year of tapping, South Africa [J. Coppen, NRI].



16. Quality assessment: Collection of a sample of resin from *Pinus merkusii*, Thailand [J. Coppen, NRI].

Table 12
Principal producers and production volumes of gum turpentine (and rosin)
(tonnes)

	Turpentine	Rosin
Total	140 000	710 000
Of which:		
China, People's Rep. of	78 000	390 000
Former Soviet Union	17 000	85 000
Portugal	16 000	73 000
Brazil	8 000	36 000
Indonesia	6 000	39 000
Mexico	6 000	28 000
India	4 000	20 000

Source: NRI, estimated using 1987-89 data

Table 13
Exports of gum turpentine from Indonesia, and destinations, 1988-92
(tonnes)

	1988	1989	1990	1991	1992
Total	3421	3403	4935	3989	7234
Of which to:					
India	1619	2030	2470	2559	4121
Japan	1128	552	292	204	95
Taiwan	269	96	82	152	68
Germany	-	349	360	65	165
New Zealand	327	54	-	-	-
Netherlands	-	163	-	192	38
Thailand	-	109	14	-	41
UK	-	50	312	42	164
Singapore	34	-	-	59	-
USA			631	39	209
Italy			227	126	754
Belgium/Luxembourg			394	20	123
France			97	237	508
Canada				152	379

Source: Indonesian national statistics

CHAPTER 9

OLIBANUM (FRANKINCENSE), MYRRH AND OPOPANAX RESINS AND OILS

DESCRIPTION AND USES

Olibanum[1/], myrrh and opopanax are the hardened, resinous exudates obtained from trees of certain *Boswellia* and *Commiphora* species. The resins, particularly olibanum, are used in unprocessed form for both fragrance and flavour purposes.

The major fragrance use is for burning as incense in religious ceremonies. Small amounts of resin are distilled to yield volatile oils and these have their own characteristic, balsamic odours which find use in perfumery. Solvent extracts are also prepared (see VALUE-ADDED PROCESSING below) and both resinoids and absolutes are used as fixatives in perfumes.

The "clean", distinctive flavour of certain types of olibanum makes them highly valued for chewing and this constitutes an important use in some markets. Myrrh and opopanax oils are occasionally used as flavouring agents: the former in oral preparations such as mouthwashes and some beverages which require a slightly bitter flavour, and the latter in liqueurs.

The main use for olibanum, myrrh and opopanax imported into the People's Republic of China is in the preparation of traditional medicines.

WORLD SUPPLY AND DEMAND TRENDS

Markets

Demand for the resins is very difficult to quantify accurately. Official statistics are not always available from the major producing countries and when they are, they are often aggregated as "other natural gums, resins and balsams". There is also a great deal of unofficial trading across the borders of producing countries.

Notwithstanding these remarks, exports of "incense gum" and myrrh from Somalia for the periods 1975-80 and 1976-79, respectively, together with destinations, are shown in Tables 14 and 15. Exports of incense gum from Ethiopia for 1981-83, with destinations, are shown in Table 16.

The data serve to give some indication of individual markets although demand today is believed to be less than was current in the late 1970s/early 1980s. The Middle East and the People's Republic of China are seen to be the major consumers. Germany has imported significant amounts of Ethiopian incense gum.

1/ The terms olibanum and frankincense are used somewhat interchangeably in common parlance. They are also used rather loosely at times with no clear indication of which botanical source the resins are derived from. The term olibanum is used here and, unless indicated otherwise, denotes the resin obtained from northeast African and Arabian species of *Boswellia*.

More recent data are available for Indian olibanum exports and these are shown in Table 17 for the years 1987/88-1992/93.

An overview of world trade in olibanum, myrrh and opopanax was given by COULTER in 1987 and the discussion below draws on this information.

The People's Republic of China is the largest market for all three resins, mainly for use in traditional medicines. Imports of olibanum (mainly the Eritrean type from Ethiopia and Sudan) and myrrh were each significantly in excess of 1,000 tonnes in 1984; opopanax imports amounted to about 400 tonnes. Long-term demand was judged (1987) to be increasing, although difficult to estimate given the unpredictable nature of Chinese buying.

In Europe and Latin America, substantial amounts of Eritrean-type olibanum are used as incense by the Orthodox and Roman Catholic Churches (approaching 500 tonnes in 1987). Similar quantities are imported into North African countries where it is used for chewing.

The Middle East, particularly Saudi Arabia, is another important market for the chewing grade of olibanum, this time the higher quality "maidi" type from Somalia (approximately 500 tonnes in 1987). Smaller quantities of lower grade maidi are employed in the Middle East for burning in the home, although the use of maidi is declining in favour of other fragrance materials such as sandalwood.

Of the order of 50 tonnes pa each of olibanum, myrrh and opopanax are used in Europe (mainly France) for the production of essential oils and extracts.

Supply sources

The principal producers of olibanum, myrrh and opopanax and estimates of their exports in 1987 are shown in Table 18.

Somalia and Ethiopia are by far the biggest producers of the three resins. Somalia supplies most of the world's myrrh and opopanax (ca 1,500 tonnes in 1987) although some of this originates in neighbouring Ethiopia and, more recently, Kenya. Somalia is the only source of maidi-type olibanum, exports of which were estimated at 800-900 tonnes in 1987. Smaller quantities of the "beyo" type of olibanum are produced.

Ethiopia and Sudan produce the most widely traded olibanum, the Eritrean type, and in 1987 this was reckoned to amount to some 2,000 tonnes. More recent estimates are not available although production is believed to have declined as a result of severe droughts in the region and some loss of demand.

Most Indian olibanum is used domestically for making incense sticks. Volumes of exports have been erratic in recent years but averaged about 90 tonnes pa for the six years 1987/88-1992/93.

Some countries outside the natural range of *Boswellia* and *Commiphora* (for example, Indonesia) sometimes record "frankincense" in their export statistics but the botanical source in these cases is not known and they have been ignored in the present discussion.

Quality and prices

The resins are sorted and graded according to size, colour and state of cleanliness before being bagged for export. In Somalia there are up to seven grades of maidi (olibanum from *Boswellia frereana*) and three grades of beyo (olibanum from *B. sacra*). The larger, paler lumps used for chewing are more highly valued than the smaller, darker coloured pieces and the powder and siftings.

Myrrh is usually only classified as cleaned or uncleaned. It is more susceptible to quality variation than olibanum because of the mixture of species that often exists in export shipments. Pieces of good quality selected myrrh should be slightly sticky on breaking, rather than crystalline, indicating a high oil content. It is important to use high quality material such as this for production of essential oil (not only for myrrh but also olibanum and opopanax oils).

There are no international standards for the distilled oils. Quality is judged on aroma as perceived by the prospective buyer.

In early 1994, Grade 1 Somali olibanum (used for perfumery purposes) was priced at about US$6/kg C & F Hamburg. Top-grade Eritrean-type olibanum (for incense) was approximately US$3/kg.

Clean Somali myrrh was available at US$5/kg (early 1994). Somali opopanax was priced at US$3.50/kg (clean) and US$3.00/kg (natural).

PLANT SOURCES

Botanical/common names

Family Burseraceae:

Olibanum

Boswellia sacra Flückiger (syn. *B. carteri* Birdw.)	Arabic: mogar (tree) sheehaz (resin) Somali: mohor (tree) beyo (resin)
B. frereana Birdw.	Somali: yagar (tree) maidi (resin)
B. serrata Roxb.	Indian olibanum, salai guggul

Myrrh

Commiphora myrrha (Nees) Engl. (syn. *C. molmol Engl.*)	Somali: didin (tree) molmol (resin)
C. mukul (Hook. ex Stocks) Engl.	Indian bdellium, false myrrh

Opopanax

Commiphora erythraea (Ehrenb.) Engl. (syn. *C. erythraea var. glabrescens*) — Somali: hagar

C. kataf (Forsk.) Engl.

The botanical origin of the incense resins and the names ascribed to their sources has been a subject of much uncertainty and discussion over many years. Olibanum of Middle Eastern origin is said by some sources to come principally from three species of *Boswellia*: *B. carteri* and *B. frereana* in Somalia and *B. sacra* in southern Arabia. Some other *Boswellia spp.* are minor sources of resin and these include *B. bhau-dajiana* and *B. neglecta* in Somalia and *B. papyrifera* in Ethiopia.

THULIN and WARFA (1987), however, have concluded that *B. carteri* is simply a variable form of *B. sacra* and should not be afforded separate species status. *B. frereana* is a distinct and fairly uniform species, easily distinguished from *B. sacra*.

The situation for *Commiphora*, the source of myrrh and opopanax, is even more complex than for *Boswellia*. True myrrh is produced by *C. myrrha* but numerous other *Commiphora* spp. yield resin and it is not clear to what extent these enter commerce (either as adulterants or as inferior types of myrrh). These other species include *C. abyssinica*, *C. foliacea*, *C. playfairii* and *C. serrulata*.

The name opopanax is derived from that of its original source, Opopanax chironium, but production today is entirely from *Commiphora spp*. The main source is the *C. erythraea-C. kataf* complex but resin is also collected from species such as *C. guidottii* and *C. holtziana*.

Description and distribution

The *Boswellia* species which yield the classical olibanum of commerce are all small trees or shrubs growing in the dry areas of northeast Africa and southern Arabia. They are able to grow in very steep or exposed situations and are often found in rocky slopes or gullies.

B. sacra is a small tree, occasionally up to 8 m tall, branching from the base. It occurs in South Yemen, Oman and northern Somalia. (Those who regard *B. sacra* and *B. carteri* as distinct species identify the former as growing in Arabia and the latter in Somalia.) *B. frereana* grows to a similar height as *B. sacra* but is restricted to northern Somalia.

B. serrata, the source of Indian olibanum, occurs in the drier parts of northern India.

Commiphora species are small trees or shrubs with short, thorny branches. True myrrh is produced by *C. myrrha*, a variable species found in southern Arabia and northeast Africa (chiefly Somalia) as far south as northeast Kenya. Other resin-producing *Commiphora* occur in southern Arabia, Sudan, Ethiopia, Eritrea, Somalia and Kenya. *C. erythraea* and *C. kataf*, the main sources of opopanax, are abundant in many parts of southern Arabia, Somalia, eastern Ethiopia and Kenya.

Effects of resin production on the natural resource

In some cases, as in Somalia, the wild *Boswellia* stands belong to extended families who live in the resin-producing areas. There is therefore some incentive on the part of those who tap the trees not to do it in such a way as to damage the trees and jeopardise their livelihoods. On the other hand, it is impossible to prevent grazing of livestock and in times of drought nomads cut branches for fodder. Severe drought also affects the trees directly, slowing their growth and causing problems of regeneration. The more accessible trees are often tapped continuously through the year, with no rest periods, and this puts them under further stress.

There are no ownership rights over *Commiphora* species in Somalia and the trees are exploited by nomads on a less systematic basis, and with less concern for their state of health, than *Boswellia*.

HARVESTING/PRIMARY PROCESSING

Most resin is obtained by making deliberate incisions into the bark of the tree. The milky liquid that exudes hardens on exposure to air into droplets or "tears" which are then easily detached by the collector. Occasionally, some tears are produced by accidental injury or from splits which occur in the stems or branches of the tree.

Details of the tapping, particularly the time of year it is undertaken, its duration and the interval between individual tappings, vary according to the species and the customs in the area of production. In Somalia, there are usually two periods when *B. sacra* (*B. carteri*) is tapped, each lasting 3-4 months and involving successive tappings at approximately 15-day intervals. *B. frereana* is tapped over a single 8-9 month period with a longer, but variable, tapping interval. In both cases the timing of the tapping periods depends on the onset and extent of the rains.

Tapping involves removing small areas of bark from the tree, sometimes using a specially designed tool, otherwise an ordinary axe. New tapping points are made at the same place as old ones after removing hardened resin from the previous cut. If the tapping interval is short then a light scratching of the wood is usually sufficient to cause the resin to flow again.

Sorting and grading of the resin, referred to earlier, is the only form of primary processing undertaken, although this is usually done by the local merchant to whom it is sold rather than the collector.

Yields and quality variation

It is not possible from official records alone to estimate how much resin, on average, is obtained from a tree. Figures of 1-3 kg per tree per year have been cited for olibanum in Somalia. It is known that yields and quality decline during each tapping season as well as over the longer term, particularly in prolonged periods of drought. Drought conditions also affect yields indirectly since there is more competition for labour: watering and grazing places for livestock need to be sought more actively by the herdsmen and there may be less time devoted to tapping.

Unlike most essential oils, there has been no systematic study of the intrinsic variability of olibanum, myrrh and opopanax oils within the natural resource. This is due in large part to the fact that the botanical origin of any particular consignment of resin is not known with any certainty, at least in the case of myrrh.

VALUE-ADDED PROCESSING

Oils are obtained from the crude resins by steam distillation and are then normally used whole for flavouring and fragrance applications.

As an alternative to production of essential oil, all three resins may be extracted with organic solvents to furnish either a "resinoid" or an "absolute".

The resinoid is prepared by extraction of the crude resin with a hydrocarbon solvent. Evaporation of the solvent yields a dark, viscous mass with somewhat plastic consistency. It should contain all the available essential oil from the crude material, although low-grade resinoids can be produced from resins which have previously been distilled.

Strictly, an absolute should be prepared by alcohol extraction of the resinoid. In the case of olibanum, myrrh and opopanax, however, absolutes are usually prepared by direct extraction of the resin with alcohol. Like the resinoids, they may be extracted cold or hot to give products with somewhat different olfactory properties.

PRODUCTS OTHER THAN RESIN

Apart from their use for browsing or as sources of fodder, the trees are not of a size or form which enables them to be utilized for timber production or other large-scale use.

DEVELOPMENTAL POTENTIAL

Although reliable information on the distribution and abundance of the resin-yielding species is not available, and the scattered occurrence of the trees makes detailed surveys a difficult and expensive option, it is believed that the total size of the natural resource and its potential productivity significantly outweigh demand for the products. COULTER (1987) cites official estimates in 1981 of 23,000 tonnes pa for the potential production of olibanum in Ethiopia. With such a large resource base there would appear to be little incentive to domesticate the trees. The inputs (such as irrigation) needed to establish and maintain trees in cultivation would also be extremely costly. Nevertheless, a Swedish aid project in Somalia during the 1980s was aimed specifically at studying the conditions for domestication of *Boswellia*. The outcome of this research is not known.

Value-added processing in the country of origin is one area that could be developed and this offers the possibility of modest gains in foreign exchange for the national economy. Volumes of oil (or extract) which could be traded would be small but high in value.

Research needs

Two areas of research are readily identified. The greatest need is for up-to-date information on the present scale of production and markets for the resins and value-added products. Without this knowledge it is impossible to know how much scope there is for increased production, what types and grades of resin are in demand, customers quality requirements, deficiencies in quality of present consignments, etc.

Coupled with this is the need to undertake surveys in selected areas to try and assess the size and productivity of the resource, the extent to which it may be under- or over-utilized (and therefore capable of meeting any increased demand) and the state of health of the trees.

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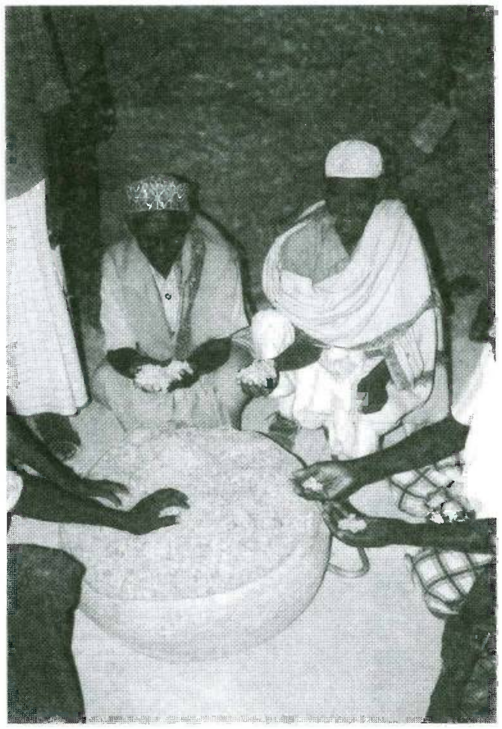
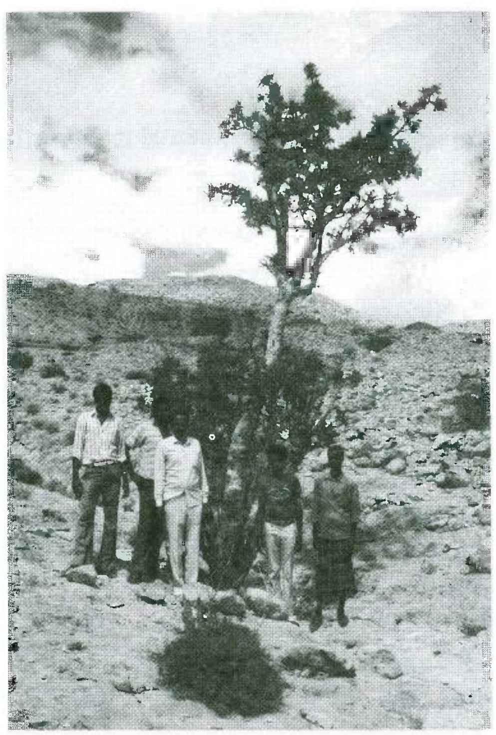


17. Olibanum ("beyo") collected from *Boswellia sacra*, Somalia [J. Coulter, NRI].



18. *Boswellia sacra*, Somalia [J. Coulter, NRI].

Table 14
Exports of incense gum from Somalia, and destinations, 1975-80
(tonnes)

	1975	1976	1977	1978	1979	1980
Total	684	173	86	81	118	373
Of which to:						
Saudi Arabia	na	156	-	11	67	na
United Arab Emirates	na	-	70	-	22	na
China, People's Rep. of	na	-	-	60	-	na
Djibouti	na	-	16	-	29	na
France	na	16	-	-	-	na
Italy	na	-	-	11	-	na

Sources: Frankincense and Gums Trading Agency, Somalia
Somali national statistics

Table 15
Exports of myrrh from Somalia, and destinations, 1976-79
(tonnes)

	1976	1977	1978	1979
Total	1352	497	199	421
Of which to:				
China, People's Rep. of	1017	361	70	248
Saudi Arabia	199	-	10	83
Djibouti	33	3	30	11
Yemen, People's Dem. Rep. of	69	61	-	-
Italy	-	36	8	16
France	-	10	79	37
Kenya	-	7	-	26

Source: Somali national statistics

Table 16
Exports of incense gum from Ethiopia, and destinations, 1981-83
(tonnes)

	1981	1982	1983
Total	318	831	1122
Of which to:			
W. Germany	138	155	568
China, People's Rep. of	-	486	265
France	64	147	40
Djibouti	55	-	11
Hong Kong	-	-	94
Switzerland	-	-	72
UK	1	-	25

Source: Ethiopian national statistics

Table 17
Exports of olibanum/frankincense from India, and destinations, 1987/88-1992/93
(tonnes)

	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
Total	167	81	19	75	70	113
Of which to:						
USA	25	8	2	15	4	15
United Arab Emirates	30	5	-	-	23	-
Saudi Arabia	13	-	-	12	6	8
Hong Kong	13	13	-	1	-	2
Singapore	9	19	1	9	4	17
Trinidad	8	6	6	15	7	3
Spain	3	6	-	4	-	2
France	10	5	2	7	-	-
Malaysia	5	3	1	4	-	4
Japan	10	-	-	-	-	54

Source: Indian national statistics

Table 18
Principal sources of olibanum, myrrh and opopanax and estimated world trade, 1987
(tonnes)

	Producing country	World trade
Olibanum		
Eritrean type	Ethiopia, Sudan	2,000
Maidi	Somalia	800
Beyo	Somalia	200
Indian type	India	200
Myrrh	Somalia, Ethiopia, Kenya	1,100
Opopanax	Somalia, Ethiopia, Kenya	400

Source: COULTER, 1987

CHAPTER 10

CEDARWOOD OILS

DESCRIPTION AND USES

Although termed cedarwood oils, the most important oils of this group are produced from distilling wood of a number of different junipers/cypresses (*Juniperus* and *Cupressus spp.*), rather than true cedars (*Cedrus spp.*). A cedar leaf oil is distilled from *Thuja occidentalis* but is not discussed here.

Cedarwood oils each have characteristic woody odours which may change somewhat in the course of drying out. The crude oils are often yellowish or even darker in colour and some, such as Texas cedarwood oil, are quite viscous and deposit crystals on standing. They find use (sometimes after rectification) in a range of fragrance applications such as soap perfumes, household sprays, floor polishes and insecticides. Small quantities are used in microscope work as a clearing oil.

All the cedarwood oils of commerce contain a group of chemically related compounds, the relative proportions of these depending on the plant species from which the oil is obtained. These compounds include cedrol and cedrene, and while they contribute something to the odour of the whole oil they are also valuable to the chemical industry for conversion to other derivatives with fragrance applications. The oils are therefore used both directly and as sources of chemical isolates.

In India, *Cedrus deodara* oil has been shown to possess insecticidal and antifungal properties and to have some potential for control of fungal deterioration of spices during storage. However, its commercial use for this purpose remains, at present, speculation.

WORLD SUPPLY AND DEMAND TRENDS

Markets

Excluding the People's Republic of China, for which the magnitude of consumption of domestically produced cedarwood oil is not known, the United States, Western Europe and Japan are the major markets for the oil. (After processing, the derivatives that are produced and their formulated products have a more diverse range of markets.)

The USA utilizes much of its own Texas and Virginia cedarwood oils but also imports significant quantities of Chinese oil. Imports for the period 1989-93, and their sources, are shown in Table 19. Levels of imports over the five years averaged just under 400 tonnes annually, with a range of 320-460 tonnes but no clear trend.

Japanese imports for the same period are shown in Table 20. They averaged about 170 tonnes pa, most of which was from the USA. This suggests that imports are intended mainly for derivative manufacture - Chinese oil has a lower cedrol content than American oil and is used more in its own right as a fragrance oil than as a source of chemical isolates.

In Europe, demand for oil is mainly of the Chinese type. Essential oil dealers indicate that demand is good and should remain so providing supplies continue to be adequate from this source.

Supply sources

Production data are not available for either of the main producers, the People's Republic of China and the United States, and export statistics are also incomplete (US exports of cedarwood oil, for example, are not recorded separately but included with clove and nutmeg oils). It is not possible, therefore, to be precise about the scale of world production or trade. However, Chinese exports are probably of the order of 400-500 tonnes pa, with American exports something over half of this.

East Africa used to be an important source of cedarwood oil but over-exploitation of the wild resource has meant that only very occasional shipments are now available.

Morocco produces cedarwood oil from trees growing in the Atlas mountains but the volumes are believed to be small.

Himalayan cedarwood oil is a relatively recent addition to the list of cedarwood oils produced commercially. Production began in India in the late 1950s and was estimated twenty years later to be around 25 tonnes pa. Most of the oil is consumed domestically. In the seven years 1986/87-1992/93, average recorded exports amounted to less than one tonne pa.

Quality and prices

While overall olfactory properties are important and will be judged by prospective buyers, the use of cedarwood oils as raw materials for derivative manufacture means that chemical composition is also important.

International (ISO) standards exist for Texas and Virginia cedarwood oils. For the former, an alcohols content (expressed as cedrol) in the range 35-48 percent is specified, with a minimum cedrol content of 20 percent. For Virginia oil, a maximum cedrol content of 14 percent is stipulated. Various physico-chemical data are also defined.

In the United States, recent FMA standards replace older EOA ones and are available for Chinese as well as Texas and Virginia cedarwood oils. Compositional data for the American oils are somewhat different to those cited in the ISO standards and illustrate the fact that standards can only be treated as guidelines for facilitating the assessment of quality and not as definitive statements. The alcohols content ("cedrol and related isomers") is specified as falling in the ranges 25-42 percent and 18-38 percent for the Texas and Virginia oils, respectively. For the Chinese oil, the alcohols content is required to be 8 percent minimum.

The price of Chinese cedarwood oil has been quite stable in recent years. In the period early 1991 to early 1994 it has been available from London dealers at US$2.90-3.50/kg, the most recent price being at the lower end of this range. In comparison, Texas and Virginia cedarwood oils at the same time were approximately US$7/kg and US$13/kg, respectively.

PLANT SOURCES

Botanical/common names

Family Pinaceae

Cedrus deodara (Roxb.) Loud.	Himalayan cedarwood, deodar
C. atlantica Manetti	Atlas cedarwood

Family Cupressaceae

Cupressus funebris Endl.	Chinese cedarwood
Juniperus virginiana L.	Virginia cedarwood, Eastern red cedar
J. mexicana Schiede [correct name said by ADAMS (1987) to be *J. ashei* Buch.]	Texas cedarwood
J. procera Hochst	East African cedarwood
Widdringtonia whytei Rendle	Mulanje cedarwood

Cupressus funebris is commonly stated to be the source of Chinese cedarwood oil but one Chinese source indicates that *Juniperus chinensis*, *J. formosana* and *J. vulgaris* are also used.

Description and distribution

Cedrus deodara is a tall, evergreen tree up to 50 m high, occasionally more. It grows extensively on the slopes of the Himalayas in northern India, Pakistan and Afghanistan and is often the most important conifer at elevations of 1650-2400 m.

Cedrus atlantica occurs in the Atlas mountains of Morocco and northwestern Algeria.

Cupressus funebris is an evergreen tree or shrub with a wide distribution in Guizhou, Gansu and Sichuan provinces in the People's Republic of China.

Juniperus virginiana is a slow-growing evergreen tree, up to 18 m tall. It occurs in North America and in the USA is distributed widely from the east coast to the mid- west. Young forests are commonly formed in abandoned fields from seed spread by birds.

J. mexicana is a small tree, up to 6 m tall, and occurs in the southern United States (Texas), Mexico and parts of Central America. In the USA, like *J. virginiana*, it invades abandoned fields and overgrazed rangelands.

J. procera is a tall tree, up to 30 m or more. It is found in the drier highland forests of East Africa, particularly Kenya, at elevations of 1000-3000 m.

Widdringtonia whytei is a tree of rather restricted occurrence in Africa. The greatest concentration is in the Mount Mulanje area of southern Malawi.

Effects of oil production on the natural resource

Most of the cedarwood oils are obtained from wild trees but little information is published on the extent to which oil production may have affected the natural resource. In Kenya, as already noted, there has been a serious depletion of the wild trees as a result of over-exploitation for timber and oil. The position in the People's Republic of China is not known. American oil production utilizes waste wood from trees felled for timber as well as the considerable areas where the junipers grow as invasive "weeds".

HARVESTING/PRIMARY PROCESSING

For those cases where the trees are utilized for both timber and oil production sawdust, wood shavings and other waste wood materials from the saw mills are taken to the distillery for steam distillation and recovery of oil in the normal manner. Sawdust should not be exposed to direct sunlight before distillation, otherwise oil yields and quality are diminished.

In other instances, where the trees are not of a size or form that makes them suitable for primary timber utilization, such as *J. mexicana*, the trees themselves are cut, chipped and steam distilled. Heartwood and stumps contain the most oil although the latter are not widely utilized.

Yields and quality variation

Not unexpectedly, oil yields vary widely according to the type of cedarwood oil produced and the form in which the wood is distilled (sawdust vs chips). Heartwood is richer in oil than sapwood and commercial distillers of Texas cedarwood oil recognize higher yielding trees to be the older, slower growing ones with a strong, central axis. Yields of oil are in the range 1-5 percent.

Some chemotaxonomic studies have examined foliage oils from the various species but little systematic research has been conducted on wood oils. The variability between, and particularly within, species (for even-aged trees) is not known in any great detail. ADAMS (1987) has reported the heartwood oil yield and composition of eleven *Juniperus spp.* growing in the United States. The relative proportions of the important aroma constituents of the oils (alpha- and beta-cedrene, cedrol and thujopsene) varied markedly.

VALUE-ADDED PROCESSING

Rectification of the crude oil to obtain fractions with different olfactory properties, and to isolate individual constituents for derivative manufacture, is carried out either in the country of origin - where there is large-scale production and domestic consumption (e.g. China and USA) - or by end-users in importing countries (e.g. Japan and Europe).

PRODUCTS OTHER THAN OIL

Some of the species are utilized for timber purposes. *Cedrus deodara* is one of the most valuable Indian timbers and is used for railway sleepers and in constructional work requiring beams, posts and frames. It is also used for making pencils. The strong odour of the wood and its oily nature limits its use for indoor work.

Juniperus virginiana produces a light-weight timber which is used for some items of furniture and pencil making. In the southern United States it is sold as an ornamental tree, especially at Christmas.

J. procera is used in Kenya for pencil making, joinery, flooring, etc.

DEVELOPMENTAL POTENTIAL

For those countries which possess sufficiently large areas of *Cedrus*, *Juniperus* or *Cupressus* to consider sustainable oil production, then an examination and trade assessment of trial lots of oil would be worthwhile. Acceptance of oil from a new source for the international market, however, will depend on its quality (composition) and price *vis-à-vis* traditional cedarwood oils. If there is already some use of the wood for timber purposes then waste residues could be utilized to advantage.

Those species such as *Widdringtonia whytei*, which have a limited distribution, could only provide very small quantities of oil to a local market (utilizing waste sawdust from sawn wood). Economic production of such an oil could probably only be undertaken in conjunction with other oils in order to make full use of the distillation facilities.

Research needs

Areas of research that deserve attention include the following:

- Screening of indigenous *Juniperus, Cupressus* and *Cedrus* species. As noted earlier, there is little published information on the wood oil characteristics of many of these species. Leaf oil composition is often very different from wood but may contain the same types of chemical constituents and should also be examined.

- Field surveys of the resource for those species which appear to have some potential. Exploitation of wild trees is only warranted where there is a high degree of natural regeneration or where the plant is considered a weed. In these cases some form of controlled, semi-formal cultivation might be possible.

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Table 19
Imports of cedarwood oil into the United States, and sources, 1989-93
(tonnes)

	1989	1990	1991	1992	1993
Total	457	461	338	317	366
Of which from:					
China, People's Rep. of	259	342	na	na	na
Hong Kong	158	58	na	na	na
Canada	23	15	na	na	na
UK	14	32	na	na	na
France		14	na	na	na

Source: US national statistics

Table 20
Imports of cedar oil into Japan, and sources, 1989-93
(tonnes)

	1989	1990	1991	1992	1993
Total	159	191	157	195	140
Of which from:					
USA	126	179	157	193	138
China, People's Rep. of	32	12	-	1	2

Source: Japanese national statistics

APPENDIX 1
BASIC PRINCIPLES OF STEAM DISTILLATION

Most essential oils are obtained from the plant material by a process known as steam distillation. Descriptions and explanations of the theory and practice of steam distillation are given elsewhere (AMES and MATTHEWS, 1968, and DENNY, 1991) and the reader is referred to these for detailed discussions of equipment needs, distillery layout and methods. An indication of what is involved is given here.

The fundamental nature of steam distillation is that it enables a compound or mixture of compounds to be distilled (and subsequently recovered) at a temperature substantially below that of the boiling point(s) of the individual constituent(s). Essential oils contain substances with boiling points up to 200°C or higher, including some that are solids at normal temperatures. In the presence of steam or boiling water, however, these substances are volatilized at a temperature close to 100°C at atmospheric pressure. The mixture of hot vapours will, if allowed to pass through a cooling system, condense to form a liquid in which the oil and water comprise two distinct layers. Most (but not all) essential oils are lighter than water and form the top layer. The steam that is used for the distillation is generated either within the steel vessel that contains the plant material (by boiling water contained at the base) or by an external boiler.

The use of steam generated within the vessel requires that the leaf be supported above some boiling water by a grid. The water is heated either directly using a fire or by heat exchanger coils. The simplicity of the method makes it suitable for small-scale distillation of essential oils.

If steam is generated, instead, by an external boiler it is introduced into the base of the vessel via an open coil, jets or similar device(s). The advantages of this type of distillation are that it is relatively rapid and capable of greater control by the operator. The vessel can be emptied and recharged quickly and with the immediate reintroduction of steam there is no unnecessary delay in the commencement of the distillation process. Oils produced by this means are more likely to be of acceptable quality than those produced using the more direct method.

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Flavours and fragrances are an important group of non-wood forest products. This publication contains information about the sources, uses, manufacturing processes, markets, research needs and development potential of nine selected flavours and fragrances of plant origin representing the different varieties or types of the product. Countless flavours and fragrances have found their way via essential oils into everyday life. They are found, for example, in foods, drinks and confectionery items; in products of personal use such as perfumes, deodorants, shampoos, soaps, toothpastes and mouthwashes; in pharmaceutical preparations to mask disagreeable tastes; and in items used in the house or office or in industry such as air fresheners, detergents and cleaning agents. The purpose of this publication is to disseminate useful information on this important group of products and thereby to promote their development.

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