Report

on

A Study into the Potential of Aromatic Plants

for

Essential Oils

in

Mozambique

by

MBB Consulting Services South (Pty) Ltd
Stellenbosch, South Africa

In association with

African Business Access
Cape Town, South Africa

July 2006

Project No. J1002/2

Reg. No: 2005/009287/07

<u>Report</u>

on

A Study into the Potential of Aromatic Plants

for

Essential Oils

in

Mozambique

by

MBB Consulting Services South (Pty) Ltd
Stellenbosch, South Africa

In association with

African Business Access
Cape Town, South Africa

July 2006

Project No. J1002/2

A STUDY INTO THE POTENTIAL OF AROMATIC PLANTS FOR ESSENTIAL OILS IN MOZAMBIQUE

TABLE OF CONTENTS

SECTION 1:
TERMS OF REFERENCE

Introduction – Context

The Mozambican great aromatic plant diversity and good overall knowledge at a botanical level are signals of potential fore developing of essential oil production from wild plants. The possibility of this activity be exploited either by small scale operators in rural areas and commercial farmers and the multiplicity effect of generating considerable jobs, income, added value, and the contribution to poverty reduction of the local population and of the country are some of the reasons why the CPI – Investment Promotion Centre of Mozambique, is keen to promote the sector.

CPI is seeking the basic elements of this sector in Mozambique, in order to promote it in a credible manner. Therefore, it is advisable to undertake a general survey of the sector. The proposed intervention is one of the follow-up actions to the in-depth sector study carried out by the CDE in 2002/2003 on the essential oils production in Malawi, Mozambique, Tanzania, Uganda and Zambia.

Objective of the Mission

To undertake a general survey of the sector in Mozambique, given the large number of wild plants collected in the herbarium, the first phase of the study would be to look at all the plant families that are susceptible to yield essential oils of interest and to cross this list with the herbarium's already considerable list of medicinal and fragrant plants.

The initial deskwork would already allow for a first list of potential plants and to know their general geographic distribution.

A second phase would be to organize the collection of plant material and to undertake trial distillations (extractions) in order to have sufficient essential oil samples to undertake the necessary analysis to determine its potential interest for the various market segments.

Once a smaller number of promising essential oil plants have been identified, it will be necessary to undertake simple field surveys to determine their areas of greater abundance and to determine if it could be harvested in a sustainable manner and in sufficient quantities to launch commercial oil production, without posing an environmental threat.

In parallel, the survey will also look at the potential for introducing other well-known essential oil crops in the different agro ecological regions of the country, in order to generate rapid revenues from essential oil production in these areas.

The synthesis of this information would become a precious guide for the development of such an activity and should be published as a technical guide or handbook, aimed at the newcomers in the essential oils sector.

It is of paramount importance to make sure that this survey is not a pure scientific research document, but rather a practical technical document that shows where the potentialities are and what the necessary steps are to launch essential oil production in a successful way. This is why it is recommended that the coordinator of this study will be an expert in the field of essential oil production who will have the necessary technical and market knowledge to steer the survey towards practicality rather than scientific perfection.

The national center for agronomic research, in particular the department of botany headed by Dr Calane da Silva, will be the key technical body, which the consultants will work with and liaise with between visits.

The coordinating expert will also have to keep in permanent contact with the CPI in order to link the technical recommendations to the legislative framework, in order to test the viability of the recommendations with Mozambique's present business context, and within the world markets for essential oils.

Output of the Survey

The various parts of the survey should be published as a single document that will contain the following main parts:

A general description of essential oil production principles

- A listing with technical data sheets for the most promising essential oil plants identified
- A listing of the most promising areas for essential oil production and for given types of products
- A summary of legislative issues affecting directly essential oil production
- A list of useful contacts for distillation equipment and marketing of essential oils.

Reports

In all cases, the final report will have to contain the following parts:

- running of the mission
- results achieved at the end of the mission (comparison between the initial and final situation);
- recommendations for follow-up (addressed to CPI and CDE);
- documents provided for the beneficiary (for example: procedure manual);
- photos and other documents illustrating the mission results, when relevant

In the above will also be included:

- a field survey manual
- data analysis and interpretation
- the incentive framework needed by CPI to encourage essential oil production
- handbook and recommendations for follow-up and for presentation of the findings (to be used by CPI and CDE)
- photos and other documents illustrating the results of the mission, when relevant.

SECTION 2
EXECUTIVE SUMMARY

This Report confirms the expectation that Mozambique could become a major global producer of aromatic oils. A strategy to achieve that objective is proposed. A strategy will be impotent without plans followed by actions. We[1] are so convinced of the potential of aromatic oils in this country that we are determined to be part of, if not instrumental to, the process, which will turn the proposed strategy into reality.

Introduction

The Terms of Reference for this study places great emphasis on the need that its outcome, in its recorded formats, must serve as a manual or handbook for all in Mozambique wanting to become active participants in the field of aromatic plants and the oils extracted from these plants. This is understood to mean that the Report on the study must provide clear guidelines, with both practical information, but also strategic content, on aromatic plants in Mozambique. This requires information on the production of oils from these plants, but also strategies and tactics the entrepreneurs, operators and financiers should follow to place Mozambique on the global map as a producer of quality aromatic oils, meeting all the demands of international marketers and end-users.

During this study we have:

- Identified 175 plant species, indigenous to Mozambique, from which aromatic oils, both fixed and essential, could potentially be extracted From this list we have selected 23 species with high potential to deliver commercially valuable oils. Of these 23 species, the oils from 3 species have already been identified and are recognized as commercially important;

- Identified 53 plant species, alien to Mozambique, but established to the extent that they should be considered as forming the basis for extracting aromatic oils on a commercial basis. From these we have selected 24 species, which could have commercial potential in the short term. The fact that these species, a number of which are already being beneficiated commercially elsewhere in the world, are already adapted to Mozambique, emphasizes the potential of producing commercially known plants and their oils in Mozambique;

- Investigated the feasibility of establishing well-known plants in Mozambique with potential to extract aromatic oils, which are already in demand in international markets. We have identified 51 species whose oils are not only in demand but will be ideally suited to agricultural conditions in Mozambique;

- Made a wide selection of plants in Mozambique with potential medicinal applications, but also because of the fact that they contain aromatic oils;

---

1 Who are **we**? We are firstly the team of specialists who undertook this study and then produced this Report. But we are also the networks, active in the field of aromatic oils we represent and have access to.

In our Report we make a number of recommendations of which a few need to be highlighted already at this stage:

- That no attempt be made to harvest any of the selected indigenous plants for beneficiating their aromatic oils until such time that:

    - the extent, including the size and location, of the natural population of a particular plant has been determined;
    - the knowledge base regarding the natural propagation and multiplication of the plant has been established;
    - the oil extracted from the plants has been fully assessed on a small scale in terms of its market acceptance, including the quality criteria, which the market will demand. The higher the potential of "new" oil, the higher the risk that the potential supply will be overwhelmed by demand. It will require stealth-like actions to introduce such an oil into the market and avoid the risk of unsustainable harvesting;
    - the science and technology of the propagation and cultivation of the plant in a nursery environment has been fully developed, making it possible to replace beneficiation from natural resources with cultivation for commercialization, at short notice;

- That a process be implemented which will enable emerging rural and established commercial farmers to start with the cultivation of known commercial plants for the production of established oils, as soon as possible, and to ensure that market access for these oils is obtained. This initiative will also require that pilot projects need to be started urgently, including the capacity to extract oils at the location of the pilot projects;

- That both emerging rural and established commercial farmers be guided to understand the uncompromising demand for quality of oils from users in international markets;

- That the capacity be created in Mozambique to understand the science and technology of aromatic oil production and marketing. This will include propagation of plants through cultivation to extraction and ultimately packaging and logistics. This capacity will be necessary in a developing economy such as Mozambique. A mechanism must be created to disseminate this understanding and knowledge to all involved in this sector in the country. With this recommendation in mind, we further recommend that:

    - A Centre of Expertise be established in the Chemistry Department of the Eduardo Mondlane University (EMU) to become a fully internationally accredited laboratory for the analysis of aromatic oils and their certification as well as to guide the quality assurance and control measures which will be required;

    - A Centre of Expertise be established at the Instituto Nacional De Investigação Agronómica (INIA) in Maputo, to undertake the development of the science and technology of the propagation and cultivation of all plant species considered for commercialization, to establish a large scale nursery for providing plant material to large scale growers and to ensure that the genetic integrity of all species being commercialized, is determined and safeguarded on an ongoing basis;

  - A Centre of Expertise is established in the Department of Biological Sciences at the Eduardo Mondlane University to have the capacity to train botanists and horticulturalists, at undergraduate and postgraduate levels to find employment in the growing aromatic oil industry; to conduct the necessary research in identifying promising species of indigenous plants; to propagate and cultivate these plants on large scale and to establish an experimental farm to cultivate selected plants on a large scale and to demonstrate their commercial viability. This Centre must also build capacity in extraction technologies and to provide the technical inputs necessary for the extension services offered by the National Department of Agriculture of Mozambique.

- A Centre of Market Information must be created and geared to supply international market information, including pricing levels of oils, demand patterns, value chain developments and the like on a continuous basis to all stakeholders in the industry in Mozambique. Ultimately such a function could be performed by a "Mozambique Aromatic Oils Producer's Association" representing all these stakeholders, but initially it could be accommodated in, for example, the CPI.

- That links with international marketing organizations be established already at the early stages of creating a Mozambican aromatic oils industry, with a clear commitment of long-term involvement and to a slow, progressive strategy of gaining market presence and maintaining it over the long term. Our own marketing network is ready to perform such a function.

These recommendations, from a larger number presented later in this Report, are emphasized up-front because they form the basis from which strategies, tactics and actions will flow during the implementation of projects.

Countries with a long, historical presence and success in aromatic oil production and marketing all have great depth of knowledge about, and skills on, the technologies and principles which drives this industry, all embodied in people. These countries have also invested, over time, in the physical capacity, including the land for cultivation and the equipment necessary to successfully practice agriculture and manufacturing, to the extent that they have achieved substantial production outputs. They have also built, over time, reputations as producers of quality oils, with the capacity to verify the quality of their products on a continuous basis. Through ongoing efforts, they have managed to gain and maintain a presence in the global market place, which has proven profitable enough for them to reinvest into their aromatic oil industries. For them, aromatic oil production and marketing has become integral parts of their national economies.

Mozambique has declared its intention to become another successful participant in this market. Like working towards a medal in the Olympics, this is a slow and arduous process and the desired medal is in the marathon and not the sprints. We believe this Report will prove to be the ideal training manual to start the process towards self-reliance in all aspects of aromatic oil production and marketing.

Success in global aromatic oil markets hinges around information, knowledge and skills. This report provides the framework within which information, knowledge and skills could be mobilized.

The Biology of Oils Extracted from Plants

It is necessary for every person involved in the production of aromatic oils to have some understanding of the biology of the oils. This includes the anatomy and physiology of the plants producing the oil and why a certain extraction technique is better suited for the extraction of a particular oil than another. How the extraction process is handled is one of the most important factors in determining the quality of the oil. In the Report we deal with this aspect in some detail, but it will be an important function of the Centres of Expertise, which we have already referred to above, and deal with again in more detail later on, to ensure that everyone involved in aromatic oil production in Mozambique, from the rural community farmer to a qualified commercial producer, gain a minimum understanding of the biology of oils extracted from plants.

Principles of Aromatic Oil Production and Marketing:
International Norms for Sustainable Agriculture.

There is a growing global consumer-driven trend, followed by manufacturers, not to deal with any supplier or producer of aromatic oils whose sustainability credentials are suspect. A country like Mozambique is particularly vulnerable to strict norms of sustainability – it will, for the foreseeable future, have a predominant rural agriculture and it is trying hard to escape from years of political and economic hardship. In the rush to escape practices, which will ensure sustainability, may not enjoy the priority it deserves.

- The international norms for sustainable agriculture place great emphasis on agriculture, which is ecologically sound, which places a big question mark over attempts to harvest any valuable plant material directly from nature. In a developing agriculture, raising production is often the primary goal. But any ecosystem has an upper limit of productivity – if it is exceeded, the ecosystem will collapse, and fewer people will be able so survive on the remaining resources than before. Although economic viability, social justice, being humane and adaptable is also part of the sustainability equation, once an ecosystem has collapsed, these other ideals will only be rhetoric.

- The main threat to plant diversity is selective species utilization. The idea that a species could be harvested from nature in a sustainable way is a fallacy – except if it is done, based on detailed scientific investigation followed by sound management practices. Scientifically grounded information must be available confirming that the survival of that specific species will not be threatened by harvesting and beneficiating it directly from nature. In rural based agriculture this presents a huge challenge.

- Sustainable cultivation of species with economically viable aromatic oil content presents a much more attractive proposition. At least until the system necessary to harvest sustainably from nature – not underestimating the factor of economic viability – has been worked out. It is also a more attractive proposition to harvest indigenous species from cultivated crops, making it urgent to master the techniques of propagation and cultivation of indigenous species with viable aromatic oils.

Principles of Aromatic Oil Production and Marketing:
The Technologies of Extraction of Aromatic Oils –
Appropriate Techniques for Mozambique

The quality of an aromatic oil is initially made during the cultivation of the plant producing the oil, but finally made – or broken – during the extraction process, and the handling of the oil thereafter. A lack of sophistication in the technique of extraction used and the skill of the operator, has many times resulted in inferior oil, which delivered minimal returns. The skills required to extract high quality oils from aromatic plants differs from cultivating these plants, making it unlikely that a single rural farmer will be able to extract a high quality oil – the investment and management skills required will necessitate the formation of a cooperative between farmers who then provide the required capacities. Delivery of quality product – meeting international demands – is the key to profitability. The quest for quality should be instilled in all persons involved in the production process, particularly those who are the closest associated with the actions, which will deliver quality.

Four major extraction technologies are used in extraction of aromatic oils and will be applicable to the situation in Mozambique. These technologies are discussed at great length in the main Report and will only be referred to here.

- Distillation, where four methods are used: hydro distillation, water and steam distillation, steam distillation and vacuum distillation.

  We propose that the technique of steam distillation receive the most emphasis as it incorporates the best control over distillation conditions and will, if properly operated, deliver the better quality oils. The main difference between this technique and others involving steam is that a separate steam boiler is used to generate the steam, before it is let into the charge vessel, containing the plant material from which the oil is to be extracted. The fact that the plant material is not in direct contact with the steam generation process results in better control of distillation conditions and the delivery of a higher quality oil.

  Steam distillation is the most widely accepted process for the production of essential oils on a large scale and is regarded as the standard practice throughout the flavour and fragrance industry. The only drawback of steam distillation is the high capital expenditure needed to build a system. Nevertheless, we recommend that every effort be made to make steam distillation the standard practice for the distillation of essential oils in Mozambique.

- Vacuum distillation is another distillation technique, which warrants closer attention. In this technique the plant material is placed under a vacuum of varying intensity, depending on the plant material and the composition of the oil required. Under vacuum the boiling points of all the constituents is lowered, resulting in accurate control of the distillate.

Vacuum distillation is normally used when redistilling (refining) oils to separate wanted from unwanted constituents (purification) or improve a particular property or concentrate a particular fraction of the oil (rectifying). It is seldom used to distill oil directly from the plants. We can foresee that, in time, there could be a vacuum distillation operation based in Maputo for the purpose of purification of oils produced elsewhere in the country, before being shipped into export markets.

- Solvent extraction involves the passing of a low boiling solvent through the raw plant material in which the oil then dissolves. The solvent and oil is then separated, normally through distillation. The process can take place under atmospheric conditions and at ambient or elevated temperature, in a partial vacuum or in the presence of a gas. This technique aims to produce the highest yield and quality combination in oils. It is effective to extract quantity but can also produce quality, especially where oils, or constituents of oil, are particularly sensitive to heat. It is a technique, which could be used in large operations where large masses of plant material need to be processed and the quality requirements of the oil is very strict.

- Cold pressing is a mechanical technique used almost exclusively to extract less volatile fixed oils. It is also used in the culinary oil industry, such as the extraction of olive and canola oils. The mechanical system employed does exert great mechanical force on the plant material (normally nuts or seeds or the kernels of nuts), which results in the raising of temperature. The system could be constructed to include the cooling of the process. The use of cold pressing in Mozambique will depend on the strategy, which will be followed in extracting oil from the Canhu or Marula (*Sclerocarya birrea subsp caffra*), Baobab (*Adansonia digitata*) and other oil seeds with aromatic oils. Issues such as location and size of cold pressing units will have to be addressed and the question if the use of super critical extraction won't be more suitable, particularly for the extraction of high quality oil from Canhu.

- Carbon Dioxide of Super Critical extraction was developed during the search for a technique, which will extract oils without doing any damage or resulting in any adulteration. The heat involved in steam distillation techniques does effect the composition of the essential oils. Carbon dioxide, when at sub-ambient temperatures is a liquid and acts as a natural solvent. When passed through the plant material, the oil is dissolved. A subsequent separation step recovers the oil and gas. Its low viscosity allows it to penetrate plant material for efficient extraction and it can afterwards be removed without leaving any residue.

  Producers, moving up the scale of sophistication in extraction techniques, have to consider Super Critical extraction, sooner or later. The technology is expensive, which means that it is unlikely that more than one facility will be considered for Mozambique, but it can create competitive advantages. It will have to be a centrally situated facility, requiring plant material to be transported over long distances to it. It will therefore be better suited for materials such as nuts, kernels and seed, as well as wood or bark; materials, which can be transported without losing oil content or quality.

Principles of Aromatic Oil Production and Marketing:
Quality – The Ultimate Trade Barrier

Perceptions exist among consumers in Europe and North American that African producers are not fully capable and reliable in producing and delivering products conforming to international standards of quality. To them, Africa does not represent a "culture of quality". Another reality is that international quality standards are set by organizations such as ISO, AFNOR, WHO and WTO, and users and consumers in markets worldwide rely on these organizations when considering criteria to measure quality. Aromatic oils produced in Africa need to comply with all international standards, plus more (there are perceptions to change!). The playing field can only be levelled through the visible practicing of science, delivery of verifiable information and complying with all international standards, which may be applicable.

In the Report we venture into a fair amount of detail on how some of the product legislation in the EU and the USA impacts on aromatic oils in general, with pointers to the situation in Mozambique.

During the production of aromatic oils, like all other products, two processes are used to ensure that quality is delivered: Quality Assurance (QA), which includes all interventions which comply with high quality throughout all the processes from pre-cultivation to end-consumer, and Quality Control (QC) which includes the application of all tests required to evaluate the compliance of products with quality specifications, and to report thereon.

Quality systems were developed by the food industry to assure that food is suitable and safe for consumption. These systems include: Good Agricultural Practices (GAP) which is a wide ranging system including raw materials, the environment, genetic resources, harvesting, the soil, documentation and records and human related issues; and Good Manufacturing Practices (GMP) which details with the detail of the manufacturing process and how each step can influence quality. QA and QC also include the practices of tracking (trace-ability), which provides the ability to trace and follow a product through all stages of production and distribution, all the way to the consumer, and quality control analysis. The necessity to have an internationally quality assurance and control laboratory within the systems of GAP and GMP is made quite clear. The fact that Mozambique has the makings of such as laboratory in the chemistry department at the UEM, is a major advantage, to be developed further.

GAP and GMP provide the bases for more complex systems such as the HACCP (Hazard Analysis Critical Control Point) system and various ISO (International Standards Organisation) systems.

The bottom line is: for any producer, be it an individual or a country, participating in international aromatic oils markets, a commitment to quality, as prescribed by international norms, is inescapable. Before anything else happens, Mozambique will have to make that commitment.

Principles of Aromatic Oil Production and Marketing:
Legislative Issues within Mozambique

A major challenge facing Mozambique is to have a proper and effective legislative framework in place to protect the biodiversity of the country. A clear message is presently being delivered at international forums: "Africa's biodiversity is in big trouble". Over exploitation of many of the continent's natural resources, including its plant species, have contributed to the current state of decline the continent is experiencing. A decline in natural resources which unavoidably result in a decline in country's ability to address issues such as poverty alleviation through the sustainable use of its natural resources and the protection of biodiversity and ecosystems. Eco-system protection, or the lack thereof, has short-term impact on issues such as clean water and air, issues, which directly impact on the daily lives of people. Any potential growth in factors of income, such as eco-tourism, will also be dependant on the abilities of countries to constructively address them.

Within Mozambique there is the realization that measures have to be implemented to promote the sustainable use and conservation of biological diversity throughout the country. This is confirmed by the fact that information has been presented on the country's biological biodiversity in a number of critical areas to be used in any constructive attempt to beneficiate a particular resource. One such collection of information is " A preliminary checklist of vascular plants of Mozambique" published by SABONET in 2004. In this document a large number of the indigenous plant species of Mozambique are identified and listed. We have used this list extensively in our surveys to compile this Report. It was also pointed out that the main threat to plant diversity is the selective utilization of species. As a result of these considerations we had to recommend, in the strongest possible terms, that not a single indigenous species be harvested in Mozambique for the purpose of extracting aromatic oils, until such time that convincing scientific proof could support the management regimes, ensuring sustainable exploitation, under which it is proposed to be done. We also recommended that such a policy should be formalized in appropriate legislation.

In this section we also deal with issues regarding:

- Intellectual property rights,
- Protection of traditional knowledge, and
- Legislation on bio-prospecting.

The need to timeously address these issues, to the extent that it has not been done already, is highlighted. This has to be done before the attraction of the country's biodiversity and the intellectual property and knowledge it may contain, becomes too tempting to those with no regard to the sustainable use of countries' natural resources.

Principles of Aromatic Oil Production and Marketing:
Organic Production

It is recognized that there is a worldwide and unstoppable trend towards organic products. This is the case particularly in countries where consumer awareness about the health factors of food, affecting themselves, but also the environment, is strong. This trend has now spilled over to personal products, such as cosmetics and perfumery. The value chains of organic foods are increasingly becoming more transparent to consumers, as the regulatory frameworks, including obligatory and clear labeling, provide the consumer with more information, and the ability to make more informed choices. This increased flow of information is starting to impact on the demand for organic personal care products.

Markets are approaching the stage where organic personal products will not only be accessible to the so called expert organic addicts, but will be readily available to all consumers. The regulatory frameworks, including the certification criteria and processes, so well established for organic food, are starting to fall into place. More and more companies, involved in any of the links in the value chain for organic personal products, are being certified by organizations such as the Soil Association. The Soil Association's standards are based on principles that require the maximum amount of organic ingredients, minimum synthetic ingredients, minimum processing of ingredients and clear labeling so that the consumer can make an informed choice about the product they are purchasing. The standards also contain criteria that means ingredients must be assessed not to be harmful to human health and their manufacture and use must cause the minimum environmental impact.

There is an opinion in the global retail sector, which holds that organic cosmetics are now expanding from niche retail outlets into the wider market. Consumers are becoming increasingly aware of the content of personal products, what they bring into direct contact with their bodies, particularly their skin. The debate whether organic ingredients are better, healthier, than others, is an ongoing one. This should not be the major claim of producers of organic personal products, but rather that consumers should be aware of an holistic picture: human health, environmental health and also the health of the systems of bio-diversity represented by the ingredients contained in these products.

Survey of the Floral Potential for the Extraction of Valuable Oils in Mozambique

Various data-bases have been used in surveying the current and future floral potential of Mozambique. For the indigenous and alien flora, we relied heavily on the SABONET Report No 30, which is a very recent (2004), but preliminary checklist of the vascular plants in Mozambique. This list was produced and published by the Southern African Botanical Diversity Network and records 3 922 indigenous plant taxa in Mozambique of which 177 are endemic and 300 listed on the country's Red Data List. Also 516 taxa of alien or exotic plants are listed. These lists were built on plant specimens kept in the LMA and LMU Herbaria. Other data bases used are included in the international literature on aromatic oil bearing plants.

Using these data bases we identified 175 indigenous plant species, which could have aromatic oil potential from which we selected 23 species requiring initial attention. We also identified 53 alien species from which we selected 24 as species with aromatic oil potential where a number of them are already established aromatic oil producers. Our methodology of identifying and selecting these species is described in the Report. The list on medicinal plants includes medicinal plants with aromatic oil content. For our list of selected commercial plants, we have relied on our international network in trade and marketing of aromatic oils for information on oils, which will find an off-take in the international market place if they are produced meeting the required quality standards and in the volumes demanded by international users.

The selected species in the indigenous, alien and commercial groups are listed below.

As far as the indigenous and alien species are concerned, we have provided, wherever the information was readily available, Reports on their Location as well as Technical matters, which will assist with initiatives to cultivate plants, extract their oils and the process to secure and maintain market entry.

The Agro-Geography of Mozambique with Reference to Aromatic Plant Beneficiation

Success with agricultural development projects is the one economic factor, which will finally put the years of political strife behind the people of Mozambique. The natural resources of Mozambique all point at agriculture as the future driver of its economy. But, these very resources are at risk, partly because of the country's recent history, but also because of overexploitation as these resources are so readily available to alleviate the pressures of daily survival.

A country's climate is both friend and foe of anyone relying on it for their daily bread. We have considered the agroclimatic variables as well as soil as these occur in Mozambique. Agroclimatic variables are the uncontrollable variables, while we maintain that soil condition is a controllable variable. With the correct inputs, at the right time, almost any type of soil could be conditioned to be suitable for the cultivation of any crop, including aromatic plants.

In the Report we have considered a wide range of agroclimatic variables against the background of the unique topography of Mozambique and the five climatic zones which it creates: rainfall over 7 zones considered over the countrywide periods of rainfall, which result in zones with varying erosion hazard levels; allowing different soil types to exhibit varying water capacities, but in certain cases create water logging hazards; the temperature zones across the country indicating, for most of the country, quite acceptable conditions for cultivation of aromatic plants. The consideration of all the agroclimatic variables resulted in the conclusion that certain parts of the country will be suitable to grow a variety of aromatic plants without irrigation, but for other parts it will be advisable to have a source of water, and an irrigation system, available for irrigation.

These observations tie in with the range of indigenous species, from across the country, identified as potentially aromatic oil producers. The distribution of the number of alien species with potential for aromatic oil delivery confirms that agroclimatic conditions throughout the country will support the cultivation of a wide variety aromatic plants.

As stated before, we regard soil condition as a controllable variable. Placing an emphasis on the carbon content of soils, and where carbon content is not adequate, using various approaches to increase its levels, such as composting, use of mulches and the inclusion of humic and fulvic acids in fertilization programs will convert infertile soils to soils which are fertile, healthy with the ability to add sustainability to a farm's agricultural practices

Information on Markets and Current Marketing Strategies

Africa's market share of the global market for aromatic oils is less than 1%. The essential oil sector of this market was estimated by one source as at some $US 13.2 billion in 2004. Another quoted the global market at $US 18 billion for the same period. The United States of America is the largest user and importer ($US 321 million in 2003) while European Union member countries imported essential oils to the value of $US 601 million in 2004. In the European Union, France is the leading importer of essential oils at $US 182 million.

In 2003 China was the world's leading producer of essential oils at just less than 17 000 tons and the Côte d'Ivoire the only African country amongst the top producers at 210 tons for the same period. Morocco has an established position as a supplier to world markets; so has Egypt and South Africa is slowly gaining recognition as a trusted supplier.

These countries have attained positions as suppliers to, for example the United States based on the extraction of various cultivated plants. The only oil from an indigenous plant, which has gained a recognized position on world markets in recent years, is the oil from the Bucchu plant, *Agathosma betulina* and *A. crenulata*. *A. betulina* occurs only in South Africa and has a restricted natural distribution area in the mountains of the Western Cape Province. It is cultivated on a small but increasing scale. As a matter of fact, it is quite difficult to cultivate and there is a growing school of thought, who maintains that the industry has relied too long on harvesting from the wild and that developing the cultivation techniques should have started sooner. The existence of Bucchu oil and its benefits, both medicinal and as an oil with a unique aroma, has been known for more than 200 years.

This emphasizes the fact that the quest for the "unique" indigenous oil will be a slow and arduous process, and the initial thrust should rather be, in a country like Mozambique, aiming to be a recognized player in aromatic oils, towards the cultivation of a range of aromatic oils which will be in demand in the worlds market places in the short term.

A Strategy for an Aromatic Oil Industry in Mozambique

The process of designing a strategy for Mozambique to become a valued participant in the global supply of aromatic oils included a number of actions. Information was gathered from a wide range or sources on the factual situation in Mozambique regarding its floral resources, in particular the value of country's biodiversity and the potential threats thereto; the views of many of the stakeholders in a future aromatic oil industry were obtained through personal interaction over three missions to the country; and a workshop was held in Maputo, involving a number of these stakeholders in a SWOT's analysis exercise, capturing many insights and understanding into the realities found in Mozambique.

Our own experience in the field of aromatic oils, as well as other comparable fields, allowed us to synthesize the strategic content presented in this document. No final word can ever be delivered in any process around strategy design – it has to be ongoing and dynamic, and this Report can only be, at best, another contribution to this process, with hopefully some landmarks along the way indicating that successful implementation is possible.

Recommendations

A number of, in our view, critical recommendations are presented in this Report. Some of them have already been highlighted at the beginning of this Executive Summary, because we want to stress their extreme importance. All our recommendations are detailed in the Section: Recommendations in the Report. They also represent a range of proposed actions, which could be executed within definite timeframes, thereby emphasizing the urgency that implementation must now become the priority.

The recommendations place a strong emphasis on the implementation of pilot projects throughout the country and the fact that these projects will have to include funding which will help to alleviate the risks associated with pilot projects. Furthermore, it is recommended that the capacities must be put into place (referred to already at the beginning of this Executive Summary), which will ensure the achievement of quality to international criteria and also the productivity in terms of the variety and volumes, which will be demanded by the markets.

Some of the Recommendations indicate that certain indigenous plants, such as *Sclerocarya birria* subsp, *caffra* (canhu or marula) and *Adansonia digitat*a (baobab) could already be beneficiated in the short term, despite our strong recommendation that harvesting from the wild is so fraught with dangers as far is its sustainability and risks to biodiversity are concerned, that it should be avoided, at least until serious scientific investigative work has been completed. And then for each project only within the framework of a well-designed business plan.

Other Recommendations refer to the need to establish pilot projects in the northern provinces of Niassa, Cabo Delgado and Nampula. We indicate that this is possible, again within the frameworks of proper business plans, which will mobilize the necessary funding.

Throughout this Report we refer to the idea of Mozambique, having to build the capacity to present itself to the world, and the markets it intends to serve with quality aromatic oils as, **Mozambique, the Green Country**. The trend, driven by consumers worldwide as well as macro factors such as global warming, will produce great rewards for this country.

We also recommend that we be given the opportunity to use this Report to source the necessary funding to implement a range of pilot projects. We will be greatly enabled to achieve these goals if we could receive a mandate to do so from the most appropriate authority in Mozambique.

Strategy Implementation: Future Imperatives: Prospects and Initiatives.

We consistently recommended great caution when considering harvesting form nature any indigenous plant for the purpose of beneficiating its aromatic oil content (for that matter, anything of value which could be derived from such a plant). We provisionally recommended that two species, canhu or marula, and baobab could be considered for short-term beneficiation, but even then certain realities will dictate an approach, which will be best achieved if a detailed business plan could be designed for each project. The case of canhu or marula has been used to present a scenario for a typical approach to a pilot project. This strengthened the argument that pilot projects will strategically be the most sensible way to start building an aromatic oil industry for Mozambique. These projects will need funding, which is not as risk averse as conventional sources of funding are.

We emphasized that the success of these pilot projects will be dependent on the availability of the capacity to ensure that quality and productivity demands will be met. Again, we have to argue strongly in favour of the need to establish these needed capacities at the Departments of Chemistry and Biology at the Eduardo Mondlane University as well as INIA. We also feel strongly that the development of an experimental farm at the UEM will be critical for the success of a future aromatic oil industry in Mozambique.

The possible role of ASSNAP, Agribusiness in Sustainable Natural African Plant Products, is referred to. ASSNAP has indicated their keen interest to become involved in capacity building around these three institutions in Maputo.

The negotiation of market access becomes a fairly simple matter once the quality and supply of an aromatic oil can be guaranteed. It is therefore the capacity to achieve targets in these areas, which will ensure that market based goals will be achieved.

Other future imperatives, and the prospects and initiatives entailed, include the deliberate implementation of specific pilot projects, such as the proposed projects in Maniça and Bobole, the castor oil project in Nampula and then pilot projects, still to be identified, in the northern provinces of Niassa, Cabo Delgado and Nampula.

Strategy Implementation: Financial Modeling

The financial aspects of any operation, including the production of an aromatic or essential oil, and whether on a national scale or a small rural farm, needs careful and continuous consideration. In the end, it is net cash in the bank, which is the measure of the success of any business.

Furthermore, the capital requirements of a new venture, especially in a developing country such as Mozambique need careful consideration. It is unlikely that any of the proposed pilot projects proposed will be able to get of the ground without some form of grant funding.

The financial modeling touched on in the Report aims to provide some insight into these parallel approaches: how to measure, on a continuous basis, the viability of an aromatic oil operation and how to use this information to ensure that adequate capital is available, especially during the start-up, therefore the high-risk phase of a project.

These models, not remotely comprehensive, will have to be expanded for inclusion into the business plan of each pilot project with a major aim to raise the necessary funding for their establishment.

SECTION 3:
THE BIOLOGY OF OILS EXTRACTED FROM PLANTS

When all types of plants in the world are considered, only about 700 plants are taken as aromatic and are therefore important for the production of aromatic oils. A combination of limited source of supply and small volumes of oils contained in each aromatic plant add more value to the oil.[2]. The yield of essential oils from plants varies widely and the broad range is 0,03 – 18,0% of mass[3]. Fixed (or Fatty) oil yields are much higher with levels of more than 50% not unusual. Aromatic oil crops, particularly for the production of essential oils, are therefore regarded as high value, low volume commodities, making them ideal crops to grow and process for smallholder farmers and farmers in communities which are remote and where transport constraints prevent them from producing and marketing high volume cash crops[4].

The biology of all oils extracted from these plants is similar in the sense that the anatomy, physiology and biochemistry of plants dictate that the mechanism of oil production and the loci of secretion and storage in plants are comparable. This includes all vegetable and plant oils, including the well-known edible oils used in culinary practices, as well as aromatic oils used in applications such as cosmetics, perfumery, aromatherapy and pharmaceuticals.

However, under the heading of aromatic oils, this Report will deal primarily with fixed (or fatty) oils and essential oils and will differentiate between these two categories for purposes of production of the oils and directing them into markets.

Fixed (or Fatty) oils These vegetable oils are non-volatile and has to be (cold) pressed from the seed or fruits of plants. They are insoluble in water and have higher boiling points than essential oils. These oils are often described as acylglycerides because they consist of a glycerol molecule attached to various types of fatty acids. Castor oil (from the seed of *Ricinus communis*) is a typical example of an oil with medicinal uses, but also in cosmetics, with the bulk of castor oil production finding application in various industries, such as polymers. Other fatty oils, such as olive and safflower oil, are used as carriers in liquid formulations and ointments used in, for example, aromatherapy.

Essential Oils These oils are more volatile than fixed oils, which allow them to be extracted from plants through a process of steam distillation. Other extraction techniques such as solvent extraction, are often used when better suited to the composition of an oil. The composition of essential oils are mainly monoterpenoids, sesquiterpenoids, phenylterpenoids and coumarins. These compounds are not only used for providing essential oils with their varying aroma's, but are also important as active ingredients in medicinal plants.

---

2 Davis, E et al, 1997. Essential Oils. Washington State University, Agricultural Processing, Pullman, USA. Available on Internet: http://www.wsu.edu/~gmhyde/433_web_pages/433Oil-web-pages/essence/essence-oils.html

3 Sankarikutty, B. and Narayanan, C.S. 1993. Essential Oils In. Eds. Macrae,R. et al, *Encyclopaedia of Food Science, Food Technology and Nutrition* 1655 – 1668. Academic Press, London, United Kingdom.

4 Axtell, BL and Fairman, R.M. 1992.Minor oil crops. Food and Agricultural Organisation of the United Nations, Rugby, United Kingdom.

The oils in plants are contained in parts of plants or structures, specially adapted for the purpose to provide cavities or ducts in the epidermis such as in eucalyptus leaves or the peel of citrus fruit or the glands or hairs originating from epidermal cells as in the modified leaf hairs of geranium.

Different parts of plants often contain different active ingredients, with the sought after oil only occurring in one part. Other parts may contain a different compound, used in medicinal application. An example is the castor oil plant, *Ricinus communis*, where the seed contains up to 50% of a fixed oil while the cake left after expression contains a very poisonous toxalbumin called ricin as well as an alkaloid, ricinine, and the leaves and the bark all have different application in traditional medicine. It may also be possible to manufacture textile fabrics from the fibres derived from the leaves.

Within the plant kingdom, volatile oils are synthesized, stored and released to the environment by a variety of epidermal or mesophyll structures, whose morphology tends to be characteristic of the taxonomic group. These structures, on leaves, roots (including bark), floral parts and fruit, include: oil cells (e.g. ginger, turmeric, vanilla); secretory glands (bay, *Citrus* spp., clove, *Eucalyptus* spp.); secretory ducts (vittae) or canals (Artemisia spp., Angelica spp., anise, Pinus spp.; and glanular hairs or trichomes (Labiatae, Compositae, Geraniaceae, Solanaceae)[5]

Oils may occur in roots of plants (such as the oil from vetiver grass, *Vetiveria zizanoides*), rhizomes (such as the oil from ginger, *Zingiber officinale*), bulbs (such as the oil from garlic, *Allium sativum*), bark (cinnamon bark, such as *Cinnamomum camphora* and *C. zeylanicum*), wood (such as the oil from sandalwood, *Santalum album*), leaf (the various *Eucalyptus* species), flowers (such as oil from cloves, which are the flower buds of *Syzygium aromaticum* or the petals of the rose flower of *Rose damascena*), fruits (such as the oil from the dried fruit of juniper berries, *Juniperus communis* or only the peel of the bitter-orange, *Citrus aurantium*) and seeds (such as the true oil from the nuts of the castor oil plant, *Ricinus communis* or the kernel taken from the nut inside the marula fruit, *Sclerocarya birrea*)

It is not the aim of this section to give a detailed account of the biology of volatile oil production and storage in plants. However, any producer of aromatic plants should have a basic understanding of their relevant biology.

For example, the Family Lamiaceae (Labiatae) will play an important role in a future Mozambican volatile oil industry. Species in this Family carry a great diversity of epidermal hairs, many of which are non-glandular. Glandular trichomes, which do store volatile oils, vary in morphology between species, while the number of grandular trichomes per unit area of epidermis varies considerably amongst labiate species. The reference mentioned at the bottom of this page, and a great body of additional literature, expands greatly on this topic. It is a useful Family to build understanding of the biology of volatile oil production and storage on, and to include in future capacity building initiatives in Mozambique.

---

5 Hay Robert K.M. and Waterman Peter G.1993. *Volatile Oil Crops: their biology, biochemistry and production*. Longman Scientific and Technical. UK.

The question why plants secrete oils or waxes has yet to be fully answered. A number of reasons have been linked to responses from the environment: browsing animals could be deterred, the odours act as insect repellents or the compounds contribute to disease resistance, while terpenes leached from, for example eucalyptus leaves, contribute to allelopathic effects on the forest floor thereby inhibiting germination and growth of competitors. Highly scented oil contained in flowers aids reproduction by attracting pollinators – which explains why bee-keeping and honey production is a good (and potentially profitable) parallel activity to commercial production of essential oil crops.

SECTION 4:
PRINCIPLES OF ESSENTIAL OIL PRODUCTION AND MARKETING: INTERNATIONAL NORMS FOR SUSTAINABLE AGRICULTURE

Background

Any future producer of aromatic oils, including essential oils, in Mozambique will need at least a minimum understanding of the strategic environment, which guides this agricultural sector globally.

Mozambique currently has, and will have for the foreseeable future, a predominantly rural agriculture. In global agriculture, both large scale commercial and small-scale rural agriculture, the concept of sustainability has increasingly become recognized as the foundation of future agricultural practices. The rural farmers in developing economies such as Mozambique, particularly because the country is now working hard to emerge from years of political strife with its unavoidable economic deterioration, are specifically vulnerable and prone to employ agricultural practices and technologies which are not sustainable – in the rush to catch up and recover the lost years.

This section in our Report is not a thesis on sustainability, but rather aims to highlight areas of activity, which could encourage producers to operate with sustainability norms as their guiding lights.

1. International norms for sustainable agriculture

Sustainable agriculture has been described as " the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."[6]

It may be helpful to widen this definition, judging agriculture to be sustainable if it is[7]:

- **Ecologically sound**, which means that the quality of natural resources is maintained and the vitality of the entire agro-ecosystem – from humans, crops and animals to soil organisms – is enhanced.
- **Economically viable**, which means that farmers can produce enough for self-sufficiency and/or income, and gain sufficient returns to warrant the labour and costs involved. It is measured not only in terms of direct farm produce (yield) but also in terms of functions such as conserving resources and minimizing risks.
- **Socially just**, which means that resources and power are distributed in such a way that the basic needs of all members of society are met and their rights to land use, adequate capital, technical assistance and market opportunities are assured.

---

[6] The Technical Advisory Committee of the Consultative Group on International Agriculture Research (TAC/CGIAR 1988). FAO. Rome.

[7] Gips T. 1986. What is sustainable agriculture? In: Allen P. and van Dusen D. (eds.) *Global perspectives on agroecology and sustainable agricultural systems*: Proceedings of the 6th International Scientific Conference of the International Federation of Organic Agriculture Movements (Santa Crus: Agroecology Program, University of California), Vol. 1, pp63 – 74.

- **Humane**, which means that all forms of life (plant, animal, human) are respected. The fundamental dignity of all human beings is recognized, and relationships and institutions incorporate such basic human values such as trust, honesty, self-respect, cooperation and compassion.
- **Adaptable**, which means that rural communities are capable of adjusting to the constantly changing conditions of farming: population growth, policies, market demand etc. This involves not only the development of new appropriate technologies but also in social and cultural terms.

These different criteria of sustainability may conflict and can be seen from different viewpoints: those of the farmer, the community, the nation and the world[8]. There may be conflict between present and future needs; between satisfying immediate needs and conserving the resource base. The farmer may seek high income through high prices for farm products; the national government may give priority to sufficient food at prices, which the urban population can afford. Choices must be made in the never-ending search for balance between the conflicting interests. Therefore, well-functioning institutions and well-deliberated policies are needed on all levels – from village to global – in order to ensure sustainable development.

In agricultural development, raising production is often given primary attention. But there is an upper limit to the productivity of ecosystems. If this is exceeded, an ecosystem will degrade and may eventually collapse, and fewer people will be able to survive on the remaining resources than before – basic ecological principles oblige us to recognize that agricultural productivity has finite limits.

2. Sustainable harvesting from nature

As in most other southern African countries, timber, medicinal and ornamental species are the most important groups of plants used in Mozambique[9]. Close to 70% of the Mozambican population uses medicinal plants for basic healthcare (World Conservation Monitoring Centre 1992). Urban markets in Maputo and Beira sell medicinal plants collected in many parts of the country.

The main threat to plant diversity is selective species utilization[10]. Other threats are related to uses of a non-sustainable nature and include heavy exploitation of natural resources for fuelwood, industrial development, traditional agricultural practices, and human settlements and urbanization[11].

The idea that a plant could be harvested from nature in a sustainable way is a fallacy – except if it is done, based on detailed scientific investigation and sound management

8 Reijntjes C, Haverkort B and Waters-Bayer A. 1994. Farming For The Future: An introduction to low-external-input and sustainable agriculture. The Macmillan Press Ltd. London.

9 Da Silva, M.C., Izidine, S. and Amude, A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. Southern African Botanical Diversity Network Report No.30. SABONET, Pretoria.

10 Mangue, P. 1999. *Community use and management of Licuati Reserve and surrounding areas*, In: P.V. Desanker and L. Santos (eds), Integrated analysis and management of renewable resources in Mozambique.

11 Izidine, S. & Bandeira, S. 2002. Moçambique. In: J.S. Golding (ed.), Southern African Plant Red Data Lists. *Southern African Botanical Diversity Network Report* No.14: 43 – 60. SABONET, Pretoria.

practices. Scientifically grounded information must be available that the survival of that specific species will not be threatened by harvesting and beneficiating it directly from nature. In rural based agriculture this becomes highly unlikely. There could be a number of reasons.

Let us assume that a plant yields 1% (this is a high figure) of a particular essential oil. That means that 1 ton of plant material will yield 10 kg of raw oil. Let's assume further that the extraction process was such that a high quality oil was produced which gives the farmer an income of, say, US$ 20 per kg, that is US$ 200 for the 10 kg oil produced.

If the total plant was used, that plant has been permanently removed from its natural population; if only the aerial parts were used, there may not be re-growth, which means the plant was destroyed anyway; if only the flowers were used, the means of propagation of the plant was destroyed; if the seeds were used, the same means of propagation was removed from the life cycle of the population; if the roots were used, its means of extracting water and nutrients from the soil is endangered. The whole process is fraud with danger of destroying the very resource, which was supposed to develop into a (additional) livelihood for the farmer, and the US$ 200 income, soon disappears.

There are more risks. To collect a ton of plant material from nature may involve a process, which is spread over many square kilometers, with logistical problems of handling and transporting the material. The harvesting process will have to be done by hand and to collect one ton of, say, flowers, is a very difficult task, especially if damaging the plant (and the flower) is to be avoided. If the extraction process, such as distillation, does not start within a limited period of time, the yield and the quality of the oil produced may be compromised and the farmer may end up with only 5 kg of oil for which a price of only, say, US$ 10/kg could be achieved, giving him/her/them only an income of US$ 50 from the ton of material.

This little case study related above, does represent, unfortunately, a very stark reality. That is why we strongly recommend that, before any harvesting from nature is attempted, the scientific approach be adopted. The means the following:

- The size, location and density of the population of a targeted species must be scientifically determined. The capacity to undertake this must be in place. The more species are targeted, the more urgent this becomes;
- The scientific basis of the natural propagation process of a species must be scientifically determined, to be able to make projections for the survival of the species, should it be harvested from nature;
- The propagation process of the targeted species must be duplicated in a nursery environment. This will require the capacity to propagate the species on a large scale;
- The cultivation process, to be able to deliver large numbers of plants to out-growers, must be fully researched and understood and the capacity in place to deliver these numbers;
- Trial plantings, harvesting and oil extraction, under experimental farm conditions, of the targeted species must be started.

3. Sustainable cultivation

The ideal is therefore not to harvest any species from nature, at least not until the scientific base of the process from propagation through cultivation, harvesting, extraction to chemical analysis for that species is well researched and understood. Furthermore, we advocate that it will be more sustainable, including economically viable, to harvest, even indigenous species, from cultivated crops. Crops are cultivated under controlled agricultural conditions, concentrated on ideally situated sites, close to the extraction facility and within reach of an access point to the market – all factors which will contribute the best quality oil extracted from the highest yielding plants. Any aromatic oil, once it is properly extracted and correctly packaged, has an almost indefinite shelf-life. It transports well, so this site of cultivation could be even in the most remote corner of Mozambique, as long as the agricultural conditions are ideal and the people involved are committed.

Sustainable cultivation will present the best opportunity for the largest number of rural farmers and communities to benefit from the establishment of an aromatic oil industry. Rather than rely on the "luck of the draw" – a rural community just happens to be settled near a source of a potentially viable indigenous plant, which they can benefit from, while others have nothing, a sustainable cultivation approach would rather rely on factors such as the suitability of climate and the ability to render the soil of an area suitable to produce a specific crop.

Sustainable cultivation will also ensure a long-term investment into the soil. Whereas ongoing harvesting from nature ultimately results in the mentality that " Mother Nature " will always provide, giving humans the right to recklessly grab whatever is available, sustainable cultivation breeds the approach of farming and living in harmony with nature – to reinvest any dividend after a fair livelihood has been provided.

4. Sustainable harvesting, again

Cases are referred to in this Report where harvesting from nature will have to be, at least initially, the approach for collecting the required plant material for extraction. Two cases are prominent: *Sclerocarya birrea subsp.caffra* (canhu or marula) and *Adansonia digitata (boabab).* There are apparently large and established populations of these trees at specific locations in Mozambique. It stands to reason that the immediate approach must be to start harvesting from nature while gathering all the necessary information to do it, as soon as possible, in a demonstrably sustainable way. Amongst a variety of actions which need to be taken, it must also be determined to what extent it could be possible to start cultivating these trees for ultimate harvesting from such a newly created resource.

It so happens that quite a number of the indigenous species we have identified are large trees where the fruits, nuts or seeds are attractive for the production of an aromatic oil. Amongst these are *Calophyllum inophyllum* (Tamanu) and *Schinioziphyton rautanenii* (mungongo or manketti). As stated before, the problem starts with the fact that no information is available on population sizes at the locations these trees occur. Furthermore, no information exist within Mozambique on how these populations maintain themselves in nature and what impact indiscriminate harvesting will have on these species to sustain themselves.

If Mozambique wants to present the country to the markets of the world as a country which adheres to the principles of sustainable agriculture, these are the issues which must be addressed up-front, and it must be made known, throughout the international community that they are of critical importance, currently and into the future.

SECTION 5:
PRINCIPLES OF ESSENTIAL OIL PRODUCTION AND MARKETING: THE TECHNOLOGIES OF EXTRACTION OF AROMATIC OILS – APPROPRIATE TECHNIQUES FOR MOZAMBIQUE.

Background

To cultivate an aromatic plant – whether through human endeavors or by Mother Nature – and then harvesting the aromatic crop, is only one part of the process towards a desirable and marketable end product. The method of extraction of the desired oil and the sophistication with which it is done, is another important part.

In the past, and still today, poor quality oil was produced as a result of crude extraction methods and producers received minimal returns for their efforts. More efficient and modern plants – which do not necessarily mean much more expensive – can ensure the production of oils whose composition is accurately controlled and conforms to accepted international standards, meeting the requirements of discerning end-users.

The expertise and skills required to extract high quality oils from aromatic plants are quite different from that of propagating and cultivating these plants, with the result that it is unlikely that a single small farmer will be able to extract a high quality oil – the investment and management skills required often necessitates the formation of a cooperative between farmers which then provides these capacities. Furthermore, no producer aiming to deliver to the international fragrance market could operate in ignorance of the quality demands of these markets and should have some understanding of their quality criteria and a capability to measure product quality to these criteria. An appreciation for the value of quality of product should be instilled in people involved throughout the value chain, at all levels of production, but particularly the lower levels, which are most often closely associated with the actions which deliver quality.

This present the challenge to any producing country or individual producer that an understanding of the factors which will ensure the quality, and therefore continuous acceptance by buyers, start at the lowest levels of knowledge and expertise. This means that rural farmers, even workers in the field, must have a minimum knowledge and skill of the technical factors, which will determine quality. For example, understanding that it is necessary to process the bulk of the plant material rapidly after harvesting, as oil could be lost due to evaporation is a core understanding needed. The extraction method itself also requires such a minimum knowledge and skill.

To gain a better understanding of the extraction technologies used it is necessary to know some of the terminology used in the field of aromatic oil processing. For this the reader is referred to the GLOSSARY at the end of this Report.

1. Major Extraction Technologies:[12] [13] [14]

Four major extraction technologies are used predominantly in the extraction of aromatic oils and which are applicable to the situation in Mozambique:

- Distillation,
- Solvent extraction,
- Cold pressing and
- Carbon dioxide (super critical) extraction.

It will be necessary for all participants in Mozambique's aromatic oil industry to have a more than adequate knowledge of all the extraction technologies, their benefits, but also shortcomings, particularly where the market demands for quality are high. Actual producers of oils will require even more detailed knowledge to ensure that the extraction step does not compromise all their efforts to cultivate a plant which will give a top quality aromatic oil. The extraction procedure remains the key controlling step in obtaining the best quantity and quality of aromatic oils.

2. Distillation, where four methods are used: hydro distillation, water and steam distillation, steam distillation and vacuum distillation.

Distillation is a physical method used for the isolation of volatile essential oils. With this method, the plant material is placed in a distillation vessel and steam is passed through the material. This is illustrated in Figure 1. As the steam condenses on the plant material, the oil glands are ruptured due to the release of the latent heat of the steam. The molecules of the volatile oils then escape from the plant material and evaporate. Once the vapour containing both water and the volatile oil is condensed, the oil either floats on top of the water or sinks to the bottom, depending on its density, and can thus be separated.[15]

The essential oil of a plant consists of a number of compounds that generally boil between 150°C and 300°C. If attempts are made to extract these compounds with dry distillation, many will decompose and the oil will be ruined. However, the compounds are steam volatile and can be distilled from the vegetal material at below 100°C.[16]

[12] *The Extraction of Essential Oils from Herbaceous Materials by Steam Distillation*. Colin Talanda. 2006. Institute for Agricultural Engineering , Agricultural Research Council of South Africa. Also presented at the International Aromatic Plants and Essential Oils Symposium. Stellenbosch, South Africa. February 27 – March 1, 2006. Gratefully acknowledged.

[13] Aroma Chemicals Derived From Essential Oils. FRIDGE 2004.

[14] *Essential Oils Crops*. Weiss E.A., 1997. Published by CAB International

[15] Lawrence, B.M. 1995. The Isolation of Aromatic Materials from Natural Plant Products. In: Ed De Silva, K.T., *A Manual on the Essential Oil Industry*, ch. 3, 57-154. United Nations Industrial Development Organisation, Vienna, Austria.

[16] Axtell, B.L. and Fairman, R.M. 1992. *Minor Oil Crops*. Food and Agricultural Organisation of the United Nations, Rugby, United Kingdom.

The preparation, the packing of the material into the charge vessel and the rate/type of distillation must be determined for any particular essential oils crop. It is important to remember that the balance of plant constituents vary from day to day as the plants develops further and that there is not only one profile for a particular oil[17]. Variables such as plant variety, geographical origin, climate, soil type, rainfall, period of harvest, moisture content and distillation conditions effect the oil content and chemical composition[18]

Essential oils isolated from plants may either be superficial (surface borne) or subcutaneous oils (beneath he outer surface). The location of the oil in the plant affects the isolation process.

Four types of distillation are important for the extraction of essential oils:

2.1 Hydrodistillation (or water distillation)

The method of hydrodistillation is used more frequently than any other to extract essential oils from plant materials. It is fairly simple and cost effective making it possible for a small grower or cooperative of growers to operate a small hydrostill; the temperature of the still could be raised firing it with readily available fuels such as wood or even using the spend residues from extracting oils. The principle of this form of distillation is to boil a suspension of an aromatic plant material in water. The vapour then passes through a condenser and the oil, which is immiscible with the water, is then separated. Most of these distillations are performed in rural areas where a steam boiler is not available. With a hydrodistillation system it is important that the water present in the still must always be in excess to last throughout the distillation, to prevent the plant material from burning.

As the method is quite simple, the production of quality essential oils is more dependent on operators' skills, which, in remote areas will also influence the selection and preparation of the plant raw materials. Oils extracted using hydrodistillation tend to have a lower quality than oils produced by other methods for a number of reasons:

- Oxygenated compounds like phenols have a tendency to partially dissolve in the still water resulting in incomplete removal by distillation.
- Some of the oil components like esters are prone to hydrolise while others like acryclic monoterpene hydrocarbons may undergo polymerization.
- As hydrodistillations tend to be small, it takes a long time to accumulate significant quantities of oil. This results in good quality oil being mixed with bad quality oil, reducing the grade of the final product.

---

17 Barson, A. 2002 Distillation of Essential Oils. Amateur Aromatherapy, Manchester, UK. Available on the Internet: http://www.andybarson.btinternet.co.uk/distillation.htm

18 Guenther, E. 1948. the Production of Essential Oils. In: Guenther, E., *The Essential Oils*, ch3, 85 – 187, D.Van Norstrand Company, Inc,. New York, USA

- Hydrodistillation is a slower process than the other methods and therefore less energy efficient.

2.2 Water and steam distillation

In this improved method, the plant material is kept above the water level by a perforated grid. This reduces the capacity of the still but results in a better quality of oil. The water is boiled below the grid and the wet steam passes through the plant charge. Like water distillation, it is widely used in the rural areas as it does not require more capital expenditure than hydrodistillation. The design of the equipment is also very similar to the water distillation equipment[19].

It is important in both water/steam distillation and steam distillation (discussed in 1.3 below) that the plant material is evenly and not too tightly packed allowing the steam to move uniformly through the plant material. Over-packing of the still can cause the steam to force holes through the plant material resulting in parts of the material not to be exposed to steam. This will result in volatile compounds remaining in the plant material in the unexposed areas and consequently a low yield[20]

2.3 Steam distillation

Steam distillation uses water heated in a separate boiler, generating steam. This technique will require a fuel with a higher calorific value than the still residues often used in water and water/steam distillation. Wood or diesel is often used. Where available, electricity is used. Solar energy is also starting to find application.

Again a perforated grid under which the steam is injected through a steam manifold as illustrated in **Figure 1,** supports the plant material. An advantage with a satellite steam generator is that the steam flow rate can be controlled and the heat contact of the plant will be no higher than 100°C, when the steam is not superheated. The heat with which the plant material will come into contact is acceptable and should not cause any thermal degradation of the essential oils distilled[8]. Further advantages of this type of "dry" steam distillation are that the distillation times are faster, energy consumption is also lower than the other distillation methods and steam is also available rapidly and continuously after starting up[9].

Steam distillation is the most widely accepted process for the production of essential oils on a large scale and is also regarded as the standard practice throughout the flavour and fragrance industry. The only drawback of steam distillation is the high capital expenditure needed to build a system.

---

19 Lawrence, B.M. 1995. The Isolation of Aromatic Materials from Natural Plant Products. In: Ed De Silva, K.T., *A Manual on the Essential Oil Industry*, ch. 3, 57-154. United Nations Industrial Development Organisation, Vienna, Austria.

20 Axtell, B.L. and Fairman, R.M. 1992. *Minor Oil Crops*. Food and Agricultural Organisation of the United Nations, Rugby, United Kingdom.

Since steam distillation is the most popular and widely accepted process and also regarded as the standard method by the flavour and fragrance industry, knowledge about the scientific principles guiding the technology is essential. However, it is beyond the scope of this Report to venture into too much detail. It is recommended that at least certain scientists and engineers in Mozambique gain an understanding of these principles. There is considerable information contained in the literature on the technology of distillation. It will be the task of the Centres of Expertise to ensure that such information is disseminated into the industry.

2.3.1 Preparation of Plant Material for Distillation

What is necessary, however, is a good understanding of the Preparation of Plant Material for Distillation**.** This understanding is valid for all methods of distillation, but particularly Steam Distillation.

On the morning of harvesting, it is recommended that the plants receive a couple of hours of sunlight. This is mainly to reduce the moisture content of the plant material caused by dew (or overnight rain). The increased moisture can increase the distillation time and also increase the amount of reflux during the distillation process, depending on the absorptive capacity of the plant material. With some crops there are valuable chemical components whose percentages increase when the plant warms up and hence it is advantageous to harvest crops only once they have warmed up. During wet periods it is recommended that the plants receive 1 to 2 days of sunlight before harvesting, due to the same reasons as discussed above[22].

The preparation of plant material for distillation varies with the material to be distilled[23]. Many plant materials (dried roots, seeds, woods) can be effectively kept for several months without significant loss of essential oil content if the storage room is cool, dark, dry and free from air circulation[24].

For plants bearing superficial oils in thick leaves, actual evaporation of the volatile oil through the walls of the plant tissue cannot readily take place because the oil must first be brought to the surface through hydrodiffusion. This is however not the case with flowers and leaves with thin walls as the volatile oil can easily diffuse through the thin walls and then evaporate from the plant materials surface. This process mainly affects the high-boiling volatile components.

Alternatively, with plant material containing high water content, it is sometimes advantageous to dry the material prior to the distillation process. When leaves of such plants, for example mint, are steamed, liquids from collapsing aqueous cells, as well as condensation from the steam flood their surfaces. The oil glands collapse, but the oil floats on the water and no intermingling between the oil and water can take place.

---

22 Advice provided by Dr Maria de Figueiredo, KwaZulu-Natal Department of Agriculture and Environmental Affairs, Pietermaritzburg, South Africa.

23 Axtell, B.L. and Fairman, R.M. 1992. *Minor Oil Crops*. Food and Agricultural Organisation of the United Nations, Rugby, United Kingdom.

24 Barson, A. 2002 Distillation of Essential Oils. Amateur Aromatherapy, Manchester, UK. Available on the Internet: http://www.andybarson.btinternet.co.uk/distillation.htm

Instead a thin circumferential line of contact between the oil and the water is formed around the perimeter of the surface oil patch. As a result, distillation is exceedingly slow because the transference of latent heat is minimal without mixing at the interface. The yield of oil is also poor, usually due to the strong reflux flow washing down to the bottom of the still. If the plant material has however previously been wilted to a moisture content of about 25%, the material will have a slightly absorptive surface on which the oil and water will intermingle at the interface and hence distillate will be rich in oil and the extraction more rapid[25]. For subcutaneous oils, the volatile oil loss from storing plant material before comminution is not as significant as in the case of comminuted material. Therefore, if a delay in the distilling of the plant material cannot be avoided, the plant material should be stored in its natural condition.

It can therefore be concluded that proper storage and preparation of plant material prior to distillation is vital as it can have an effect on both the yield and the efficiency of the distillation. The extracted oil yield and the distillation times are also affected by the way the plant material is packed into the charge vessel. The plant material packing densities are thus important for oil recovery and also needs to be considered.

2.3.2 Packing Densities and Charging Methods

The method of charging a still with plant material and then discharging it is extremely important, as it effects the amount of labour involved and also the production of the system. Any labour saving device will in the end increase the economy of the process[26]. Hence there has been a drive towards increasing the charge weights, by stamping the herb mass into the still with the assistance of steam to soften the plant material. Studies (using lavender) have however shown that this practice is not cost effective as shown in the table below [14].

	Dry Pack	**Steam Pack**
Mass of Herb (kg)	420	425
Extraction Time (min)	21.43	25.34
Yield Oil per kg Herb (ml)	10.58	9.61
Distillate Ratio oil:water	1:17.41	1:19.68

From this Table it can be seen that the steam pressed charge took 18% longer to distil, yielded 9% oil and consumed 13% more steam. It can thus be deduced that when the density of dry plant material is increased without the help of steam, both the extraction time and the oil yield increases. A uniform packing density of plant material into a charge vessel will be an advantage because if the material is not packed uniformly, the steam will find passages along the less dense areas of the material. As a result oil will not be extracted from the more dense areas that receive no steam.

The conclusion is therefore that tight, dry packing of the herb charge saves time, fuel and increases the oil yield.

25 Denny, E.F.K. 1999. *Field Distillation for Herbaceous Oils*. McKenzie Associates. Tasmania, Australia.

26 Guenther, E. 1948. the Production of Essential Oils. In: Guenther, E., *The Essential Oils*, ch3, 85 – 187, D.Van Norstrand Company, Inc,. New York, USA

2.3.3 Construction of a distillation unit

All the component of a distillation unit has a direct influence on the yield and the quality of the essential oil, which has to be produced. A distillation unit is an assembly of a number of sub-assemblies:

- The charge vessel
- Condenser
- Boiler
- Oil separator.

For a distillation unit of a particular size, all sub-assemblies must be designed and manufactured to form a balanced system. For example, the boiler must be sized to deliver the right amount of steam needed to process the intended amount of material per unit of production time, such as four charges over an 8-hour day. The condenser must be able to condense all the vapours at the maximum flow steam rate to the desired condensate temperature and the separator should be designed to accommodate the maximum condensate flow and be able to completely separate the oil from the water. Steam production and the rate of flow are always related to pressure and the total steam distribution system must be able to accommodate maximum steam flow within the required pressure range.

Essential oils are extremely corrosive. Therefore the materials used for the construction of a distillation unit must be able to withstand the corrosive environment. Therefore, both vapours and liquids must be in contact with stainless steel (either Grade 316 or 304) or glass. These three materials are easy to clean after each distillation, as they do not have any absorbtive properties. The absorbance of essential oils onto the material of construction of the distillation plant should not be allowed as residual odours may be transferred to the next batch, which may be a material from a different plant. Such a contamination will spoil the fragrance of a different type of oil and the value of the oil will be reduced. Where gaskets are used, the material of choice is Teflon, also known as PTFE, which is a polytetra-fluoroethylene plastic that is extremely corrosion resistant and can operate under temperatures greater than 400 ^{0}C and will not melt under the high temperature in the distillation unit.

According to SASSDA[27] the relevant properties of 304 and 316 stainless steel are:

- Excellent corrosion resistance.
- Easily cleanable and has an excellent hygiene factor for product purity and prevents the contamination and tainting of foodstuffs.
- Excellent welding properties.
- Good elevated high temperature strength.
- Excellent fabrication properties.

27 SASSDA. 1999. *A Guide to Stainless Steel Surface Finishes*. Southern African Stainless Steel Development Association, Johannesburg, South Africa.

- **Charge Vessel**

The charge vessel is the container or sub-assembly into which the plant material is placed for distillation. The size of the charge vessel will obviously be determined by the size of the distillation operation, which must be undertaken.

This vessel usually has a grid plate at the bottom that supports the plant material. The steam is injected under the grid, through a manifold which ensures even distribution of the steam. The design and construction of the charge vessel must allow for easy charge and discharge of material to ensure that down time is minimized. Various systems could be used for easy loading and discharging material form the charge vessel after distilling. A tipping mechanism, which allows the charge vessel to be swung around within a frame is the most common method. With this system the entire vessel can swivel and be tipped to remove the distilled plant material. To assist the tipping process, the swivel points are positioned in such a way that the charge vessel is slightly top heavy when full, tilting easily, and correcting itself to upright when empty. Costly lifting equipment is not necessary in this system. A drawback of this system is that the plant material has to be lifted to the top of the charge vessel for loading.

A second method for charging the vessel is a basket system. With this method a basket into which the plant material is loaded is positioned into the charge vessel. Once the distillation is complete, the basket is lifted out of the charge vessel with a mechanical or electric hoist and then discharged and reloaded at ground level. There are also systems where only the grid supporting the plant material is lifted from the charge vessel with the exhausted plant material. After distillation, the plant material is relatively compacted and intermingled and hence sticks together without side support.

The charge vessel should be insulated in order to reduce excessive condensation within the charge vessel that can lead to wetting of the plant material – in the discussion earlier it was pointed out that the most effective way of distilling is where the plant material is exposed to dry steam and not boiled in water as it results in longer distillation times and lower yields due to reflux flow. With the basket system the vessel is most often designed in such a way that a gap exists between the outer wall of the basket and the tank wall. The gap is filled with steam during distillation, surrounding the basket with steam and acting as an insulation layer. With the first system, described above, a second vessel or container into which the plant material is placed is fixed inside that charge vessel with a gap between the two vessels, also creating an insulation layer and reducing the amount of condensation that forms on the inner walls of the basket. The disadvantages of this method are that the charge vessel accommodated less plant material due to the reduction on cross sectional area and the cost of the charge vessel is significantly higher due to the second vessel.

Unavoidably vapours will condense in the charge vessel, which then need to be drained. For this purpose the vessel should be equipped with a suitable drain valve. This drain can then also serve as the outlet for the water used for washing the vessel. To avoid steam leaks, with the oil, which will be lost as well, between the top cover and the charge vessel, these two parts must be clamped together with a suitable gasket in-between. Another type of seal often used for this purpose is a water seal. This seal consists of a lid with its outer rim positioned in a water-filled gutter (**Figure 2**). This method eliminates all the clamps, which has the added benefit that less time is required to remove the lid for loading and discharging after a distillation. The water gutter must be deep enough to overcome the slight steam pressure, which may develop inside the charge vessel. The method of sealing will therefore not be suitable for high-pressure steam. During a distillation, water will evaporate from the gutter, which means that the method is not recommended for distilling roots or woods that require long time to process. It is more suitable for distilling grass, flowers or herb material. Some plant materials are quite voluminous and certain materials often swells and expands up to a third of its original volume. These factors need to be kept in mind when designing the charge vessel. The design height of the still pot in relation to its width depends on the porosity or absorptive capacity of the plant material that the distillation unit will be used for. The ratio of height to diameter for porous material can be greater for materials that are less porous as the amount of moisture that the material will need to absorb increases higher up the charge vessel.

- Effect of charge height on the distillation process

  The charge height in the charge vessel influences the oil content of the distillate with a difference noticeable between superficial and subcutaneous oils. The charge vessel diameter does not have any impact on oil content, but only influences the speed of the steam through the charge.

  With subcutaneous oils (oils occurring beneath the surface of the plant material), the amount of surface oil at the top of the still increases proportionally with charge height. As the steam passes through the layers of plant material, it gathers oil. For each successive layer of plant material (the higher the charge height), the concentration of oil inside the plant, over the concentration on the surface at that level, is reduced by a certain factor. This has the result that the rate of diffusion declines and the extraction time of the top layer, which now represents the whole charge, will increase accordingly.[28]

In the case of superficial oils (oils occurring on the surface of the plant material), as the charge height increases, the oil content of the mixing vapour in the overall mixing space within the plant material, will tend to increase with it. The oil then forms a greater part of the overall vapour pressure, resulting in a reduction of the temperature of the general vapour space. As the saturation temperature on the surface of the plant material always stays constant, the temperature gradient then decreases. As a result the rate of evaporation also decreases due to a reduction in transfer of latent heat causing longer distillation times for higher charge heights[17].

[28] Denny, E.F.K. 1999. *Field Distillation for Herbaceous Oils*. McKenzie Associates. Tasmania, Australia

The vapours pass through the condenser once it exits the charge vessel. The condenser is a vital part of the distillation unit. There are a few different designs of distillation units with varying degrees of simplicity and function.

- **Condenser**

The function of the condenser is to convert all the steam with the dissolved oil vapours into liquid. There is an ideal temperature to which the condensate must be cooled for the oil and water to best separate and decrease separation time. Condensate temperatures at the point of drainage of 25 to 35 ^{0}C are sufficient, but quicker separation times are obtained at higher temperatures. It is important to remember that condensate exit temperature can have a significant effect on the chemical composition of the extracted oil.

In the simplest type on condenser, the vapours pass through a coiled tube contained in a water bath supplied with running cold water, and the condensate is obtained at the bottom of the condenser tube. This system is illustrated in **Figure 3**[29]. Its disadvantage is that the flow of vapours through the system is often hampered, thus creating a backpressure.

A far more efficient type of condenser is the multi-tubular type (**Figure 3**) in which a series of parallel tubes are mounted inside a cylindrical jacket through which the cooling water is passed. This design provides a large surface area for cooling in relation to its volume[18]. The main differences between these two types of condensers are:

Coiled Tubular Condenser	Multiple Tube Condenser
Easy to manufacture	Difficult to manufacture (Requires a well equipped workshop)
Poor heat transfer	Good heat transfer
High pressure build-up during distillation	No pressure build up during distillation
Needs tank of water with sparse use of running water. Non-economical water use.	Needs running water. Economical use of water.
Large in physical size	Smaller in size

The main design requirements for a tubular condenser are[30] also well illustrated in **Figure 4**:

- There must be no tendency for laminar flow on either side of the tube walls for efficient hear transfer. Tubular condensers usually have a series of baffles that redirect the coolant water through the unit to prevent laminar flow of coolant water.

[29] Axtell, B.L. and Fairman, R.M. 1992. *Minor Oil Crops*. Food and Agricultural Organisation of the United Nations, Rugby, United Kingdom.

[30] Denny, E.F.K. 1999. *Field Distillation for Herbaceous Oils*. McKenzie Associates. Tasmania, Australia

- The hot distillate and the cold water moving in opposite directions must pass each other at a maximum practical speed. This means that there must be minimum idle space between the tube bundle and the enclosing shell wall.

- The cross-sectional area of entry and passage through the unit must allow for the expulsion of air when the distillation starts. Air is about 1,5 times more dense than steam which means that the condenser backpressure will be greatest when expelling air at the start of a distillation.

- It must be easy to clean the tubes and to disassemble and reassemble the unit.

- The required condenser size depends on the rate of distillate flow, the acceptable pressure under the still lid when air is being expelled at the start of the distillation, the temperature and quantity of the available cooling water, the desired exit temperature of the condensate and the factors effecting the properties of the heat transfer through the tube wall and the dissolved liquid. A condenser should be designed slightly larger than required, as the condenser surface must be large enough to cool the distillate sufficiently, even at a very high rate of distillation. Slow wetting has many disadvantages, such as hydrolysis of esters, and wetting and conglomeration of the plant charges. These can cause a reduction in the oil yield.

- **Oil separator**

The oils separator, also called the Florentine flask or container, is the most critical component in overall product recovery and the profitability of the plant. The condensate flows from the condenser into the separator, which has the function to quickly and completely separate the oil from the condensed water. The volatile oil and water are mutually insoluble and due to the differences in their specific gravities, they separate into two layers. The position of each layer depends on their specific gravities which means that if the oil is denser than water it separates to the bottom; and remain at the top of its is less dense than water. Since the total volume of water condensed will always be larger than the oil, it is necessary to remove the hydrosol (the condensed water component) continuously during the distillation process.

Oil and water often do not separate immediately in the oil separator. The distillate or condensate must therefore not flow into the separator too rapidly and any turbulence must be avoided to decrease separation time. As a result the condensate should enter the separator at the bottom with a curved outlet (**Figure 5**) in order to create a vortex as a result of the angular entry, which prevents airlocks from forming in the entry pipe. Turbulence is also reduced by the baffle, which is effectively a cylinder on the bottom of the separator.

The distillate flow rate and the rate at which the oil rises through the water phase need to be taken into account when designing a separator. It should be designed and sized to allow for enough time for the solution to settle and separate, while the hydrosol continuously discharges from the outlet at the bottom and the oil continuously pours out of the top outlet. The distillation can then continue without the separator limiting the process. If the separator is sized too small and there is not enough time for the oil to separate, some of the oil will flow out with the hydrosol and will be lost, except if the trouble is taken to recover it from the hydrosol.

The outlets for the oil and hydrosol must be relatively positioned in such as way that both the oil and the hydrosol can continuously discharge. The relative density of the oil is less than hydrosol; the hydrosol outlet will have to be slightly higher than the oil outlet with the actual height difference depending on the relative density of the oil. Since the relative density differs for different oils from different plants, and the actual depth of the hydrosol within the oil separator changes due to a varying distillate flow rate caused by surges from the boiler, the height of the hydrosol outlet should be adjustable.

- Fundamentals of oil separation from water.

  The relative densities of the oil and water are the primary factor in the separation of essential oil from water in the combined condensate following distillation. A significant difference between densities will result in a rapid and more complete separation leading to a higher yield of oil. Oils with a density just slightly less than water will not readily separate from the water phase at room temperature; it will form milky suspensions or emulsions. Separation of such oils will benefit from increasing the temperature of the condensate. As the temperature of the solution increases, the density of the oil decreases more rapidly than that of the water. The increasing difference in density between water and oil will result in more effective separation.

  While increasing the temperature and reducing the density of the oil, the viscosity of the condensate water is decreased more significantly than the oil, thereby overcoming the barrier preventing minute oil particles coalescing into droplets, which will readily separate from water. Certain oils have a higher density to water when their temperature increases. However, due to this reduction in the condensate water viscosity the separation of oils that are denser than water when the temperature is increased, is improved, despite the fact that their density has moved closer to water. For continuous and complete separation the temperature in the separator must be maintained to give sufficient time for the droplets of oil to either rise or sink.

- **Boiler**

The boiler has to produce the steam required to complete a distillation. The size of the boiler will therefore be determined by the amount of steam required to adequately remove the optimum amount of oil from the charge in the still. According to Denny[31], the steam flow rate should be at least between 2 and 4 liters per minute per square meter of cross sectional area of the charge. Boilers in field distillation units generally have a working pressure of about 7 bar, with the stills operating at atmospheric pressure.

There are many different types of boilers available such as electrode, coal fired, diesel fired, gas fired and heavy furnace oil boilers. It is also possible to construct a boiler, which operate with wood as the fuel. Certain factors influence the type of boiler selected such as the size of the required unit, cost of fuel, existing infrastructure on the farm or in the community, the location of the unit on the farm, future expansion plans and preferences of the management of the operation. Each boiler type could also be made available in different sizes with steam flow rates produced under a variety of pressure ranges. Boilers operating at high pressures (approximately 7 bar or higher) are used to attain higher temperatures rather than merely to force the steam through the plant material contained in the charge vessel. Higher temperatures and pressures penetrate the plant material more effectively with less condensation in the still. As a result, these boilers can be more efficient with regards to distillation, by shortening the distillation time when required.

Steam tends to become superheated when it is produced at high pressure in the boiler and enters the charge vessel at a far lower temperature. When steam is superheated, the temperature within the charge vessel will no longer stay close to the boiling point of water, but will increase to the temperature of the superheated steam. The operator of the distillation unit must monitor the temperature within the charge vessel to avoid overheating.

With subcutaneous oils, most of the oil is only vaporised once it has diffused to the outside of the plant material. But diffusion can only take place if hot water is present on the surface of the plant material; diffusion will be slowed down or stopped when the charge is completely dried by the superheated steam. With superficial oils, the oils start evaporating from the plant materials' surface at the points where intermingling of the oil and water occurs. Superheated steam will again slow down the extraction process especially in plant materials with low internal moisture content.

It is therefore advisable to start the distillations with steam produced at low pressures. Once the oil content present in the plant material has decreased, towards the end of the distillation, and when mainly the high boiling constituents of the essential oil remain in the plant material, the pressure of the steam can then be increased. This operation will require considerable technical acumen and understanding of distillation and the use of steam, from the operators of the distillation unit.

---

[31] Denny, E.F.K. 1999. *Field Distillation for Herbaceous Oils*. McKenzie Associates. Tasmania, Australia

2.3.4 Storage and packaging

Under suitable conditions most essential oils can be stored for long periods of time. During storage the oils should be free of water, not in contact with air or sunlight and should be kept cool.

Once the oil has been separated from the hydrosol, it should be filtered to remove any debris that has found its way into the oil. During storage, if even small amounts of water have remained, various aging reaction could take place. Therefore the oil should be stored only once all water has been removed. This could be achieved by filtering the oil through a drying medium such as anhydrous sodium sulphate. Oils, which are dry, should not be cloudy. Even when the oils are stored dry and in clean new drums, inferior odours or flavours may develop in the product due to the action of oxygen present in the small space of air between the oil and the top of the drum or container. A remedy for this problem is to replace the air with dry nitrogen gas. Nitrogen is denser than air and settles under the air, driving the air out through the opening of the drum. It is also good policy to keep the containers as full as possible with oil.

Small amounts of oil could be best stored in tinted glass containers while larger quantities are best stored in metal drums; either mild steel drums, that are lined with epoxy resin or stainless steel drums, which will be costly. When second-hand drums are used, these must be thoroughly cleaned, dried and their epoxy lining properly checked before being filled with essential oil. Under no circumstances must plastic drums or containers be used!!

Fleshly distilled oils often posses some still odours that are unpleasant. These generally disappear after a period of storage. Some oils gradually improve during storage and require a fuller, more rounded aroma.

2.3.5 Oil quality

The value of any essential oil is directly related to the quality of the oil. The distillation step in the production of essential oil is a crucial step where quality is made or broken. Conditions of distillation must be carefully established and controlled according to the nature of the raw plant material to ensure optimum yields and quality of the oil. Too long periods taken by distillation will adversely affect the oil quality and also the cost of distillation. Therefore it is important that unnecessary time spent on distilling be avoided; the distillation must be stopped at the point when it is no longer economically viable to proceed. However, with certain oils such as vetiver or angelica root, the most valuable constituents are extracted at the end of the distillation process, these being the highest boiling fractions. When these plant materials are distilled, the distillation process must be prolonged for hours, even though it seems as though no further oil is extracted. In these cases, experience will have to tell when to stop the distillation, as valuable high boiling constituents may not be distilled resulting in an oil with reduced value.

Any essential oil aimed at worldwide markets has to meet the international standards of odour, chemical composition and overall quality. The uniformity of the odour or flavour between different batched of oil produced is also important to the buyer as a formula for a product can not be changed with every container of oil opened. The environment, climate, soil conditions, time of harvest and post harvest handling all have an effect on the characteristics of the oil; there will always be a certain extent of variation in the chemical composition of oils produced. Attention must also be paid to the purity of the oil, which requires that impurities of both chemical and physical nature must be avoided.

Commercial essential oils are required to comply with a range of standard such as those of the International Standards Organisation (ISO). These standard include quantifiable measures such as numerical values of refractive index, optical rotation, ester values, freezing points, acid values, carbonyl values, phenol contents and chemical compositions, all with lower and upper limits. Oils whose numerical values fall within the accepted range for a particular oil will be acceptable in the market and uses in various industries globally.

2.4 Vacuum distillation

Vacuum distillation obtains oil from plants under a vacuum, varying in intensity, depending on the material. Placing a distillation system under vacuum lowers the boiling point of all the constituents. This technique allows for very accurate control of the distillate since it can be adjusted according to the boiling points of the various oil constituents[32]. Under vacuum boiling points could be varied to a fraction of a degree Celsius. It enables the operator not only to fractionate the distillate very accurately, but also ensures that no physical damage is done or chemical modification of degradation of compounds occurs.

This type of distilling is usually used when redistilling (refining) oils to improve a particular property or concentrate a particular fraction of the oil i.e. rectifying oils. It is very seldom used to distil oil directly from the plant. However, it is possible to enhance the occurrence of certain constituents in an oil by doing the extraction deliberately under vacuum.

Figure 6 represents a diagrammatic description of a vacuum distillation system.

3. Solvent extraction

Figure 7 describes a solvent extraction plant. This extraction method involves passing a solvent through the raw plant material in which the oil then dissolves. The solvent and oil is then separated. The process can take place under atmospheric conditions and at ambient or elevated temperature, in a partial vacuum or in the presence of a gas. Commercial plants use batch, battery or continuous-flow systems, single or multi-solvent techniques, and include solvent recovery and oil-refining equipment.

---

32 *Essential Oils Crops*. Weiss E.A., 1997. Published by CAB International

4. Cold pressing

In 1994 the total world production of vegetable (or fixed) oils amounted to approximately 68 million tons, of which 80% originated from five crops: soybean, oil palm, sunflower, rapeseed, and coconut. Many other plants also produce the vegetable oils of which the major constituents of fatty acids are in most cases sought after for applications outside food production, and including cosmetics and even various industrial applications such as paints and lubricants.

Vegetable oils are extracted, mostly cold pressed (as apposed to warm pressed where additional heat is added to the system), and mainly from the whole fruits or their flesh (such as olives), or the seeds (such as safflower and flax), nuts (such as macadamia) or the kernels (such as marula or canhu) of various plants. These oils do not have the volatility of essential oils, and their higher boiling point and imbeddedness in the cellular structure of the plant therefore means that they cannot easily be distilled from the plant materials.

Solvent extraction is also used sometimes, but we will not concern ourselves with the detail of its technology at this stage. Solvent extraction is a complex operation. It is not suitable for small-scale processing because of high capital and operating costs and the risks of fire and explosions from solvents. Waste management will also present problems.

As far as Mozambique is concerned, the extraction of different or new vegetable oils could develop into a major part of an aromatic oil industry, and knowledge of the various extraction techniques and skills to use them could prove to be as important as those needed to extract essential oils. Many of the materials from which vegetable oils are extracted are also primary food crops such as pumpkin and carrots. Extracting the oils from their seeds is another opportunity to add value to the overall crop in increase income potential. There are opportunities to produce culinary oils for the growing natural foods markets throughout the world. The oils expressed from sesame, safflower, pumpkin, carrot and grape seeds, the kernels of apricot and the nuts of hazelnut and walnuts are examples of unique oils experiencing growing demand in these markets. Other than their recognized culinary uses these oils are also finding their way into natural soaps, body and hair oils, detergents and even paints.

We can envisage that the ability to extract special vegetable oils from locally available plant material, whether from a natural resource on cultivated for the purpose, could present opportunities to communities to generate income on the same scale as essential oil crops.

The supply of the equipment needed for the expression of oils such as olive, canola, sunflower and soy have developed into industries themselves. We will deal with only two of the techniques used to express vegetable oil, and which are appropriate to smaller operations, as could be expected where oils are expressed in rural settings, close to the source of the plant materials. These techniques are still able to deliver a high enough throughput to achieve income levels to sustain a small business and help provide a livelihood to a family or community.

Often the oil recovery from plant materials could be improved by cooking the material beforehand. Substantial experimentation will be required to determine the most ideal combination of conditions suitable for a particular plant material and a cooking step will of course add a cost factor to the whole process, but, on the other hand, lower press rates and increased oil recovery may easily compensate for any additional costs. But, most importantly, as the foremost consideration should rather be the production of quality (often rather than quantity) oils, then any application of heat may do damage to the very constituents which determines an oil's quality and the reason for its demand in the market place. Then it may be advisable to rather lower the temperature of the extraction process by deliberately cooling it down.

Often the ability to claim that an oil has been produced using truly cold press techniques designates special qualities to discerning markets. The possibilities to produce oils for niche markets such as the organic market, should also not be underestimated.

Other factors of extraction, such as the moisture content of the plant materials, just prior to expression, are also important, which again emphasizes the need for experimentation and the fact that, in a country such as Mozambique, considerable assistance at a high level of technical capability will have to be available to farmers and rural communities. Hence our recommendation that Centres of Expertise be created to develop technologies and provide the necessary inputs for establishing these technologies where needed.

We will focus on only two appropriate technologies used for the expression of vegetable oils: a fairly simple model of a ram press machine and a screw press.

4.1 The Bielenberg Ram Press Machine

This machine was invented and designed by Carl Bielenberg in 1986 at the company Appropriate Technology International, now known as Enterprise Works Worldwide (EWW), in the USA. Since then the machine has been widely used for sunflower oil expression in many African countries. The machine has a simple design, its cost of manufacturing is low, it has reliable performance and is quite easy to operate. In its simplest form it is a single stroke, manually operated, low speed machine, based on a slider-crank mechanism[33]. This simple model has a long piston of relatively small diameter that presses a measured amount of oil-seeds into a metal cage where, due to the high pressure developed, the process of expression of the oil from the seeds takes place.

A simple Bielenberg ram press weighs about 20 kg and can process 50 to 60 kg sunflower seeds per day.

There are a number of important considerations when using a ram press[34]:

---

33 Uziak J, Loukanov I.A. and Foster J.D.G. *A simplified model of an offset ram press for sunflower expression*, African Journal of Science and Technology, Science and Engineering Series, Vol. 3, No. 1, pp. 61 – 68.

34 Bachman, Janet. 2004. *Oilseed processing for small-scale producers*. National Sustainable Agriculture Information Service: ATTRA. www.attra.ncat.org.

- The seeds or plant materials used must be dry. Moist seeds will lead to low yields and clog the cage. Moist seeds may also get mouldy, presenting all sorts of toxicity problems, even making it unsuitable for human consumption or contact.

- The seeds must be clean. Fine dust in the plant material may clog the cage. Chaff left in the seed will absorb the oil and keep it from getting squeezed out of the cage. This stresses the importance of de-chaffing any seeds before pressing – winnowing is a simple method of de-chaffing seed. Sand will wear the press out. Stones will badly damage the piston.

- If the plant material is warm, it will yield the most oil for the least effort. Warm means sun-warm, not necessarily by applying additional heat or boiling. Remember the quality issue.

- For any extraction technique, seeds, nuts, kernels and other materials such as copra (dried coconut flesh) must be preconditioned by crushing it to the size of peas to improve the efficiency of the extraction process.

4.2 Screw operated oil expellers

Expellers have a rotating screw inside a horizontal cylinder that is capped at one end. The screw forces the nuts or seeds through the cylinder, gradually increasing the pressure. The material is heated mainly by friction (further heat, using heating elements could also be applied – but remember the comments above about what heat can do to quality). The oil escapes from the cylinder through small holes or slots, and the press cake emerges from the end of the cylinder, once the cap is removed. Certain models are designed to extrude the residual cake on a continuous basis at the end of the cylinder, in a sausage-like shape, which means the process is truly continuous.

A well-known oil expeller is the Komet Vegetable Oil Expellers, manufactured by IBG Monforts in Germany. See **Figure 8** for a typical design of a Komet Expeller. These expellers feature a special cold pressing system with a single conveying screw to squeeze the oils from various oil-bearing seeds. The machines operate on a gentle mechanical press principle that does not involve mixing or tearing or the seeds. The standard equipment can press virtually all oil-bearing seeds, nuts, and kernels without adjusting the screws or oil outlet holes.

The vegetable oil produced needs no refining, bleaching, or deodorizing, as long as the natural taste, smell and colour are acceptable. Normally, any sediment in the oil will settle to the bottom of the collecting vessel after approximately 24 hours and form a hard cake. The oil can then be poured through a paper or textile filter to remove any remaining impurities.

Since the vegetable oil will not reach temperatures higher than approximately 50 to 60 ^{0}C, all its vital components will be preserved. Therefore, it will be ideally suitable for use in nutritional products. As long as it is stores in a dark, cool, place, it will have a long shelf life.

5. Carbon dioxide (Super Critical) extraction.

Carbon Dioxide or Super Critical extraction was developed during the search for a technique, which will extract oils without doing any damage or resulting in any adulteration. The heat involved in steam distillation techniques does effect the composition of the essential oils. Carbon Dioxide, when at sub-ambient temperatures is liquid and acts as a natural solvent. Liquid carbon dioxide, under pressure and at a regulated temperature, is passed through the plant material. A subsequent separation step recovers the oil and the gas. **Figure 9** is a diagrammatic representation of a carbon dioxide extraction process. The method is considered superior to liquid solvents, because important unstable or heat-sensitive components are preserved and it also requires less energy.

Carbon dioxide is safe, non-combustible, odourless, tasteless, inexpensive and readily available, ideal properties for an extraction solvent, while its low viscosity enables it to penetrate the material being extracted and its latent heat of evaporation allows it to be easily removed without residue.

The critical point for CO_2 is at 31°C and a pressure of 73.8 bar. Sub-critical liquefied CO_2 (between –55 and 31°C and 5 to 74 bar) behaves as a non-polar solvent. CO_2 operating within normal working conditions, between 0 and 10°C and 50 to 80 bar, act as a selective solvent. In this range, CO_2 has the density of fluid, low viscosity and the diffusion properties of gas. By varying the temperature and pressure of the gas, an extract with specific flavour or odour could be obtained.

Due to the relatively low temperature of CO_2 extraction, the extracts are different from steam-distilled oils. The liquid CO_2 extracts also include light fractions of resins, giving the extract an element of an "absolute". In this manner the liquid CO_2 extract is more representative of the original botanical material. This improved property is not always widely accepted by end-users as it does mean an increase in cost.

The main benefits of CO_2 extraction are[35]:

- No solvent residues. Extracts prepared with organic solvents are heated under vacuum to remove the residual solvent. The heating can negatively impact on the top notes, which evaporate. In some cases to preserve the top notes a residue of solvent is maintained.

- No "off notes". During steam distillation the heat causes decomposition of certain material and generates traces of nitrogen and sulphur compounds. These give unpleasant "still notes". Although these still notes sometimes age and disappear if the oil is kept, this requires storage for up to 6 months. CO_2 extracted oils have no such still notes.

---

[35] David A Moyler, Liquid CO_2 extraction in the Flavour and Fragrance Industries. Chemistry and Industry. 17 October 1988.

- More “top notes”. Due to the lower operating temperature the volatile top notes are preserved.

- More “back notes”. Since CO_2 extracts the character of the “absolute” – molecular weight 200 –400, these components add to the overall character of the extract.

Why is this technology potentially important to a future aromatic oils industry in Mozambique? If Mozambique wants to become, as soon as possible, recognized as a country, which wants to, and can, compete with the leading international producers of aromatic oils, super critical extraction is a technology it will soon have to invest in. There are certain quality criteria, which can only be met by extracting the oil using this technology. The oil from *Sclerocarya birrea* subsp. *caffra* (canhu or marula) when intended for the pharmaceutical market, is best extracted when using CO_2 extraction. Even certain culinary markets prefer the taste and aroma, which can only be achieved using this technique.

SECTION 6:
PRINCIPLES OF ESSENTIAL OIL PRODUCTION AND MARKETING – QUALITY – THE ULTIMATE TRADE BARRIER

1. Producers of aromatic, including essential oils in Africa have to face a number of realities[36]:

- Based on informal studies, consumers in European and North American markets have the perception that African producers are not fully capable and reliable in production and delivering products conforming to international standards of quality. This has to do with a current prevalent image of producers and products from the continent and the level of adherence to international quality standards. It is not just a matter of ability to invest in adherence, but often due to an absence of a "culture of quality" in production.

- International Quality Standards are set by organizations such as ISO, AFNOR, WHO and WTO and users and consumers in markets worldwide rely on these organizations when considering criteria to measure quality.

- African essential oils need to comply with all international requirements plus more. The playing field can only be levelled through the visible practice of science, the delivery of information and complying with all international standards, which may be applicable.

- Specific country requirements, such as the Bio-Terrorism Act in the United States, emphasises the need for traceability protocols in countries from Africa wishing to export to the US. In general terms, all food (aromatic oils, including essential oils are defined as food in the US) imported into the US must be handled under a quality assurance program, including traceability of lots produced, to ensure food quality and safety.

- EU product legislation on environmental and consumer health and safety issues is compulsory even though there is no specific regulation on essential oils; each sectoral application of essential oils is guided by specific directives– for example, essential oils directed at the food market have to comply with legislative requirements for food products; essential oils directed at the cosmetics industry have to comply to legislative requirements for cosmetic ingredients.

- The White Paper on Registration, Evaluation and Authorization of Chemical (REACH) is the proposal for a new regulatory framework for chemicals in the European Union. As essential oils consist of many substances, including naturally occurring chemicals, and the scope of REACH is chemicals, essential oils will be included unless the are specifically exempt. There is an estimated number of 150 essential oils on the EU market, of which about 90 – 100 substances will fall under

[36] Simon J.E., Juliani R. and Govindasamy R. 2006. *Marketing requirements for national, regional and international trade and the US regulatory dilemma for dietary supplements*. Paper delivered at the ASSNAP Symposium on South African Essential Oils: from germplasm to distillation, extraction and quality control. 27 February to 1 March 2006. Stellenbosch. South Africa.

reach. The industry estimates that about 30% of the oils will no longer be used in the EU, since obtaining all the required documents will be too costly.

- **Quality Assurance and Quality Control in Mozambique**

What is quality? All products, whether manufactured using simple or highly technological processes or produced by agriculture, such as aromatic oils extracted from plants, contain the element of quality. The user such as the engineer designing and manufacturing a machine, the consumer standing in front of the fridge in the shop wanting to buy milk, or the perfumer in Paris formulating a new perfume, demand quality. What is this element, which each and every product contains to a larger or lesser degree? For which the user or consumer is prepared to pay a premium if it is present at levels, which exceed his or her expectations, or will reject the product if it is not?

From the perspective of production, including the production of aromatic oils, the processes, which deliver quality, could be grouped into two groups[37]:

- Quality Assurance (QA), which includes all interventions which comply with high quality throughout all the processes from pre-cultivation to end-consumer, and

- Quality Control (QC), which includes the application of all tests to required to evaluate the compliance of products with quality specification, and to report thereon.

Quality systems were developed by the food industry to assure that food is suitable and safe for consumption. These systems include:

- Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP), which are the guidelines to comply with safety and quality. Quality assurance and quality control also include the practices of tracking (trace-ability) and quality control analysis. The objectives of these practices are to ensure compliance to procure high quality aromatic oils through the production and processing of raw materials;

- GAP and GMP are the bases for more complex systems such as HACCP and ISO.

1.1 Good Agricultural Practices (GAP) provide guidelines for:

- The production and processing of raw materials focusing on the identification of those critical steps that are needed to comply with quality;

- Environmentally sound and sustainable practices;

[37] Juliani H.R., Hitimana N. and Simon J. 2006. *Comprehensive quality assurance system for the production and processing of essential oils in Rwanda*. Paper delivered at ASNAPP Symposium on Southern African Essential Oils: From Germplasm to Oil Distillation, Extraction and Quality Control. 27 February to 1 March 2006, Stellenbosch, South Africa.

- Starting plant material, including the selection of the correct cultivar, ecotype, chemotype or phenotype as key factors when introducing a new crop and that the principles of good plant husbandry, crop rotation, organic matter build-up of the soil should be followed (Conservation agriculture).

- The soil, should contain appropriate amounts on nutrients, organic matter and other elements to ensure optimal plant growth and production of essential oils. Soil analysis should be done to determine the initial status of the soil;

- Harvesting, including the considerations of:

- the best time of harvesting according to the yield of the active principle and not vegetative growth;
- the avoidance of foreign matter in the harvested material;
- that plants should be harvested under best possible conditions, avoiding dew, rain or exceptionally high humidity;
- that underground parts (roots) should be removed as soon as they are harvested;
- that the decomposition of plants should be avoided is this may result in microbial contamination.
- The effect of diurnal variations (the difference between harvesting at noon (12h00) and night (24h00). On the yield and composition of oils.

- Documentation and records, which require:

    - extensive record keeping of all activities regarding crop cultivation and production;
    - field records showing previous cropping and inputs (previous crop, seed used, name of plant cultivated, exact location of field, any treatment the crop was exposed to);
    - A complete traceability between the cultivation and processing of the plant material.

– Human related issues, including:

  - reasonable wages must be paid and no exploitation of workers, especially women and children should take place;
  - production inputs should preferably be sourced from locals, including merchants supplying materials and contractors supplying technical services.

1.2 Good Manufacturing Practices (GMP) provide guidelines for:

- The extraction, handling and storage of essential oils: focusing on the identification of those critical steps that are needed to comply with good quality:

- Preparation of distillation unit:
  - no water leaks should be observed coming out of the distillation unit
  - ensure that the distillation tank and condenser are washed out and clean and free on contamination from other distilled oils, and from any dirt, debris and insects.

- Plant charge.
  - The plant material should be packed into the charge vessel at a density which will allow for an even flow of steam through the material.
- Vapour pressure:
  - vapour pressure from the boiler should be kept constant throughout the process which means the heat source (e.g. fire) should be kept at constant rate;
  - plenty of fuel (e.g. wood) should be available near the distillation unit.

- Condenser.
  - The condenser should be effective to ensure that all vapours condense and that none of the more volatile fraction pass through the system and escape.

- Florentine flask:
  - The design, construction and operation of the Florentine flask should ensure the complete separation of oil and water and the recovery of the maximum amount of oil.

- Collection of oils:
  - the oil should be collected without any water.
  - it must be ensured that oil is only put into containers with the same type of oil. The containers must be clean and sanitary and should not contain (even trace amounts) of fuels such as petrol or diesel or any other chemical or contaminants.
  - the recipient of the oil should be made of glass or stainless steel and should be absolutely clean. No plastics should be used wherever contact with oil will be possible as plastics contain phthalates (used as plasticisers), which will contaminate extracted oils resulting in its rejection.
  - make sure all containers are labelled and cross checked with the field distillation notebook.

- Distillation time, the distillation time and progression of distillation of each type of essential oil should be closely monitored and recorded by way of keeping graphs of kg of essential oil (cumulative) vs time in minutes.

- Oil storage, which include all materials for collection and storage. All aromatic oils, but particularly essential oils must be protected from:
  - Air
  - Light
  - Metals (except good quality stainless steel)
  - High temperatures.

- Tracking system for aromatic oils, including essential oils: definitions and advantages:

- Traceability: the ability to trace and follow a product through all stages of production and distribution, all the way to the end-user;
- Traceability enables consumers to be provided with targeted and accurate information concerning products.
- A system of traceability generates consumer confidence.
- Such a system helps to monitor the production of natural products for possible problems e.g. drop in yields.

- Tracking system – the system itself[38]:

For all oils, both essential and fixed, there must be clear grades, standards, and definitions of each product. Producers must ensure that the process and each product conforms with ISO standards and European grades (AFNOR). Producers from Africa, with many African pressed oils and unique essential oils, are often confronted with the fact that no grades or standards are available. Then " simulated standards " need to be developed which could be used as a selling point in selling the African product.

- **SOP I**. Standard Operating Procedures for harvesting and collecting – must be completed by growers/pickers/collectors.

- **SOP II**. Standard Operating Procedures for essential oil extraction – for all forms of extraction including distilling and must be completed by the person doing the processing.

- **SOP III.** Standard Operating Procedures for transportation of natural products, from, for example, the distillery to processor – must be completed by the transporter.

- **SOP IV**. Standard Operating Procedures for the specification of plant essential oils.

- **SOP IV**. Quality Control Analysis: Laboratory analysis for product sample. All laboratory results will be returned to the owner of the oil. All analysis will be done in approved laboratories. Quality Control Reports will include:

  - Origin of sample, details of processor, transporter, and exporter with all the associated dates.
  - Genus, species and common name of the plant, which produced the oil.
  - Proper labeling of pre-shipment samples
  - Foreign matter analysis

[38] Simon J. and Juliani R. 2006. *Quality Control of essential oils: Developing product specifications, crop profiles and products standards.* Paper delivered at the ASSNAP Symposium: Southern African Essential Oils: From Germplasm to Oil Distillation, Extraction and Quality Control. 27 February to 1 March 2006. Stellenbosch, South Africa.

- Organoleptic profile, which include the determination of aroma, colour, haziness/cloudiness, presence of foreign matter (water, dirt, rust, extraneous debris) and viscosity. Microbiological testing is also often necessary
- Preparation of test sample
- The chemical profile of the oil, which predominantly relies on the gas chromatographic (GC) analysis of the oil of which the sample is representative. Often GC has to be combined with mass spectroscopy (MS) for a more detailed analysis (then called GC/MS). High-pressure liquid chromatography (HPLC) is also used, often in combination with MS. More recent techniques for rapid testing include the use of near infrared spectroscopy (NIS).
  All these tests have become critically important as adulteration of natural oils with inexpensive synthetics have become common practice – a practice which is totally rejected by the serious producer of high quality products.
- The physicochemical properties of the oil which include the refractive index, relative density, optical rotation of the oil, the solubility of the oil in ethanol, and often the ester factor.

• Training and capacity building related to all aspects of GAP and GMP: it is extremely important to educate and train all personnel dealing with all aspects of GAP and GMP.

• Advantages and disadvantages of GAP and GMP:

▪ The systematic approach provided by GAP and GMP provides feedback throughout the system to continuously improve quality.
▪ To apply the system is time consuming with associated labour costs, however, the system properly implemented will improve quality and increase market access.

1.3 Other important quality systems

• Environmental, social, health and safety issues are becoming increasingly important in the EU market.

▪ SA8000 of the International Labour Organisation (ILO) includes a number of Conventions and Recommendations setting minimum standards for basic labour rights. SA8000 is voluntary global standards for ensuring social accountability. SA8000 includes standards in the form of a “ Code of Conduct “ which defines what is considered social accountability, as well as requirements for a management system, which ensures the implementation of these standards in business policy.
▪ ISO 14001: This standard is to enable the international recognition of an individual company’s environmental management system. Although voluntary, consumer pressure is resulting in the ISO 14001 environmental standard becoming a de facto requirement for being able to compete in many regions of the global marketplace.

- The Hazard Analysis Critical Control Point (HACCP) system.

  HACCP is of increasing importance and refers to good quality management. EU legislation as laid down in Directive 93/43/EEC applies to producers within the EU, although European importers may in turn require it from the non-EU producers. In addition, as from January 1, 2006, a new Regulation (EC) 852/2004 will come into force that will make HACCP obligatory also for developing country exporters dealing with EU member states.

- ISO 9000: The International Organisation for Standardization (ISO) developed the ISO9000 series for quality management and assurance of the production process.

  The ISO 9000 standards represent an international consensus on the essential features of a quality system. Producers who have obtained an ISO 9000 series certificate possess an important asset. It is a major selling point when doing business in the highly competitive EU market.

2. Organic Production

EU standards for organic food production and labelling are laid down in regulation EEC 2092/91. This regulation and subsequent amendments establish the main principles for organic production at farm level and the rules that must be followed for the processing, sale and import of organic products from third (non-EU) countries.

For the USA, standards now defined by the USDA and all organic products, including essential oils must be certified within USDA grades and standards.

A number of IFOAM (International Federation of Organic Agricultural Movements) accredited certification organizations are active in Africa, and can provide the necessary certifications to enter the EU and USA markets.

3. Fair Trade Practices

The international organic agriculture and fair trade movements represent important challenges to the ecologically and socially destructive relations that characterize the global agro-food system[39]. Both movements critique conventional agricultural production and consumption patterns and seek to create a more sustainable world agro-food system. The international organic movement focuses on re-embedding crop and livestock production in "natural processes", encouraging trade in agricultural commodities produced under certified organic conditions and processed goods derived from these commodities. For its part, the fair trade movement fosters the re-embedding of international commodity production and distribution in "equitable social relations", developing a more stable and advantageous system of trade for agricultural and non-agricultural goods produced under favourable social and environmental conditions. The international market for both organic and fair trade products has grown impressively in recent years.

[39] Raynolds, L.T., *Re-embedding global agriculture: the international organic and fair trade movements*. Agriculture and Human Values. Vol. 17, Number 3. 2000. p 297 – 309. Springer Netherlands.

Yet the success of these movements is perhaps better judged by their ability to challenge the abstract capitalist relations that fuel exploitation in the global agro-food system. While the organic movement currently goes further in revealing the ecological conditions of production and the fair trade movement goes further in revealing the social conditions of production, there are signs that the two movements are forging a common ground in defining minimum social and environmental requirements.

In many developing countries, alternative trade organizations, based on philosophies of social justice and/or environmental well-being, are carving out spaces alongside traditional agricultural export sectors by establishing new channels of trade and marketing. Coffee provides a case in point, with the fair trade and certified organic movements making inroads into the market place[40]. In their own ways, these movements represent a type of economic and social restructuring from below, drawing upon and developing linkages beyond traditional boundaries of how coffee is produced and traded.

An examination of the philosophies of the fair trade and organic coffee movements reveal that the philosophical underpinnings of both certified organic and fair-trade coffee run counter to the historical concerns of coffee production and trade. Associations of small producers involved in these coffees face stiff challenges – both internal and external to their groups.

Can a similar situation evolve in Mozambique with regards to the establishing of an aromatic oil industry, and with the implementation of the correct strategies to be exploited to improve the possibility of success of this industry? It seems that the largest part of the available agricultural land in Mozambique is, by definition, certifiable organic. Furthermore, a major objective in the country, together with a range of goals, of establishing such an aromatic oil industry, is to alleviate poverty, to create employment, to create mechanisms of wealth creation amongst those levels of the population where it is not only currently totally absent, but need to become sustainable, even in the smallest of ways.

This sounds like the ideal opportunity of putting the principles of the organic and fair trade movements into practice.

Mozambique is almost like a blank sheet of paper. The master-plan, which has to be designed on it can go in any direction, take any shape: why not steer it in the direction where the values expounded by the organic and fair trade movement form the basis of its own value-system?

The way to start is with one or more pilot projects. It will require that the location, including the participating community, ideally with an established commercial farmer, who can also function as mentor, be identified. The aromatic oil plant crop(s) have to be decided. What is also important is that the process towards organic certification and fair trade recognition has to be started as early as possible. This means that formal contact with the representatives of these two movements must be established. The community, which will be the human factor in the pilot project has to be orientated and trained to understand

[40] Rice R.A., *Noble goals and challenging terrain: organic and fair trade coffee movements in the global market place*. Journal of Agricultural and Environmental Ethics. Volume 14, Number 1. 2001. p39 – 66. Springer Netherlands.

the implications of implementation but also the desired outcomes of the project. The market has to be informed of the project so that maximum market exposure could be achieved. Quality assurance protocols must be in place, recognizing that organic products are measured as stringently as conventional products. As soon as the first product flows from the project, it must move through the quality control protocols – again, there is no leeway for organic products. Once this product, which now has been produced within the total value systems of the organic and fair trade movements, is accepted in the market, international marketing actions can now start blowing the trumpet that Mozambique is now really committed to these value systems, but is also able to produce marketable products.

SECTION 7:
PRINCIPLES OF AROMATIC OIL PRODUCTION: LEGISLATIVE ISSUES WITHIN MOZAMBIQUE

1. Status of biodiversity in Africa

A very recent conference on the status of biodiversity in Africa, held in Antananarivo, Madagascar, delivered a message of critical importance: Africa's biodiversity is in big trouble! It was stated that Africa's attempts to alleviate poverty will fail unless great progress is made with the protection of the biodiversity and ecosystems on the continent. The purpose of the conference was to focus on how the continent's natural heritage can contribute to the alleviation of poverty.

Mr Russel Mittermeier, president of Conservation International (CI), pointed to Madagascar itself, which has already lost 90% of its tropical forests due to deforestation on a massive scale, and is now focusing its economic recovery program on improved biodiversity management. Plans are underway to, by 2008, increase the number of protected areas by a factor of three to about 6 million hectares. About 28 000 tourists visited the country last year (2005) compared to about 7 000 in 1990, largely because of renewed efforts to emphasize eco-tourism and promote the island's unique biodiversity.

Madagascar, with only 1% of the planet's land area, is playing host to more than a quarter of all known plant species, and is regarded as one of the most important burning-points concerning biodiversity in the world. This concept refers to areas of international conservational interest, which requires urgent conservational intervention. Africa holds 9 of the planet's 34 biodiversity burning-points. In Africa these burning-points accommodates about 230 million people as well as two thirds of all language groupings in the world.

Effective conservation is also necessary for the functioning of eco-systems, including clean water and air, on the continent and neighbouring islands. It is projected that the continent will not meet too many of the United Nation's millennium development targets. This is ascribed primarily to environmental decay on a large scale. Ms Sarah Frazee of the CI stated that conservation and the investments required for that purpose probably hold the key to an "African regeneration". She also stated that biodiversity and its importance to the provision of people's means of existence, should figure much more prominently in the policies of the continent's governments. Pres. Ellen Johnson-Sirleaf from Liberia, stated in a video recording that her country is focusing its economical recovery program on the protection of natural resources, particularly forestall regions. Natural resources were used for too long to fuel civil war.

What is the relevance of all this to Mozambique?

2. Biodiversity and the legislative environment in Mozambique.

There is undoubtedly a strong realization within the Government of Mozambique about the importance of biodiversity to the country's economic future and an emphasis on measures for its protection and sustainable beneficiation.

The First National Report on the Conservation of Biological Diversity in Mozambique has been prepared in accordance with Article 26 of the Conservation of Biological Diversity (CBD), which requires Parties to prepare periodic reports of the measures taken to implement CBD provisions abs the effectiveness of such measures. The First Report in 1997 covered CBD implementation activities carried out during that year and highlighted the then status of biodiversity in Mozambique, trends in biodiversity, an institutional and legal framework for biodiversity conservation and the formulation of a draft National Strategy and Action Plan which seeked to integrate biodiversity considerations into cross-sectoral policies, plans and programs.

In 1997 the National Policy and Strategy of the Department of Forestry and Wildlife (DNFFB) which seeked to realize the potential of forests and wildlife resources through the sustainable use and conservation of biodiversity, was officially adopted by the Government of Mozambique. The DNFFB strategy recognized the need to rehabilitate protected areas as well as the need to implement measures to promote the sustainable use and conservation of biological diversity outside protected areas.

The draft National Strategy then already identified as a highest priority the need to update and acquire information in order to identify and monitor the important components of biological diversity, recognizing that conservation and sustainable use depends on such information.

One such collection of information is: "*A preliminary checklist of the vascular plants of Mozambique"*[41] which was published only in 2004. This extremely valuable, although only provisional checklist, records 3,932 indigenous plant taxa for Mozambique. Of these 177 are endemic and 300 are listed on the country's Red Data List. Already in 1999 it was recognized by Mangue that the main threat to plant diversity is selective species utilization[42]. For this very reason we have consistently maintained, throughout this Report, that we cannot, with a clear conscience, recommend that a single indigenous species be utilized for its aromatic oil content until such time that strong and absolutely convincing scientific evidence indicates that it can be done without compromising the value of any species as a natural resource, and then only under very strict management regimes. For example, we could not find any detailed information on the population size of any of the indigenous species we identified and selected, within the locations they we purported to occur and a substantiated knowledge base on the species' natural propagation processes and abilities to recover from human interventions such as harvesting from the wild.

[41] Da Silva, M.C., Izidine, S. and Amude, A.B. 2004. A preliminary checklist of the vascular plants of Mozambique. *Southern African Botanical Diversity Network Report No 30*. SABONET. Pretoria.

[42] Mangue, P. 1999. Community use and management of Licuati Reserve and surrounding areas. In: P.V. Desanker and L. Santos (eds.), *Integrated analysis and management of renewable resources in Mozambique*. www.mozambique.gecp.virginia.edu/Publications/-Book Project/Mangue.pdf.

We want to recommend strongly that this recommendation of ours be formalized and taken into the current legislation, which must guide the sustainable use of natural resources in Mozambique, in general terms as far as the use of any species for commercial gain is concerned, but then specifically as far as the use of indigenous plant species for purposes such as the extraction of aromatic oils.

3. Other legislative issues

Apart from the legislative issues, which concerns biodiversity in Mozambique, there are others which will also require attention.

These other issues concerns matters such as intellectual property rights and recognition and protection of traditional knowledge. It is not clear if these matters have already been adequately addressed in the Mozambican legal system, but these will become increasingly important as Mozambique's indigenous resources gain increasingly international exposure.

3.1 Intellectual property rights

The discovery of unique products, processes of manufacturing and uses of compounds, which are indigenous to Mozambique. It has to be ensured within legislation, that Mozambique, as a country, the communities, which may be the historical guardians of any natural resource, and individual Mozambicans, whose efforts ensured that the value of such a resource could be unlocked in a sustainable manner, will benefit from any discovery or invention arising from any indigenous resource.

We could not determine whether the current legislative frameworks will ensure that this will happen, and whether past events have not already resulted that the country has missed out on opportunities to realize the full value of an indigenous resource.

3.2 Protection of traditional knowledge

It has to be ensured that traditional knowledge regarding the indigenous resources of Mozambique be legally protected to ensure that the country, but also communities, who are the keepers of this knowledge will receive due recognition and reward when such knowledge result in commercial gain. Traditional knowledge is often difficult to define, but if no attempt is made to do so, also considering the economic benefits which may accrue to individuals and communities if it is done correctly, the situation will always remain vague and open to abuse by people and organizations who do not have the best interest of Mozambique in mind.

3.3 Legislation on bio-prospecting

Bio-prospecting involves the process whereby local or foreign researchers deliberately seek, amongst the wealth of a country's indigenous wealth, those opportunities represented by species' and active compounds contained in a species which will result in successful commercial exploitation, most often, an tragically so, outside the country of its origin, an the exclusive benefit of a few people unrelated to that country.

Mozambique must ensure that the necessary legislative framework is in place to ensure that adequate safeguards are in place, guarding against over-exploitation of a natural resource, but also that Mozambique will receive its due reward in cases where economic benefits arise from the use of an indigenous resource. This will obviously have to be done against the background of international frameworks.

SECTION 8:
PRINCIPLES OF AROMATIC OIL PRODUCTION AND MARKETING: ORGANIC PRODUCTION.

1. The unstoppable trend to organic products

The growth in demand for organic food, particularly in countries where consumer awareness about the health factors of food, affecting themselves, but also the environment, is strong, is a well-documented fact. This trend has now spilled over to personal products, where demand for cosmetics, perfumery and other personal products, are increasingly dictated by health, safety and environmental concerns. The value chains of organic foods are increasingly becoming more transparent to consumers as the regulatory frameworks, including obligatory and clear labeling, provide the consumer with more information, and the ability to make more informed choices. This increased flow of information has further increased the demand for organic food. This trend may very well be repeated in organic personal care products.

As far as cosmetics are concerned, it is recognized, both in North America and Europe, that clear definitions and credible labelling are still lacking. This sector is not where the food sector is, yet. Manufacturers, government agencies and certification organizations still have to adjust their regulations to meet with product innovations.

About three years ago, the Council of Europe objected to the fact that: "many cosmetic could be found on the European market which are referred to as natural cosmetics, although they may contain many ingredients which are not natural ingredients." The Council therefore tried to establish basic criteria regarding the use of the term "natural cosmetics". The Council's document was based on the guidelines developed by the German certification organization, BDIH, in 1996. Unfortunately, this organization had pioneered the certification of " natural products " but was not addressing " organic cosmetics " as such.

The situation is in the process of changing, pulled along by consumer interest and demand.

2. Creating consumer confidence and product value

Reliable markets figures for natural or organic market figures are not available, largely because of the lack of harmonized definitions. In 2002 the " natural personal care " segment was valued at $US 4 billion, of a total market estimated at $US 30 billion for that year. It is further estimated that the segment is growing between 4 to 16 percent per year. Germany is leading the markets in Europe regarding consumer awareness and acceptance of " natural " and " organic " products. The 2002 market in the country for "natural cosmetics" was estimated at Euro 450 million.

The labelling reliability of certified organic food has resulted in the increasing popularity of the products – consumers need clear and simple marks to guide them among the thousands of products available. As long as only expert organic addicts are able to locate the real " organic cosmetics " on the shop shelves, the market will not take off on the scale organic food has.

In the US, the main regulatory reference is the National Organic Program's (NOP).

Final Rule. Established to govern food products, this regulation has been extended to all "consumable" products that contain certified ingredients and wish to make label claim. The NOP Final Rule allows for three levels of marketing claims: "100% organic" (products must contain exclusively certified organic agricultural products); "organic" (products must contain 95% certified organic ingredients, with the remaining 5% coming from the National Organic Standards Board's list of allowable synthetic substances" and "made with organic ingredients" (products must contain 70% certified organic agricultural products). In practice, these stringent requirements prevent most cosmetic products from being certified using the NOP Final Rule.

In Europe, the BdiH guidelines only address "natural products" and do not cover "organic" claims. Only the UK's Soil Association Standards for Health and Beautycare Products, Italy's AIAB Regulations for the Certification of Organic Cosmetics and France's Ecocert Organic Cosmetic Standard offer the chance of certified organic claims.

The Soil Association launched its standards for health and beauty products in 2002 and now certify a wide range of companies and products to the standards. Their standards were launched in response to companies that were making organic beauty products that wanted independent verification that was geared towards these types of products, and also in response to consumers who wanted to know which products were truly organic.

Now, in order to reach a better harmonization, these four organizations have initiated regular meetings, with the aim to develop a common standard and then to propose this to the EU authorities, hopefully to achieve an integration of the European market.

The Soil Association standards are based on principles that require the maximum amount of organic ingredients, minimum synthetic ingredients, minimum processing of ingredients and clear labelling so that the consumer can make an informed choice about the product they are purchasing. The standards also contain criteria that means ingredients must be assessed not to be harmful to human health and their manufacture and use must cause the minimum environmental impact.

The French standard seems to be the most convenient base for harmonisation. It allows for two levels of claims: "ecological cosmetics" (95% of ingredients from natural origin, with organic ingredients representing 5% of the total compounds and 50% of vegetal ingredients) and "organic cosmetics" (95% of ingredients representing 10% of the total of compounds and 95% of the vegetal ingredients).

Inspections and certifications were started in 2002. Fifty companies are already certified, representing around 600 products, and requests for certification are continuously increasing. At the moment fifteen companies are being processed, with countries outside France, including Canada, Belgium and Portugal also in the queue.

Certified companies must pass two inspections annually. Product compliance is checked, as well as the ingredients, the storage, the manufacturing process, the packaging and each manufacturing site's waste management practice.

A product that carries the Soil Association symbol will meet similar criteria. Also the ingredients in the products, other that those certified as organic, must be proven to be non-GM and can only be used if the organic version of the ingredient is not available, or they are from a restricted list of synthetic chemicals that have been assessed against criteria to demonstrate that they have no detrimental impact on human health and minimum environmental impact.

Organic standards do require greater imagination from formulators to create good emulsions, reduce water, increases oil or to find an alternative foaming agent that the consumer will accept. Certain ingredients are not available yet: more preservatives are needed, as are texturising and foaming agents. These demands create new challenges to invest into organic product development

An organization like the Soil Association admits to the unavoidability that chemical ingredients, such as preservatives, have to be used in certain cases. Organic beauty products that contain oils and oil-based ingredients such as balms and body butters can be made using 100% organic ingredients and do not required the addition of preservatives. Sometimes they may use mild antioxidants such as tocopherol or ascorbic acid, which are permitted under organic food standards (both the EU regulation and Soil Association Standards) and naturally derived.

However, products that contain water, and water and oil based ingredients such as creams, lotions and shampoos need to have some kind of preservative system so that they are safe to use. In addition they may need an emulsifier which mixes together oil and water ingredients and stop them separating.

Sometimes organic preservatives can be used such as organic grapefruit seed extract, or naturally derived antioxidants, as mentioned above, but if these are not effective then a preservative that meets strict toxicological and bio-degradability requirements can be used. The toxicity and bio-degradability criteria ensure that the ingredient is not harmful to health and has minimum environmental impact. In addition emulsifiers must meet the same requirements, and are often naturally derived. For example, decyl-glucoside, which can be made from corn starch, but is not yet available in an organic form.

All standards are subject to change and development through the process of consultation, which exists between the major certification organization and various interest groups, including the chemical industry. All current standards have been developed from a precautionary point of view and will tend to ban ingredients or processes until substantial evidence and research supports their permission in the standards. For example, new standards in 2005 included the recommendation that ingredients resulting from nanotechnology were prohibited until further research is available, and also that any wild harvested ingredient, e.g. sandal wood, must not come from an endangered species.

3. Organic Benefits

Certified organic cosmetics are newcomers on US and Europe's retail shelves. The response of consumers indicates that there is a sustained growth phase ahead. Where, in the past organic cosmetics only reached the consumer through specialized organic retailers, it has now moved into mainstream retail outlets such as drugstores. There is an opinion in the retail sector, which holds that organic cosmetics are more than niche products. They are expected to spread to into the wider market, increasing the awareness amongst consumers about ingredients they put on their skin. No major boom is expected in developed markets, but rather a steady growth, for example, up to 10% in France within the next ten years.

These levels of growth figures will also depend on demonstrable benefits from organic products. Consumers want more than an added element of trust from an organic endorsement; they also look for visible results.

The debate on benefits is an ongoing one. The fact that organic vegetal ingredients are free from pesticides is a very important consideration, especially because highly concentrated essential oils are used. Organic certification allows for the traceability of vegetal compounds and avoids any adulteration, which would affect the efficacy of active ingredients. Organic standards also imply a higher concentration in active ingredients, such as essential oils. Major producers, like Sanoflore, are launching innovative products as part of their range of facial care organic dermo-cosmetic products.

One view is that, as the skin is the largest organ in the body, and individual ingredients in cosmetics vary in their ability to penetrate the skin, extreme caution has to be taken when allowing contact with the skin. Some ingredients are absorbed in tiny amounts while some can reach the blood vessels below the skin and be transported around the body. While one product may contain very small amounts of some of these ingredients, it is the cumulative effect of applying various products regularly that causes concern.

Over the past few years there have been certain cosmetic ingredients that have been highlighted in the media due to their links with health scares, which has led some people to choosing organic as a safer alternative. In addition people that suffer from sensitive skin or conditions such as eczema or psoriasis report that organic skin care products work better for them as they contain either tiny amounts of synthetic chemicals, or no synthetic chemicals at all.

Parents are increasingly choosing organic products for the babies and children as their bodies are still developing and are more susceptible to chemicals in non-organic products and more likely to develop allergic reactions to ingredients such as fragrances. Others choose organic products because they eat organic food, and want to continue to support the positive benefits on the environment that their choices make.

The future will be bright for organic cosmetics manufacturers, but they have to have the capacity to cope with both the technical and regulatory obstacles that stand in their way.

SECTION 9:
SURVEY OF THE FLORAL POTENTIAL OF MOZAMBIQUE FOR THE EXTRACTION OF VALUABLE OILS

1. Introduction: a) Indigenous plants b) Alien plants c) Commercially viable plants d) Medicinal plants

Mozambique is characterized by a wide diversity of ecosystems and including islands of Afromontane habitats, many different woodland/forest types, edaphic grasslands and a variety of wetlands, coastal and marine habitats.

In 1997, it was reported that, notwithstanding this rich diversity, remarkable little was known about the state of Mozambique's biological diversity[43].

It was then reported that no coordinated, comprehensive surveys of Mozambique's biological resources have been carried out. This was partially due to long period of civil unrest that affected much of the country and consequently there was a profound lack of information regarding the conservation status of Mozambique's biological diversity, and no Red Data Books for Mozambique's fauna and flora then existed. At that time, many ecosystems were poorly documented, especially the woodlands and forests of Northern Mozambique and the Afromontane areas.

In 2004 a preliminary checklist of the vascular plants of Mozambique was produced and published by the Southern African Botanical Diversity Network[44]. This provisional checklist records 3,932 indigenous plant taxa for Mozambique. Of these, 177 are endemic and 300 are listed on the country's Red Data List. Also, 516 taxa of alien or exotic plants are listed. These are an indication of how well plants from other parts of the world have adapted to the unique climatic conditions of Mozambique.

Mozambique has two herbaria. The National Herbarium is located at the National Institute fro Agronomic Research (INIA) complex and is designated the LMA Herbarium, while a second, much smaller herbarium is administered by the Department of Biological Sciences, at the University Eduardo Mondlane and is designated the LMU. The LMA and LMU herbaria together house about 102,000 plant specimens, most collected between 1940 and 1974. These plant specimens formed the basis of the checklist. It is noted, in the SABONET Report, that use was made of various literature sources, which added taxa to the checklist, but made it more complete. In the SABONET Report it is noted, however, that, the number of these specimens do not reflect the actual diversity of the flora of the country. There are quite a number of reasons for that. Selective collection, prior to 1974, lack of activity during the war, and a lack of taxonomists, and the threat of landmines after the war, resulted in very few collections being undertaken between 1975 and 2002. Plant collection expeditions are still being constrained by difficult access to some areas of the country (as a result of landmines planted during the war) and a lack of financial resources. A previous

---

[43] Ministry for the Coordination of Environmental Affairs. 1997. First National Report on the Consevation of Biological Diversity in Mozambique. Maputo.

[44] Da Silva, M.C., Izidine, S. and Amude, A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. Southern African Botanical Diversity Network. Report No. 30. SABONET. Pretoria.

emphasis on the south, at the expense of the northern regions, led to a far higher representation of plants with a southern distribution on the checklist.

There remains a huge backlog of plant specimens requiring identification because of the lack of qualified technicians and researchers. Many plants were omitted as *incertae* (only sparse or incomplete and often irrelevant information on the labels in the herbaria). The need for future research on listing and describing the wealth of flora in Mozambique, to progress the records to a stage of completeness, is an important observation in the SABONET Report No.30. This is a current and future task, which must be seriously supported by the Government of Mozambique and international organizations, which could support such initiatives.

However, for the purpose of this study on the potential of aromatic plants in Mozambique, specifically for the beneficiation of valuable aromatic oils extracted therefrom, we found that the available information already indicates a potential which could result in large scale commercialization of products, derived from a relatively small selection of plants.

But, the shortcomings already referred to above, together with the (quite understandable, considering the recent historical circumstances of Mozambique) lack of information on, for example, the size of populations of indigenous species, the location of clusters of species and the rate of natural propagation and conditions affecting it, obliged us to follow a specific approach in assessing the floristic resource of Mozambique. This approach is then strongly reflected in our recommendations as well as the strategy and actions we propose towards the establishing of a valuable aromatic oil industry for Mozambique.

2. Methodology of plant selection

The aim of selecting groups of plants was to present prospective producers of valuable aromatic oils in Mozambique with a shortlist of plants from which to choose one or more for the purpose of establishing a production capacity. We used the SABONET Report No. 30, referred to in fair detail above, as the primary source of information. This was supported by the relevant information contained in the Herbaria, together with other sources, contained in the scientific and commercial literature, specifically regarding plants containing known aromatic oils.

Many of the major aromatic oil producing plants occur in families such as the Lamiaceae/Labiateae family to which well known essential oil producing plants, such as *Lavandula spp*. (lavender oils), *Ocimum basillicum* (basil oil), *Origanum marjorama* (marjoram oil) and *Melissa officianalis* (Melissa oil) belongs. So, it is fair to suspect that any member of the Lamiaceae family, occurring as an indigenous plant in Mozambique should have potential to produce a valuable essential oil. This was confirmed by the identification of *Satureja biflora*, and further reaffirmed by the fact that Satureja species have become increasingly popular in recent years as plants, which could deliver " new " oils with unique compositions. (See the Technical Report on *Satureja spp*.) Furthermore, under the grouping of " alien plants " other members of the family Lamiaceae was found, for example, *Salvia farinaceae* (Clary Sage) and *Mentha* *pulegium* (Peppermint), which is a clear indication that members of the family adapts well to the climatic and soil condition of Mozambique.

The Family *Geraniaceae*, with the genera *Geranium* and *Pelargonium,* are well represented in the SABONET Report No30. A total of seven species have been selected for further assessment. These two genera include a number of species, which are already large volume oil producers for international markets. Therefore, the selected indigenous species warrant serious effort to determine their potential. See the Technical Report on these two genera.

Other indigenous species are obvious candidates for the extraction of valuable aromatic oils, because these oils were identified before, and are already beneficiated across the borders of Mozambique. An example is *Sclerocarrya birrea* subsp. *caffra*, known in Mozambique as canhu, but in South Africa as Marula, where a considerable industry has already developed beneficiating the pulp and juice of the fruit, but also the aromatic oils contained in the kernel of the nut. Considering the (mostly anecdotal) reports of vast number of canhu in Mozambique, it presents an opportunity to establish a unique industry in the country.

Another interesting selection was *Linum usitatissimum*, in the family of *Linaceae*. *L. usitatissimum*, commonly known as flax or linseed produces an oil known as flax oil (used in medicinal applications) and linseed oils (well known in the chemistry of paint formulations). It is reported that *L usitatissimum* is near endemic in Mozambique with a listing in the Red Data Book. This leads to the question that this plant may be unique, probably a new landrace, and should therefore be dealt with great circumspection. It does show great promise for commercialization.

The family *Poaceae* is well represented by a wide selection of species, within two genera. As this family includes the well-known lemon grass and vetiver grass, it warrants an in-depth investigation into the selected *Cymbopogon* species and also *Vetiveria nigritana*.

The presence of a number species within families, amongst the listed alien plants, known for their aromatic oils, widened the range of potential plants which could be considered for the extraction of aromatic oils. For example, the presence of *Cananga odorata*, within the family *Annonaceae*, points towards the potential of producing the well-known ylang-ylang oil, of which Madagascar is still regarded as a major producer.

We make a recommendation, emphasized throughout this Report, and in our view of major importance, that Mozambique should not allow the harvesting from natural resources, by any party, until very strict conditions are met, including the creation of the capacity to propagate and cultivate, within a controlled environment, any indigenous or alien plant which has the potential to deliver an oil of commercial significance. This will be particularly important where the size and locations of populations of a selected plant in nature are uncertain and the viability of its natural propagation is unknown. We recommend that Mozambique should rather start building its industry in aromatic oils by starting to cultivate and harvest well-known plants whose oils have already gained international market access. This will require that factors such as quality of products should rather be developed into sustainable strengths.

We underpin this recommendation by presenting a list of internationally established plants. All these plants produce oils, which have existing positions in international markets. Their propagation and cultivation is well known and the agricultural conditions are well suited to many of these plants.

Although medicinal plants were not a major focus of our study, we have investigated the wealth of medicinal plants present in Mozambique from the perspective of plants, which also contain a valuable aromatic oil. We have selected a few medicinal plants, which could be cultivated for their aromatic oils as well. As with many of the plants in the other groupings, many of these plants require further investigation to determine the extent of the potential of their oils.

3. Four lists of selected plants

Using the broad-based methodology described above we have compiled four lists of selected plants:

- Plants indigenous to Mozambique
- Plants alien to Mozambique but occurring in the country.
- Recommended commercial plants for cultivation in Mozambique
- Medicinal plants occurring in Mozambique with potential for valuable aromatic oils.

These lists are included below.

These lists could serve as a basis for building an aromatic oil industry in Mozambique. The lists and their content will only be useful if they are recognized as incomplete, requiring continuous work and development. This will be a shared responsibility between all who want to participate in the future aromatic oil industry in Mozambique.

The gathering and recording of information on the species listed, particularly those showing promise for producing commercially viable oils, will be a part of this responsibility. In our lists of indigenous and alien plants, we have highlighted those species, which we believe show the most immediate promise for beneficiation. We have tried to create a framework within which future information could be added to currently available information by including Location and Technical Reports on selected plants, as single species or as they occur within families. Our Reports cuts across indigenous, alien and commercial plants, within grouping, demonstrating the commonalities, which exists within plant families.

The Location Reports aim to serve as a collection framework for all information on the location of a plant at the species level, particularly indigenous plants but also where commercial plants are cultivated, within Mozambique. It should not only include information on the size of populations of species and concentration within clusters at specific locations, but also place them within the context of climatic zones, including rainfall, and other agriculturally important factors such as soil types and availability of water for irrigation. Infrastructural factors, such as access to a location, which is targeted for commercial activity, should also form part of the information base on location. As the northern provinces warrant a particular emphasis, for a variety of economical reasons, location based information will be an integral part of implementation plans and actions.

In the Technical Reports we started a process of gathering current information on a variety of technical factors important for successful production of oil, considering the comprehensive value chain of an oil. The future aim should be not only to continue gathering information developed elsewhere, but also to start generating information within Mozambique. Al these actions should happen within a variety of fields, including:

- General information on the plants and their oils
- Propagation of plants
- Actions necessary to establish and maintain the genetic integrity of species
- Nursery operations
- Soil preparation, including fertilization
- Cultivation, including irrigation and pest management.
- Harvesting
- Extraction of oils
- Refining and purification of oils
- Chemical and physical analysis of oils
- Packaging and shipping

The information contained in the two Reports as contained herein does not lay any claim to comprehensiveness or completeness. This was beyond the scope of our Study. Rather, we hope, that we started a process of gathering information in a certain format, which will have increasing value to future growers of aromatic plants and producers of aromatic oils in Mozambique.

We have gone into a fair amount of detail on a number of species, dealing with many of the fields of action mentioned above. The information contained therein is based on our own experience as well as extracted from the international literature. The aim was not to provide comprehensive manuals on these species, but rather to stress that where information is not available, based on experiences elsewhere in the world concerning a particular species that information will have to be created within Mozambique. This is where the Centres of Expertise, as proposed, will play critical roles. These Centres will then disseminate this information to growers and producers, either directly or through the extension services provided by the Department of Agriculture or other channels dealing with farmers.

As stated on a number of occasions in our Report, it is the lack of information on matters such as size of populations of indigenous species, selected as potentially viable aromatic oil producers, and knowledge on the propagation dynamics of these species, which prevent us from recommending that harvesting from the wild is an attractive commercial proposition.

We therefore recommend that a process of information gathering and knowledge creation be started as a matter of urgency, at least on the selected species, as they are highlighted in the attached lists.

Reports: A01.01.01

Family: Anacardiaceae
Genus: Sclerocarya
Species: birrea subsp. caffra

Common names: In Mozambique: Canhu, medangwa, m'tula, nkokwo, tchumbo
English: Marula
Shona: Muganu, mufura, ikanyi
Swahili: Mugongo
Zulu: Umganu

Location Report:

1. General Habitat and Distribution[45]

The plant occurs in the drier savannas of northern tropical Africa, usually on sandy soils and sometimes on lateritic or stony soils. It can thrive in areas with rainfall as low as 300 mm per annum; in higher rainfall areas, 450 – 800 mm, the tree is often conspicuous as an emergent tree through the canopy of the neighbouring savanna trees. It is distributed in the savanna belt between Senegal and Ethiopia, and the drier areas of southern Africa. The sub-specie *caffra* occurs only in southern Africa.

2. In Mozambique[46]

Sclerocarya birrea subsp. caffra occurs in nine of the Provinces of Mozambique[47]:

Gaza
Inhambane
Manica
Maputo
Nampula
Niassa
Sofala
Tete
Zambezia

Other than anecdotal information that there are vast numbers of the species throughout Mozambique, no exact quantification of the size of the population has been done to date, neither has any cluster identification been made. There is therefore no basis from which projections could be done regarding sustainable beneficiation of the fruits of this species.

---

[45] Maurice, M. Iwu.1993. *Handbook of African Medicinal Plants*.CRC Press Inc, Florida, USA
[46] Photograph of specimen in National Herbarium included in this Section
[47] M.C. da Silva, S Izidine and AB Amude, 2004. *A Preliminary checklist of the vascular plants of Mozambique*. SABONET Report No 30.
* Photograph of specimen in National Herbarium included in this Section

It will be necessary to do a survey of the population density as well as natural propagation dynamics of this species in any region where economical and logistical factors warrants the consideration of beneficiating the fruits of the tree. (See: A South African Case Study)

Technical Report:

1. Description[48]

Medium to large deciduous tree with an erect trunk and spreading, rounded crown; sexes separate, on different plants; occurring in bushveld and woodland. Leaflets usually 3 – 7 pairs plus a terminal one, dark green above, much paler and bluish green below; margin smooth, but distinctly toothed in juvenile growth and coppice shoots; petioles often tinged with pink. Flowers in unbranched sprays before the new leaves, yellowish, tinged with pink. Fruit fleshy, almost spherical, ripening to yellow after falling to the ground; stone very hard, with two or three lids.

The fruit is edible, eaten either fresh or made into a delicious jelly; also makes a popular alcoholic beer; a marula liqueur is available commercially. Kernels of the stones are edible and highly nutritious, but difficult to remove intact. Leaves browsed by game and the bark stripped by elephants. Bark widely used for medicinal purposes (proven antihistamine and anti-diarrhoea properties) and to obtain a pale brown dye. Wood used to make household utensils. Several moths breed on the tree, including the beautiful green African moon moth (*Argema mimosae*).

The Beneficiation of *Sclerocarrya birria* subsp. *caffra* (Marula).
A South African Case Study.

(Taken from Landbouweekblad, 11 February 2005 with acknowledgement to Isabel Stoltz)

In the Limpopo Province of South Africa thousands of unemployed people derive a substantial part, if not all, of their livelihoods from the fruit of the Marula Tree, as it is known in that part of the world. It is the income stream, which allows them to purchase food and clothing and pay children's school fees. The project for the extraction of marula juice and oil, including the pickers in the veld, provides employment to about 6 000 people resulting in a total of about 60 000 people benefiting from the beneficiation of the Marula.

However, there is deep concern about the sustainability of this resource. About 80 million fruits from the marula tree are needed to supply Distell for their popular Amarula cream liqueur. About two tons of fruit is harvested per tree per season in an area with a radius of 400km in the Limpopo Province, just across the border from Mozambique. Now a definite reduction in the occurrence of small trees has been observed.

This observation should be seen together with the fact that existing trees are well protected as the local population recognizes these as a source of income. However, a major concern is the other fact that trees in nature is not multiplying as no growing small trees are

[48] Braam van Wyk en Piet van Wyk. 1997. *Field Guide to Trees of Southern Africa*, Struik Publishers, Cape Town

observed. The ideal is not to clear bush for the planting of trees but rather to propagate trees in the veld under natural conditions. All actions, such as this, aimed at ensuring the sustainable beneficiation of the Marula Tree, will require dedicated research and the necessary funding.

In South Africa the Marula Tree, Sclerocarya birrea subsp. caffra, is on the national list of protected trees. This means that the trees and their products may not be beneficiated without a license. The goal with these protective measures is not to prevent people from beneficiating the tree, but to manage this beneficiation to ensure sustainability. A matter of concern is the fact that the seed resource is removed from the habitat of the trees preventing the natural dispersion of seed through the movement of animals, such as elephants, using the fruit as part of their diet. A further concern is that the wood of the tree is also used for handicraft.

People collecting the marula fruit in the veld deliver the fruit by a variety of means to the factory while lorries of the factory will also collect fruit from places where the fruit has been gathered. Payment for the marula fruit is cash upon delivery. About R12 000 is paid out daily and the average daily crop varies between 42 tons to 45 tons during the season. The factory processes 90 crates of fruit of 0,5 tons each per day. Some of the workers earn up to R300 per day.

In an effort to support all the people doing collections, all fruit delivered are taken in and paid for. However, this result in a great deal of pressure to develop new products and markets, which could absorb the large volumes.

Workers are paid twice. The first payment is for the marula fruit collected. The nuts are returned to them after the juice and pulp has been extracted. People then remove the kernels from the nut by manual or semi-mechanical means, returning the kernels for a second payment.

The season lasts about three months, but during periods of drought, the trees drop their fruit much quicker. There are attempts to increase the season to four months through improved selection, again emphasizing the importance of research.

Marula fruit has great potential for wide ranging uses. The fruit contains four times as much Vitamin C as citrus. Apart from its high protein content, the nut contains 30% of a very stabile oil while the skin contains 54 different fibres and a number of as yet unused flavourants. These properties already find use in a number of products such as condiments, salad sauces, juices, vinegar, the Amarula liqueur, mentioned before, and a range of cosmetics. The potential of the kernel-cake, after pressing the oil, as an animal feed, is being investigated.

Research into the macula fruit is already being conducted in South Africa, as well as countries such as Israel, Australia, India and Botswana focusing not only on product development but also on methods of propagation and cultivation as well as fruit improvement.

Reports: A26.01.01

Family: Bombacaceae
Genus: Adansonia
Species: digitata

Common names: In Mozambique: chimuho, mulapa
English: Baobab

Location Report:

1. General Habitat and Distribution[49]

Adansonia digitata occurs also in the northern part of South Africa, bordering in the southern regions of Zimbabwe, across the border of Zimbabwe and Zambia and then across the continent through the northern regions of Botswana and Namibia. The tree also occurs upwards into northern Africa where a number of countries, such as Senegal, have already started to beneficiate products from the tree on a large scale.

2. In Mozambique[50]

The Sabonet Report No 30[51] indicates that *Adansonia digitata* occurs in Maputo, Manica, Nampula, Niassa, Sofala and Tete Provinces and with no exact information in the National Herbarium, probably because of the extremely wide distribution throughout the Provinces mentioned.

Technical Report:

2. Description[1]

A. digitata, as it occurs in countries and regions where it is already a recognized valuable commercial crop, is an grotesque, comparatively short, deciduous tree with a hugely swollen trunk, occurring at low altitudes in hot, dry bushveld. Its bark is smooth and folded. Leaves, with 3 – 9 leaflets in mature plants, simple in seedlings and juveniles. Flowers solitary in leaf axils, large, pendulous, white: stamens numerous, spreading from a central column. Fruit ovoid to elliptic, about 120 mm long, with hard woody shell, densely covered with yellowish, gray hairs; seed numerous, embedded in white, powdery pulp.

3. Constituents

Also known as the " tree of life ", the baobab tree has traditionally provided the population where it occurs with food and medicine, and is used to help treat fever, diarrhea, dysentery, malaria, smallpox and inflammation.

[49] Van Wyk, B. and Van Wyk. 1997. *Field Guide to Trees of Southern Africa*. Struik Publishers. Cape Town. South Africa.

[50] Photograph of specimen in National Herbarium included in this Section

[51] Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

The bark yields an excellent fibre, used to make floor mats and other woven articles. Young leaves are cooked as a green vegetable. Seeds are edible, and a good coffee substitute, when roasted. The white powdery pulp surrounding the seeds is rich in Vitamin C and minerals and makes a refreshing drink when mixed with water or milk. The bark and other parts of the tree are used in traditional medicines.

The tree bears fruit once a year. It contains naturally dehydrated fruit pulp, which contain six times the vitamin C present in oranges, as well as vitamins A, B1, B2, B6 and PP. It is reported that the fruit pulp of the Baobab has an anti-oxidant activity of about four times that of kiwi or apple pulp.

The seed of *A. digitata* is a by-product of the production of the pulp and yields a rich, gently scented golden oil, when the seeds are cold or hot pressed. The seed endocarp is said to contain naturally occurring Omega 3, 6 and 9. The choice between hot or cold pressing is determined by customer preference, but cold pressing is mostly required.

The oil is richly endowed with essential fatty acids, which contribute towards the maintenance of a healthy skin and thus the oil has found use in cosmetics. The highly polyunsaturated fatty acid (PUFA) profile (Vitamin A, D, E and F) of the oil makes it also suitable as a food oil. This precious oil is highly stable and preserves for long periods with no fear of it turning rancid. The oil is one of the products marketed under the **Mpuntu** brand of ASSNAP.

The pulp of *A digitata* produces a cream to white coloured powder that is packed with nutrition. Apart of its high Vitamin C content as well as other vitamins riboflavin and niacin, it also contains essential minerals such as calcium, potassium, iron, sodium, zinc, magnesium and phosphorous. All this constitutes the well-known food ingredient, Cream of Tartar. This product is potentially highly viable, presenting a sustainable business opportunity to communities.

However, the concerns we have expressed about the sustainable harvesting of any product from the wild, such as Baobab, should be taken seriously and procedures implemented to ensure that Baobab remains a sustainable resource. There are too many reckless and glib comments made in the industry about the " limitless supply of Baobab materials ". It is reported that 900 000 tons of Baobab materials are expected to be harvested during the next season throughout Africa. The mere mentioning of this figure should make the red warning lights flash!!

Senegal's Baobab Fruit Company claims to be the largest global harvester and producer of Baobab ingredients. The African firm, which began by designing equipment capable of extracting raw materials from the tree in 1999, has recently joined forces with Canadian Company BaobabTek, which is to market these ingredients in North America.

Products containing baobab ingredients are currently already available in Italy, France, Switzerland, Spain, the UK, Canada and the US.

Reports: A24.01.01

Family: Lamiaceae (Labiateae)
Genus: Satureja
Species: biflora

Location Report[52]

The plant *Satureja biflora* has been located in the Provinces of Manica and Sofala. More specifically, information in National Herbarium, related to the location of samples collected of the species, is:

Manica Province in the grasslands at Tsesera village.
Mavita village: from Massambuzi to Quedas do Rio Rotunda, from Manica village to the Posto Fiscal (Administrative Office) at Penha Longa

The comment is made that the taking of floristic inventories has to carry on in order to gather more information on occurrence and distribution of this species but also other species, which may occur in Mozambique.

This fairly scant information emphasizes the fact that much more information needs to be gathered on this species, and possibly others of the genus *Satureja* before serious activities aimed at beneficiation of the plant could commence.

Technical Report

1. **Introduction**

Why an emphasis on *Satureja biflora*? In our survey of the indigenous plants of Mozambique it became apparent that this plant has the potential of delivering a unique oil for commercial beneficiation. This is based on the fact that other *Satureja* species, in various parts of the world, has in recent years gained prominence for the properties of their essential oils. Considerable work has already been done of various species.

In our view this plants, if only then the species *biflora*, but also others which may be uncovered, warrants a careful and responsible approach. In line with our recommendations, this plant should be properly investigated to determine population occurrence and densities, and isolation and propagation procedures should be established as soon as possible.

***2. Satureja* in other parts of the world**.

More than 30 species of Satureja has been identified throughout the world. The family Lamiaceae (Labiateae), also known as the mint family, has a world-wide distribution, with around 200 genera and between 2000 and 5000 species of aromatic herbs and low

52 Photograph of specimen in National Herbarium included in this Section

shrubs[53],[54]. (See Technical Report on the Family Lamiaceae). A remarkable amount of work has already been done on the isolation and compositional determination of essential oils extracted from *Satureja spp.*. It is not the aim of this study to provide a comprehensive overview of this work, but rather to highlight its potential.

(i) The composition of the leaf essential oil of *Satureja punctata* (Benth.) Briq. From Zimbabwe[55].

Satureja punctata from Mrewa, Zimbabwe, was hydro-distilled and the essential oil produced in 0.9% v/w yield was analysed by GC and GC/MS. Neral (33.4%) and geranial (52,5%) were the major components.

(ii) Essential oil composition of *Satureja spicigera* (C. Koch) Boiss. From Iran[56].

Hydro-distilled volatile oil from the aerial parts of *Satureja spicigera* was obtained at yield of 3.82% w/w based on dry weight. The oil was analysed by a combination of GC and GC/MS. Fourty-eight components were identified that approximately constitute 96% of the oil. The main constituents of the essential oils were thymol (35.1%), *p*-cymene (22.1%), γ-terpinene (13.7%) and carvacrol (4.0%).

(iii) Essential oil constituents of *Satureja boissieri* from Turkey[57]

Water-distilled essential oil from the aerial parts of *Satureja boissieri* was analysed by GC/MS. Fourty-five components were characterized representing 97% of the oil. The main components were identified as carvacrol (40.8%), γ-terpinene, (26.4%) and *p*-cymene (14.5%).

(iv) Localities and seasonal variations in the chemical composition of essential oils of *Satureja montana* L. and *Satureja cuneifolia* Ten.[58] (Croatia)

The essential oils of *Satureja montana* and *Satureja cuneifolia* were subjected to detailed GC/MS analysis in order to determine possible similarities between them and also the differences in their chemical composition, depending on the locality and the stage of development. The plant material was collected prior to, during and after flowering from three different locations in the central part of Dalmatia (Croatia). For both plants the qualitative composition of the components appeared to be constant in the three phonological stages and in the three different localities.

53 Good R. 1974. *The geography of the flowering plants*, 4th edition. London. Longman

54 Heywood V.H. (Ed). 1978. *Flowering Plants of the World*. Oxford. Oxford University Press.

* Photograph of specimen in National Herbarium included in this Section

55 Lameck S. Chagonda, Jean-Claude Chalchat. 2004. *Flavour and Fragrance Journal*, John Wiley and Sons, Volume 20, Issue 3, p316-317.

56 Sefidkon F, Jamzad Z. 2003. *Flavour and Fragrance Journal*, John Wiley and Son, Volume 19, Issue 6, p571 – 573.

57 Kurkcuoglu M, Tumen G and Baser K.H.C. 2001. *Chemistry of Natural Compounds*, Springer New York, Volume 37, Number 4. p329 – 331.

58 Milos M, Radonic A, Bezic N and Dunkic V. 2000. *Flavour and Fragrance Journal*. John Wiley and Sons. Volume 16, Issue 3, p157 – 160.

However, considerable differences were found to exist in the amounts of several compounds.

(v) *Satureja montana*, also known as winter savoury, yields thymol and carvacrol as major oil components of the main chemotypes (terpene or phenylpropene

(v) Essential oils from two Peruvian *Satureja* species[59] (Peru)

The essential oils from the aerial parts of *Satureja boliviana* Briq. and *Satureja brevicalix* Epl. (Lamiaceae) from Cusco Department, Peru, were obtained by hydro-distillation in 1.03% (v/w) and 0.96% (v/w) yields related to dry weight. By GC.MS analyses, 65 compounds were identified in both oils. Oxygenated monoterpenes constituted 81.5% and 87.0% of the oils of *S. boliviana* and *S. brevicalix* respectively. In both oils, menthone (24.2% and 35.7%) and isomenthone (29.7% and 25.1%) were the main component. For *S. boliviana*, some differences were found compared with oil analysed in earlier studies, which could suggest the possible occurrence of chemical types.

(vi) *Satureja douglasii* is a prostrate evergreen perennial, which is native to the Pacific coastal zone from southern California to British Colombia, with a detached inland distribution in Idaho and Canada.

(vii) *Satureja hortensis*, also known as summer savoury, is a native of calcareous soils of the Mediteranean Basin which yield a valuable phenolic oil. Attempts have been made to get *S hortensis* to adapt to cool wet environments (Scotland)[60]

(viii) *Satureja thymbra*, growing wild in Greece, yielded < 0.1 ml/100g from stems and branches, 3.1 – 6.9 ml/100g volatile oil from leaves and 6.7 – 8.1 ml/100g from flowers[61].

3. Technical Matters

The above, very concise overview, highlights the fact that *Satureja* species has been in the focus of research in essential oils for a number of years. The only contact we had with *S. biflora* was in the National Herbarium, as we were unable to do a field survey to the locations in Manica and Sofala Provinces, cited in the Herbarium.

---

59 Felice Senatore *et al*.1996. *Flavour and Fragrance Journal*, John Wiley and Sons, Volume 13, Issue 1, p1 – 4.

60 Svoboda K P, Hay R. K. M. and Waterman P.G. 1990a. The growth and volatile oil yield of summer savory (*S hortensis*) in a cool wet environment. *Journal of Horticultural Science*. **65**: 659 - 65

61 Vokou D and Margaris N.S. 1986 Variation of volatile oil concentration of Mediterranean aromatic shrubs *Thymus capitatus* Hoffmag et Link, *Satureja thymbra* L, *Teucrium polium* L. and *Rosemarinus oficianalis* L. *International Journal of Biometeorology* **30:** 147 - 55

Plant material still has to be collected and the essential oils extracted for analysis. This undertaking should happen as soon as possible.

Satureja biflora (and any other species which should be identified) should be propagated and cultivated in the nursery. As a plant within the Lamiaceae Family, it should follow the same pattern as far as other well-known members of the Family such as *Ocimum basilicum* (Basil) and *Origanum marjorama* (Marjoram) as far as propagation, cultivation including soil preparation are concerned. The reader is referred to the Technical Reports on members of the Family Lamiaceae for more detailed information.

Reports: A26.01.01

Family: Linaceae
Genus: Linum
Species: usitatissimum

Common names: In Mozambique: No common name recorded?
English: Flax and Linseed

Location Report:

1. General Habitat and Distribution[62]

Linum usitatissimum is of Mediterranean origin and also from Western Europe. Why the *L usitatissimum* found in Mozambique is designated as indigenous and near-endemic, is unclear and will have to be investigated further. It may be a genetic strain, which could provide unique properties. Nevertheless, it is a plant, which could provide a valuable crop to Mozambique and the current population should be expanded, properly researched, including techniques of cultivation on a large scale, and developed into a commercial product.

2. In Mozambique

The Sabonet Report No 30[63] indicates that *Linum usitatissimum* occurs only in Maputo Province and information in the National Herbarium details only one location: The cultivation line at the experimental station Umbeluzi.

Furthermore, the Sabonet Report designates L. usitatissimum as Near Endemic under the IUCN Red Data Lisi Category of VUD2 meaning that the“ Population is very small or restricted in the form of either of the following: Population is characterized by an acute restriction in its area of occupancy (less than 100 km^2) or in number of locations (less than five)

Technical Report:

4. Description[1]

L. usitatissimum, as it occurs in countries and regions where it is a valuable commercial crop, is an erect annual herb growing up to 1 m in height with slender stems bearing small, hairless leaves and attractive blue flowers. The fruit capsules contain reddish-brown, smooth seeds. Some cultivars are grown for stem fibres (flax); others for the seed and seed oil.

---

62 Van Wyk, Ben-Erik and Wink, Michael. 2004. *Medicinal Plants of the World*. Briza Publications. Pretoria. South Africa.

63 Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

Flax is an ancient cultigen (probably derived from *L angustifolium*) with large, indehiscent capsules and large seeds.

The seed of the plant contains between 35 and 45% oil (including linoleic acid and α-linolenic acid, ALA), 25-25% proteins and 25% fibres. Also present are sterols and triterpenes (cholesterol, campesterol, stigmasterol, sitosterol and others, together with up to 1% cyanogenic di- end monoglycosides (linustatin, neolinustatin, and linamarin, lotaustralin, respectively). Large amounts (6 – 10%) of mucilage are present in the external wall of the outer cell layer of the seed.

Reports: A14.03.01

Family: Clusiaceae
Genus: Calophyllum
Species: Inophyllum

Common names: In Mozambique: Mtondo
English: Tamanu, Forah

Location Report:

1. General Habitat and Distribution[64]

Calophyllum inophyllum is indigenous to Southeast Asia, and grows profusely on the numerous islands of Melanesia and particularly Tahiti. The tree is now fairly widespread in countries with similar climate. It is therefore now also found in countries such as Thailand, Burma, Vietnam, Malaysia, South India, and Sri Lanka. In the Society Islands the tree is known as by the names Tamanu and Ati, and various others, in other parts of the region, but the name of Tamanu has become the name by which it is most commonly known.

Though the tree can be planted inland, it naturally grows profusely along coastal areas. The dispersal of Tamanu throughout the Pacific islands is ascribed to the fact that nut containing fruit drops from the trees and floats to other coastal areas where they sprout and root. Tamanu is unusual, in that unlike most other trees it favours salty, sandy soils.

2. In Mozambique[65]

The Sabonet Report No 30[66] indicates that *Calophyllum inophylum* occurs in the Province of Cabo-Delgado and is designated an indigenous plant. The reason it is designated as such is unclear seeing that it is accepted to be of Southeast Asian origin. The size and exact location of populations is also unknown which makes it difficult to project the commercial potential of the plant. Nevertheless, the Tamanu tree is easy to propagate, and under ideal climatic and soil conditions, commercially viable populations could be established fairly quickly.

---

64 Van Wyk, Ben-Erik and Wink, Michael. 2004. *Medicinal Plants of the World*. Briza Publications. Pretoria. South Africa.

65 Photograph of specimen in national herbarium included in this section.

66 Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

Technical Report:

1. Description[67]

Calophyllum inophyllum, or Tamanu, is a tree, which grows up to 25 meters high, with long spreading limbs. The tree trunk is typically thick with dark, cracked bark. The Tamanu branches are covered with shiny, dark green oval leaves, and small white flowers with yellow centers. The blossoms give off a delightful, sweet perfume. The fruit of the tree, about the size of an apricot, has a thin flesh and a large nut hull inside.

The Tamanu nut is a botanical oddity. When the fruits of the tree are collected and cracked open, the blond nut kernel inside contains no apparent oil. But when the kernel dries on a rack for a month or so, even up to two months, it turns a deep, chocolate brown, and becomes sticky with rich, pleasant smelling oil. It takes about 20 kg of nuts to produce 1 kg of oil. Using a simple screw press, the oil is squeezed from the dark kernels. The cold-pressed and unrefined oil is then purified into a virgin oil by removing unwanted resins before being bottled. The resulting oil of Tamanu is dark green and luxurious. Though oil of Tamanu is thick and rich, once it is applied to the skin it is readily and completely absorbed, leaving no oily residue. The oil stores well under most conditions but extreme heat will lessen the shelf life.

2. Essential oil composition and specification

The oil from the Tamanu kernel has a high content of essential fatty acids (EFA's), which have exceptional moisturizing, regenerative and antiseptic properties. The total free fatty acid content is about 3%, of which the typical fatty acids composition is:

Fatty acid composition of Tamanu Oil	
Fatty acid	**Percentage**
Oleic acid	34%
Palmitic acid	12%
Linoleic acid	38%
Linolenic acid	0,3%
Strearic acid	13%

Oil of Tamanu also contains three classes of lipids, with the lipid content stated in brackets: neutral lipids (92%), glycolipids (6,4%), and phospholipids (1,6%).

Composition of lipids					
Neutral lipids	**%**	**Glycolipids**	**%**	**Phospholipids**	**%**
Monoacylglycerols	1,8	Monogalactosyldiacylglycerol	11,4	Phosphatidylethanolamine	46,3
sn-1,3-Diaglycerides	2,4	Acylated sterolglucoside	13,1	Phosphatidylcholine	8,1
sn-1,2(2,3)-Diaglycerides	2,6	Monogalactosylmonoacylglycerol	22,2	Phosphatidic acid	8,1
Free fatty acids	7,4	Acylmonogalactosyldiacylglycerol	53,3	Phosphatidylserine	6,1
Triacylglycerols	82.3			Lysophosphatidylcholine	5,7
Sterols, sterolesters, hydrocarbons	3,5				

67 Extracted from research done by Chris Kilham, Founder of Medicine Hunter Inc, Explorer in Residence at the University of Massachusetts, Amherst. Compiled by Ian Mclean.

The oil also contains a unique fatty acid called calophylic acid, and a novel antibiotic lactone and non-steroidal anti-inflammatory agent called calophyllolide. These and the other components of Tamanu oil, including anti-inflammatory coumarins, account for some of the oil's beneficial activity. The oil, upon analysis, result in the following specification:

Specification of Tamanu Oil	
Colour	Dark green
Odour	Heavy, fatty and oudiferous
Free fatty acids	3,0%
Peroxide value	<7%
Non saponifiables	0,6%
Saponification Value	180-200
Iodine value	100-112
Specific gravity	0,91
pH	4,03

Based on the known activity of known constituents, it is clear that oil of Tamanu possesses antibacterial and anti-inflammatory activities.

3. Commercial value of the oil

The value of the oil is quite high – it sells for about US$ 250 per kg. Since the 1920's Oil of Tamanu has been studies in hospitals and by researchers in Europe, Asia and the Pacific Islands. It has been established that Tamanu oil possesses a unique capacity to promote the formation of new tissue, thereby accelerating wound healing and the growth of healthy skin. This process is known as cicatrisation. In traditional medicine of the Pacific Islands, Tamanu oil is applied liberally to cuts, scrapes, burns, insect bites and stings, abrasions, acne and acne scars, psoriasis, diabetic sores, anal fissures, sunburn, dry or scaly skin, blisters, eczema, herpes sores, and to reduce foot and body odour. Tamanu oil is also massaged into the skin to relieve neuralgia, rheumatism and sciatica. Polynesian women have used Tamanu oil for ages to promote healthy, clear, blemish-free skin. It is also used to present diaper rush and skin eruptions.

Tamanu oil and cicatrisation. It is particularly the impressive cicatrizing properties of Tamanu oil, which has caught the attention of researchers. In the French medical literature on Tamanu oil, several instances of its successful use in cases of severe skin conditions have been reported. The unique cicatrizing properties of Tamanu oil are not yet explained in the existing scientific literature, though this activity is established and accepted.

Anti-neuralgic and skin-healing activity. Tamanu oil has a history of the topical use of relieving the pain associated with sciatica, shingles, neuralgia, rheumatism and leprosy neuritis. Tamanu oil has been used successfully to heal severe burns caused by boiling water, chemicals and X-rays.

Anti-inflammatory activity of Tamanu Oil. The oil demonstrated significant anti-inflammatory activity. The activity is due partly to the 4-phenyl coumarin calophyllolide, and to a group of xanthones in the oil, including dehydroxycycloguanandin, calophyllin-B, jacareubin, mesuaxanthone-A, mesauxanthone-B and euxanthone. All the xanthones in

Tamanu oil show anti-inflammatory activity. This explains reduction of rashes, sores, swelling and abrasions with topical application of the oil.

Antibacterial and antifungal activity of Tamanu oil. Tamanu oil demonstrated significant antimicrobial activity, as shown in antibacterial and antifungal tests. The oil contains several powerful bactericidal/fungicidal agents, which demonstrated efficacy against various human and animal pathogens. These antimicrobial phytochemical agents include friedelin, canophyllol, canophyllic acid, and inophynone.

Antioxidant activity of Tamanu oil. Xanthones and coumarins in tamanu oil demonstrate antioxidant properties, specifically inhibiting lipid peroxidation. Cell membranes are made of lipids. The antioxidant activity of tamanu oil helps protect skin cells from damage by reactive oxygen species ant other oxidative antagonists.

Tamanu for cosmetics. Oil of Tamanu is suitable for general skin and cosmetic purposes. The oil's unique absorption, its mild and pleasant aroma and its luxurious feel make it ideal for use in lotions, creams, ointments and other cosmetic products. The oil adds a glow to the skin, without any residual greasiness or oiliness. Considering that Tamanu is a potent healing agent with proven benefits, it is only a matter of time before Tamanu breaks through to more widespread use, and assumes a position among other successful tropical and cosmetic ingredients.

4. Tamanu oil and sustainable harvesting.

In rural, native communities, the nut-containing tamanu fruits are collected from the ground after they have dropped from the trees. Because the nut-containing fruits of the tree are collected after they drop to the ground, there is no negative impact upon the tree itself as a result. The trees are themselves are neither touched nor harmed. The habitat is not negatively impacted, as neither the land nor the surrounding plants are disturbed as a result of collection. It is accepted that tamanu collection is a low, impact, environmentally sustainable activity.

However, the question remains what impact tamanu fruit collection has on the propagation of tree populations, as the means of propagation, the seed is removed from the environment, without replacing it. It seems that, in very large, widespread populations, the impact of collecting from nature may not be noticeable, but that in smaller, concentrated populations damage may be done to the ability of the population to sustain itself. It will still be advisable to master the technology of large-scale cultivation, including the establishment of large nurseries where the trees are propagated before planting into plantations.

As far as Mozambique is concerned, it will be absolutely necessary to determine the size of existing populations and their mechanism of natural propagation before large-scale collections from the wild, for the purpose of extracting the oil, should start. A program of cultivation should also be seen as a priority.

5. Summary

Tamanu oil is an excellent example of a traditional remedy, which has percolated to broader attention due to a combination of selective use in traditional settings, and scientific research corroborating its benefits.

Tamanu oil fulfils three significant ideals. It provides a healing benefit to the users, the collection of the nuts and the manufacture of the oil cause no damage to the environment (to be confirmed), and the collection and processing of the nuts provides income to communities, enhancing their economic welfare.

Reports: A17.03.01

Family: Euphorbiaceae
Genus: Schinziophyton
Species: rautanenii

Common names: In Mozambique: Mungongo
English: Manketti Tree

Location Report:

1. General Habitat and Distribution[68]

Schinziophyton rautenenii occurs in the northern parts of Namibia, south-eastern Angola, northern Botswana and across the border with the western part of Zimbabwe. It also occurs in Zambia, small populations on the border of South Africa and Botswana and some populations are present in the northern Provinces of Mozambique.

2. In Mozambique

The Sabonet Report No 30[69] indicates that *Schinziophyton rautenenii* occurs in Cabo, Manica, Niassa, Sofala Tete and Zambezia Provinces, again with detailed information on the size of populations unavailable.

Technical Report:

5. Description[1,70]

Schinziophyton rautenenii is a large tree with a spreading, rounded crown, sexes separate, on different plants, occurring on sandy soils, such as in the bushveld on Kalahari sand and sometimes on almost pure sand.

Young branchlets, leaf buds and stalks with reddish-brown furry hairs. Latex present. Leaflets 5 – 7, pale velvety-grey below with 1 – 3 flat, dark-coloured glands present at junction with the leaf stalk. Flowers in slender, loose sprays, yellowish which forms the fruit, which is egg-shaped, up to 35 x 25 mm, velvety; and ripens and falls to the ground from the end of March to April or May. Seeds are with very thick woody walls, containing numerous pits. Each fruit has a thin, fleshy layer around this hard pitted shell that covers the nutritious nut.

---

[68] Van Wyk,, Braam and Van Wyk, Piet. 1997. *Field Guide to Trees of Southern Africa*. Struik Publishers. Cape Town. South Africa.

[69] Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

[70] Van Wyk, Ben-Erik and Gericke, Nigel. 2003. *People's Plants – A Guide to Useful Plants of Southern Africa*. Briza Publications. Pretoria. South Africa.

The dried fruit-pulp is pleasantly scented and is used to make a porridge. The kernel of the seeds is rich in oil and protein, tasty and very nutritious. It is an important food source, also because the fruits and nuts remain edible for such a large part of the year. Peeled fruits are then cooked in water until the maroon-coloured fruit flesh separates from the hard inner nut. The wood is comparable with balsa wood: pale yellowish and strong.

Analysis of the nutrient content of the fruits and nuts has shown that they compare well with some of the world's most nutritious foods. The kernel is rich in various fats (~ 40%) and proteins (~38%). The oil from the nuts is used as a body-rub during the dry, winter months to clean and moisten the skin. It is now also used in modern cosmetics. Mungongo has a 57% oil content, is high in Xitamin E and when the oil is extracted, the protein content in the residue is 72%. Oil composition profiles were determined by Rutgers University, USA.

In Zambia, ASSNAP is supporting a project involving the collection of nuts and the extraction of the oil through cold pressing. The oil is used in facial creams and other oil-based products. Sustainable harvesting practices aim to ensure that the germplasm is maintained.

Reports: A18.02.01

Family: Erythoxylaceae
Genus: Croton
Species: gratissimus

Common names: In Mozambique: Njiwanjiwa
English: Lavender Croton

Location Report:

1. General Habitat and Distribution[71 72]

The distribution of this small shrub or tree extends over large parts of the northern part of South Africa, as well as Zimbabwe, Botswana, Namibia and Angola.

2. In Mozambique[73]

The Sabonet Report No 30[74] indicates that *Croton gratissimus* is found in Gaza, Inhambane, Maputo and Tete Provinces. No detailed information is available on population sizes at the locations where it is found.

Technical Report:

1. Description[1]

This shrub or small tree of up to 10 metres in height has a rough grey bark and btight green aromatic leaves which are silver grey and gland-dotted on the lower surfaces.

Very little information is available on the potential use of this species, other than it may contain a usable aromatic oil. *Croton tiglium* contains phorbol esters and was used as a strong purgative in traditional medicine. It is no longer use as it is suspected that its active ingredients are co-carcinogens. In the case of *Croton gratissimus*, bleeding gums are treated by brushing them with the charred and powdered bark of the plant.

Its powdered leaves are used as an important traditional perfume, used in much the same way as buchu. Powdered leaves have been used with oil or fat to anoint the body, and hot water extracts were once made as a substitute for lavender water. With these indications that it is a possible commercial plant it is clear that more work is needed to determine the full potential of this plant.

71 Van Wyk, Ben-Erik and Wink, Michael. 2004. *Medicinal Plants of the World*. Briza Publications. Pretoria. South Africa.

72 Van Wyk, Ben-Erik and Gericke, Nigel. 2003. *People's Plants – A Guide to Useful Plants of Southern Africa*. Briza Publications. Pretoria. South Africa.

73 Photograph of specimen in National Herbarium included in this Section

74 Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

Reports: A36.01.01 to A36.01.04

Family: Poaceae
Genus: Cymbopogon
Species: excavatus
giganteus
nardus
pospischilii

Common names: In Mozambique: chisugumbi, wangono, bundo, hingwe
English: Lemon grass

Location Report:

1. General Habitat and Distribution[75],[76]

The well known *Cymbopogon citratus* (the "classical" Lemon Grass) is reported in the literature as synonymously belonging to the family of either Gramineae or Poaceae. We will place it within the family Poaceae, as all the indigenous species of the genus *Cymbopogon* are recorded in the SABONET Report No30.

Its origins go all the way to India and Sri Lanka, where it has been used in Far Eastern cuisine for many ages. Its abundant growth and easy propagation has made it a sought after herb.

Cymbopogon citratus has also been recorded in the SABONET Report No. 30 and in Maputo and Gaza Provinces. It is known that the operation **Africa Naturally** is already cultivating lemon grass in the Beira region. In this Report we will not concentrate on *C. citratus* and the lemongrass oil it produces, but rather on *C. nardus*, the species, which produces citronella oil, and where an indigenous variety occurs in Mozambique.

2. In Mozambique

The SABONET Report No 30[77] indicates that the indigenous species of *Cymbopogon* as recorded occur in practically all the provinces of Mozambique. The exact location of populations of these four species we have selected, and their sizes are unknown. Of great interest is the occurrence of *Cymbopogon nardus* as indigenous to Mozambique. This species is also known as " Ceylon citronella " and the source of the well known citronella oil of international trade. In Mozambique this species have been recorded in Cabo, Gaza, Maputo, Nampula and Sofala Provinces. What the link is with *C. nardus,* which is commercially cultivated almost exclusively in Sri Lanka for its " Ceylon citronella ", is uncertain, and will have to be determined. It is most likely a wild variety, which established itself in Mozambique. These uncertainties emphasize the need to analyze the

[75] Roberts, M. 2002. *The essential Margaret Roberts – my 100 favourite herbs*. Spearhead Publishers, Claremont, Cape Town.

[76] Weiss, E. A. 1997. *Essential Oil Crops*. Published by CAB International. United Kingdom

[77] Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

oil from the local *C nardus* (and the other indigenous species as well, for that matter), a process we have already initiated.

The very wide range of oils identified in many *Cymbopogon* species is also an indication of the range of material available to plant breeders, not only in respect of novel oils, but also within exiting commercially exploited *Cymbopogon* species. In particular, there exists considerable potential for selection and breeding strains high in a specific oil component. It is in this regard that the indigenous species of *Cymbopogon* may realize their true value.

For the purpose of this Report we will focus on the technicalities related to *C nardus*, which will, most likely, be as valid for the other species.

Technical Report:

1. Description

All species of Cymbopogon are perennial plants with typical grass-like features. *C. nardus* is a tufted, perennial grass, with long narrow leaves, and numerous stems arising from short, rhizomatous roots. The species is a vigorous grower. It exists in a variety of forms, some wild, others known only under cultivation, together with local cultivars in countries to which it was introduced. *C nardus* has an extensive and penetrating root system, which enables it to withstand periods of drought. Its root system also allows it to grow in a variety of soil types, including soils of lower fertility. The ability of *C. nardus* to persist for 10 – 15 years under cultivation probably owes a great deal to these wide spreading roots. Its multiple stems, up to 2,5 m long arises from its underground rhizomes. Its leaves are long, narrow and a uniform to dark often yellowish green. Mature leaves from uncut plants are 70 110 cm long and leaf width 1 – 2 cm. Micro-hairs are present on its leaves, and a relationship apparently exists between their occurrence, type density and leaf oil content, which could aid selection of higher oil content strains.

The oil content of leaves is important as there is little oil in stems and roots, to illustrate: in India average oil content was, in percent: leaf blade 1,0, inflorescence 0,38, leaf sheath 0,33, condensed stem 0,32 and root 0,02. The oil content of leaves differs significantly and young leaves synthesize and accumulate most essential oil. During leaf expansion, citronellal, geraniol and citronellol content increase, but decrease with maturity. Leaf-oil content varies with age, time of cutting and soil fertility.

Flower oil is of little importance, is small in relation to total oil yield, and would not compensate for the loss of leaf oil content should citronella plants be allowed to flower before cutting.

2. Essential oil composition and specification

The two types of citronella oil, traded as Oil of Citronella Java and Oil of Citronella Ceylon, differ in their composition, characteristics and odour, and are neither substitutes not alternatives to the other.

Citronella Oil Ceylon varies in colour from yellow to brownish-yellow, sometimes dark greenish yellow, and may be clear or slightly turbid due to contained water. The odour is quite distinctive and described as floral, with woody, grassy, leafy notes due to the camphene borneol-methyleugenol complex. The main constituents are the monoterpene hydrocarbons, and major components, in percent, geraniol to 60, citronellal to 15, citronellol to 10, not necessarily in the same sample.

Citronella Oil Ceylon is considered an industrial oil and used extensively in detergents, waxes, household soaps and cleansers, for masking unpleasant odours of insecticides and similar preparations, and to a minor extent in cheaper perfumes and toiletries. The oil is frequently used as a domestic insect repellent, being placed in jars with wicks, which allows slow evaporation, or ignited and slowly burns. The oil is a raw material for geraniol, citronellol, citronellal and menthol production.

Citronella Oil Java is colourless to very pale yellow; the odour sweet, fresh and lemony. The main constituents are, in percent, citronellal to 50, citronellol to 20 and geraniol to 45, not necessarily in the same sample.

The oil is used extensively in perfumes and toiletries, and household or semi-industrial products. It is a raw material for a range of important isolates, including citronellal, menthol, geraniol and geraniol esters, citronellol and its esters.

A major reason why citronella oil is still so widely used is that many perfumers favour products of natural origin over synthetics; especially hydroxycitronellal with its lily of the valley fragrance strongly preferred in high-class perfumes. Geraniol and its derivative citronellol both have a rosy odour, and are often called rose alcohols and are used extensively in perfumery.

Regional variations in characteristics are well-recorded facts. These variations have to be determined, as it could present interesting possibilities to plant breeders.

	Java Type			**Ceylon Type**	
	ISO	**BSS**	**EOA**	**BSS**	**EOA**
Relative Density at 20^0C	0,880 0,895			0,890 0,898	
Apparent Density at 20^0C		0,880 0,892			0,893 0,910
Specific Gravity at 15^0C			0,883 0,900		
Refractive Index at 20^0C	1,4660 1,4730	1,4660 1,4730	1,4660 1,4750	1,4790 1,4850	1,4790 1,4850
Optical Rotation at 20^0C	-5^0 0^0	-5^0 0^0	-6º -0 30º	-18^0 -9^0	-18^0 -9^0
Solubility (v/v) (80% ethanol at 20^0C	1:2	1:2	1:1,2	1:2	1:1,2
Total alcohols as geraniol	85% min	85% min	85-97%	59-65%	55-65%
Total aldehydes as citronellal	35% min	35% min	30-45%	7-15%	7-15%
All figures in columns are ranges					
ISO: International Standards Organisation; BSS: British Standards Organisation; EOA: Essential Oil Association USA					

Wide variation is noticeable in published data of regional oils. For example, Java citronella has been reviewed in detail and the main characteristics of commercial samples from selected origins are shown in the table below.

Characteristics of Java citronella oil from selected origins			
	Indonesia	**India**	**Taiwan**
Specific Gravity (15^{0}C)	0,880 0,897	0,875 0,900	0,881 0,902 (20^{0}C)
Refractive Index (15^{0}C)	1,469 1,472	1,460 1,480	1,465 (20^{0}C)
Optical Rotation	-0,5^0 -4,0^0	-1,0^0 -3,5^0	0^0 -4^0
Solubility (v/v in 80% alcohol	1:1	1:1,5	1:1
Total alcohols (%) (as geraniol)	85-95	75-90	85-95
Total aldehydes(%) as citronellal	35-55	30-45	35-45
Average commercial samples. Figures in columns are ranges			

3. Cultivation

Cymbopogon nardus is a tropical grass. The species can be grown successfully from sea level in Sri Lanka to 1 500 m in East Africa. At all altitudes a well distributed rainfall and high humidity is most important to ensure high herbage yield.

C. nardus requires a rainfall of 2 000 – 2 500 mm annually to produce high oil yield, and although the species is less susceptible to dry periods, than *C. winterianus*, oil production will decrease under water stress, and will therefore, under extremely dry conditions, require irrigation. Warm mists or high relative humidity can compensate to a considerable extent for insufficient rain. Conversely, cool wet conditions usually retard growth, and may also reduce leaf-oil content.

A sunny climate with no temperature extremes generally produces highest oil yield. A daytime temperature of 22 – 30^{0}C is most suitable, with higher and lower temperatures affecting either leaf oil content or oil constituents

The reaction of *C. nardus* to temperatures above 30^{0}C and to high nighttime temperatures is of considerable importance to growers. Oil produced at high temperatures has increased levels of some very undesirable components, the monoterpene hydrocarbons and camphene-bornene compounds, which greatly reduce the oil's commercial value.

Frost causes severe damage and a heavy frost is usually fatal. Hail can seriously damage newly established plants, and a heavy storm can shred leaves on those more mature and greatly reduce oil content.

C. nardus prefers a well-drained, light-textured soil, but will grow well on sandy or stony hillsides provided there is adequate soil moisture. The extensive root system allows the plant to explore a greater soil volume for both moisture and nutrients. A neutral to slightly acid soil is preferred, although plants will tolerate slightly alkaline soils, but not waterlogging except for very short periods.

Citronella has been classified as an exhausting crop similar to lemongrass. The large amounts of green material removed, 20-60 t/ha annually, is an indication of the level of nutrients removed from the soil and therefore makes it essential that the nutrient status of soils is maintained to ensure continued high production. Under conventional farming conditions a balanced program of chemical fertilization should be followed. Where chemical fertilizers are not readily available, crops must receive whatever plant and animal residues are available, preferably in a well composted form. Organic farming will in any case have to rely almost entirely on these materials as sources of fertilization. Well-composted farm manure at levels of at least 15t/ha should be ploughed in prior to planting and followed by additional applications, especially when it becomes apparent that oil yields are starting to decline.

Growers who are serious about the commercial viability of their operation will ensure that they fully understand the fertilization needs of their crops. Citronella, as a crop, responds differently to the various nutrients under different climatic and soil conditions. Nitrogen is essential for high leaf yield, but there is often considerable variation in the response to both amounts and types. Nitrogen at planting, often in an NPK formulation or as diammonium phosphate, usually promotes increased and quicker growth and thus reduces time to the first cut. The NPK fertilizer used at planting should have a low ratio of nitrogen to phosphate and potassium, sufficient only for initial growth. Where there is little choice and nitrogen content is high, it is probably cheaper to choose a phosphate-potassium mixture and apply the nitrogen as top-dressing. The main effect of nitrogen top-dressing is to increase the number of tillers and number and size of leaves, but the response in terms of increased herbage or oil yield may fall in succeeding years, especially to high levels of nitrogen.

The larger root system of *C. nardus* enables it to obtain greater amounts of available soil phosphate, a major reason why the plant can continue to produce oil for many years with little or no fertilizer. It cannot continue to do so indefinitely, and to maintain production nitrogen and phosphate are necessary; one without the other is usually unprofitable. Where rock phosphate (or bone meal) is available it can be broadcast and ploughed in prior to planting splits. The benefits of using these slow release phosphate based fertilizers in comparison to chemical sources of P, such as single superphosphate, should be weighed by growers.

Potassium is best applied as part of a compound fertilizer at planting and the range recommended by suppliers should be sufficient. Potassium should be applied again after 2 or 3 years, and its impact monitored thereafter to determine further applications.

The small amounts of minor elements normally required to alleviate a local deficiency should be included in a compound mixture applied to the seedbed or drilled alongside plant rows after a cut.

Plants can be raised from seed, which is normally viable, but this is lengthy and tedious. Propagation is usually by dividing clumps to produce splits, a year-old clump will provide 50 – 60 splits, and 1 ha of clumps is normally sufficient for 7 – 8 hectares. A spacing of 90x60 cm requires about 18 500 plants per hectare, and 60x60 cm 27 000 plants per hectare. Certain plants may die-off for a variety of reasons and must be replaced as soon as possible. After about 4 weeks all healthy plants should begin to tiller. It is essential to maintain the optimum number of plants per hectare, as this directly affects herbage and oil yield. High rather than low numbers of plants per hectare also tend to suppress weed growth.

Weed control in citronella is usually manual or mechanical, hand weeding is generally the most effective, but any cultivation should be shallow, to avoid uprooting plants.

C. nardus is not ideally suited for intercropping because the plant grows to a large size, but has been underplanted amongst trees such as coconut and similar tall-tree plantations.

Watering splits at planting is necessary and again in the following week if no rain falls. In practice those crops which can be irrigated are planted in the wet season, irrigated after each cut in the dry season to promote regrowth, and at other times only when water is available.

4. Harvesting

The first harvest of citronella is usually 6 – 8 months after planting, ideally just prior to flowering, then 3 – 4 times in each following 12-months, depending on rate of regrowth. The profitable life of a commercial plantation is very variable: for *C. nardus* it can be 6 to 10 years but up to 20 years. The most productive period in terms of oil yield per hectare is the first 4 to 6 years for *C. nardus*, but better management, adequate fertilization and efficient harvesting could easily prolong the useful life of most plantations and raise the average annual oil yield. Since replanting is expensive and in practice means the loss of a year's oil yield, every effort should be made to keep an existing plantation in profitable production.

The number of cuts per year could vary from region to region and circumstance to circumstance, but between four and six cuts for *C. nardus* should be possible. Height of plants could be used as a guide; a case has been recorded where highest oil yield per hectare was obtained from plants cut eleven times at 130 cm.

Herbage yield per hectare could vary greatly, and depends on size of the plantation and standard of management; for *C. nardus* yields of 10 000 to 40 000 kg/ha annually has been recorded.

The oil yield per ton of herbage varies with the season, normally highest in the driest and lowest in the wettest period. Oil content of *C. nardus* in Sri Lanka was 1,2 – 1,5 and 0,25 – 0,50% respectively.

5. Distillation

Cut herbage is normally wilted before distilling, between 3 – 4 hours sun drying is usual, longer if the grass is wet following rain. In certain cases wilting periods of up to a month has been recorded. Trials will have to determine the optimum conditions for a specific location. While withering to reduce water content is normally advantageous, changes can occur in oil composition depending on the method used and the period. The ideal withering period, and whether shade or sun withering produce the best result need to be determined, as there are no fixed rules.

Distilling citronella herbage present few technical problems. Steam pressure and duration of distillation influences the yield of oil and its quality. Again, experimentation will be required to determine the ideal parameters at various locations in Mozambique.

The charge used will firstly depend on the charge vessel, but it is unproductive to use a charge vessel, which is too small. In Sri Lanka the usual charge is 500 – 600 kg chopped grass, firmly pressed into the charge vessel. Normal distillation is 2 hours, and double with a 1 000 – 1 500 kg charge. Oil recovery in the first hour is 55 – 65%, in the second to fifth hours 25, 10 – 11, 6 – 8 and 45% respectively. Distillation is seldom continued beyond 2,5 hours, and distilling to exhaustion produces an inferior oil. The profile of distilling *C. nardus* (or any other Cymbopogon species) in Mozambique will have to be determined experimentally, but some guidelines could be provided by experiences in other countries such as Sri Lanka.

There is always the interesting question on what to do with the spend plant material after distillation, as in major operations this could amount to many tons of material. Fact is material such as spend citronella grass is high in organic matter (well over 80 and up to 95%) as well as other elements such as nitrogen and phosphorous. It was found that although fresh citronella grass is not palatable to cattle, dried spent grass is an acceptable stock feed. There are cases where the grass is also used for the production of kraft paper pulp. An interesting possibility is therefore to run a small paper making industry together with the essential oil production. The paper may even have undertones of citronella oil.

6. Pests and diseases

Most insects and other pests of these grasses are polyphagous, or attack many of the Poaceae (Gramineae), and it is usually simple to establish which are, or are likely to become, important in a particular region. The general impression is that insect pests are seldom a limiting factor and their adverse effects most easily offset by higher standards of crop management. In any case, it is of little value listing all the insect and other pests likely to occur on these grasses as this sort of information will be obtainable from local expert agriculturalists.

Diseases, unlike pests, can be a limiting factor in commercial plantations, but fortunately some of the most damaging can be controlled by simple procedures, such as fungicide treatment of seedbeds and splits before transplanting. The most damaging pathogens are those attacking seedlings or splits after transplanting, as this operation takes place at the beginning of the rains or after irrigation, when conditions for soil-borne fungal attacks are most favourable.

Reports: A47.01.01

Family: Verbenaceae
Genus: Lippia
Species: javanica

Common names: In Mozambique: Mussumbe
English: Fever Tea, Lemon Bush, Wild Sage, Wild Tea.

Location Report:

1. General Habitat and Distribution[78]

The family Verbenaceae is a family of herbs and shrubs and small trees, often with aromatic leaves. There are 36 genera and approximately 1035 species in tropical and sub-tropical regions, with just a few representatives in temperate areas. There are 8 genera and approximately 40 species in Southern Africa. There are 6 indigenous species of *Lippia* in South Africa.

Lippia javanica occurs in large parts of Southern Africa, with the exception of the Western Cape. *L.javanica* grows from the Eastern Cape northwards, extending into tropical Africa including Botswana, Swaziland, Mozambique, Malawi, Tanzania, Zambia and Kenya. It grows in open veld, in the bush, as well as on forest margins. This plant also occurs in Java, hence the epiphet "javanica".

2. In Mozambique

The Sabonet Report No 30[79] indicates that *Lippia javanica* occurs in Maputo, Nampula, Tete and Zambezia Provinces.

Technical Report:

1. Description[1]

L.javanica is an erect woody shrub of up to two metres in height and is multi stemmed. The leaves are hairy with noticeable veins. The plant has highly aromatic leaves, which give of a lemon smell when crushed. It is said to be one of the most aromatic of Southern Africa's indigenous shrubs. The small cream flowers can be found on the shrub from summer to autumn in some areas and in others are produced all year. These flowers are arranged in dense, rounded flower heads. It is similar to *L. scaberrima*, but the latter has conspicuous leaf-like bracts in the flower heads. The fruit are rather inconspicuous, small and dry.

---

[78] Van Wyk, Ben-Erik and Gericke, Nigel. 2003. *People's Plants – A Guide to Useful Plants of Southern Africa*. Briza Publications. Pretoria. South Africa.

[79] Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

2. Essential oil composition

Previously, the aerial parts of *Lippia javanica* were collected, by others, from various localities in southern Africa to study the essential oil composition and its antimicrobial activity. The volatile oil was extracted using hydrodistillation of leaves, flowers and stems and characterized by GC-MS. A cluster analysis was performed on the essential oil dataset.

In general terms, the volatile oil of *L. javanica* contains myrcenone, caryophyllene, linalool, p-cymene and ipsdienone. A preliminary study indicated that the essential oil chemistry varies dramatically both within and between natural plant populations. From 16 samples (representing five natural populations), 5 chemotypes were identified: a myrcenone rich-type (32 – 48%), a carvone rich-type (61 – 73%), a piperitenone rich-type (32 – 48%), an ipsenone rich-type (42 – 61%) and a linalool rich-type (>65%). The study referred to here reported that the myrcenone and linalool chemotypes have been mentioned in the literature before, but the carvone, ipsenone and piperitenone chemotypes have not previously been reported for *Lippia javanica*.

3. Commercial value of the oil

The commercial value of the oil as a repellent and its possible use to control bark beetles of the genus *Ips* have been investigated. As the microbial activity may be directly related to the specific composition of the oil, the activity may also fluctuate. The oil was tested for antimicrobial activity on cultures of *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus*, and found to completely inhibit *Staphylococcus aureus*, *Escherichia coli*, *Salmonella gallinarum*, *Klebsiella pneumoniae*, *Candida albicans* and *Pseudomonas aeruginosa* at concentrations of µg/ml.

4. Cultivation

Lippia javanica can be grown from seed, but also grows easily from cuttings. The species is not very particular and seems to do well in most soil types. It is known to colonise disturbed areas, making it a pioneer plant. These plants are usually very hardy and can grow under difficult circumstances, requiring little maintenance and manage under relatively dry conditions.

5. The case of *Lippia multiflora* from Ghana

ASSNAP is in the process of launching, under its MPUNTU brand name, a tea made from *L. multiflora* from Ghana. This plant has a long history as a therapeutic drink that relieves stress, fatigue and coughs and colds. It makes a rich golden-green infusion with a crisp, sweet natural flavour and aroma. Currently the tea is collected from the wild. ASNAPP has done its research in collaboration with Kwameh Nkrumah University of Science and Technology.

The Center for Scientific Research into Plant Medicine (CSRPM) is buying the production for the local markets. The Center is using *L. multiflora* in their clinics. New Jersey and California companies in the USA are interested in commercializing the tea in the US.

Reports: B03.01.01/C01.01.01

Family: Annonaceae
Genus: Cananga
Species: odorata

Common names: In Mozambique: Ylang-Ylang
English: Ylang-Ylang and Cananga Oil

Location Report:

1. General Habitat and Distribution

The family Annonaceae belongs to the order Magnoliales with 120 genera including many tropical species, about half in Asia, Australia and Polynesia, one third in tropical America and the remainder in Africa. The genus Cananga contains two species of which *Cananga odorata* has found prominence as a result of the remarkable aromatic oil, known as Ylang-Ylang of Cananga Oil, it produces. At one stage cananga oil was produced in a number of countries where cananga became naturalized, but now the main producers are Indonesia and Madagascar. The name cananga refers to the Malaysian term kenanga; adding to the belief that it is the country of origin of the genus. The term cananga is used when oil obtained from natural resources is referred to while ylang-ylang is used when the oil originates from cultivated plantations. Ylang-ylang oils are therefore the result of a process of selection by growers, resulting in oils with required characteristics.

Cananga odorata was introduced to Madagascar during the early 20th century, in 1905, to be exact, probably via Mauritius. From this introduction and successful cultivation in the northern parts of the country, particularly the island of Nossi-Be, an aromatic oil industry grew. It is reported that Madagascar, already in 1925, exported 12,8 tons of cananga oil and further reports noted a regular production of between 20 and 30 tons after 1939. This oil is part of a group of three oils, the others being clove and cinnamon oils, for which Madagascar has gained international prominence. Madagascar is now the second largest producer of cananga oil for the world market with about a dozen companies involved in its production, using high capacity and modern distillation units.

The industry has experienced periods of decline, such as during and after the Second World War, and neglect, as trees increased in size, with no replanting of trees, resulting in decreased productivity. The periods of political strife also did not help Madagascar to maintain its leading position. The quality of its oil declined, compromising the country's position in world markets. There are serious efforts currently underway to correct the situation and these are strongly focused to produce quality rather than quantity.

2. In Mozambique

The Sabonet Report No 30[80] indicates that *Cananga odorata* has established itself in Maputo, and Zambezia Provinces. The sizes of the populations are unknown.

Technical Report:

i. Description[81]

Cananga odorata is a fast growing, medium to tall evergreen tree, growing to 35 m, usually pruned to less than 3 m when under cultivation. It has a deeply penetrating taproot. It normally has a single trunk to 15 cm diameter at breast height. The trunk is much branched, the brittle branches tending to droop. Leaves, which are numerous, also produces an essential oil, but of no commercial value. The flowers, which are also numerous, large, yellow-green, strongly scented, and borne on slender light-green stalks in axillary clusters, are the carriers of the essential oil. Flowering could be year-round and a large tree or a plantation in full flower is a sensory delight. Main flower harvests are in the early dry season, as in the case of Nossi-Be, usually April – June.

The fruit is a fleshy green ovoid resembling an olive, 2,5 – 4,0 cm, on a short stalk. Twelve, sometimes more, fruits can develop from a single flower appearing as green clusters along branches. Birds that void the undigested seed, and are thus a significant factor in tree distribution and establishment of a naturalized population readily eat the fruit. Seeds are disc-shaped, 6 – 8 mm in diameter, brown to reddish brown when ripe, and there are approximately 13 000 per kg, but seed size and weight are very variable. Viability is also very erratic, the reason still to be determined.

2. Essential oil composition: products and specifications

Two types of oil are produced from the flowers of C *odorata*; cananga oil from forma *macrophylla* and ylang-ylang oil from forma *genuina*. Cananga oil is the total amount of oil recovered by water distilling whole flowers; ylang-ylang oil is obtained by selective steam distilling flowers or reprocessing cananga oil, sold by grade.

Cananga oil is a yellow to orange –yellow, or yellow to greenish-yellow rather viscous liquid, whose colour rapidly darkens on exposure to air of light; odour heavier, more harsh than ylang-ylang, but sweet, fresh floral, with a characteristic woody-leathery note. The usual designation is Javanese Cananga Oil, which indicates the main source not the actual origin, does not imply a standard quality, and is a trade name.

The main use of cananga oil is in soaps where its tenacity is valuable, toiletries, especially those for men, and less expensive perfumes and similar products. It was previously the main ingredient of Macassar hair dressing, popular in Victorian England. Cananga oil is often adulterated or blended with other synthetic material mainly to modify its odour, but

---

80 Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

81 E.A.Weiss. 1997. *Essential Oil Crops*. Published by CAB International. United Kingdom

this is easily detected. Lower boiling-point fractions from production of ylang-ylang oil are also sold as cananga oil.

Ylang-ylang oil is normally available in four grades: extra, first, second and third. The first and second grades have little appeal and are not well defined; extra and third will probably become the main grades traded. Ylang-ylang extra oil has a high level of p-cresyl methyl ether, methyl benzoate, linalool, benzyl acetate and geranyl acetate in comparison to the other grades, and the probable relationship between these compounds and characteristic odour has been described in the literature. Extra oil is a clear, pale yellow to yellow-orange mobile liquid; odour sweet, floral, very powerful and distinctive but not as true to the natural flower scent as the absolute. Extra grade is extensively used in high-quality perfumes where its powerful odour enables inclusion in very small amounts. However, there can be hypersensitivity to cosmetics containing the oil, attributed to eugenol and related compounds. While there is considerable production of the extra grade, it is frequently adulterated with a range of other essential oils, oil fractions and synthetics.

Ylang-ylang third oil is a clear (occasionally slightly turbid) yellow, somewhat oily liquid; odour tenacious, sweet-floral not resembling extra quality with which it is neither interchangeable nor a substitute. Third grade oil is extensively used in less expensive soaps, toiletries and fragrances. It is frequently adulterated, but also deliberately modified by exporters to produce an exclusive oil. Third-grade is often confused with cananga oil for which it is neither a substitute nor alternative, since cananga oil is a complete (whole) oil. Approximately 60 compounds have been identified in ylang-ylang oil. The relative composition of four grades of Madagascar ylang-ylang and cananga oils are shown in the table below:

Approximate % of oil components	**Ylang-ylang**				
	Extra	**1**	**2**	**3**	**Cananga**
Alpha-pinene	0,3	0,1	0,1	0.1	ng
p-Cresyl methyl ether	8,4	3,1	1,0	0,4	1.1
Benzyl alcohol	0,5	0,2	ng	ng	ng
p-Cresol	0,1	0,1	ng	ng	ng
Methyl benzoate	4,0	1,0	0,3	0.1	ng
Linalool	10,3	5,5	3,2	2,0	1,7
Benzyl acetate	12,6	4,2	1,2	0,5	ng
Alpha-terpineol	0,1	ng	ng	ng	ng
Methyl salicylate	0,1	0,1	ng	ng	ng
Geraniol	0,2	0,2	0,2	ng	0,6
Linalyl acetate	0,2	0,2	0,2	ng	ng
Safrole	0,3	0,1	0,1	ng	ng
Methyl anthranilate	0,1	ng	ng	ng	ng
Eugenol	0,2	0,2	0,4	0,3	ng
Geranyl acetate	4,0	3,0	2,2	2,0	1,8
Isoeugenol	0,2	0,4	ng	ng	ng
Beta-caryophyllene	6,8	11,5	12,8	16,3	37,0
Alpha-caryophyllene	3.1	4,2	4,1	8,8	10,5
Farmasene	18,0	16,8	17,0	21,0	12,2
Delta-cadinene	8,9	15,1	20,4	16,3	5,4
Gamma-cadinene	2,0	5,3	7,0	7,5	7,6
Nerolidol	0,5	0,8	0,5	1,8	1,0
(Z), (E)-Farnesol	0,9	1,7	1,7	1,4	1,1

Benzyl benzoate	4,3	8,5	9,7	5,3	2,9
Benzyl salicylate	1.9	8,5	2,7	1,7	0,1
Ng: not given					

Ylang-ylang absolute is produced by alcohol washing concentrate with a yield of 75 – 85%, and a pale yellow oily liquid with an intensely sweet-floral, extremely powerful odour, characteristic of the natural flower. It is extensively used in high-quality perfumes and toiletries of all kinds and, because of its power, can be used in very small concentrations. The taste is bitter but can be modified to be used in sweets, drinks, ice-cream and similar products. Both concentrate and absolute have a higher content of linalool, geraniol, geranyl acetate, benzyl benzoate and benzyl salicylate than ylang-ylang extra oil.

Various ylang-ylang oils or flower extracts are available commercially described as complete oil or absolute oil, and also special grades of cananga oil; most are of suspect composition. A range of synthetic or semi-synthetic products simulate, with varying degrees of success, the odour of ylang-ylang oil, but none reproduce the true flower scent and are easily identified by the experienced perfumer.

The specifications of all essential oils including cananga and ylang-ylang oils present the tell-tale information necessary to ensure its quality but also to differentiate it from other, often inferior products. It is part of the history, which will accompany an oil from its origin to its final application in a product ready for consumption.

An essential oil is obtained by steam distilling fresh flowers with reported yields of (percent) 0,3 - 0,5 from Manila in the Philippines, 1,0 - 2,25 from Madagascar (Nossi-Be), with 0,5 - 1,0 from wild cananga trees from Java and 0,2 - 0,5 from Fiji and Samoa. The forma providing the flowers basically determines oil characteristics and composition. Origin is a major determining factor, but so are the production techniques.

Cananga whole oil has a high sesquiterpene content but is low in alcohols and esters; conversely ylang-ylang contains a high proportion of alcohols and esters. The approximate composition of ylang-ylang is (percent): alcohol and esters 52 - 64; sesquiterpenes 33 -38, phenols and their esters 3; terpenes 0,3 - 0,6; aldehydes and ketones 0,1 - 0,2. Similarly to oil characteristics there is wide variation in published analysis of the oils. The British Standard Specification for cananga oil is (all at 20^0C): specific gravity 0,903 - 0,920; refractive index 1,495 - 1,503; optical rotation -15^0 - -30^0; ester value 13 - 35.

Typical specifications for ylang-ylang oil are shown in the Table below:

Characteristic (at 20^{0}C)	A	G	R
Specific Gravity	0,950 0,965	0,946 0,982	0,950 0,986
Optical Rotation	-45^0 -36^0	-40^0 -25^0	-40^0 -25^0
Refractive Index	1,501 1,509	1,498 1,509	1,498 1,509
Acid value	< 3	< 2,8	< 2,8
Ester Value	125 160	130 182	132 162
Figures in columns are ranges			
Source: A: AFNOR[82]; G: Grasse Essential Oil Association; R: Réunion			

3. <u>Cultivation</u>

Cananga is native to monsoon areas with a rainfall of at least 3000 mm annually. It also grows well under more dry conditions, but trees which suffer a moisture stress flower less profusely and flowers have a lower oil content but not necessarily of lower quality. Cananga is basically a forest tree and requires shade when young, but heavy shade when mature retards growth and plantation trees must be spaced so all receive direct sunlight. Shelter belts are advisable when there are strong winds. Cananga plantations are usually established at low elevations, but there are no data on the effect of increasing altitude on tree growth, flowering, or oil content of flowers. Where low winter temperatures are expected, extra precaution has to be taken using straw or plastic sheeting barriers to minimize frost damage. However, preferably cananga should not be grown in areas where frost occurs.

Cananga grows naturally in forest soils, but under cultivation is planted on a range of soils. Shallow soils or soils with hard or impacted subsoil are not suitable, as trees produce a long and penetrating taproot and, if this root is not able to develop fully, the tree is invariably stunted. The exception is, of course, if it is possible to cost effectively prepare the soil with adequate compost and other biological fertilizers introduced, mixed with the soil, into a planting hole, which must be at least one meter cube. Cananga may tolerate waterlogging for extended periods, but permanently marshy areas should be avoided, as should saline and alkaline soils.

A neutral to somewhat acid soil, pH 6,0 to 7,5 is most suitable. Trees grow well in soils of varying fertility, but to produce well-branched individuals with abundant flowers trees must be well nourished. Since only forma *genuina* is cultivated, selection of soil type is of great importance. When soil fertility is low, plant nutrients must be supplied, but plantations have usually received only bulk materials, such as plant and animal residues, relying on nutrients being released from the mineralization of decaying material. There is no recorded information on the result of, for example, a well planned fertilization program on a plantation using chemical fertilizers in combination with carbon based fertilizers such as well composted chicken manures and humic and fulvic acids. The use of mulching

---

82 AFNOR: Association Française de Normalisation, Paris, France

around tree trunks is always recommended. If the choice is made to grow cananga trees for organic oil production, precaution should be taken to ensure that all the criteria for obtaining and maintaining organic certification are adhered to. All indications are that cananga trees should be ideally suited for organic cultivation.

To establish a plantation, the area must be cleared mechanically or by hand, and all debris removed ideally for composting but burning as an alternative as long as the ash could be spread as fertilizer. Where high winds are common, it is advisable to leave existing trees on borders or between planted sections as windbreaks.

Plants may be grown from seed sown in nursery beds, but the long, easily damaged taproot, which is quickly produced following germination, renders transplanting difficult, and seed should preferable be sown in prepared pits where trees are to grow. Alternatively, pots should be large enough to allow unrestricted root growth and made of biodegradable material to allow planting directly into holes. Several seeds should be sown per pot or pit, thinned to the most vigorous. Seed viability is frequently low but as seed is normally available in large quantities, this presents few problems. Fresh seed reportedly germinates less readily than seed 6 – 12 months old, and there may thus be a dormancy period. Soaking seed in hot water for several hours is considered to hasten and assist germination on Nossi-Be. Propagation by cuttings is also possible but seldom used.

Pits should be prepared well in advance of sowing, be at least 50 cm deep to allow for unrestricted taproot growth, and filled with topsoil mixed with well-composted organic materials. Seed should be placed about 5 cm deep and seedlings kept moist and shaded. Initial spacing should be at least 6 x 6 m, with alternate trees removed to leave a triangular spacing should this be necessary as trees mature; on sloping land or hillsides trees should be planted in rows following the contour. A circular around seedlings should initially be kept weed-free and inter-rows slashed or mown. Herbicides are seldom used. Cananga can be intercropped in the first 2 – 3 years with low-growing food crops such s pulses or various other legumes (also to add to the nitrogen content of the soil). Underplanting Cananga in plantations of other trees is seldom successful.

Trees are usually topped at about 3 m and pruned to maintain this height, and may also be grafted. Topping encourages growth of naturally drooping lower branches, which are also pulled down by ropes attached to small posts to keep flowers within reach of pickers, since branches are brittle and climbing to pick flowers can cause extensive damage.

4. Harvesting

Trees flower from the second year, when a small harvest may be taken, and flower profusely from the fourth or fifth year. Flowers have little fragrance initially, and green petals covered with fine white hair, which disappear with maturity. After 12 – 21 days the petals become pale green, then yellow and their scent progressively stronger. When two small reddish spots appear on the base of the petals the flowers are ready for picking. This should be done as early in the morning as possible when oil content is highest, and normally ceases by 10 a.m., as in strong sunlight the oil content rapidly diminishes. Composition and characteristics of the oil changes as flowers develop, with the light oxygenated compounds highest at maturity; it is therefore detrimental to oil quality to include immature oils in the material to be distilled.

Rain has apparently little effect on oil content, but distilling wet flowers reduces still efficiency and may adversely affect oil quality. Maximum flowering normally follows cessation of the rainy season, when 50 - 60% of the flower yield is obtained. Oil content is usually highest early in the dry season and also of higher quality.

Flowers are picked manually and this limit commercial production to areas where labour is readily available and cheap. Flowers within reached are plucked by hand, those higher up the tree by long-handled cutters. Pickers often climb wild trees to reach the higher flowers, a dangerous practice since branches are very brittle. Experienced pickers harvest 20 kg of flowers per shift, but as most are paid on weight of flowers delivered, there is a natural tendency to be unselective. An adequate inspection procedure is therefore necessary or inferior oil will be produced. Mechanical picking has been investigated but there is currently no economic pressure to do so in traditional producing areas. A 7-year old tree in a well-managed plantation can produce 30 – 100 kg of flowers annually; a fully mature healthy tree to 300 kg, but average yield from poorly managed trees (the majority of cases) seldom exceeds 20 kg. The inclusion of buds, immature and over-mature flowers reduces yield per unit of material and also substantially alters its scent and characteristics. Rough treatment of flowers after picking also alters the character of the oil, as bruised or partially fermented flowers produce off-odours. The productive life of a Cananga plantation can be 50 years and depends basically on the standard of management.

5. Distillation

Flowers should be distilled immediately after picking to obtain highest yields of best quality oil, but some delay is usual and flowers should be thinly spread on some suitable surface out of the sun, as it is essential to avoid fermentation. Wilting or delayed distillation normally reduces oil yield but the effect on oil composition is less obvious, there is apparently little change in oil characteristics. The main effect of air-drying Philippine flowers from 1 to 7 days before distilling was to change specific gravity (20^0C) from 0,93 –0,96 to 0,913 – 0,914, and ester number from 120 – 190 to 145 – 150.

Distillation is frequently in small, direct-fired water stills, and heating water to near-boiling prior to adding flowers results in higher-quality oil. Charge vessels should preferably be undercharged with flowers, since this reduces spot fermentation or overheating, either being detrimental to oil quality. Distillation by any method must be carefully controlled since the oil fractions in the distillate have different characteristics and market value. Modern Madagascan distilleries produce four, sometimes five grades of ylang-ylang oil: Premier (mainly to order), Extra, First, Second and Third with quality and price decreasing in the same order. In general, specific gravity, total esters and saponification number decrease, while optical rotation significantly increases. Lower grades are also virtually insoluble in 90% alcohol.

The weight of flowed to produce 1 kg crude oil varies from 350 – 700 kg depending mainly on time of year and flower maturity. In a modern steam distillery a total yield of 2,0 – 2,5% is usual, about 25 – 30% being the first two grades. The time of year flowers are picked can directly affect the proportion of esters in fractions; in the wet season a high moisture content frequently reduces the proportions of extra grade, while the reverse occurs when the rain cease. Since the two lower grades also have a substantially lower market price, distillation may be stopped once the higher fractions in the oil have been obtained. Smaller operators producing Cananga whole oil frequently prolong distillation and may also remove spent flowers and recharge the still, merely topping up the water. This reduces oil quality by retaining unwanted artifacts in the water, which react with the desired esters.

Ylang-ylang and cananga oil are light sensitive, and must be stored in full, dark, sealed containers.

Flowers can be solvent extracted with petroleum ether of benzene to give a yield to 1,3% and the resultant concentrate has an odour virtually identical to the natural flower. Main characteristics of the concentrate are usually: specific gravity (20^0C) 1,020 – 1,035; optical rotation $–5,5^0$ to $–6,5^0$; refractive index 1,50 – 1,52 (20^0C); ester number 200 –250; but quoted data varies widely for no apparent reason.

6. Pests and diseases:

The pests of cananga are poorly investigated, mainly because a considerable proportion of the oils are obtained from wild or naturalized trees, which receive minimum attention. Additionally, a number of reports originate from botanic gardens or arboreta, and thus are not generally applicable. The most important insect pests are various stem-borers, twig wilters and flower eating beetles, since these are a direct cause of flower loss. A similar situation exists in respect of diseases of cananga, and these are little published information, which accurately identifies the pathogen concerned, or the degree of damage.

Reports: B09.01.01 and D12.05.01

Family: Euphorbiaceae
Genus: Ricinus
Species: communis

Common names: In Mozambique: hiafura, musaci, ricino, tchafurra
English and international: Castor oil plant, Palmer Christi, Ricin (French), Christuspalme (German), ricino (Italian, Portuguese and Spanish)

Location Report:

1. General Habitat and Distribution[83 84]

Ricinus communis originated probably in north-east Africa and India where it is an ornamental plant and naturalized weed in tropical and sub-tropical regions. It is now pantropic and cultivated for its oil-bearing seeds, and as a source of a local soup flavour, ogiri (Igbo). One view is that it is best cultivated as an annual with fresh seeds being planted every year, another that it could be regarded as a perennial plant, which could be harvested for a number of years. Major producers are India, China and Brazil.

2. In Mozambique

The Sabonet Report No 30[85] indicates that *Ricinus communis* occurs in Maputo, Tete, Zambezia, Inhambane, Manica, Sofala and Gaza Provinces. It is listed as an alien plant but was selected because of its recognized commercial potential and the fact that the company Ricino Moçambique, Lda of Ms Judite C.M. Pinto has already ventured into a commercial operation in Nampula Province.

Technical Report:

1. Description[1]

R communis is shrub or small tree up to 4 m in height, branchy at its bases with very large, hand shaped leaves. Male and female flowers are borne separately and appear near the tip of the branches. The fruit is a three-seeded capsule with spine-like projections. Each seed is somewhat flattened, about 10 mm long, 6 to 9 mm wide and 4 to 8 mm thick. The seed coat is thin and brittle, conspicuously shiny and irregularly mottled with silver, brown and black spots and strips. At one extremity of the seed there is a prominent and usually pale coloured caruncle, from which the raphe runs along the ventral surface as a distinct line to the other extremity, where it terminates in a raised chalaza. The caruncle can be removed easily, disclosing the hilum beneath as a dark spot. A delicate, slivery-white oily endosperm, which encloses the embryo with two large, papery cotyledons.

---

[83] Van Wyk, Ben-Erik and Wink, Michael, 2004. *Medicinal Plants of the World*. Briza Publications. Pretoria. South Africa.

[84] Iwu, Maurice M., 1993. *Handbook of African Medicinal Plants*, CRC Press. Florida USA.

[85] Da Silva M.C., Izidine S. and Amude A.B. 2004. *A preliminary checklist of the vascular plants of Mozambique*. SABONET Report No. 30

2. Fixed oil composition

The seeds contain about 50% of fixed oil, which consists mainly of glycerides of ricinoleic, isoricinoleic, stearic, and dihydroxystearic acids. The fatty acid ricinoleic acid accounts for about 90% of the triclyceride fatty acids in the oil. The cake left after expression contains a very poisonous toxalbumin called ricin (a lectin), the crystalline pyridine alkaloid, ricinine, and a very active lipase and enzymes. Ricin is among the most toxic compounds; two seeds may be fatal. The seeds also contain some peptides, starch, and mucilaginous substances.

3. Commercial value of the oil

Castor oil is a well-known and effective purgative medicine. During the 17^{th} and 18^{th} centuries, a fortnightly purging was considered necessary for good health, but the ritualistic purgation of children and the excessive use of laxatives have virtually disappeared from modern medicine. In traditional medicine the oil is also used as a dressing for sores, burns and ulcers. In cases of toothache, the seeds are ground and boiled, and the oil is rubbed in the effective area of the cheeks. This remedy is also used for mumps. A paste of the roots is applied to the affective tooth to alleviate the pain.

The main application of castor oil in modern times is as an industrial product as lubricants and starting material in the manufacture of polymers.

It has also found use in formulations creams, ointments, clear soaps and lipstick. Its use in cosmetics and similar products present great scope for product development.

4. Cultivation

Castor oil plants are propagated from seed. It can be planted directly into the soil where a castor oil plantation is being established or the seeds could first be germinated in bags or containers and then replanted when mature enough.

The debate whether the plant should be considered as an annual and replanted using fresh seed or the plant performs well as a perennial and could be viable for optimum seed production for more than two years, can only be settled in Mozambique, by trailing both approached under field conditions. The selection of the right location, depending on its climatic conditions, preparation of the soil prior to seeding followed by subsequent fertilization and overall crop management throughout the seasons, may be determining factors.

All indications are that *R. communis* will be an ideal plant to cultivate organically.

5. Commercialization in Mozambique

R. communis has adapted so well to Mozambique that large scale cultivation and extraction of the oil is an attractive business proposition. We were very interested to learn more about the venture of the company Ricino Moçambique, Lda of Ms Judite C.M. Pinto, and had the benefit to discuss her plans at length with her. She has a concession of 1000 hectares of land about 50 km from Nampula in Nampula Province. She has planted castor oil on about 3 ha, but would like to expand the operation to about 500 ha. We have agreed in principle to get involved in her business and on an agreed commercial basis help her to turn it into a viable commercial venture.

Reports: C08.08.01

Family: Lamiaceae/Labiateae
Genus: Pogostemon
Species: patchouli

Common names: In Mozambique:
English: Patchouli oil.

Location Report:

1. General Habitat and Distribution[86]

The family Lamiaceae (syn. Labiateae) to which the genus *Pogostemon* belongs, is one of the ten largest families of flowering plants, comprising 9 subfamilies, 200 genera and about 3200 species. Producing an essential oil, a spice or both. In our list of plants with known and marketable essential oils, we have selected 12 species to seriously consider cultivating in Mozambique. This list includes species producing such well-known oils as Melissa oil (*Melissa officianalis*), Rosemary oil (*Rosmarinus officianalis*), Peppermint oil (*Mentha piperit*), Lavender oil (*Lavandula angustifolia*), and Basil oil (*Ocimum Basilicum*).

We have highlighted *Pogostemom patchouli* because it is fairly representative of the essential oil bearing species in the family, and, in its own right, will be a valuable plant to cultivate in Mozambique for marketing its oil on international markets.

The 40 species of the genus *Pogostemon* are mainly native to South East Asia bordering on China, with 20 also occurring in India. *Pogostemon cablin* is the prime source of patchouli oil; other species' oil is regarded as inferior to that of *P. cablin*. Plants in other genera also produce oil, which is described as patchouli oil, but has not replaced patchouli oil in application where it really matters. Patchouli oil has a long history of use by humans and there is evidence indicating that true patchouli was cultivated in ancient China 2000 years ago. Growing patchouli for its essential oil began in the nineteenth century in Malaysia using plants obtained from the Philippines. Patchouli has been successfully grown in Mauritius, some Caribbean countries, West Africa and Vietnam, but only India, Brazil, Taiwan and Seychelles established commercial oil production.

2. In Mozambique

There is no information that any *Pogostemon* species occurs in Mozambique.

[86] E.A Weiss. 1997. *Essential Oil Crops*. Published by CAB International. UK.

Technical Report:

1. Description[1]

P. patchouli is an aromatic, herbaceous, perennial shrub, with erect stems, large green leaves and small white pink flowers. Unlike many other members of the Lamiaceae, there are no horticultural varieties, and patchouli is seldom seen outside its natural habitat. The roots are extensive, branching and, in mature plants which are allowed to grow unchecked, penetrating to some depth. The stems are erect, up to 1,5 m, sometimes higher. The leave size varies especially between cultivars, but mature leaves are usually 5 – 10 X 2,5-8 cm. The essential oil is contained in glands located mainly on the underside of leaves. Fresh leaves have very little of the patchouli scent, which only develops after fermentation. Freshly cut leaves contain 0,25 – 0,75% oil, varying with local cultivars, age and stem position. Leaves are normally dried before distilling and lose 80 – 85% moisture, while naturally dried leaves yield 1,8 – 2,5% oil when distilled by small producers, but to 5% in modern plants.

2. Essential oil composition

The main constituents of patchouli oil are the patchouli alcohols 23 – 55% (averaging 33%) and minor alcohols 0,4 – 0,6% (mainly norpatchoulenol). There is little information on oil biosynthesis and the mechanisms involved. Thus vital data on which to base crop improvement and plantation management programs are lacking. For practical purposes oil is contained only in the leaves, and factors directly affecting this plant part are of greatest interest to producers. Fertilizers affect growth, number and also oil content of leaves.

Pogostemon hortensis occurs naturally only on the island of Java, and is probably not a true species but a long established cultivar of *P. cablin*. General growth is more vigorous than patchouli, less fragrant with a lower oil content than patchouli leaves. Dried leaves are frequently mixed with patchouli leaves for distilling or export, and the oil is a common adulterant of patchouli oil.

The main characteristics of patchouli oil are shown in the table below.

	Sumatra	**India**	**Malaysia**	**Seychelles**
Specific Gravity (15^0)	0,950 0,990	0.955 0.986 (25^0C)	0,970 0,990	0,940 0,969
Refractive Index (20^0)	ng	1,503 1,516 (25^0C)	1,503 1,515 (15^0C)	1,502 1,510
Optical Rotation	-40^0 -70^0	-45^0 -68^0	-48^0 -55^0	-47^0 -52^0
Acid Number	3,0 6,5	<5,0 -	2,2 2,8	1,5 2,5
Ester Number	2,0 10,0	2,0 14,0	2,0 4,8	2,0 3,5
Ester number after Acetylation	ng	10 – 28	ng	ng
Solubility (v/v 90% Alcohol	1:10	1:10	1:7	1:10-12
ng: not given				

3. Commercial value of the oil

Crude patchouli oil is a viscous, dark or orange-brown liquid depending mainly on the method of distillation and storage; refined oil or oil produced in modern stills is a pale orange to light amber colour. The odour is distinctive, very rich, sweet-herbaceous, spicy and aromatic; the odour of crude or newly distilled oil is more harsh, less sweet and spicy, but softens with age. The taste of the whole oil is spicy, sweet, never bitter, somewhat hot on the tongue; refined oil is more bland. Patchouli oil is used mainly as a whole oil, and not processed for individual components, although it may be refined to remove impurities or slightly modify its colour. Since the odour of the oil improves with age when correctly stored, users generally maintain relatively large stocks.

The oil is mainly used in perfumes of all kinds, cosmetics, toiletries, especially soaps. Flavour and odour are quite distinctive, and patchouli flavoured sweets are especially popular in Asia and Arabia. The oil is used to flavour foods, mainly processed products such as baked goods, some meats and sausages, but very seldom as a culinary spice although frequently present in speciality cooking oils.

The whole oil has antimicrobial and insecticidal activity, but is normally too expensive for these uses to be commercially exploited.

Patchouli oil is extremely complex, is in demand as a whole oil, and is a very important perfumery raw material. Some 60 constituents have been detected, including sesquiterpene hydrocarbons and patchouli alcohols. Azulene has also been reported in the oil. Patchouli oil can be adulterated with oils having a similar basic odour, but most other adulterants are detected on analysis, or by the formulator's nose.

Patchouli concrete or resinoid is obtained by solvent extracting dried leaves, and is a very viscous liquid whose colour depends on the solvent used; benzene produces a dark, orange-brown, petroleum ether pale orange to dark amber. The odour is finer than that of distilled oils, very sweet, aromatic, rich and spicy, and improves with age. Concrete is mainly used as a direct substitute for patchouli oil.

4. Cultivation

Land selected for patchouli cultivation is often cleared to a greater extent than for other crops, with trees felled and burned. This practice, as mentioned elsewhere, has resulted in the destruction of vast natural forests. When grown as an intercrop in plantations, patchouli benefits from the generally higher standard of management, and has been cultivated successfully between young rubber and oil palms in Indonesia and Malaysia, young and mature citrus in Malagasy and Malaysia, coffee in Malagasy and Brazil, pepper vines in several South East Asian countries and under coconut palms in Seychelles and Mauritius.

Cuttings, preferably from the central section of semi-mature stems, normally propagate patchouli. In Indonesia, cuttings from 9-month-old stems gave the highest strike rate. Use of growth hormones increase rooting. Cuttings 5 – 10 cm long are often planted in shaded nursery beds and are normally ready for transplanting in 3 – 5 weeks. When propagating material is limited or for multiplication of selected elite plants, 2,5 – 5,0 cm of stem including a leaf node can be used provided the node is completely buried in the rooting medium. Such cuttings require careful handling as the survival rate is often low when repotted or transplanted. Tissue culture has also been used as a propagation technique.

Field planting is normally manual, but the operation is easily mechanized. Small farmers usually dig individual holes suitable for cuttings 30 – 40 cm long inserted at an angle of 60^0 with at least three nodes below ground level; several can be placed per hole but one is sufficient if rooted cuttings are used.

Spacing is often arbitrary, but 60 – 90 X 30 – 45 cm between plants or 60 X 60 cm on the square is most common, with 100 X 100 on very fertile soils. A high plant population is preferred. Close spacing suppresses weed growth and tends to increase branching, and as oil content is highest in upper leaves, this increases oil yield per hectare.

Patchouli is normally grown in small plots and weed control is usually manual, carried out as necessary until the canopy closes in about six months and suppresses most weeds. When patchouli is grown as an intercrop in young rubber or oil palms, herbicides may be essential for general weed control, and glyphosate, oxadiazon, prometryn and terbacil have been used in directed sprays. When farming organically these chemicals are, of course not allowed, and more natural ways of weed control has to be used.

Patchouli flourishes in areas with high average temperature and high relative humidity, but can be grown successfully wherever mulching, partial shade, or ridge planting in marshy areas can achieve similar conditions. An annual rainfall of 2 000 – 3 000 mm well distributed throughout the year is the optimum, 1 700 – 2 000 mm acceptable, but it is unlikely that patchouli will be commercially profitable below 1 500 mm without irrigation. Although patchouli has a high water requirement, seedlings and young plants cannot tolerate waterlogging, and 3 – 4 days of standing water can be fatal. Relative humidity should be high and a minimum monthly average of 85% is considered necessary for sustained growth in Indonesia.

It is doubtful if patchouli would be profitable as a wholly irrigated crop, as total water requirement is high and the cost of supplying water may be prohibitive. In areas where high rainfall is followed by dry periods, on a regular basis, mulching can successfully keep soil moist and maintain plant growth.

Bright sunny days are necessary for maximum leaf-oil content, although plants tolerate partial or intermittent shade. The effect of shade is substantial: shaded plants have a much lower leaf oil content. Although shaded plants have a much higher herbage yield, it lacked vigour, regenerated more slowly after cutting and leaves, although longer, were thinner and had lower oil content. Shading could be useful where patchouli is grown outside it natural habitats.

For maximum growth an average daily temperature of 25 – 30^0C seems to be desirable. It is widely considered that patchouli grows better at higher altitudes, but this could be due to better drainage on slopes, since lower soils generally have impeded drainage. Wind can cause severe damage to mature patchouli in open fields but, and this factor should be considered when planting allowing for protection where necessary.

5. Harvesting

Patchouli is ready for harvesting 4 – 7 months after establishment when plants are usually about 1 m in height and the foliage becomes pale green to light brown, and thereafter at 3 – 6 months intervals over its productive life. Small farmers normally cut plants 10 – 20 cm above the soil, but where only on annual harvest is possible, as in Russia, plants are cut as low as possible. When using machinery, the optimum cutting height should be established, since cutting too low can kill plants especially if followed by a dry period. Harvesting should not take place following rain when leaves are saturated nor early in the morning if wet with dew. During hot or dry periods, however, cutting in the morning or evening is preferable.

All plant parts contain oil, but as oil in leaves is the main source, ideally only leaves should be harvested. Harvesting includes stems and leaves and may amount to 5 - 10 t/ha, exceptionally 15 - 20 t/ha in the first year, falling to 1 - 5 t/ha in subsequent years with leaves usually accounting for 50 - 60% of the total. A major factor reducing average leaf yield is the general use of unselected planting material, as there is substantial variation in leaf yield between individual plants. Selective harvesting, cutting only the three to five uppermost pairs of leaves, is possible for smallholders, where stems with three to five pairs of leaves of mature leaves which have not turned yellow or brown are cut, while those with young leaves are left to mature. Such as system not only promotes rapid regrowth, it also ensures more efficient working of the usually small local stills.

Under smallholder management the normal life of a patchouli planting is 2 – 3 years as fertilizers are seldom used, growers relying on natural soil fertility. Thus patchouli was seldom replanted on the same land, and the plot abandoned in favour of a newly cleared area. This practice has, unfortunately, resulted in the rapid destruction of mature forests in many countries, and the amount of land to produce patchouli is continuously being reduced.

When grown as a plantation crop, patchouli is usually replanted after 3 years, but up to five years, when rate of regrowth makes retention unprofitable.

6. Distillation

Unlike other members of the Lamiaceae, fresh patchouli leaves should not be distilled as they yield only a small proportion of their oil unless distilled under pressure or with superheated steam. Normal distillation does not rupture cells within the leaf, but drying or light fermentation changes the cell structure, which becomes more permeable and allows oil to be liberated.

Stems with leaves are dried for 2 – 5 days and how this is accomplished is extremely important since it basically determines oil yield when locally distilled, or quality of dried leaves if these are to be distilled elsewhere. Fresh herbage must not be piled in heaps as this quickly encourages mould growth, or uncontrolled fermentation. Cut material is usually dried by spreading on wooden racks, clean, hard-packed earth, or specially constructed concrete floors, adjacent to a distillery, and regularly turned to ensure uniform drying. Herbage must be protected from rain and heavy dew, and some covering must be used. Although sun-drying is normal, shade-drying with air circulating freely over cut herbage is preferable. Sun-dried herbage may also become over-dry, with consequent loss of oil or leaves through shattering, while a drying temperature of 40^0C in Malaysia resulted in 80% oil loss.

Following drying, leaves are stripped from stems and placed in woven baskets containing about 15 kg to allow fermentation, which a skilled grower controls by smelling the leaves. Over-fermentation produces a mouldy note in the oil, while under fermentation reduces oil yield but has no effect on oil quality. Dried leaves can be stored for long periods provided they are kept free of moisture and no additional fermentation occurs. Storage facilities at rural stills are usually inadequate, and in these circumstances it is preferable temporarily to cease harvesting. A yearly minimum of 40 – 60 t of dried leaves is required to establish a small district distillery'. In Malaysia 20 - 25 t dried leaves are required for an estate distillery to be viable.

Smallholders produce the bulk of patchouli oil and the crude oil sold to larger operators for cleaning and refining. Many small operators use direct-fired stills with leaves kept above the water level with a grill, and a second grill may be used to keep layers of leaves separate. A charge is normally 75 - 100 kg of dried leaves, which may be moistened with water during filling. In these stills distillation time is generally 6 - 8 hours, but up to 24 hours depending on the skill of the operator, since the most desirable oil fractions distil over last. Oil yield averages 1,5 - 2,5%, and is directly influenced by the amount of non-leafy material included in the charge, depth of the charge, and amount of heat used to boil water or steam temperature. Distillation temperature affected yield but not oil characteristics in Indonesia; doubling the temperature increased oil yield from 1,32 to 2,21%.

Substantial changes may occur in the characteristics of crude, bulked and unrefined oil directly related to type of container and storage conditions; specific gravity, acid number and ester number rose with storage period in Indonesia. Storage in aluminium and green glass also had varied effects. In general, full, sealed glass or stainless steel containers are the best. Under no circumstances is plastic containers used!

7. Pests and diseases

With little information available on patchouli pests it still seems that the most damaging insects are those attacking roots and leaves. Nematodes can cause extensive damage to roots. This factor results in replanting in the same land to be avoided, until the nematode problem is reduced through other means. Various biological means of controlling nematodes could now be used, as soil fumigation is not acceptable any more.

Pest such as moles, crickets, grasshoppers, and snails, all could be a problem and appropriate way should be used to control them. Larvae, of various moths, the leaf-rolling caterpillar, are more serious pests. Stem borers could present a problem, so can various mites.

As with pest, there are only few reports of diseases affecting patchouli. Root diseases are mostly localized problems, and should be monitored. These can limit production in certain areas. Symptoms attributed to viral infections were reported in various countries, with the patchouli mosaic virus identified in India. In this case, the mass propagation of virus free seedlings for distribution to growers was the only satisfactory method of control.

Reports: C08.08.01

Family: Rutaceae
Genus: Citrus
Species: Various citrus species.

Common names: In Mozambique: *Citrus limon* is called mundino.
English: Bitter Orange, Bergamot Orange, Petitgrain Orange, Grapefruit.

Location Report:

1. General Habitat and Distribution[87]

The Rutaceae is a large family containing 130 genera in seven sub-families, with the Aurantioideae important fruit and oil producers. *Citrus* consist of two sub-genera of which *Eucitrus*, including ten species, of which eight are cultivated, several on such a large scale that they are industries in their own right. The taxonomy of *Citrus* is confused, exacerbated by the proliferation of hybrids and numberless cultivars. The genus *Citrus* is variable; some members are small, others large trees; some have small, others very large fruit; and there is similar variability in the essential oil obtained. Most produce an edible fruit, and some have been extensively cultivated, including orange, lemon and grapefruit, while others such as bergamot and bitter orange have specialized uses.

It is impossible to say when citrus was first domesticated since no truly wild ancestors have been identified. Citrus fruits have been eaten by Asian peoples for thousand of years, and later became equally popular in European countries and thereafter the Americas. Although the genus is tropical in origin and species can be found in all tropical countries, the main areas of commercial production are generally in subtropical regions.

Technical Report:

1. Description related to citrus in general[81]

Mozambique used to have a citrus industry of sizeable proportions. There will be considerable knowledge and expertise present in Mozambique capable to re-establish a citrus industry. It is therefore not our aim to provide information on citrus cultivation for the production of various citrus fruits, but rather point towards the possibility that a future vibrant citrus industry could also become a recognized producer of the various aromatic oil contained in the genus *Citrus*. We will therefore concentrate on factors, which directly affect oil production, oil content or oil composition. A noteworthy demand for organic citrus oils has developed in recent times. This may present a unique challenge to Mozambique to produce both organic citrus juice and oils. With these aims in mind we will furthermore highlight only a few species, but rather for the value of their oils than fruits, in particular the following:

[87] E.A Weiss. 1997. *Essential Oil Crops*. Published by CAB International. UK.

- *Citrus paradisi* - Grapefruit
- *Citrus aurantium* - Bitter orange
  - subsp. *bigaradia* - Bergamot orange
  - subsp. *amara* - Petitgrain orange

All the citrus species discussed are evergreen shrubs or small trees, with extensive but frequently shallow roots, normally a single stem, very hard wood, and extensive branching. The flowers are fragrant, the leaves aromatic and the fruit frequently palatable. The leaves are gland dotted and from some species an essential oil is obtained.

The flowering patterns of citrus vary with climate, especially temperature. Flower drop and the percentage of setting into fruit are important factors when considering flower viability.

The fruit is of great importance since, mainly the peel, contains an essential oil. Therefore the rate of fruit development is of great importance to essential oil producers. Maturation of the fruit varies with species and there may also be changes in peel oil composition between early and late maturing fruits. The anatomy of the fruit is important as the oil is contained in numerous glands (oil sacs), which are enclosed in the tissue of the exocarp, underneath the flavedo (peel) and the cuticles of the fruit. These glands fill with essential oil under considerable pressure (turgot pressure), which develops in surrounding cells. Mechanical cold-pressing of the fruit yields a watery emulsion, which could then be passed through a centrifuge to separate out the essential oil.

Some citrus oils are also found within the leaves (Petitgrain) and flower parts (Neroli).

With a few exceptions, essential oil production from citrus fruits is generally a by-product of large-scale canned fruit or juice production by utilizing its waste products. About 45% by weight of fruit remains as cannery waste after juice extraction, consisting of peel, pulp, rag (internal membranes and core tissue) and seeds. Where oil is not extracted prior to juicing, it is this material that is further processed to obtain the oil.

When establishing a citrus orchard the considerations of agro-climatic variables and soil will be aimed at achieving optimum fruit production and highest juice content and quality. Factors, which will enhance essential oil production, will be at best secondary considerations, if considered at all. Exceptions will be made where essential oil production can become a substantial part of the overall profitability of the operation.

2. Commercial value of citrus oils[81]

Although unprocessed citrus oils are frequently used by manufacturers, most are concentrated, especially in flavourings. No single compound is responsible for the characteristic odour of any citrus oil. Responsibility is shared by a complex mixture of related metabolites of terpenes and secondary metabolites of unsaturated fatty acids. The individual odours of the different citrus fruits and their various cultivars are not due to various different chemicals but rather to the proportions of the various components. The main chemical components responsible for flavour are the aldehydes, particularly citral, although generally accounting for only a small proportion by volume, and (+)-limonene, which could be up to 97% of the oil, and represents the base sensory character of citrus oils. Another terpene is (-)-limonene which possess a different odour such as found in pines, peppermint and eucalyptus oils. This bulk of terpenes posses a relatively low flavour value, are insoluble in water and in some cases chemically unstable. Fatty aldehydes also contribute to the aroma odour of citrus, especially octanal and decanal. Citral, mentioned above, is an aldehyde that is also part of the chemistry if citrus oils, and always occurs as a mixture of its stereoisomers geranial and neral.

The sesquiterpene ketone (+)-nootkatone possesses a citrus-like aroma and a bitter taste and occurs in all citrus peel oils. It contributes a lot to the overall aroma character of any oil in which it is found. Its other enantiomer (-)-nootkatone lacks the citrus aroma.

The stereoisomeric farnesenes occur in all citrus oils. They are very important for apple flavour. The isomeric sinensals are aldehydes of the corresponding farnesenes and are found in all citrus oils. Even trace amounts of these aldehyde components have high aroma value because of their strength of odour.

Cold-pressed oils also contain up to 4% of low volatile constituents, such as flavonoids or triterpenes that are the bitter principle.

Removal of all or some of the terpenes improves oil odour, increases solubility in water and enhances stability. The most concentrated citrus oils are those with all terpenes removed, terpeneless oils. At slightly higher terpene levels are concentrated oils or more commonly folded oils; a ten-fold oil contains 10% of the original terpenes, but in practice maximum strengths are generally five-fold for lime oil, ten-fold for lemon oil and twenty-fold for sweet orange oil. Such oils are expensive, but are also so concentrated that only very small amounts are required.

The concentration or deterpenation processes may involve distillation, solvent or poroplast extraction. Solvent extraction removes virtually all the wax, which is a important stabilizer of whole unprocessed oil, but is considered a disadvantage in concentrated oils. Most citrus oils deteriorate on standing or with age, and suitable storage and containers are necessary to protect the required properties, prevent contamination and allow oil to be transported.

The most important aspect of concentration is the large volume of terpene residue, widely used in cheap flavourings and perfumery; lime, lemon and orange terpenes are generally available. Residues of solvent extraction are of better quality and higher value than those from distillation, and referred to as washed citrus oils as distinct from terpenes. Washed citrus oils may be used in their own right, but are widely used to extend citrus oils to produce a cheap but good-quality flavouring. The residue or effluent from fruit processing contains useful ingredients, which can be recovered when their sale or utilization is profitable, or where effluent discharge content is legally controlled. The major constituents are limonene, various sugars, yeasts and a small proportion of oil.

Citrus oils have a very wide range of uses and research is continually finding additional applications. Major outlets for citrus oils are in foods, beverages, perfumery and cosmetics, soaps pharmaceuticals and condiments, with secondary uses in the masking of unpleasant odours in domestic and industrial insecticides, washing liquids, textiles and rubber products. The most important market is the flavour industry, which consumes large amounts of natural oils and concentrates. In the industrial field, new uses are regularly developed: waterless hand cleaners based on solvent properties of terpenes in citrus oils, or as a solvent in animal shampoos and similar products, while considerable amounts of terpenes from citrus oils are used in resins and adhesives, and orange oil is a source of *d*-limonene.

Citrus derivatives, such as distilled oil, essence oils and various types of terpeneless oils are used where citrus flavour or odour is required without the disadvantage of colour, or to blend with or enhance other oils. The terpene, *d*-limonene, has a wide range of uses, one of the best known is in production of synthetic spearmint oil flavour. Use of synthetic citrus compounds in flavouring is legally restricted in many countries. It is, however, legally permissible to use compounds consisting of blends of a whole citrus oil, a washed oil and perhaps other components of the natural oil, such compounds being known as lime oil WONF, lemon oil WONF etc. the suffix meaning with other flavours. Washed oils are technically more suitable for use in composite oils than extracted terpenes, although the latter are more generally available and widely used. The growing trend by consumers worldwide to pressure manufacturers to use only natural additives and colourants in food and related products is an important factor in maintaining and expanding citrus oil usage. Another important property of citrus oils, especially seed oils, is their often very high antimicrobial activity. It is foreseen that this will develop into quite a lucrative application of this part of the oils extracted from citrus.

3. Extraction methods of citrus oils in general[81]

Citrus oils are frequently obtained in a secondary operation following expression of citrus juice. Lime, lemon and orange juice are all major commodities, an exception being bitter orange whose juice is of little value. Flower and leaf oil processing are very specific to particular species. Peel oils are contained in spherical or egg-shaped sacs or vesicles in the peel, and must be ruptured either by pressure or rasping.

There are basically two methods whereby citrus oils are recovered, which also serve as a description of the oil: cold-pressed and distilled. Most lemon and sweet orange oils are cold-pressed, mainly in a single operation in which pressure is applied to the fruit, and the oil and juice drawn off in separate channels. The oil may also be removed from the peel before juice extraction, oil generally being released from the peel cells by a combination of abrasion and pressure and large volumes of water are necessary to prevent the oil being reabsorbed by the peel. The emulsion is filtered, desludged and centrifuged, and the resulting oil is dewaxed and may be again filtered and clarified. Ultra-filtration and reverse osmosis techniques are were introduced to improve oil recovery rates. Oils are also obtained during concentration of citrus juice, especially sweet orange. Excess water (to 25%) containing some oil, is removed under vacuum and the oil is separated via a stripping column and condenser.

The simultaneous drawing-off of juice and oil also applies to cold-pressed lime oil, but unlike lemon and orange oil, most commercially traded lime oil is distilled rather than cold-pressed. Initial crushing yields a mixture of liquid and pulp which is allowed to settle into three layers; the middle layer of lime juice is run off, leaving the top and bottom, pulpy, oil-rich layers to be distilled, Distilled orange and lemon oils are comparatively uncommon; are usually produced by steam distillation of spent skins which contain a little oil after the main crushing operation; or much less commonly by vacuum distillation of juice which can contain very small amounts of oil, although quantities are of little significance in relation to those contained in peel. The two methods of oil extraction produce oils with different properties. Another cold process is ecuelling, where whole fruit is manually or mechanically rolled over sharp projections, which rupture oil cells in the peel and release oil. This process is still used to produce high-quality bitter orange or like oil, but is largely superseded by modern mechanical processes.

4. Bitter orange and Petitgrain orange[81]

In this part we will elaborate more on the uniqueness of bitter orange as a producer of a range of essential oils.

4.1 Description of Bitter orange and Petitgrain orange

The bitter, or sour orange, also known as the Seville orange, originally native to South East Asia, became established in Spain and other parts of Europe, with passage through the Middle East. Bitter orange trees may live to a great age under suitable conditions with recording of trees more than 400 years old.

All cultivars of bitter orange bear fragrant flowers, which contain an essential oil, but when this oil was first produced remain uncertain. Fresh and sometimes crushed orange flowers were used in scent baths and toilet water from early recorded history, especially in Asia. The first use of distilled oil in Europe was in the early sixteenth century; its wider use is attributed to the wife of Flavio Orsini, prince of Neroli, who in the late sixteenth century perfumed her gloves with the oil, and later introduced the oil into perfumery; the oil is named after her.

Introduced into Paraguay and other South American countries in the sixteenth century, trees became naturalized over large areas. The pettitgrain industry of Paraguay was established in the early nineteenth century, by Benjamin Balansa on the Paraguay River east of Asuncion, where there were extensive areas of wild bitter orange.

The major modern use for bitter orange was as rootstock since seedlings produce a well-developed root system possessing a high degree of resistance to many important diseases; it is now less favoured. There are a number of bitter orange cultivars, which differ considerably in physical characteristics and appearance. The true bitter or Seville orange is used here for purposes of description.

Citrus aurantium Swingle is commonly known as the bitter, sour or Seville orange. Bergamot orange is now classified a *C. aurantium*. subsp. *bigaradia* and petitgrain orange as *C. aurantium.* subsp. *amara*. Bitter orange is source of a number of important products, although these are not usually produced from the same subspecies. Most important are leaf oils, chiefly petitgrain, flower oils, mainly neroli, and peel and fruit oils.

Bitter orange is a medium sized tree to 10 m, usually less under cultivation, normally with a central stem bearing a number of stout branches. All species of bitter orange bear aromatic leaves, which yield an essential oil on distillation, but that known as true petitgrain oil derived from *C. aurantium*. subsp. *amara* is the most important.

Leaf oil is obtained as a secondary product from trees grown to produce another oil, or grown especially to produce leaves for processing, but the method of obtaining oil is essentially similar once leaves have been picked. The most important constituent of leaf oil and that, which defines its quality, is ester content, calculated as linalyl acetate, and is sold commercially based on its content.

The highly scented white flowers are borne singly in leaf axils or in small clusters on axillary racemes and are larger than those of sweet orange with 20 - 24 prominent stamens. An essential oil, neroli oil, can be obtained by distillation or enfluerage. A form of orange with scentless flowers and lacking oil glands in leaves has been noted. In Cuba. Neroli oil is produced from flowers of several *Citrus* spp; that obtained from bitter orange is neroli bigarade, from sweet orange neroli Portugal, and from lemon neroli citronier.

An essential oil is obtained from the skins of the fruit, and to a minor extent from pulp. A major use for whole fruits is in (Seville) marmalades and the juice is a valuable source of vitamins A and B.

4.2 Cultivation of Bitter orange and Petitgrain Orange

Bitter orange is basically a warm-region species and flourishes where the minimum temperature remains above 0^0C except for very short periods. An average annual temperature of 20 - 25^0C is considered most suitable, but up to twice this will be tolerated provided soil moisture is adequate. Best growth for flowering happens in bright sunny conditions. Frost normally causes extensive damage to small branches, and a severe frost or icing is frequently fatal. Plantations are normally below 500 m and trees flourish from sea-level to 300 m. That altitude modifies general tree growth and also oil characteristics is well illustrated in Paraguayan oils, where oil from trees growing in hilly Cordilla Department is higher in esters than that from trees growing on the plains. A rainfall of 1000 mm annually falling mainly in spring and early summer is the optimum, and irrigation is necessary where annual rainfall is below 750 mm or seasonally erratic. Very strong winds may cause damage by fracturing branches, while hot, dry winds during spring growth reduce leaf size and number and, at flowering cause extensive withering.

In general, the natural conditions affecting sweet orange peel also affect bitter orange but, as the latter is not as valuable, only climatic variation is of importance. The most important seasonal factor is rainfall, since below average rain results in fewer and smaller fruits with lower peel content. If a prolonged period of dry weather occurs after fruit has set, a high proportion may be shed before maturity. Although fallen fruit can be processed for oil, its quality and odour are inferior to oil from mature fruit. The oil yield varies widely, 0,1 - 0,4%, as there are many local cultivars.

Soils suitable for sweet orange are equally suitable for bitter orange, but as the former is generally more profitable in those regions where both are grown commercially, bitter orange is usually relegated to less fertile soils. On the other hand, if the producer is serious about producing bitter of high quality and utilizing all sources of oil, it will be profitable to employ a proper fertilization program. The cost of fertilization may be contained by relying on locally produced fertilizers, such as composted biomass and manures such as chicken manure. A capacity to make these fertilizers on-site may make it easy to farm organically. Various foliar fertilizers will impact favourably on oil output and need not be very expensive.

Weed control is one of the major challenges when growing bitter orange. Cultivation should aim at maximum weed reduction. Planting other crops on the cleared land, even inter-planting essential oil producing shrubs to start suppressing weeds on cleared land, could be a way to create fairly weed-free land on which to establish bitter orange.

Seeds are sown in pots or seedbeds, where seedlings remain for up to 12 months. This will require a nursery capacity if the orchard is going to be established in a remote area. No particular care is necessary when planting out seedlings except to ensure that each is firmly rooted; if soil moisture is adequate and holes are of sufficient depth to allow quick growth of roots, most seedlings survive.

4.3 Harvesting of bitter orange and Petitgrain orange

Under normal conditions first harvest is from 3-year old trees, which are cut back to 12 - 15 cm above ground level. All material is transported to stills, where leaves and twigs are stripped, and larger branches used as fuel. When bitter orange is grown for flowers or fruit, the annual pruning supplies leafy material for distillation. Trees can be cut at approximately 9-month intervals and regular cutting maintains a leafy bush, which produces the maximum foliage. When world price of oil is low or demand falls, plantations in Paraguay are virtually abandoned until harvesting is again profitable. Trees, which have been left uncut for several years, can be recoppiced without harm, and normal cutting resumed. There is thus a resilience in this type of production eminently suited to local conditions. Cutting may be at any time; in Paraguay mainly in October - March; pruning is generally in July - October in France, February - April in Italy. On Haiti, leaves can be harvested throughout the year, but the highest quality oil is obtained in May - October after the flower harvest. Oil in Paraguay increases steadily to the fifth year, then remains constant for decades under good management.

The most important factors affecting leaf-oil content are seasonal, varietal and to a lesser extent geographical. In Paraguay, annual and seasonal variation is high since the local climate directly influences leaf oil content and oil characteristics. In that country the highest oil content generally occurs in January - June, the lowest in August - October; in Italy, yield rose as the weather became warmer from February to April; in Brazil, the highest oil content is in warm months but linalyl acetate is frequently highest in cool months. Two major operations affecting oil yield are directly under producer control; time of cutting and number of cuts annually. Regular cutting produces bushy plants with a high proportion of young leaves, which have a higher oil content than those more mature. In Italy, where leaf oil is of secondary importance, young leaves had an oil content of 0,29, older leaves 0,21%.

Two commercial leaf oils are recognized, bigarade and petitgrain Paraguay. The former is obtained solely from leaves, petioles and often small twiglets of true bitter orange; the latter from similar material from various forms of bitter orange common in that country. That there can be substantial differences between oils from various countries is well known, but even in a specific country there can be regional differences.

The growth factors affecting flower oil yield are similar to those affecting leaf oils. Wide seasonal variation exists, indeed there can be considerable variation within one season if weather conditions vary substantially during or preceding flowering. Bright, sunny and dry but not hot weather is most suitable for flower production and harvesting. Cloudy, misty or sultry conditions reduce flower numbers and oil content. Such conditions are also unsuitable for flower picking, since blossoms may be moist or damp, easily damaged and ferment while awaiting or being transported. Variation in oils will occur if the flowers of other citrus species are included, where they grow in close proximity and pickers are generally, or deliberately when paid by weight, unselective.

Flowers are picked by hand when they have just opened but not full-blown, as early as possible in the morning for the finest quality oil. Inclusion of unopened buds and wilted flowers gives a grassy odour; inclusion of small leaves and petioles produces an off note. Flowers are usually stored overnight in thin layers in special stores before being distilled.

4.4 Distilling of Bitter orange and Petitgrain orange

Leaf and oil yield vary widely; in Paraguay individual trees provide 10 - 15 kg leaves annually and 200 - 300 kg yields about 1 kg oil; in Haiti, 300 - 400 kg about 1 kg oil and in France, 500 kg for only 1 kg of very high quality oil. A charge normally consists of leaves, twiglets and sometimes small branches. Still operators consider that inclusion of a reasonable amount of twigs stops consolidation and channelling thus ensuring more efficient distillation. While time of cutting in terms of leaf maturity effectively controls potential oil yield, treatment after cutting can directly affect oil per ton of material. Distilling fresh leaves gives the highest yield, in Italy, fresh flowers yielded 0,28%, after three days storage 0,23%. Those factors affecting oil content also basically affects oil composition, but incorrect or prolonged distillation has a greater adverse affect on ester content.

Flowers are now generally distilled for oil, while solvent extraction of flowers and orange water yields various absolutes. Distillation differs from that of leaf oil as flowers are placed directly into a still body containing water, which is then indirectly heated. A significant quantity of oil is dissolved in the water and recovered by solvent extraction. Thus two products are obtained, Neroli oil and orange flower water. When only unadulterated flowers are distilled about one gram of oil is obtained per kilogram of flowers, while 3000 kg of solvent extracted distillation water yields about 1 kg orange water absolute. Peel oils are obtained from all types of bitter orange fruit, and although it is not strictly an essential oil it is widely considered as such under the name bitter orange oil, but more correctly called peel oil. Probably the most important factor affecting oil quality and type is method of expression and subsequent treatment.

Peel oil is obtained by rupturing oil-containing cells in peel either by pressure or abrasion, and the method of expression affects total yield, since some producers only partially express peel, which is then sold for other purposes. Expression may be manual or mechanical, should be cold, and the fruits as uniformly mature as possible. Inclusion of unripe fruit causes a proportionally greater reduction in oil quality than inclusion of those more ripe. Fallen or diseased fruit should be rejected, since these produce off notes in oil. Peel may be distilled following expression to recover a poor quality residual oil. Peel oil is more expensive than sweet orange oil as there is no significant use for juice. Important constituents are citronellal, linalyl acetate, 1,8-cineole, and non-volatile coumarins to 0,25% not found in sweet orange oil.

4.5 Product uses and specifications

The most generally accepted designation for leaf oil is petitgrain oil but, as with so many terms used in the essential oil trade, it is in fact incorrect. The French word means " little seed " referring to the small unripe fruits from which the oil was originally obtained, but the name was retained when leaves and twiglets became the main source. The designation Petitgrain bigirade is normally accepted as applying to oil derived from *Citrus aurantium* and not its subspecies, which are traded under their own names as noted elsewhere. Oils obtained from other citrus species may also be labeled petitgrain but are generally of little or no commercial use.

Petitgrain bigirade is produced mainly in Europe and north Africa, while petitgrain form other localities is usually designated the country of origin, i.e. petitgrain Paraguay, Haiti etc. Leaf oils, however, are widely and frequently misnamed thus the designation petitgrain is virtually meaningless in respect of oil composition, odour or suitability for a particular product. Adulteration is also a major problem. The main characteristics shown in the table below should be used as a general indication, since there can be a wide variation in petitgrain oils even within a specific region; Algerian differs from Moroccan and both from French and Italian.

Main characteristics of leaf oils

	France[a]	**Paraguay**[b]	**Brazil**[b]	**Sicily**[b]	**Algeria**[a]
Specific Gravity (20^0)	0,891 0,897	0,882 0,901	0,880 0,892 (25^0C)	0,891 0,899 (15^0C)	0,881 0,895
Optical Rotation (20^0)	-4^0 -6^0	-4^0 $+2^0$	-5^0 -7^0	-2^0 -6^0	$-0{,}30^0$ $-5{,}5^0$
Refractive Index (20^0)	1,45 1,46	1,465 1,460	1,450 1,459 (25^0C)	1,460 1,466 (15^0C)	1,4656
Solubility (v/v 70% alcohol)	1:3,5 4,0	1:4	2:3 4,0	1:2 3,5	1:2,5 4,0
Acid number	ng	max 2,0	max 2,0	max 2,0	0,4 - 1,0
Linalyl acetate (%)	64 - 68	35 - 55	50 - 85	50 - 75	25 - 35
Linalool (%)	ng	min 54	5 - 10	10 - 20	30 - 40
Citral (%)	ng	ng	<1.5	<2,0	<0,2
[a]laboratory analysis; [b]commercial samples; ng not given					
Figures in column are ranges					

The main constituent of an Algerian petitgrain oil is shown in the following table:

Main constituents of petitgrain oil from Algeria			
Alpha-pinene	1,19	Bicycloelemene	0,21
Beta-pinene	1,76	Linalyl acetate	28,94
Sabinene	1,58	Gerenyl formate	2,00
Delta-carene	0,20	Geranylacetate	3,54
Myrcene	1,82	Linolool	36,10
Limonene	1,25	Terpenin-4-ol	0,42
Cyclo-fenchene	0,57	Alpha-terpineol	6,80
Beta-ocimene	1,92	Nerol	1,51
p-Cymene	0,16	Geraniol	3,97
Terpinolene	0,31	Phytol	0,23
Beta-caryophyllene	0,21	Neral	0,12

Petitgrain bigarade oil is pale to mid-yellow (amber) but crude oil is almost black. The odour is pleasant, floral-sweet and orange-like, and the taste orangy and bitter-sweet, with the high linalyl acetate content considered responsible for the strong sweetness. The oil is extensively used in perfumery, and flavouring to enhance the frequently harsh synthetic compounds used in food, sweets, soft-drinks and cordials. North Africa oils generally conform to this quality, since most plantations were established from French material. The strong regional differences in the oils, however, mean they are not readily interchangeable. Petitgrain Paraguay is pale to dark-yellow, the odour is sweet, strong woody-floral; the taste is bitter-orangy. The odour may vary considerable since it is affected by length of period storage, the container, and often by the extent and type of adulteration. Crude or bulk Paraguayan oil can be very variable in quality, is seldom consistent, often contains water, and should be filtered and dried before evaluation. The Paraguayan Government has established export standards for oil and shipping containers, which only a few major exporters observe. The oil is extensively used in soaps and similar products, and in inexpensive perfumes. Petitgrain Haiti is even more variable, mainly due to type of material distilled. Its uses are similar.

Terpeneless petitgrain oil is normally derived by vacuum distillation of Paraguayan oil with a volume loss of 25 - 35%. Terpeneless oil contains mainly linalyl acetate, linalool and methyl anthranilate, and is almost colourless. The extent to which terpenes are removed basically determines the oil's odour, which is often the individual preference of a company or a perfumer. Deterpened oils are important in perfumery where the greater solubility is an asset; in food and drinks they are used in conjunction with natural or synthetic fruit flavours.

Petitgrain bigarade sur fleurs d'oranger is a pale to a very pale yellow, with a sweet orangy odour. It is produced in small quantities mainly in the Grasse region of France by distilling bigarade oil over flowers from the same type of bitter orange. The ratio of oil to flowers is not fixed, thus there is a wide variation in the final product. The odour of this oil is considered by perfumers to be superior to bigarade oil, and is extensively used to enhance other flower oils in fine perfumes; the oil suffers from numerous inferior imitations with the same name. A similar oil is produced by mixing bigirade oil with neroli oil, but it is of little value to perfumers. Another speciality oil is obtained by distilling together leaves, twigs and flowers whose characteristics and odour differ as the proportion of the three parts varies.

Petitgrain bergamier is obtained from leaves of *C. aurantium* subsp. *bigaradia* and has an odour similar to Paraguayan petitgrain. The oil is seldom used alone but commonly as an adulterant or extender of other citrus oils. A number of other leaf oils have been produced from various *Citrus* spp. growing in the Philippines, East and West Africa and the Caribbean, but none are of economic importance and unlikely to become so. Some have specific characteristics noted in the relevant literature. The further development of these oils probably depends on their use by a particular manufacturer seeking a novel product.

Flower oils are generally known as neroli oil, and usually differentiated by a country or quality suffix. They suffer from the same problem of adulteration and inferior substitutes. Neroli bigarade is the highest quality, obtained by steam or water distilling flowers of the true bitter orange. Haitian neroli is steam distilled from flowers of various species of citrus, and is quite different in its characteristics and odour. Neroli oil can also be obtained by hot enfleurage, but this operation has now virtually ceased. Flower oils are produced mainly in the Mediterranean region, the Caribbean, Latin America, Southern Africa and China and although manufacturers frequently prefer a specific origin, the highest quality oils are French and Tunisian. The major components are linalyl acetate, limonene, linalool, methyl anthranilate and geraniol.

Neroli bigarade oil is a clear, pale to very pale yellow mobile liquid, becoming viscous and darker with age. Fresh oil has a strong, attractive orangy-floral odour, but little persistence. The oil quickly darkens and the odour deteriorates unless kept in well-sealed containers in a cool dark place sore. The main characteristics of neroli bigirade of various origins are shown in the following table, but there can be substantial regional, indeed seasonal variation.

Main characteristics of flower oils (neroli).

	France	**North Africa**	**Sicily**	**Spain**	**Haiti**	**Commercial Range USA**
Specific Gravity *	0,87 0,89	0,87 0,88	0,87 0,88	0,86 0,88	0,86[a] 0,87	0,863[a] 0,880
Refractive Index *	1,47 1,48	1,47 1,48	1,4 1,5	1,4 1,6	1,47 1,49	1,0[a] 2,2
Optical Rotation *	$+3^0$ $+7^0$	$+6^0$ $+9^0$	$+5^0$ $+7^0$	$+8^0$ $+10^0$	$+22^{0a}$ $+25^0$	$+1{,}5^{0a}$ $+9{,}1^0$
Solubility (v/v 70% alc	1:2-3	1,2-4	1:1-2 (80%)	1:1,5 -2,0	1:1 - 1,3	1:1 1,5
Acid number	<2	<2,0	<2,0	<3,5	<3,0	<3,0
Linalyl Acetate (%)	10 - 15	15 -25	8 - 10	15 - 25	12 - 15	ng
Linalool (%)	25 - 40	25 - 45	55 - 65	25 - 35	ng	ng

* all at 20^0C; [a]figures in columns are average ranges; the ranges can be much greater; [b]25^0C; ng: not given

Distilling methods and techniques also have a major effect on the oil, particularly to the extent to which certain alcohols are hydrolysed. Al large Spanish producer uses copper rather than stainless steel equipment, claiming its products has a superior odour. At least 40 components have been identified in neroli oil and analysis of two oils shown in the following table:

Partial analysis of neroli oils			
	French	**Egyptian**	**Commercial**
Alpha-pinene+camphene+diterpene+paraffin C-27	5,0	4,26	0,8
Camphene		5,50	Ng
Sabinene	ng	2,55	Ng
Beta-pinene	ng	8,67	15,0
Myrcene	ng	2,15	1,6
Delta-3-carene	ng	2,46	Ng
Limonene	ng	22,43	Ng
Limonene + *cis*-ocimene			16,1
trans-Ocimene	ng	ng	6,0
Terpinene	ng	4,14	Ng
Alpha-terpineol	2,0	1,87	3,0
Linalool	30,0	2,52	30,6
Linalyl-acetate	7,0	0,87	9,1
Geraniol + nerol	4,0	1,02	2,0
Nerol (including farnesol + unknown)	ng	6,97	0,2
Geranyl acetate + neryl acetate	4,0	3,74	2,9
Neryl acetate			1,7
Citronellol	ng	1,87	0,2
Citral	ng	2,41	Ng
Beta-citral	ng	1,87	Ng
Nerolidol	6,0	ng	7,6
Farnesol	ng	ng	4,0
Methyl anthranilate	0,6	1,89	0,3
All figures in table are percent. ng, not given			

Buccellato presented a very interesting review in 1980 on the contribution various constituents make to oil odour, stating that hydrocarbons provide the bright, fresh, citrus character, alcohols the floral body, esters the fruity component, while phenols and nitrogenous compounds modify the whole. Neroli bigarade normally contains a high proportion (approximate percentage in brackets) of hydrocarbon monoterpenes (35); linalool (30); aldehydes (12); linalyl acetate (10); and nerolidol (7). Although many analysis of neroli oil have been published, they often fail to state the origin and are thus of limited value. A characteristic of fresh neroli oil is the blue fluorescence caused by anthranilates when the oil is dissolved in alcohol; this rapidly fades on exposure to daylight and the reaction is less brilliant when aged oil is used.

The main use for neroli oil is in perfumery, especially colognes and, although neroli and petitgrain have basically the same odour, perfumers consider that neroli can lift and make a top note more radiant, while petitgrain is flatter. It has a limited use as a flavour material in sweets, soft drinks and liqueurs. Neroli oil is a weak antiseptic, but has a strong bactericidal action against *Staphylococcus aureus*. In traditional medicine it was believed to induce a semi-trance when inhaled warm. Nerol bigarade is often difficult to obtain and expensive, thus a number of synthetic substitutes known as neroli bases are available, and it is also frequently adulterated. Haiti neroli cannot be directly substituted for neroli bigarade. And is used in its own right in perfumery. Similar in appearance to neroli oil, but often darker, it has a harsher less orangy note, since the often prolonged distillation hydrolyses esters and in particular reduces the important linalyl acetate content.

Orange flower water is the liquid remaining after flower distillation, and as neroli oil is slightly water soluble a small amount remains dissolved. This solution was formerly sold as orange flower water, *Eau Bigarade Petales* in various concentrations, double, quadruple, etc. The liquid is now solvent extracted to recover the oil, known as orange flower water absolute. It varies from dark to brownish yellow and darkens further with age; the odour is only faintly orange although strongly floral. A major use is in perfumery as an enhancer or blender. The main components are shown in the table below.

Main components of orange flower absolute		
Figures in table are percent	**Orange flower absolute**	**Orange flower water absolute**
Alpha-pinene	Trace	Ng
Beta-pinene	0,4	1,1
Myrcene	0,1	Ng
Limonene + cis-ocimene	5,1	0,5
trans-Ocimene	0,6	0,2
Linalool	32,0	44,1
Phenyl ethyl alcohol	4,5	1,9
Alpha-terpineol	2,4	18,5
Citronellol	0,5	0,2
Nerol	0,9	2,8
Linalyl acetate	16,8	Ng
Geraniol	1,5	6,4
Indole	1,0	0,1
Methyl anthranilate	3,0	4,1
Eugenol	0,8	0,5
Neryl acetate	0,1	0,5
Citronellyl acetate	0,2	Ng
Geranyl acetate	0,6	0,5
Nerolidol	7,6	1,7
Farnesol	7,7	0,5

The absolute contains significant amounts of terpineol, linalool and methyl anthranilate, but terpenes are virtually absent. *Eau de Brouts* is an interesting absolute obtained from water remaining after distilling a mixture of flowers, leaves and twigs. It is of a very variable composition, since the charge may consist of different proportions of flowers and foliage.

Orange flower concrete is obtained by solvent extracting freshly picked flowers, and is an orangy or darkish-brown pasty substance with a very strong, sweet floral odour. On dilution, the scent is almost identical to that of natural flowers. The concrete is seldom used, since it is basically the raw material for production or orange flower absolute by solvent extraction with a yield around 50%.

Absolute is a dark to dark orangy brown, rather viscous liquid with a warm, rich, floral, tenacious odour similar to that of the natural flower. This absolute is of major importance in perfumery and has a multitude of uses. It is also used in flavouring, especially sweets and drinks. The main components are shown in the following table.

Major components of bitter orange and bergamot peel oils.		
Component	**Bitter orange**	**Bergamot**
Alpha-pinene	0,40-1,30	0,90-1,50
Beta-pinene	0,30-6,00	4,50-7,00
Sabinene	0,05-1,30	0,75-1,25
Myrcene	1,80-2,20	1,00-2,00
d-limonene	45,00-95,00	35.00-55,00
Gamma-terpinene	1,10-9,00	5,50-7,50
Decanol	0,40-1,50	0,10-0,40
Citronellal	1,00-2,00	0,50-1,50
Linalool	12,00-14,00	12,00-14,00
Linalyl acetate	9,00-11,00	30,00-35,00
Alpha-terpineol	1,10-3,00	0,08-0,10
Geranial	2,59-3,50	0,30-0,50
Nerol	0,30-0,60	0,05-0,10
Geraniol	0,45-0,85	0,01-0,02
Camphene	0,49-0,90	Ng
1,8-Cineole	1,00-8,00	Trace
Octonal	1,25-2,50	0,10-0,15
Nonanal	0,10-0,40	Trace
Nonyl acetate	ng	0,80-1,00
Isopulegal	0,25-0,50	Ng
Geranyl formate	0,25-0,60	Ng
Terpinen-4-ol	0,25-0,45	0,25-0,40
Ng, not given; Figures in columns are range percent. Note wide ranges of component		

Oils obtained by first solvent extracting fresh flowers and distilling the residue had the following characteristics (at 15^0C): specific gravity 0,888 - 0,943; optical rotation -0^0 - 5^0; refractive index 1,47 - 1,50; total esters 25 - 35%; total alcohols 50 - 60%.

Fruit oils are obtained by expressing peel of bitter, bergamot and petitgrain orange, and differ in composition and commercial use. In general, bitter orange oil is used mainly in flavouring, bergamot oil in perfumery, petitgrain oil as a blender or extender. The organization of the genus *Citrus* has changed drastically over the last decade. Care should be taken to compare current analytical results with the current organization of the genus. These oils are not considered essential oils as they contain non-volatile components, but to ignore them for this reason will be pedantic, since they are widely regarded and internationally traded as essential oils. The highest quality is obtained by cold-pressing peel of mature but unripe fruits, and inclusion of oil distilled from expressed peel sharply reduces quality and odour. The oil is normally a darkish-yellow, but can vary between pale olive to brownish yellow depending of regional origin. Crystalline sediment may appear after prolonged storage. The odour is distinctive, fresh, biting, with rich sweet floral undertones, and tenacious; the taste is bittersweet. The oil is used as a flavouring, particularly in orange beverages from soft drinks to liqueurs, cake mixes and confectionary of all kinds. It is also used as a blender or enhancer of high-class perfumery. Major components of the oil are the terpenes approximate 90%, with, in percent: d-limonene (min 50), linalyl acetate (2-10), myrcene (1-4) and decanol (1). The main components of peel oil are shown in the following table; the very wide range of individual component must be noted.

Main characteristics of bitter orange peel oil

				USA	
	France	**Italy**	**India**	**Florida**	**EOA**
Specific Gravity (20^0C)	0,86 0,87	0,845 0,851	0,86 0,87	0,846 0,850	0,845[a] 0,851
Optical Rotation (20^0C)	$+86^0$ $+92^0$	$+91^0$ $+97^0$	$+84^0$ $+88^0$	$+90^0$ $+95^0$	$+88^0$ $+98^0$
Refractive Index (20^0C)	1,470 1,480	1,473 1,476	1,473 1,475	1,470 1,474	1,4725 1,4755
Solubility (v/v 90% alc	1:4-8	1:4	1:8	1:4-5	1:4
Aldehyde content	<1,0	0,5-1,5	ng	0,50-0,15	0,5-1,0

[a] 25^0C; ng, not given; EOA, Essential Oil Association, USA.

Bitter orange peel oil is frequently adulterated with extracts from other citrus oils, synthetics and less valuable citrus oils. So desired are true oils that producers may be contracted in advance to supply oils of a specific type. These oils are expensive but economical since they can be used in very high dilutions without loss of odour. In international trade, oil originating in Guinea (West Africa) and Spain are considered the finest quality. Concentrated oil is produced by vacuum distilling whole oil, which reduces the terpene content to a specific level. The concentrated oil, tenfold oil, is a yellowish or orangy brown. A completely deterpened, almost colourles oil is also produced from whole oil with a yield of 3%. All deterpened oils have a flatter odour, which can limit their other advantages. Bitter orange oils are also produced from other citrus species, invariably of lower quality and in erratic supply. One in particular, Curacao peel oil produced on the West Indian island of that name, is used almost exclusively to flavour Curacoa liqueurs.

5. Bergamot orange[81]

This subspecies of *C aurantium* in now known as *C aurantium* subsp. *bergamia*. Argument continues regarding its origin, status, and whether it is a mutation or hybrid. Development of the toilet water known as *eau-de-cologne*, originally made in Italy by the Feminis family in the sixteenth century, stimulated bergamot production, as the oil is an essential ingredient. The fruit is bitter and inedible, however, it is available candied and eaten with bitter coffee as a sweetmeat in Greece. Bergamot orange has a much more restricted distribution than bitter orange, and was originally confined to the west coast of Calabria, southern Italy. Although bergamot has been introduced elsewhere, only the Ivory Coast, Guinea, Morocco and Corsica produce oils comparable with Calabrian oils, and Italy remains the most significant producer.

5.1 Description of Bergamot orange

Bergamot is an upright tree with a single trunk and numerous branches. It is kept at about 5 meters in height. The leaves and flowers are typical of the species. The very regular, spherical shape of bergamot fruits and the evenness of peel thickness greatly facilitated the introduction of mechanical processing equipment. Bergamot oil is obtained from the peel, the juice is of minor value. The fruit yields about 0,5% essential oil.

The most important producing regions of Calabria have a mild equable climate where temperatures only rarely fall below 10^0C or exceed 30^0C. The success of the West African plantations with a very different climate indicates that agronomic skill is probably more important. Frost causes serious damage to trees and , if prolonged, is often fatal. Low temperatures at flowering or when fruit is setting drastically reduces yield. Strong, hot winds have a similar affect and shelterbelts are recommended where there are seasonally high winds. An annual rainfall of 500 - 700 mm is adequate if augmented by irrigation. Plantations are normally established below 400 m in Europe, at higher levels only on southern slopes or sheltered valleys.

5.2 Cultivation of Bergamot orange.

Soils in the Calabrian region are generally poor, and the more fertile free-draining valley soils are favoured for bergamot plantations. In north and west Africa, sandy loams/clays are preferred. Poorly or seasonally waterlogged areas should be avoided, since trees are susceptible to various soil-borne diseases, which flourish in these conditions. There is a consensus that well fertilized trees are more productive than underfed trees. In all the areas referred to above prescribed NPK mixes are used, but well composted materials including chicken and other manures should also be effective. Intercropping with vegetables could mean that two crops benefit from fertilization. African soils are notoriously deficient of phosphate, which means provision has to be made at planting and during the following seasons. Rock phosphate and bone meals are slower releasing forms of phosphate.

The establishment of a plantation will follow the same principles as any other citrus. Bergamot seeds are viable, but most seedlings are budded or crafted onto other citrus rootstocks. The best choice will be one, which is disease resistant. Many plantations are intercropped to reduce establishment costs. There is a number of essential oil producing plants, which could be used for this purpose. Irrigation is normal since trees flourish in warm dry conditions. Drip irrigation, which conserves moisture and ensures regular growth, is probably the most viable system. Weed control could be manual if labour is readily available or through the discriminate use of suitable herbicides. Green manures, providing in effect an overall cover, are another way, at the same time reducing soil erosion on slopes. Pruning takes place just after harvesting and it is a skilled operation as each tree is pruned individually.

Bergamot trees mature slowly; a small harvest may be possible after 7 years, increasing annually to 12 - 15 years, and trees remain in bearing for 50 60 years with proper attention. Fruit yield from well-managed plantations in Calabria is 200 - 300 kg per tree, and average oil yield 300 600 g per tree. Individual trees have much higher fruit and oil yield and should be used to upgrade local stock. Peel oil content and its composition, however, are not only directly affected by agronomic factors but also by time of picking, handling, transport and method of expression. Peel oil content is extremely variable, and although this is partly genetic, climate directly affects oil content. Flowering begins in West Africa at the beginning of the rainy season and early maturing fruit has lower ester and alcohol content.

5.3 Harvesting of Bergamot orange

Manual harvesting is general. Fruit is harvested when mature but unripe, a factor, which will determine the stage of harvesting, carefully stored in the shade after picking and quickly transported to the processing plant.

5.4 Extraction of Bergamot orange

The unripe peel of *Citrus bergamia* is cold pressed. Several oils can be obtained from bergamot fruit other than the standard oil, including treatment of crude oil residues. In Calabria, an oil, Bergamotelle, is distilled from young fruit; another locally named Nero is expressed from ripe and fallen fruit, and others. Most important is Nero, highly aromatic and frequently used to enhance less fragrant oil. A Calabrian oil, fallen bergamot, is obtained from peel of fallen fruits, which are whole and not diseased, or rotten, and mainly used to extend true oil. An oil obtained by steam distilling peel remaining after cold-pressing fruit has a low linalool and linalyl acetate but high monoterpene content, and its main use is also to adulterate true oil.

5.5 Product uses and specification

Bergamot oil is a mid- to olive-green, becoming more yellowish or paler with are or exposure to daylight; its odour is fresh, rich, sweet and fruity. Bergamot oil is the only citrus oil in which limonene is not the dominant component. It is however, rich in linalool and linalyl acetate up to 50%. Oxygenated derivatives of the hydrocarbons of caryophyllene, germecrene D, farnescene and bisabolene contribute to the typical odour of Bergamot. The strong woody odour of the aldehyde bergamotenal is also known in Costus root oil. The main use of Bergamot oil is in perfumery, in flavourings, for food, confectionary, beverages, including the famous Earl Grey tea, and tobacco products. The oil must be used with caution in cosmetics since its bergapten content may cause skin irritation, and photosensitivity is a danger in sunscreens and similar products. The main characteristics of oil from various countries are shown in the following table.

Main characteristics of Bergamot orange peel oil						
	USA (EOA)	**Italy (Calabria)**	**Guinea**	**Ivory Coast**	**Morocco**	**USSR**
Specific Gravity (20)	0,875 0,880	0,8795 0,8845	0,8730 0,8910	0,875 0,882	0,862 0,873	0,877 0,888
Refractive Index (20)	1,4650 1,4675	1,464 1,466	1,464 1,468	1,462 1,465	1,468 1,770	1,464 1,469
Optical Rotation	$+8^0$ $+24^0$	$+15^0$ $+30^0$	$+12^0$ $+33^0$	$+6^0$ $+22^0$	$+38^0$ $+60^0$	ng
Solubility (v/v) 90% alc)	1:1	1:1	1:1	ng	ng	1:1
Ester content[a]	35-45	30-60	32-45	32-44	16-33	35-45
[a]As linalyl acetate(%); ng, not given; EOA, Essential Oil Association USA.						

Data available indicate some geographical variation in oil, but as North and West African plantations were basically established from Calabrian material, variation is thus probably due to differences in climate and distilling or extraction techniques. The considerable variation in bergamot oil composition, however, adds to the problem of identifying a genuine oil, as was demonstrated by Calabrian analyses. These showed significant changes in oil composition within specific periods and between oils from adjoining districts.

Terpeneless bergamot oil is obtained by vacuum distilling whole oil, with a yield of 66 - 75% depending on the product required. Its most important assets are greater solubility and slightly stronger and finer odour. Since it is more expensive, it is used in higher quality perfumes and similar products. Bergamot concrete produced in small amounts by solvent extraction has an excellent bergamot odour. Bergamot petitgrain is produced by steam distilling leaves and twigs from annual pruning, and is used as a partial substitute for other petitgrain oils, but is normally too expensive or available only in small quantities. This oil is a green to olive-yellow mobile liquid, with generally the same odour characteristics as South American oils.

6. Grapefruit[81]

Grapefruit is the only citrus species native to the New World and probably originated on Barbados from a natural cross between introduced parents sometime in the seventeenth century; it has since spread around the world. *Citrus paradisi* is considered to be a stabilized hybrid between *C. maxima* (pummelo) and *C. sinensis* (sweet orange).

6.1 Description of grapefruit.

Grapefruit is a large, vigorous tree to 30 m, with a single trunk, many branches, and a round to blunt conical shape when left unpruned. An oil obtained by distilling the large leaves had the following constituents (percent): sabinene 55, ocimene 10, linalool 15, gamma-terpinene 2,5, and citronellal 5. The relative proportions in leaf oil vary substantially between young and mature leaves, and between leaves sampled progressively through the growing season.

The flowers are large, up to 5 cm diameter, white, singly or to 20 in clusters. The flowers are usually very fragrant but the strength varies with the cultivar, and flowers are distilled to obtain Neroli grapefruit oil, the major constituents of which typically are sabinene, myrcene, limonene, beta-ocimene, linalool and terpinen-4-ol.

The fruit is large to 15 cm in diameter, generally spherical but often compressed laterally, light yellow to orange, and shape and colour are cultivar characteristics. Fruit are borne in clusters and, as total weight per branch can be high, heavily laden branches may break or fracture in strong winds. Fruit characteristics differ with the cultivar; the peel may be thick to very thick, the juice slightly to very acid, sometimes bitter. The fruits may be seeded or seedless, and the number of seeds varies between cultivar.

The major constituent of peel oil is limonene, while nootkatone derived from *C. maxima* gives the oil its characteristic taste. The fresh, fruity top-note is due to p-menth-1-en-8-thiol. This component is present only in very low amounts. Grapefruit oil is sesquiterpene rich, which is unusual in citrus oils. Over 100 compounds have been detected with monoterpene accounting for about 95%; including d-limonene to 95%, alpha-pinene about 1% and octanal to 0,6%. Nootkatone is mainly responsible for the odour of the grapefruit and contributes to the bitter flavour of the juice. Linalool oxides, which are found in many essential oils, constitute the second most important class of compounds. Also found in the essential oil is epoxycaryophyllene, first found in Verbena oil, and which possesses a pleasant, woody odour. The percentage of non-volatiles is high compared with orange or mandarin oils. Substantial variation exists in peel oil from cultivars grown in the same region, and from the same cultivar grown in different regions. The main characteristics of peel oil are shown in the following table.

Main characteristics of grapefruit peel oil

	USA (Florida)		**India**[b]	**New Zealand**[c]	**Brazil**[b]
	Cold-press[a]	Distilled[a]	Cold-press	Cold-press	
Specific Gravity (25)	0,8556 0,8588	0,8415 0,8539	0,8519 0,8560	0,856	0,858
Optical Rotation (25)	$+86,74^0$ $+90,25^0$	$+91,5^0$ $+96,5^0$	$+93,30^0$ $+111,30^0$	$+81,09^0$	$+93^040'$
Refractive Index (20)	1,4771 1,4770	1,4741 1,4746	1,4758 1,4878	1,4670	1,4755
Residue o Evaporation (%)	9,73 13,46	0,19 3,66	6,3	6,16	6,9
Aldehyde content (as decanal)	1,30 1,66	2,30 4,06	ng	0,56	1,0
Ester content (%)	3,47 4,41	0,08 2,52	ng	9,02	ng

[a] Average over number of varieties; [b] Varieties unspecified; [c] cultivar Golden Special; ng, not given

6.2 Cultivation of grapefruit

Grapefruit prefers a very warm to hot climate with an average annual daytime temperature of 25 - 30^{0}C and warm nights; low temperature restricts or inhibits growth and severe frost kills trees. An annual rainfall of 1200 - 1500 mm is required for commercial production, with supplementary irrigation below 2300 mm. Above 1500 mm or in areas of high humidity, fruit diseases become more frequent and the value of the fresh fruit reduces. Grapefruit plantations are usually below 500 m, but the tree will flourish and produce fruit to 1200 m in the high-altitude tropics where there is bountiful sunlight and little frost. Because of the considerable weight of mature fruit per tree, high winds can cause extensive damage. Windbreaks are frequently essential, and districts where high winds are common when grapefruit ripen should be avoided for commercial tree plantations.

Soils suitable for sweet orange are also preferred for growing grapefruit, although grapefruit will grow on a wide range of soils, provided these are free-draining. A neutral to slightly acid soil pH 5,0 - 7,0 is preferred, but more acid soils will be tolerated under good management; alkaline and saline soils should be avoided. The basic fertilizer requirements are as for sweet orange.

Cultivation of sweet orange in the same region is suitable for grapefruit including rootstock and seedling care, harvesting, transport and processing. A major difference between grapefruit and sweet orange is at maturity; grapefruit may be left hanging (held) on tree until required without loss of quality.

Smallholder yields may be only 10 t/ha, superior commercial plantations 80 t/ha but up to 100 t/ha. Trees produce a crop 4 years after planting out steadily increasing yield to 12 - 14 years, and yield may continue to increase to the twentieth year. Tree population will have a direct affect on yield, but cultivars differ in their rate of growth.

Irrigation techniques not only affects tree growth, but they're efficient use in terms of applied water directly affects plantation profitability; the most efficient are under canopy systems.

6.3 Harvesting of grapefruit

Mechanized harvesting is now routine in developed countries but even in less developed regions there is an increased need to reduce costs. Tree shape also influences the extent to which harvesting machinery could be used.

The basic factors affecting oil yield are weight of fruit per hectare and its oil content, generally under the control of the plantation manager. The total yield of oil per hectare is related to amount of peel and peel oil content, and there is significant differences between cultivars; differences which can be exacerbated by natural factors, or management techniques. Duncan cultivar in Florida for instance, had an average oil content/ton of fruit of 2.8, 2.7, 2.5 and 2.2 kg in four successive years, averaging 2,54 kg. The oil content of grapefruit diminishes greatly as fruit matures, and can be five times as high in early picked fruit as on fruit fully mature and held on trees. There is thus a conflict between oil and fresh fruit production, which must be a personal decision by individual growers.

6.4 Distillation of grapefruit

Oil is generally obtained by cold-pressing fruit, but also by steam distilling juice or pulp; there are basic differences in the oils, and the latter is considered much inferior. The main characteristics of oils from various origins are shown in the following table. All references are to cold-pressed oil.

Main components of grapefruit, mandarin and tangarine oils			
	Grapefruit[a]	**Mandarin[b]**	**Tangarine[a]**
Alpha-pinene	0,38	3,93	1,00
Beta-pinene	0,02	2,16	0,44
Sabinene	0,42	ng	Ng
Myrcene	1,37	1,80	2,03
Alpha-terpinene	ng	0,42	0,05
d-limonene	84,00	67,00	92,00
1,8-Cineole	ng	0,50	0,63
Gamma-terpinene	0,01	20,14	3,00
p-Cymene + octonal	0,84	1,34	0,40
Terpinolene	ng	0,89	0,13
Octanal	0,62	ng	Ng
Citronellal	0,10	0,01	0,04
Decanal	0,40	0.03	0,10
Linalool	0,10	0,13	0,60
Neral + terpineol	0,80	0,15	0,05

Nootkatone	0,10	ng	Ng
Thymol	ng	0,03	0.03
Figures in table are percentages; [a] USA; [b] Italy; ng, not given			

A basic difference exists between oil from white and red fleshed cultivars; the former generally has a higher aldehyde content and lower evaporative residue than the latter, which also contains a small amount of linalool. Oils from different cultivars should be held separately and offered as individual types. Physical and chemical properties of oil from different cultivars vary within a narrow range, the most commonly grown cultivars varying least. For processors to whom the oil is a valuable by-product, mid to end of season fruit thus contain an oil of higher quality and value. Leaf oil is obtained by distilling fresh leaves, and its composition and characteristics vary with leaf maturity. It is normally only produced on demand.

6.5 Product uses and specifications

Cold-pressed oil is yellow or pale orange yellow, sometimes with a greenish tinge; the odour is characteristic of the fruit, rather sweet and fresh; the flavour typically citrus but not bitter. Correct storage is important as the oil deteriorates rapidly on exposure to air, daylight or moisture and anti-oxidants are commonly added. The main components of grapefruit oils are shown in the table just above. The oil is also available as a fivefold oil, with a major reduction of d-limonene but a significant increase in nootkatone. Cold pressed oil is rarely adulterated, but often diluted with distilled oil, a substitution, which is easily detected. The main use for all grapefruit oils is in the flavour industry, with only a small amount in perfumery. Distilled grapefruit oil is produced by steam distilling pressed peel and processing residues. It is of little value *per se*, but is often mixed with other citrus oils in cheaper perfumes and industrial products.

Grapefruit seed oil is produced by expression of a vegetable oil, and seldom produced commercially. The oil has considerable antimicrobial activity.

SECTION 10:
THE AGRO-GEOGRAPHY OF MOZAMBIQUE WITH REFERENCE TO AROMATIC PLANT BENEFICIATION

1. Introduction[88] - Macroeconomic status

Mozambique, located on the south-eastern seaboard of Africa and covering an area of some 784 755 km^2, is blessed with wide varieties of habitats and natural resources including marine resources, fertile soils, minerals, forests, wildlife, and some 2 770 km of near-pristine coastline.

Following National Independence in 1975 expectations were high that Mozambique and Mozambicans would be able to achieve sustainable social and economic development. Indeed, during the early years of independence significant achievements were recorded

Unfortunately, during the 1980's and early 1990's internal conflict prevailed throughout much of the country resulting in large-scale social upheaval and stalled economic development. However, since the signing of the Peace Accord in October 1991, the subsequent consolidation of peace and the successful holding of the first national elections in October 1995 a peace dividend is now resulting in a flow of investment into the economic and social sectors.

Contrary to expectations macro-economic indicators show that Mozambique has experienced an estimated 5 - 6% economic growth per annum during 1995 and 1996. Despite this impressive growth Mozambique remains one of the poorest in the worldwide community of nations.

The natural resource base of the country is therefore coming under increasing pressure from a variety of developments. The Government of Mozambique recognizes the need to adopt sustainable development policies and programs and is committed to ensuring that this is achieved.

Already in 1990 the World Bank identified broad-base agricultural development and production as the priority for Mozambique

2. Overview - Geography and agroclimatic variables

Mozambique borders Tanzania in the North; Malawi, Zambia, Zimbabwe and South Africa in the West; and Swaziland and South Africa in the South. The country can be divided into three climatic zones – the humid tropical zone, the dry tropical zone and the high altitude tropical zone – and three altitudinal zones – coastal (0 - 200 m above sea level), middle (200 - 600 m above sea level) and high altitude (800+ m above sea level). The average annual temperature is approximately 25°C and the rainfall ranges from 400 - 2,000 mm per year, being generally higher and more reliable in the North and erratic in

[88] Ministry for the Coordination of Environmental Affairs. 1997. First National Report on the Conservation of Biological Diversity in Mozambique. Maputo.

the South[89]. This precipitation, although variable from region to region and year to year, is usually adequate for growing food crops, except in the southern inland (covering 1/3 of the country) and parts of Tete and Manica Provinces[90]. To determine the viability of cultivating plants for the purpose of extracting aromatic oils, this general statement warrants a more detailed consideration of the climate related agricultural conditions in Mozambique.

To understand the agricultural potential of a country a variety of climatic resource information is needed[91]:

- Firstly, the most important climatic resource information requirements are rainfall, temperature, wind speed, broad climatic zones etc.
- Secondly, the information that relate to agronomic practices such as
  - Time of planting and its associated possible risk
  - Crops and cropping patterns
  - Management practices
  - Expected levels of crop failure years
  - Expected level of excess water hazard
  - Climatic suitability level for irrigated agriculture etc.

These aspects have been dealt with by Reddy for Mozambique using climatic data collected through wide ranging means including 134 meteorological stations throughout the country. We have extracted from this information that which we believe will be important in designing and executing any plans to establish an aromatic oil industry in Mozambique.

When viewing a map of Mozambique which detail the Zones of different altitudes across the country, the viewer is struck by the fact of the large part of the country, which is lower than 200 meters and with about 94% of the country below 1000 meters above sea level, as described in **Figure 1**

Zone	Altitude: Meters
1	< 200
2	200 - 500
3	500 - 1000
4	1000 - 1500
5	> 1500

South of the river Save about 90% of the terrain is below 200m, Approximately 40% of the area in Cabo Delgado and Zambezia Provinces and 60% of the area in Manica and Sofala Provinces area below 200 m altitude. It is important to note that these low altitude areas are covered by mostly infertile sandy soils and locally by alluvial soils with

89 Da Silva M.C., Izidine S and Amude A.B. 2004. A preliminary checklist of vascular plants of Mozambique. SABONET Report No. 30.

90 Da Silva M.C., Alves T.,Tember J. and Munise P. Mozambique: Country Report to the FAO International Technical Conference of Plant Genetic Resource . Leipzig. 1996

91 For this Overview on the Agro Climate of Mozambique, we have relied heavily on: Reddy S. Jeevananda. 1986. *Agroclimate of Mozambique as Relevant to Dry-Land Agriculture*. INIA/Department of Land and Water, Ministry of Agriculture. Maputo.

hydromorphic properties (Zambezia, Manica and Sofala Provinces and some coastal zones), black soils (Cabo Delgado Province), and brown and black soils derived from basalts (Maputo Province). The zone of 200 - 500 m altitude, which is more or less undulating, occurs mainly over northern parts of the country. The soils are highly variable in texture varying from sands to heavy clays. The zone of 500 - 1000 m altitude occupies 25% of the area of the country with a large proportion occurring in the north.

The overall climatic make-up of Mozambique is confirmed by considering the broad climatic zones according to moisture index as described in **Figure 2** wherein five climatic zones from Arid to Humid, are indicated:

Zone	Climatic Zone
1	Arid
2	Dry semi-arid
3	Wet semi-arid
4	Sub-humid
5	Humid

The viewer will be struck by the fact that the Zone: Wet semi-arid form such a large part of the country, while the truly arid zone is a relatively small part. Arid areas are confined to low rainfall (<500 mm) areas of Gaza Province only. Dry semi-arid areas are confined to moderate rainfall (500 to 800 mm) areas of Gaza, Inhambane, Maputo, Tete, Cabo Delgado and Nampula Provinces. Sub-humid areas are confined to high rainfall (1000 to 1400 mm) coastal and elevated zones. Humid areas are confined to elevated areas of Zambezia Province, and small areas around Espangabera in Manica province with high rainfall (> 1400 mm). About 80% of the area of the country is semi-arid tropics, which constitute the primary dry-land agricultural belt.

The correlation, which exists between altitude and the climatic zones could also be extended to the mean annual precipitation across the country, which could be viewed in Figure 4. In **Figure 3** the climatic variable of the mean annual rainfall distribution is represented. In general the rainfall patterns show a sea to land gradient but in some places this is drastically modified by the orography. The mean annual rainfall varies between about 350 mm (at Pafuri, in Gaza Province) and 2348 mm (at Tacuane in Zambezia Province). The coefficient of variation varies between 20% and 40% with higher values concentrated mainly in southern Mozambique and around the belt south of the river Zambeze. There are two distinctive rainfall patterns, namely rainfall in summer and winter (coastal belts south of 19°S lat., Zambezia Province and elevated areas around Espangabera in Manica Province) and rainfall only in summer.

Zone	Mean annual precipitation; mm
1	< 400
2	400 -600
3	600 - 800
4	800 - 1000
5	1000 - 1200
6	1200 - 1400
7	>1400

The magnitude of rainfall intensities shows an increase from south to north of the country, but the frequency of occurrence of spells of intensive rains presents an opposite pattern. Annual rainfall presents a systematic variation over time. These are quite prominent at some locations (e.g. Catuane in Maputo Province) and at some others present a quite different pattern (e.g. Lichinga in Niassa Province). All these features of rainfall presented above exert significant influence upon agricultural production in Mozambique.

The rainfall erosion index (**Figure 4**) estimated using the annual rainfall, suggests that the soil erosion hazard is high over most of the elevated zones of north and central Mozambique.

Zone	Erosion hazard level
1	Very low
2	Low
3	Low-moderate
4	Moderate
5	Moderate-high
6	High
7	Very high

Figure 5 represents the distribution of the mean available effective rainy period. The available effective rainy period is defined as the period in which an adequate moisture supply is available to a dry-land crop on a continuous basis (given by a 14-week moving average of R/PE >= 0,75, where R and PE respectively are weekly rainfall and weekly potential evapotranspiration), having at the start of this period sufficient rains for sowing. The growing season is the sum of the available effective rainy period and the period that is available from conserved soil moisture at the end of the available effective rainy period, which varies according to the water holding capacity (**Figure 6**) of the soils.

Zone	Mean effective rainy period, weeks
1	< 5
2	5 - 8
3	8 - 13
4	13 - 18
5	18 - 21
6	> 21

For the purpose of cultivation of crops it is valuable to have information on the mean available water capacity of soils. Although all the information presented in this overview is focused on the cultivation of dry-land crops in Mozambique, it has direct bearing on the cultivation of crops for the production of aromatic oils, both fixed and essential oils, as the producer will always be confronted with the decision to rely entirely on rainfall for irrigation, or to invest into adequate capacity for irrigation, should water be readily available. This decision will almost entirely determine the exact location of planting the aromatic oil crop.

The available water capacity of the soils, varying between 10 mm, representing Lithosols, and 250 mm, representing Vertisols, with a majority of the area of the country with a capacity above 100mm. This information is described in **Figure 6**:

Zone	AWC; mm
1	< 50
2	50 - 100
3	100 - 150
4	> 150
AWC: Mean average water capacity of soils	

Figure 7 depicts the excess water/water-logging hazard zones. This is basically defined using wet spells **W** within the available effective rainy period in association with dry spells **D**. These are defined as:

Zone	W, weeks		Risk due to Excess water
	D<=0.7W	D> 0.7W	
1	< 4	> 3	Very low
2		3 - 4	Low
3	4 - 6		Low-moderate
4	6 - 8	4 - 6	Moderate
5	8 - 12	6 - 8	Moderate-high
6	> 12	8 - 12	High
7		> 12	Very high

Most of the elevated zones are affected by severe waterlogging problems. Also, these are the areas affected by soil erosion hazard (**Figure 4**).

The mean average annual temperature is described in **Figure 8**. Temperatures are below 23^{0}C over the elevated zones and southern coastal belt. Temperatures are more than 26^{0}C around Chicoa in Tete Province and Pemba in Cabo Delgado Province. The majority of the area in Mozambique presents 23 - 26^{0}C. In this zone the mean average monthly temperature are around 24 - 28^{0}C and mean monthly minimum temperatures are around 19 - 22^{0}C during the many rainy months. These ranges present the optimum ranges for dry-land crops in the rainy season on a level terrain (below 500 m altitude). Except over a few isolated elevated zones, the mean annual global solar radiation is more than 425 cal/cm^2/day.

Zone	T; ^{0}C
1	< 20
2	20 - 23
3	23 - 26
4	> 26
T: Mean average annual temperature.	

Figure 9 presents the expected percent of crop failure years. A year is said to be a crop failure year when the available effective rainy period is less than 5 weeks. This 5-week period represents the minimum period with reliable moisture required for even a short duration dry-land crop (equivalent to the length of the flowering phase). However, the risks levels could be modified to a marginal extent by soil available water capacity (AWC). Under high AWC soils the risks might be slightly lower while under low AWC soils it might be slightly higher. The soil factor plays an important role under high dry spells; and when dry spells are nearly equal or more than wet spells.

The risk of crop failure presents an association with climatic cycles. The risk is high over arid and dry semi-arid zones. It reaches as high as 90% around Pafuri in Gaza Province. In regions of this nature it will therefore be almost reckless to plants and aromatic oil plant without adequate provision for irrigation. The risk of crop failure is negligible over Niassa Province and other elevated zones. Again each aromatic oil plant must be judged on its won merits and some irrigation capacity may be needed to ensure that certain plants receive adequate water during their growth cycles.

It must be borne in mind that the available water capacity of soil could be dramatically improved by increasing the carbon content of the soils. This could be done, especially where crops, such as aromatic oil plants, use smaller fields for planting, through applying adequate compost just prior to planting, during the growth cycle in the case of perennial plants, and/or the application of humate-based fertilizers, in liquid or solid form, prior to planting, but also, where necessary, during the growth cycle of the plant. The use of mulches, will further improve the AWC. These actions do have a long-term effect and soil AWC will show a measurable improvement over an extended period. (See the section on Fertilization under the Technical Reports of the Selected Plant species)

Figure 10 presents the climatically suitable zones for irrigated agriculture. Climatic suitability refers to order of improvement in crop production associated with the climatic conditions if every other factor is satisfied under irrigation. This refers to one factor: how clear is the sky? This basically assumes that longer the rainy period and/or higher the relative rainfall probabilities and/or lower the risk for dry-land crops, the area is less suitable for irrigated agriculture with good management.

Zone	Suitability level
1	Very highly suitable
2	Highly suitable
3	Suitable
4	Less suitable
5	Unsuitable
6	Not suitable at all

However, the classes of suitability defined in **Figure 10** are not valid for supplemental irrigation, they do not include the high management conditions. Under these conditions the improvement in production is substantial relative to the investment.

Most of the areas with short summer rain with risks of crop failure years greater than 30% appear to be highly suitable climatically for irrigated agriculture. The areas with short summer rains with risk of crop failure years less than 30% are also suitable climatically for irrigated agriculture during the post-rainy season – but not in the rainy season.

Most of the coastal belt with winter rains and areas in Zambezia Province appear to be unsuitable/not suitable for irrigated agriculture. Supplemental irrigation could be practiced in areas along the coast with considerable risk in terms of planting time and due to drought.

Figure 11 represents the planting hazard zones:

Zone	Planting Hazard Level
1	Very low
2	Low
3	Moderate
4	High
5	Very high

Highly risky and risky zones are mainly confined to coastal belts and very low and low zones are confined to Niassa Province and elevated zones of Tete, Zambesia and Manica Provinces and Cabo Delgado Provinces. These planting hazard zones should be considered together with **Figure 12,** which describes the mean planting time.

Figure 13 describes the mean annual average wind speed distribution. They vary between 2.5 km/h and 9.4 km/h. They are high over the Ulongue-Lichinga belts in Tete and Niassa Provinces, but low over Zambesia Province and the drier parts of Tete and Gaza Provinces

Figure 14, describing the traditional crop zones, provides a good overview of the history of Mozambique's agronomy, which has a strong bearing on decisions for the cultivation of aromatic plants.

Figure 15 relates the broad vegetation types of Mozambique to the agro-climatic variables discussed in this section.

3. The soil resources of Mozambique

The country of Mozambique is blessed with a wide variety of soil types, which make it possible to consider the cultivation of a comprehensive selection of aromatic oil crops. To report on the detail of the soil resource throughout the country, and how the various soils coincide with the agroclimatic variables detailed above, is beyond the scope of this Report. A very detailed overview is provided in the map entitled:-

Soil Resource Inventory/Climatic Resource Inventory produced under the Land and Water Use Project FOA/UNDP/MOZ/75/011: Assessment of Land Resources for Rainfed Crop Production in Mozambique. Map Sheet of Field Document 35, February 1982.

The detail contained in this map, and its format, is extensive, making it almost impossible to copy into this Report.

The agroclimatic variables are of more critical importance when considering the location for cultivating an aromatic plant crop. We maintain that almost any soil, whether of an extreme sandy nature or, at the other end of the spectrum, clay, could be modified to a soil, which is suitable to cultivate any aromatic oil crop.

This is achieved through the addition of soil organism metabolisable organic matter and carbon compounds, such as well composted plant material and manures, and the use of humic and fulvic acids. These compounds are macromolecules extracted from natural sources such as lignite-type coals and present the molecular basis, which supports the revitalization and maintenance of large populations of soil organisms – which is the ultimate measure of soil fertility and life. Obviously, any comprehensive fertilization program will also recognize the importance of the primary macro-elements, nitrogen, phosphorous and potassium, the secondary macro-elements, calcium, magnesium and sulphur and the microelements iron, manganese, boron, molybdenum, zinc and copper, all needed in the right proportions for healthy plant growth. This emphasizes the importance of understanding the condition of a particular soil and therefore the ability to be able to analyze the soil to determine its status at any stage of the growth cycle of a crop.

We repeat the importance of the use, therefore the availability, of organic matter in the form of compost and other biologically active carbon compounds on a number of occasions in this Report. Emphasis should be placed on knowledge about these materials and the skills needed to use them. We cannot change, in any material way, the agroclimatic variables detailed earlier in this section, but we can materially alter the condition and improve the health of the soil.

4. Suitability of agroclimatic variables and soil resources to sustain existing indigenous flora

There is no indication that either the climate of Mozambique or the country's soil resources is not able to sustain a large diversity, and in large populations, where they could naturally occur, of indigenous flora. Rather the real risks to the country's indigenous flora has been identified as over utilization, largely as a result of economic need, but also lack of knowledge about the negative long term effect of unsustainable use of valuable natural resources amongst those who are closely dependant on these resources for their daily existence. Any future activity, which could hold promise of reducing poverty in the short term, such as harvesting aromatic plants from the wild, adds to the risk of depleting a valuable natural resource. This resource could, if utilized in a well-managed way, based on information gathered from sound scientific research, make a significant contribution to the future economic fortunes of Mozambique.

The agroclimatic variables discussed earlier, and agricultural conditions in general, are therefore regarded as favourable for the establishment of an industry producing aromatic oils, from both indigenous resources but also the cultivation of known commercial crops.

5. Suitability of agroclimatic variables to sustain cultivation of aromatic plants

We have consistently argued throughout this Report that it will be in Mozambique's long-term interest to start building an aromatic oil industry by cultivating commercial oil containing crops, while researching the most sustainable ways to beneficiate indigenous plants with aromatic oils. We further recommended that the cultivation of indigenous plants for aromatic oil extraction would be the most sustainable route, except where firm scientific proof could be presented that a sustainable way of beneficiating a particular species from the wild is possible.

We have identified 175 indigenous plant species in Mozambique with the potential to deliver aromatic oils, from which we have selected 23 species, which warrants attention in the short term. We have also identified 53 alien plant species with the potential to deliver aromatic oils, from which we have selected 24 species, which warrants attention in the short term.

The distribution of these species over the 10 Provinces of Mozambique are as follows:

Province	Indigenous Species		Alien Species	
	Identified	Selected	Identified	Selected
Maputo	55	12	42	18
Manica	58	8	11	6
Inhambane	30	2	7	3
Sofala	55	8	9	4
Nampula	29	6	5	0
Tete	47	12	0	4
Zambezia	34	6	9	3
Cabo Delgado	24	3	4	1
Niassa	37	5	10	2
Gaza	35	4	12	6

The following observations could be made:

- Although the criteria for identifying the indigenous plants were based on potential aromatic oil delivery, it is interesting to note that there is a fairly even distribution over the Provinces. As stated before, the listing of indigenous species in the SABONET Report No.30, which was the primary data-base from which the identifications were made, may be far from complete. Nevertheless, the observation could be made that the agroclimatic variables, discussed earlier, seem to sustain a wide variety of potentially valuable indigenous plants throughout the country.

- There can be no significance in the observation that in the indigenous species selected for attention in the short term seem to enjoy strong representation in Maputo and Tete Provinces.

- There is the interesting observation that Maputo Province seems to play host to a sizeable portion of the alien species identified for further investigation. Also many of the species selected for close attention in the short term seem to reside happily in Maputo Province. The reason could be simply that Maputo City and Province was the port of entry of many of the species, which found their way into Mozambique and found conditions hospitable enough to put down roots in the Province. But there is also more than adequate representation of the range of species selected, in the other Provinces, to conclude that the agroclimatic variables of Mozambique are favourable to sustain a wide variety of species alien to Mozambique, and that there are a number of degrees of freedom throughout the country to select the locations where commercial cultivation can be established.

SECTION 11:
OILS EXTRACTED FROM AROMATIC PLANTS – INTERNATIONAL MARKET INFORMATION AND A MARKETING STRATEGY FOR MOZAMBIQUE

1. Introduction

There is little doubts that markets and consumers are demanding increasingly, and on a world-wide basis, materials of natural origin to be a major constituent in food, cosmetics, pharmaceuticals and other products which directly impact on human, and animal, health. Mozambique has the potential to establish itself as a major producer of these materials, particularly the aromatic and essential oils which could be extracted from the flora, either indigenous or of alien origin, which could be cultivated on a commercial scale or harvested sustainably from natural resources.

The successful implementation of the strategy proposed, as an outcome of our study, will require that a close proximity to international markets and the key role players therein, be developed. It will also require that relevant information be collected on a continuous basis and disseminated to all who are, or want to be, active in the value chains of aromatic and essential oils in Mozambique.

The information contained in this section of the Report represents a summary of the most recent information on markets for aromatic and essential oils. A sizeable portion of this information was presented by Ramy Govindasamy, Venkata Puduri, Jim Simon and Rodolfo Juliani from the Department of Agriculture, Food and Resource Economics of Rutgers – The State University of New Jersey, USA, at the International Aromatic Plant and Essential Oil Symposium, in Stellenbosch, South Africa on February 27 - March 1, 2006. Additional information was made available by S&D Botanicals.

2. Global Essential Oil Market: Is Africa Part Of It? - An Overview

- According to the Dutch Association of Fragrance and Flavour Producers, the total size of the global market for essential oils was estimated at some US$13,2 billion in 2004. Other sources quote total global market estimations at about US$18 billion.
- Overall known essential oils are: 3 000
- Approximately 300 of these are of commercial importance (leaves, flowers, fruits, roots and wood/bark of many seasonal or perennial plants)
- Ten major essential oil crops account for 80% of the world markets for essential oils. Among them, lemongrass, eucalyptus, citronella and geranium are the most popular.
- About 28 essential oils are collected in commercial quantities from wild sources.
- The size of essential oils' export market averages US$ 8 billion a year and growing at the annual rate of 11%. (AfricaBIZ2003)

- Africa's share is less than 1% of that market.

- The United States of America is the largest user and importer (US$321 million) of essential oils (FAO STAT, 2003). It is a consumer of 40% of all essential oils)

- European Union member countries imports of essential oils amounted to US$ 601 million in 2004.

- France is the leading European Union importer of essential oils amounting to US$ 182 million. It is a consumer of 30% of all essential oils.

Essential Oils Global Market- Top 20 Countries Exports in 2003

No.	Country	US$ (million)
1	United States of America	293
2	France	192
3	Brazil	114
4	United Kingdom	108
5	India	102
6	China	59
7	Argentina	51
8	Netherlands	49
9	Germany	48
10	Italy	45
11	Indonesia	43
12	Singapore	42
13	Spain	35
14	Switzerland	33
15	Mexico	32
16	Thailand	31
17	Iran	28
18	Austria	19
19	**Morocco**	**18**
20	Australia	18

Source: FAOSTAT

On the list above, representing the top 20 exporting countries, Morocco is the only country representing the African continent. The fact of Africa's less than 1% of the global export market has to be emphasized – this means less than US$ 80 million. This is not to belittle the efforts in Africa to become a serious participant and supplier in the global markets for essential oils, but rather to highlight the targets African countries should be aiming for.

Essential Oils Global Market- Top 20 Countries Imports in 2003		
No.	**Country**	**US$ (million)**
1	United States of America	321
2	France	182
3	United Kingdom	139
4	Germany	110
5	Japan	103
6	Switzerland	80
7	Netherlands	66
8	Spain	56
9	China	56
10	Mexico	54
11	Brazil	32
12	Italy	31
13	Ireland	29
14	Singapore	28
15	Belgium	26
16	India	22
17	Thailand	21
18	Austria	18
19	Australia	17
20	Republic of Korea	13
Source: FAOSTAT		

The above table shows that no country from the Africa continent was a major importer of essential oils and that many of the major exporting countries are also major importers. This indicates a well-developed consumer based market for perfumes, flavourants and other products incorporating essential oils.

World Production of Essential Oils during 1999 - 2003 (Tonnes)					
Country	**1999**	**2000**	**2001**	**2002**	**2003**
China	15 119	16 138	16 150	16 650	16 650
Iran	50	2 000	5 000	5 000	5 000
USA	4 530	4 140	4 140	3 970	3 950
Lebanon	1 628	2 074	2 062	2 631	1 647
Greece	232	210	270	301	278
Guatamala	215	230	245	250	250
Côte d'Ivoire	**180**	**230**	**245**	**250**	**250**
Guinea	113	110	110	110	110
Comores	51	46	43	43	43
Samoa	39	39	39	39	39
Réunion	9	9	8	4	4
World	**22 166**	**25 177**	**28 277**	**28 209**	**28 181**
Source: FAO					

The above table is not a ranking of major essential oil producing countries, but merely a selection of countries, comparing large producers to smaller producers. It does not detail the value of essential oils produced. It also demonstrates that a relatively small country could be a substantial producer of essential oils and maintain a strong position over an extended period.

This emphasizes the historical presence of these countries in the markets for essential oils and the fact that any new entrant into these markets will have to be willing to adopt an entry strategy based on small, but deliberate actions to get products accepted by users interested in long term supply relationships.

World Top Traditional Essential Oil Producers:

- **China**
- **India**
- **Indonesia**
- **Brazil**

- **Large Population**
- **Cheap Labour Costs**
- **Internal Consumption**
- **Investment in Scientific and Technical Training**
- **Strong Economic Position**
- **Well Developed Export Business**

Source: Dr Hazel & David. 2002

Major producing countries rely heavily on technology, including the research and development to establish new varieties and highly productive agricultural practices, to achieve and maintain a dominant position in the global market.

Cheap labour costs should never be regarded as an indefinite and sustainable competitive advantage.

World Top Essential Oil Producers (Improved Varieties)

- **France (Dominant Position in Lavandin Production)**
- **United States of America (Peppermint)**
- **Australia**

- **Selection of Improved Varieties**
- **Establishment of Improved Varieties**
- **Simplification of Production System**
- **Sound Research Infrastructure**

Source: Dr Hazel & David. 2002

Although most African countries cannot even approach a country such as Australia as far as expenditure on research and development is concerned, it must be emphasized that a minimum investment in technology and skills, to achieve the highest levels of quality, for example, will be necessary for any country aiming to be taken seriously in the global essential oils market. A country such as Mozambique could, by focusing its efforts on only a few species, mobilizing the resources needed to built some capacity in the required fields of technology, gain a recognized position as a producer of quality aromatic oils, even in the relative short term.

United States Aromatic Oils/Essential Oils Market
• The aroma therapeutic market in the US has grown from US$ 316 million in 1996 to US$ 454 million in 2001 (Datamonitor, 2002)
• The compound annual growth rate CAGR) for aromatherapy sales in the US for 1996 - 2001 is 7,5% (Datamonitor)
• Natural personal care (NPC) markets in the US grew to US$ 4.1 billion consumer sales in 2002 (Nutrition Business Journal, 2003)
• The market (in the US) for natural personal care products will reach US$ 7,5 billion in 2006 (Datamonitor)

The information in the able above confirms that there are sectors in the larger aromatic oil and essential oil markets which are showing consistent growth on the back of a worldwide trend towards consumer product based on natural ingredients. These sectors present opportunities to growers and producers of the oils and other natural materials, but at the same time it has to be realized the increased consumer demand also go hand-in-hand with tougher quality criteria**.**

European Union Essential Oils Imports from Leading Suppliers in 2004		
Importing EU country	**Import Value (US$ million)**	**Leading Suppliers**
France	149	USA (10%), **Morocco (8%)**, Italy (8%), India (7%), China (7%).
UK	141	USA (28%), Argentina (18%), France (10%), China (7%), Brazil (5%).
Germany	97	France (21%), USA (10%), The Netherlands (9%), China (9%), India (6%).
The Netherlands	62	Brazil (22%), USA (20%), France (7%), India (5%), Spain (4%).
Spain	41	France (16%), China (14%), Indonesia (10%), USA (7%), Germany (7%).
Italy	24	France (26%), UK (25%), The Netherlands (14%), Germany (7%).
Belgium	20	USA (64%), France (15%), Germany (5%), Italy (3%), UK (2%).
Total	601	USA (19%), France (10%), China (6%), Brazil (5%), UK (5%).
Souce: Eurostat (2004/2005)		

This table indicates that only one country from Africa, Morocco, has become a major supplier to a EU member country, France. It also indicates a substantial intra-trade between EU member countries, while extra-trade is also substantial with countries with an established essential oil supply base.

African Major Essential Oils		
Products	**Botanical Source**	**Main Origin**
Bay/laurel leaf	Pimenta racemosa Laurus nobilis	Dominica, Turkey, Italy, **Côte d'Ivoire**
Caraway Seed	Carum carvi	Many Asian, Western European and **North African Countries**, USA.
Eucalyptus	Eucalyptus globulus	China, USA, Portugal, Spain**, South Africa**, Brazil, Australia, **Malawi.**
Geranium	Pelargonium graveolens	**Morocco, Algeria, Egypt**, Reunion, China, **Kenya**, **Tanzania**, East European Countries, Russia.

Tagetes	Tagetes grandulifera	**East and Southern Africa**.
Presented at the International Aromatic Plant & Essential Oil Symposium, ASNAPP, South Africa February, 27 - March 1, 2006		

This table indicates that a number of African countries and regions have already positioned themselves among other major international producers with products where they managed to grow a capacity to meet the demands of their export markets**.**

As far as a mix of products from an African country is concerned, it is interesting to note the situation in South Africa. The country has managed to build a strong presence in the United States with quite a wide range of "commodity" oils. All the plants from which these oils are extracted are cultivated in the country.

United States Essential Oils Imports from South Africa During 2001 - 2005, Cumulative	
Essential Oils	**Amount ($US)**
Lemon Oil	12,413,150
Grapefruit Oil	7,861,855
Ess Oil x Citrus	4,197,306
Orange Oil	1,447,679
Paprika Oleoresins	1,082,263
Citrus, Nes Oil	205,107
Sandalwood Oil	119,850
Mixtures< 20% Alc	113,242
Ess Oil Temp Nes	94,243
Prep for Perf/De	84,618
Eucalyptus Oil	44,633
Mix Odorfier N/A	14,979
Ylang/Cananga Oil	11,900
Lavender Oil	9,057
Geranium Oil	7,192
Perfume Oil Blend	3,777
Source: FAS, USDA	

Egypt presents a similarly interesting case, where the country maintains a substantial business with the United States with a wide range of oils from cultivated crops:

United States Essential Oils Imports from Egypt During 2001 - 2005, Cumulative	
Essential Oils	**Amount ($US)**
Ess Oil x Citrus	3,632,000
Geranium Oil	2,616,000
Jasmin Oil	822,000
Onion Ess Oil	811,000
Citrus, Nes Oil	343,000
Petitgrain Oil	314,000
Orange Oil	86,000

Peppermint Oil	83,000
Ess Oil Temp Nes	64,000
Linaloe Oil	53,000
Mint Oil, Nesoi	25,000
Ess Oil, Resinod	22,000
Attar of Rose Oil	15,000
Mixtures Contain	12,000
Perfume Oil Blend	8,000
Clove Oil	6,000
Spearmint Oil	3,000
Anise Oil	3,000
Caraway Oil	2,000
Cassia Oil	2,000
Source: FAS, USDA	

And so does Morocco:

United States Essential Oils Imports from Morocco During 2001 - 2005, Cumulative	
Essential Oils	**Amount ($US)**
Other oleoresins	1,963,000
Ess Oil x Citrus	2,018,000
Paprika Oleoresin	992,000
Rosemary Oil	403,000
Orange Oil	111,000
Cedarwood Oil	13,000
Attar of Rose Oil	12,000
Ess Oil Temp Nes	4,000
Mixtures Contain	4,000
Source: FAS, USDA	

And so does Kenya, albeit on a much smaller scale:

United States Essential Oils Imports from Kenya During 2001 - 2005, Cumulative	
Essential Oils	**Amount ($US)**
Ess Oil x Citrus	407,000
Alc Mix Other	303,000
Mix Odorifer N/A	38,000
Oil Ess Temp Nes	7,000
Source: FAS, USDA	

Studies conducted in Southern Africa have identified the following oils as representing the top 20 oils in demand in international markets (the numbers do not represent any particular ranking):

1.	Rose Geranium	11	Tagetes
2	Chamomile	12	Citronella
3	Rosemary	13	Eucalyptus
4	Peppermint	14	Marjoram/Origanum
5	Lemon Balm	15	Citrus: various including Grapefruit
6	Spearmint	16	Tea Tree
7	Lavender (including Lavandin types)	17	Lemon Grass
8	Lippia Javonica	18	Thyme
9	Buschu	19	Yarrow
10	Artemisia	20	Basil

This list corresponds closely with the oils we propose should be produced in Mozambique. From these oils a selection could be made for first stage cultivation and production and a sustained position obtained in world markets.

It is necessary to gain insight into the pricing levels for essential oils on the world markets. The Table below reports the spot prices ruling sometime during 2005 in New York. Obviously these prices do not represent prices obtained by the producer/farmer but it does highlight the different prices for different oils, giving a further indication of the oils which should considered for production.

Important Essential Oils (per liter) New York Spot Prices	
Essential Oils	**2005 prices in $US/kg**
Anise Oil (Chinese)	8.70
Anise Oil (Spanish)	18.55
Artemisia Afra	85.00
Buchu Leaf Oil	1,060.00
Coriander Seed Oil	49.50
Eucalyptus Oil	6.35
Garlic Oil (Chinese)	88.00
Garlic Oil (Mexican)	45.50
Geranium oil (Chinese)	49.35
Geranium Oil (Egyptian)	47.50
Ginger Oil (Chinese)	66.35
Ginger Oil Fresh (NEW)	128.00
Lavender Oil 40/42 (French)	49.50
Lemon Grass Oil (Guatemala)	18.70
Lemon Grass Oil (East Indian)	13.90
Parsley Seed Oil	98.00
Peppermint Oil (Indian)	24.50
Rosemary Oil (Morocco)	30.10
Spearmint Oil Native	30.50
Vetiver Oil (Haitian)	113.00
Vetiver Oil (Indonesian)	85.10
Source: Bloomberg	

In the table above there are also a number of oils we propose should be considered for production in Mozambique. This table also highlights the importance of having up to date information on pricing levels in important world markets. Of course, the higher prices do not necessarily indicate the most profitable oils to produce – often lower prices with markets secured because of consistent supply of larger volumes and high levels of quality represents the better proposition.

3. The Propects of Producing Organic Oils

A further attractive proposition to consider is the production of organic oils. Mozambique has the potential to build a solid reputation as a producer of quality organic oils. There are significant price benefits to be obtained of oils could be successfully produced organically.

In its marketing strategy Mozambique should develop and represent itself as a " green country " implementing actions not only aimed at producing a sizeable portion of its output organically, but also to harvest, where opportunities present themselves to harvest from natural resources, in an undisputed sustainable manner. A good example will be to ensure that the oil from *Sclerocarya birrea* (Maroela or canhu and medengwa) is obtained through sustainable practices. This oil should be, by the nature of its source, certifiable organic.

Selected Essential Oils: Certified Organic and Conventional FOB Price Indications at Farm Gate from S&D Botanicals With consideration to Volume and Quality		
Essential Oil	**Certified Organic $US per Kg**	**Conventional $US per Kg**
Geranium Rose	110 - 140	85 - 110
Lavender True	80 - 100	60 - 80
Lavender Grosso	20 - 30	15 - 20
Lavender Abriali	20 - 25	15 - 20
Rosemary	30 - 50	25 - 35
Melissa	1 200 - 1 500	700 - 900
Chamomile (German)	450 - 600	350 - 400
Chamomile (Roman)	225 - 260	180 - 220
Thyme	140 - 160	100 - 110
Lemon Grass (cit. and fl. range)	30 - 35	10 - 15
Basil	90 - 115	12 - 20
Marjoram	200 - 260	150 - 190
Eucalyptus (smithii)	8 - 15	5
Tea Tree	15 - 25	12 - 18
Buchu (betulina)	750 - 850	450 - 600
Buchu (crenulata)	600 - 650	450 - 550
Clary Sage	200 - 250	40 - 50
Peppermint	40 - 60	15 - 20
Spearmint	35 - 50	15 - 25
Source: S&D Botanicals		

4. A Marketing Strategy for Mozambique

Any strategic plan worth its salt details objectives and goals, but also tie these to dates and times they have to be achieved or at least progress reported on. A strategic plan cannot hang in the air – someone has to take responsibility, within each project, to ensure that agreed timelines are adhered to. We are not advocating central control of a "national strategy for aromatic oils "in Mozambique, on the contrary, enterprises in aromatic oils are entrepreneurial by their very nature. No bureaucrat in a central planning office can decree: "thou shall produce this volume of that oil at this quality ". We propose, at least during the initial stages of developing an aromatic oil industry fro Mozambique a number of pilot projects, which will have to rely on various forms of " high-risk capital " such as grants, but at the same time start opening the avenues into international markets. We must aim at that point where the first kilogram of an essential oil will arrive at a perfume house in Paris stating on the label: "Product of Mozambique – Top Quality Essential Oil", with the verifiable quality control certificate, confirming this, attached.

SECTION 12:
A STRATEGY FOR AN AROMATIC OIL INDUSTRY IN MOZAMBIQUE

1. Introduction

In this Section we describe the process followed to gather the information necessary to be able to, in the next Section, propose a viable Strategic Plan for the production and marketing of aromatic oils in Mozambique.

2. The process of designing a strategy based on a SWOT's analysis

2.1 The Workshop: 20 April 2006

During our second mission to Mozambique, a workshop was held, sponsored by the CPI, at the Pestana Rovuma Hotel in Maputo, on 20 April 2006. We proposed to CPI that such a workshop be held, trying to bring together as many of the stakeholders in the aromatic plant sector in Mozambique, as possible. The aim was to inform these stakeholders about our study, its objectives, share current information on the global markets with them and then through a workshop situation, using the SWOT's analysis approach, gain the benefit of their inputs for inclusion in a proposed strategy for aromatic plant beneficiation in Mozambique. The workshop was surprisingly well attended by the following people:

	Name	Organization
1	Mr Rafique Jusob	CPI - Director
2.	Ms Sara Taibo	CPI
3.	Ms Odette Semião	CPI
4.	Mr Antonio Macamo	CPI
5.	Mr Mathys de Wet	MBB
6.	Dr Louis de Lange	ABA
7.	Mr Andre van Aardt	MBB
8.	Ms Rute Vuma	Independent
9.	Ms Amelia Cumbi-Biologa	Independent
10.	Mr Luis Muthisse	Independent
11.	Dr[a] Samira Izidine	IIAM
112.	Dr Filesberto Pagula	UEM – Department of Chemistry
13.	Dr[a] Adelaide Augustino	MISAU – Department of Medicinal Plants
14.	Dr Helder Gemo	MADER – National Directorate Agricultural Extension
15.	Ms Albertina Alage	MADER – National Directorate Agricultural Extension
16.	Mr Roberto Albino	CEPAGRI – Centre for Promotion of Agriculture
17.	Mr Brendan Kelly	GPSCA
18.	Ms Julieta Zandamela	GPSCA
19.	Eng[o] Antonio Macamo	CPI – Linkage
20.	Dr[a] Filomena Barbosa	UEM – Department of Biological Sciences
21.	Dr[a] Anna Senkoro	UEM – Department of Biological Sciences
22.	Dr Salomao Bandiera	UEM – Department of Biological Sciences
23.	Mr Antonio Vieira	Kapenta de Mozambique Lta
24.	Ms Cecilia Corrado	Gruppo Volontariato Civile – Italia
25.	Mr Mualide de Sousa	ISCTEM – Faculty of Pharmacy
26.	Mr Antonio Gomes	SAPEL Lta – Libombos Macadamia Lta
27.	Mr Jose Carlos Rodriques	FASOL
28.	Mr Inacio T Nhancale	Ministry of Agriculture – Department of Extension
29.	Ms Ofélia Simão	MPD Directorate Rural Development

After a brief introduction on aromatic plants and the oils contained in these plants: both fixed oils and essential oils, an analysis of the international markets was presented (a summary of the comprehensive detail included in this Report). The position of Africa, as a continent, with a few countries already active in aromatic oil production, was presented as having less than 1% share of the global market.

A slide: The Way Forward for Mozambique, was then presented:

- African countries play a minor role in global essential oil markets
- All exports from Africa were recognized essential oils with established markets
- Mozambique to develop a global market entry strategy based on three product groupings:
  - Aromatic oils with established demand
  - Essential oils from alien plants with potential
  - Essential oils from indigenous plants with oil potential
- **Mozambique Essential Oils Inc** must become recognized as a valued member of the international essential oil community.
- Quality of products and consistency of supply must be the pillars of its strategy

The methodology was explained for identifying plants within Mozambique with aromatic oil potential and how a shortlist was prepared of selected plants. Plants, representative from each grouping, as detailed in this Report, were presented.

Possible strategies to integrate aromatic plant oils with post harvest value adding industries in Mozambique were then presented, for example, linking essential oils production with production of nuts and their oils, such as macadamia nuts and coconuts.

To facilitate the SWOT's process in the context of Mozambique, **the Cases of Madagascar and Reunion** were presented:

- The " French Connection ". A culture of aroma and the realization of its value.
- Long, historical presence in international essential oils markets. Reputation of delivery.
- Learned how to deal with pitfalls – strong knowledge base
- Emphasis on quality with capacity to measure and control
- Developed large production capacity in a few essential oils. Try to dominate the supply into those markets.
- A combination of small rural farming and larger commercial farming.
- A balance between harvesting from nature and cultivation.

We presented certain **Critical Success Factors**, which, in our view, needed to be considered during the workshop, and in designing a strategy for Mozambique. This presentation led to considerable discussion and exchange of thoughts:

- Understanding of the comprehensive value chain of each product.
- Capacity to be developed in each stage of production, including genetic selection, propagation, cultivation, quality assurance and control, extraction, packaging and logistics.
- Training of all operatives involved in production, such as rural farmers, in all necessary aspects of production.
- Substantial funding to build capacity including people with skills.
- Prove to a sceptical market that Mozambique can meet the tightest specification.
- Cultivation of essential oil plants will in most cases be as micro secondary crops rather than macro primary crops, except where large cultivation capacity has to be created, such as for the production of rose oil.
- Do not attempt any harvesting from a natural resource until the knowledge base and capacity exist to cultivate that plant on a large scale exists.
- Build lasting relationships with established marketing and distribution networks. Become the supplier of choice.
- Appropriate harvesting techniques must be used: manual, where possible; mechanical, where required.

We presented to the attendees a view on the **Beginnings of a Strategic Plan**, to give them the benefit of the progress we have made in the strategy designing process:

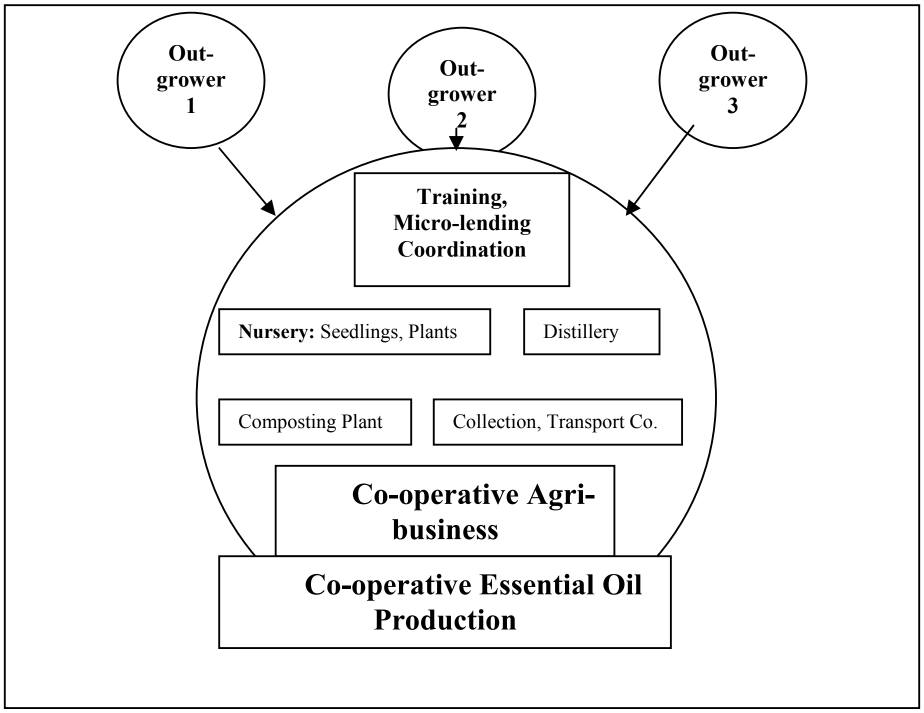
- Select a limited group of plants from the categories of indigenous, alien and commercial and develop these to the stage of commercial cultivation, extraction and delivery.
- The ability to do the genetic selection to identify the ideal geno- pheno- and chemotypes for each plant to be targeted must be developed.
- The ability to propagate each targeted plant, using the most appropriate techniques, must be developed.
- Large-scale nursery growing capacity must be developed, starting at the Botanical Gardens in Maputo, ultimately at strategic locations throughout the country.
- Start doing extractions from plants which seem readily available and not threatened (as far as we can establish) by overexploitation (while developing cultivation capacity):
    - *Sclerocarya birrea* subsp. *caffra* (Canhu, Marula)
    - *Cymbopogon* spp. (Indigenous lemon grass)
    - *Vetiveria nigritana* (Indigenous vetiver grass)
    - *Citrus* spp. (Particularly *Citrus paradisi*: grapefruit)
    - *Adansonia digitata* (Baobab)
- Start investigating a "dark horse": *Satureja biflora*
- Have the extracted oils' physical and chemical properties analyzed in the laboratory.
- "Mozambique Essential Oils Inc." should start to develop a comprehensive value chain using essential oils extracted from the country's flora.
- Start to cultivate targeted plants, which have progressed through the process of scientific development on land most suitable for a plant throughout the country.
- Farming communities in regions where certain essential oils, which could be sustainably extracted from natural resources, should be trained in all aspects of the industry.

- The capacity to manufacture extraction equipment, both distillation and cold pressing, and varying from the simples and smallest to large and sophisticated, should be developed in Mozambique.
- It will be necessary to establish a sophisticated purification plant in Mozambique once the volumes of essential oils moved into international markets become substantial.

A presentation was made on **Possible Strategies to Integrate Aromatic Plant Essential Oils with other Post Harvest Value Adding Industries in Mozambique**

The aim was to alert the attendees to our view that a future aromatic oil industry in Mozambique will, in most cases, be integrated to other agricultural ventures to the extent that, for example, cultivation of essential oil crops will happen parallel to farming with other crops, such as bananas; that processing will happen in parallel and that integration will also include production of products where essential oils are combined with products from other agricultural streams.

- The products from the coconut industry could include essential oils in products such as soaps and candles.
- Cold pressing of the kernel of Canhu (Marula), for the extraction of its fixed oil, could be integrated with the fixed oils from other nuts such as Macadamia, Cashew and Groundnut to produce unique culinary oils.
- The same species, which delivers valuable essential oils, could also produce fresh herbs for culinary purposed, such as lemon grass, garlic and rosemary.
- Processing grade citrus would be ideal for the production of citrus oils.
- When pilot projects are undertaken, opportunities of integration will have to be considered.
- In many cases the primary grades of an agricultural crop is aimed at the retail or export market, while the processing of second or third grade may present opportunities for integration with aromatic oils.
- The beneficiation of the medicinal plants of Mozambique could benefit from the same approach, for example where a cold press could be shared for a number of products.
- These techniques could also be used for the production of high quality spices, pastas, sauces etc.
- An advantage of aromatic oil production is that, if well packaged, the product has a long shelf-life, easily transportable and of relatively high value. This makes it ideal to integrate with other crops, especially in a cooperative type agribusiness, where resources could then be shared. – See Figure below for a typical model.
- Most of the pilot projects, which will have to be undertaken to establish an aromatic oil industry in Mozambique will have to be within the framework of a Co-operative Agri-business.
- Pilot projects of this nature will each require professional inputs with associated costs.



At this stage of the workshop we proceeded with the SWOT's analysis, which took the format of a free brainstorming session with, the comments, ideas and foresight of all the attendees recorded under the headings of Strengths, Weaknesses, Opportunities and Threats. The results are recorded below.

- **Strengths**

  - Large population of indigenous plants with aromatic and essential oil potential.
  - Strong knowledge base on the botany of the indigenous plants. The existing capacity at the Botanical Gardens could form the basis of a Centre of Expertise in genetic selection, propagation and cultivation.
  - Long-standing history of agriculture and horticulture.
  - Ideal agricultural conditions (climate, soil) to establish a strong essential oil industry.
  - The Chemistry Laboratory at the Eduardo Mondlane University could be developed into an internationally accredited essential oil laboratory.
  - ARORA Co. case study is a good example of a success story in this field with a small capital outlay.
  - AFRICAN NATURALLY is another case of success particularly with citronella and lemon grass.
  - Mozambique's low labour costs could initially be a strength, but no reliance should be placed on the sustainability of this factor of production.
  - The knowledge base of the traditional healers could also be tapped into to identify new opportunities.

- There is an existing home market for products containing essential oils as well as fresh herbs from which the oils are extracted.
- Favourable trade agreements exist, favouring developing countries, such as Mozambique, against developed countries. These trade agreements should be exploited.

- **Weaknesses**

- No established and internationally recognized industry in essential oils.
- Lack capacity and resources needed to drive a serious move into establishing an industry.
- High cost involved in establishing new and improved crop varieties.
- Need to establish links with trustworthy marketing and distribution networks.
- Slow rate of uptake of new technology in most of the sectors of the industry.
- Short to medium term focus must be on recognized commercial oils rather than indigenous plants. It will take a long time to establish a " new " essential oils in international markets.
- Lack of capital investment to develop processing establishments.
- Infant stage of Research and Development.
- Limited funds available for basic research.
- There is a shortage of qualified human resources in Mozambique, including those with the skills to build and maintain an internationally competitive essential oils industry such as extension officers to serve the growers cultivation aromatic plants.
- A small domestic market and need to look into international markets.
- Difficulty in entering into established markets.
- Mozambique is a vast country with large and distant areas, which will require expert inputs.
- There is a shortage of specific market based information.
- A system is lacking to protect intellectual property, derived from traditional knowledge, including the knowledge of healers representing the traditional people. What benefits will accrue to traditional communities if unique molecules, compounds and formulation, discovered in their region, are commercialized? Legislation needs to be put in place.
- Lack of knowledge and experience to implement, maintain and operate according to established Fair Trade Practices, EUREPGAP and HACCP to meet market requirements such as traceability.
- There are no accredited quality control and assurance laboratories.
- There is a lack of Government investment in the cultural aspects of traditional knowledge with specific reference to medicinal plants and medicines not used in hospitals.
- There are no incentives to invest in products derived from traditional resources.
- The cost of doing business in Mozambique (e.g. fuel, fertilization) is the highest in the sub-continent.
- Funding always seems to be available for project studies but not for project implementation.

- **Opportunities**

  - Can start an industry with a "clean slate".
  - There is a global consumer trend towards the use of " natural " over synthetic products.
  - A well thought through and implemented strategic plan will result in a growing presence in international markets.
  - Foundations exist on which to build capacity in genetic selection, propagation, multiplication, cultivation and quality assurance and control.
  - New "miracle oils" may be lurking in the indigenous flora of Mozambique. It will require painstaking work to find these and prove their value.
  - The potential exists to build and grow " Mozambique Essential Oils Inc. "
  - Growth in niche markets, where quality is more important than price.
  - International users are always looking for new oils and aromas and sustainable sources for the supply thereof.
  - Strong growth in the pharmaceutical, cosmeceutical and neutraceutical industries leading to growth in demand for essential oils and plant extracts.
  - Opportunities to extend the range of available products including new product development through biotechnology.
  - Many opportunities exist to integrate agri-industries such as:
    - Citrus production where fresh produce for both the local and export markets will be the basis for the production of various citrus oils.
    - The integration of a baby/infant food pulping plant with the production of various products from medicinal plants.
  - Growth of foreign investment.
  - A national grid of small extractions facilities such as distillation plants, even mobile plants, could be made available for small community-based farmer cooperatives.
  - Mozambicans could start their own value chains incorporating oils extracted from aromatic plants, such as indigenous ranges of cosmetics including hand and body creams, shampoos and perfumes for local consumption as well as making these products available to the growing tourist trade. However, extreme care should be taken with quality and toxicity issues.

- **Threats**

  - Rushing into creating an industry can result in failure – you only get one chance in the competitive global markets for essential oils.
  - The reputation as an untrustworthy supplier to major players, such a prominent perfume companies, will be devastating
  - Lack of a strategic plan can expose the valuable resources, both natural and cultivated, to unscrupulous exploiters
  - It will be dangerous to place too much reliance on indigenous flora to form a foundation of a future essential oils industry.
  - Competition from available synthetic products.
  - Competition from well established countries' products.

- Incorrect decisions about the genetic integrity of material use for large scale cultivation could be devastating.
- Market demand for oils and extracts can be subject to strong fluctuations.
- High cost of meeting overseas market entry standards, such as those set by the Food and Drug Administration of the US.
- The use of incorrect horticultural practices could scuttle any efforts to become an major recognized supplier.
- Any extract from plants, including essential oils, are potentially dangerous, even poisonous. Lack of highly scientific analysis and quality assurance could result in total rejection by international users and consumers.
- The ability to demonstrate the trace-ability of products is lacking, exposing risks, for example, where a product may be toxic.
- High levels of pricing in factors of production, such as electricity and fuels, as well as wide fluctuations in exchange rates.
- A shortage of skills at technical and management levels, particularly to start and maintain large scale agricultural projects.
- Mozambique is starting, and is already falling behind her neighbours in the production and marketing of essential oils.
- There is a long time lapse between identifying projects, the planning stage, finding the funding and then the implementation stage.
- This will just be another Report by a bunch of consultants, which will land on a shelf and gather dust.

2.2 Interaction with stakeholders over three missions

During the course of the study we visited Mozambique on three occasions. Each mission had a particular set of goals, including interaction with as many as possible of the stakeholders in a future aromatic oil industry.

- **Mission 1**: 8 – 10 March 2006.

  - The goals for this mission included meeting as many of the key players, who could impact on our study, as possible. This included the CPI, where we met with Mr Rafique Jusob, the CPI Director, to discuss what we aimed to achieve with our study and receive his views at the earliest possible stage.
  - Met with Dr[a] Samira Izidine of the National Institute of Agronomic Research (INIA), to discuss the Terms of Reference of our study and how we plan to achieve our goals.
  - Familiarized ourselves with the facilities at INIA, including the Herbarium and the tissue culture laboratory.
  - Met with Dr Filesberto Pagula of the Chemistry Department at the University Eduardo Mondlane, and visited the laboratory in the department to assess the capacity of the laboratory. Set up the distillation apparatus, which was made in Stellenbosch and brought to Maputo, in the laboratory. Started a distillation on a Geranium species.
  - Met with various people who may be interested in becoming involved in the roll-out of aromatic oil projects, including Mr Paolo Negrão of Citrum.

- A meeting at CPI where a number of people representing the private sector were present. It was helpful to get their views on how they see their future involvement in projects and on the potential of an aromatic oil industry.
- Had follow-up meeting with CPI. Proposed that a workshop should be held involving as many stakeholders as possible.
- Interaction at the Department of Agriculture with executives on prospects of aromatic oils and support structures offered by the Department.
- Spent time in the National Herbarium to assess the information available including information on sizes of species populations.
- Had a meeting with Mr José Armando da Cunha Ferreira of Somonav in Maputo harbour about the possibility of manufacturing extraction equipment, such as large steam distillation plants, in Maputo.

• **Mission 2**: 19 – 21 April 2006

- Continued work in the National Herbarium.
- Assessed potential of Botanical Gardens.
- Had the Workshop in Maputo on 20 April. Presentations were made and all the delegates participated in a SWOT's strategy planning session.
- Had one-on-one meetings with delegates after the workshop on their own plans to start producing aromatic oils.
- Visited possible sites for pilot projects in Maniça and surrounding areas.
- Met with Standard Bank in Maputo to assess their approach to small-scale agricultural projects.
- Further meeting in laboratory at chemistry department on extraction and analysis of plant material.

• **Mission 3**: 16 – 19 May 2006

- Continued work in the Herbarium.
- Attended the Mozambique Business and Investment Conference on 17 May 2006, between 08h30 and 14h00 in Maputo. The aim was to get an overview of how the investment community regards Mozambique, and meet key players in the structures, which direct investment into Mozambique.
- Had a working session with Dr Salomão Bandeira and his colleagues from the Department of Biological Sciences at UEM on the resources needed to create a Centre of Expertise in the Department.
- Had a working session with Dr Filesberto Pagula on the resources requires towards accreditation of the laboratory.
- Had a working session with Dr[a] Samira Izidine on the resources required to create a Centre of Expertise at INIA.
- Met with Mr Omar Mitha from PODE-Cat on his organizations funding model.
- Working session with Mrs Judite Pinto of Ricino Moçambique, Lda on expanding her castor oil farming operation in Nampula to a fully fledged large scale pilot project.

2.3 The cases of developing nations

For the purpose of designing a strategy for Mozambique, we considered the history and current developments of aromatic oils in a number of developing countries:

- Madagascar
- South Africa
- Zambia
- Rwanda

The information on these countries is dispersed throughout the Report and will not be further elaborated on here.

SECTION 13
RECOMMENDATIONS

Throughout the Report we have already highlighted a number of recommendations. We would now like to order all of our recommendations together.

1. Do not attempt to harvest from nature any (with the exception of those few species, highlighted later in these recommendations) of the indigenous plants identified and selected during our survey, for the purpose of beneficiating their aromatic oils until such time that:

   - The size of the population(s) of targeted species, at the locations where they naturally occur, have been determined;

   - The knowledge of the natural propagation and multiplication of each of the targeted species at their various locations has been gained, and the factors which will ensure sustainable harvesting from nature has been determined;

   - The oil extracted from each targeted species has been assessed on a small scale in terms of its market acceptance, including the quality criteria which the market will demand;

   - The science and technology of the propagation and cultivation of each targeted species within a nursery environment has been secured through research and development;

   - Once this science and technology is in place, a decision could be made to harvest from nature, or rather cultivate a particular species on a commercial scale, or use both approaches.

2. Commence, as soon as possible, with initiatives, including pilot projects, which will enable existing commercial and rural farmers to start cultivating plants producing known aromatic plants with established international markets for their oils. In the Report a number of species have been highlighted which will result in potentially viable ventures, already in the short term. There are specific recommendations later on regarding pilot projects.

3. Start to guide all people wishing to participate in establishing Mozambique's aromatic oil industry, particularly commercial and rural farmers, to operate within the frameworks of quality, as demanded by international markets. All operators must accept and work according to the procedures, which will ensure that the uncompromising demands for quality are satisfied. All participants must commit themselves to all aspects, which are part of international quality criteria, including traceability, sustainability, fair trade principles, the criteria of the Forestry Stewardship Council, where applicable, the criteria which define organic farming, and others. All participants must commit themselves to the value system, which will define **Mozambique, the Green Country**.

4. Start building the capacity in Mozambique necessary to understand and apply all the sciences and technologies necessary to establish and maintain an aromatic oil industry. This will include the capacity to propagate and cultivate all targeted species, the extraction of the oils and the procedures of quality assurance and control, and to disseminate knowledge gained to all participants in the industry. We recommend that a number of Centres of Expertise be created:

    - Within the Chemistry Department at the Eduardo Mondlane University (EMU) to become a fully internationally accredited laboratory to ensure that all aromatic oils marketed from Mozambique meet international criteria of quality assurance and quality control.

    - Within the Instituto Nacional De Investigaçāo Agronómica (INIA) in Maputo, to undertake the development of the science and technology of the propagation and cultivation of all plant species considered for commercialization. To establish a large nursery for providing plant material to large scale growers and to ensure the maintenance of the genetic integrity of all species being commercialized.

    - Within the Department of Biological Sciences at the Eduardo Mondlane University, to have the capacity to train botanists and horticulturalists, at undergraduate and post graduate levels to find employment in Mozambique's growing aromatic oil industry; to conduct the necessary research in identifying promising species of indigenous plants; to propagate and cultivate these plants on a large scale; to establish a large experimental farm where indigenous and commercial aromatic plants will be grown and the oils extracted, to demonstrate the commercial viability of ventures into aromatic oils. To offer the necessary support to the extension services of the Department of Agriculture.

5. A Centre of Market Information must be created. This Centre must be geared to collect, process and disseminate international market information on an ongoing basis to all participants in Mozambique's aromatic oil industry. The ideal is that it must be an Association representing all participants in the industry in Mozambique.

6. Links must be established with international marketing organizations already at the early stages of Mozambique's aromatic oil industry. These organizations must commit themselves to long term involvement with the industry and subscribe to the values of **Mozambique, the green country**. Our own marketing network is ready to join such an initiative.

7. Start to implement a number of pilot projects. Each of these projects will require outside financial support, at least during the establishment stage. We are convinced that with proper business plans, detailing each pilot project, such funding will be forthcoming. Certain projects will become financially self-sustaining sooner than others, but once started and guided by a business plan, there is no reason that all these projects will not be successful, especially if their development takes place in concert with the capacity building initiatives referred to above. All these projects will rely heavily on the capacities, which will develop in these Centres of Expertise. We recommend that the following projects be undertaken:

- The beneficiation of all products, including the aromatic oil, derived from the indigenous tree *Scerocarya birrea* subsp. *caffra,* also known as canhu or marula. Such a project will entail a number of actions to ensure that all the products, which this species deliver, are viably beneficiated. (See the Technical Report on this species). This project has to be initiated as soon as possible, as the season for marula fruit is approaching. It is recommended that a start, however small, be made already this year.

- The beneficiation of all products, including the aromatic oil, derived from the indigenous tree *Adansonia digitata*, also known as the baobab or chimuho and mulapa. As for the marula, such a project will entail a number of actions to ensure that all the products, which this species can deliver, are viably beneficiated. (See the Technical Report on this species).

- The cultivation of at least one of the annual commercially established species, selected in this Report, with the aim to establish a viable venture. (See the Technical Reports on all the commercial annual plants selected for cultivation). This could entail more than one project, as a further aim must be to produce organic oils from annual plants. It is advisable that all projects centers around a mentor who would probably be an established farmer.

- The cultivation of at least one of the perennial, commercially established species, selected in this Report, with the aim to establish a viable venture. (See the Technical Reports on the perennial plants selected for cultivation). This could entail more than one project, as a further aim must be to produce organic oils from perennial plants.

- At least one project which will demonstrate the viability of integrating the cultivation and processing of aromatic plants with other commercially viable crops, such as bananas, vegetables and others with established demand. Such a project may also entail the sharing of various capacities such as nurseries, extraction facilities and, of course, labour.

- We recommend that at least one project be initiated to beneficiate one or more of the oils extracted from *Citrus* species. Mozambique has a long history of activity in citrus production and the past experience could now be put to good use. We have gone into fairly great detail on the potential of citrus oils in international markets. Such project(s) could also demonstrate the viability of intercropping with other aromatic plants. At least one project must aim to demonstrate the viability or organic citrus oil production.

- The agroclimatic variables and soil conditions in Mozambique are ideally suited to cultivate a number of plants with established international markets for their oils and other products, including:

  - *Linum usitatissimum* - Linseed and flaxseed oil and fibers
  - *Cymbopogon nardus* - Citronella oil
  - *Lippia javanica* - Lippia oil
  - *Ricinus communis* - Castor oil
  - *Cananga odorata* - Ylang-Ylang oil

- *Pogostemon patchouli* - Patchouli oil
- *Rose damascena* - Rose oil
- *Piper nigrum* - Pepper oil
- *Cannabis sativa* - Hemp oil

8. Any one, or combination of projects referred to above, could be undertaken within the framework of what is known as an Eco-Agro Village, to demonstrate how a community centered around such a village could benefit and become self-sustaining within a relatively short period of time.

9. A number of the projects referred to above, should be undertaken specifically in the northern provinces of Niassa, Cabo Delgado and Nampula. Not only because these provinces are the most distant and reputedly the most in need of economic regeneration, but also because they have many strengths as far as agricultural potential is concerned.

10. We are concerned that this Report will have the same fate as many others, which resulted from other studies and surveys – gather dust on a shelf somewhere. We are determined not to allow that to happen. The Report contains a vast array of information, which will help any entrepreneur in aromatic oils to establish successful ventures in Mozambique. We are ready to use this information, resulting from our own efforts, to participate in the process to turn these projects into flourishing realities. We therefore recommend that we be given a mandate by the most appropriate authority in Mozambique to use this Report as basis to mobilize the available mechanisms to implement as many projects in aromatic oils in Mozambique, as possible.

SECTION 14
STRATEGY IMPLEMENTATION: FUTURE IMPERATIVES – PROSPECTS AND INITIATIVES

1. A proposed strategy

1.1 To start: cultivation rather than harvesting from nature

We have presented a strong argument that an aromatic oil industry in Mozambique must be started cultivating commercially known essential oil producing plants rather than trying to harvest indigenous plants from nature. Furthermore, the cultivation of indigenous plants will be a more viable option once the science of their propagation and cultivation is well understood and could be put into practice. We have highlighted two possible exceptions, namely marula (canhu) and baobab, but pointed out that even the beneficiating of their fruit from the wild must be done with due consideration of the factors which will ensure that it could be done in a sustainable way.

We strongly recommended that a number of pilot projects be initiated as the first steps towards implementation of this strategy. Each pilot project must be undertaken within the framework of its own business plan. Each business plan must deal with those critical questions and issues, which will determine the profitability and sustainability of each project. Here is an example of the structure of a typical, albeit simple, business plan:

Project: The Beneficiation of *Sclerocarya birrea* subsp. *caffra* (Marula or canhu)			
Action		**Cost factors**	**Income potential**
1.	Where are the most densely concentrated populations of this species	The cost of the field survey to answer these questions. It involves field workers and the cost of doing the work at the location(s) chosen.	No income yet.
2.	How many trees are there?		
3.	What tonnage of fruit can be harvested from this population?		
4.	What tonnage of pulp could be extracted?	A trial has to be done, during the fruiting season. What cost factors?	
5.	What tonnage of kernels could be retrieved from the nuts?	A trial has to be done after the fruiting season.	
6.	What is going to happen with the pulp to realize some value?	Investigative work has to be done beforehand and pulp produced	
7.	What equipment is necessary to process the pulp?	How much will the equipment cost? What other cost factors?	
8.	What equipment is necessary to extract the oil?	How much will the equipment cost? What other cost factors?	
9.	What price could be realized for the pulp in an unprocessed, alternatively processed from?	What are the cost factors to get it extracted and to market?	
10.	What price could be realized for the oil from the kernel in a raw and refined form?	What are the cost factors to extract the oil, get it refined and then to market?	
11.	Who and where is the market?	What is the market prepared to pay?	Almost there
12.	What yield of oil was achieved?	Is the yield the optimum possible?	

13.	Is the quality of the oil as demanded by the market?	What cost factors to get the quality to standard?	
14.	What are all the required quality assurance and control criteria?	What are the costs involved to meet these criteria?	
15.	The customer received the oil.	How much to get it packed and to the customer?	Almost!
16.	When and how is the customer going to pay?	What cost if payment is not cash?	Now really almost!
17.	The cash is in the bank.	Have all variable and fixed costs been covered?	Yes? The sale is done!
18.	Is the customer interested in a next sale? When? Next year?	How are we going to survive till next year?	The cash in the bank is not enough!
19.	It may help if we could expand the operation – beneficiate larger populations of trees.	What are the cost factors if we want to expand the operation to the critical size where profitability will be more certain?	How will we fund this expansion?
20.	Conclusion	Start up pilot projects of this nature will require support funding.	How much and from where?

This very simple and not remotely comprehensive scenario sketches a framework, which, in different shapes or sizes, will apply to each pilot project (or outright commercial project) to be undertaken during the establishment of Mozambique's aromatic oil industry.

Business plans, detailing each and every pilot project will have to be completed. Apart from the wisdom attached to having a well-constructed business plan for each new venture, it must be recognized that pilot projects, at least during the initial stages, will depend on the availability of external funding. This planning, followed by implementation, process will drive each project, and will be demanded as such by funding organizations interested to support (and benefit from) the establishment of such an industry.

We are convinced that with the insights generated by this Report, together with business plans detailing pilot projects to be undertaken, it will be possible to generate adequate financial support, in the form of grant funding, to fund projects, at least during their establishment stage, when the risks are the highest.

It is this conviction, which motivated us to recommend that we be given a mandate to use the Report to approach various funding organizations. Such funding will be aimed at the critical gaps in the enterprise developments process including costs related to research and presentation of the business plans.

Grant support funding will also be necessary to initiate the creating of the capacities needed to provide technological and technical marketing support to a fledgling aromatic oil industry. Even in the case of each proposed Centre of Expertise, a business plan will have to be presented to motivate requests for financial support. We are ready to drive this process.

1.2 Building capacity in strategically important areas

At the beginning of, and throughout, this Report, we have argued strongly that capacity needs to be built in a number of strategically important areas for Mozambique to succeed as a successful producer and marketer of aromatic oils.

Without any doubt, the most important factor in entering the international marketplace for aromatic oils, and maintaining a competitive position therein, is quality of product produced and marketed.

We have also stressed that quality is a multi-facetted factor, where the quality product, which arrives at the factory of the internationally branded perfume producer, is predetermined already by the agricultural and management practices employed throughout the value chain, including the quality assurance and quality control practices used.

Capacity needs to be build in each and every link in the value chain, but we would like to stress three areas, because these are not only critical for future markets access, but will require substantial attention and investment at the beginning of Mozambique's journey towards international status as an aromatic oil producer – strong capacity in these three areas is almost a prerequisite before seriously embarking on the journey. This is putting it strongly. In reality a number of actions need to happen in concert, as we spell out in the proposed strategy. But the commitment needs to be made, at the beginning, to build the required capacity in these areas, and the investment, also in monetary terms, made.

- <u>Build an internationally accredited capacity in quality assurance and quality control</u>

  It is proposed that a Centre of Expertise by way of an internationally accredited laboratory for quality assurance and quality control be established within the Chemistry Department of the Eduardo Mondlane University in Maputo.

Dr Filesberto Pagula, Head of the Department, already has extensive experience in various aspects of the quality assurance and control of aromatic oils. The laboratory already has most of the instrumentation needed to start the process of quality assurance and control. This fact presents an opportunity to expand the laboratory around Dr Pagula's knowledge and expertise. A priority will be to expand the knowledge and skills base by investing in the human capital needed for quality assurance and control in Mozambique.

As a result of discussions, at a number of occasions, with Dr Pagula on what will be required as a first stage extension of what already exists in his laboratory towards achieving the goal of internationally accreditation in quality assurance and control in aromatic oils, we completed a list of items and action which need attention and also financial inputs:

	Requirements
	Support Equipment
1	Back-up power source such as a generator: power outages can do damage to the existing instrumentation, and could delay analysis especially when the workload is high.
2.	New UPS to control power supply. Battery based. Avoid instruments cutting out.
3.	Air conditioning unit to ensure temperature controlled environment for instrumentation.
	Instrumentation and laboratory items
4.	Range of columns for gas chromatography to analyse wide range of oils
5.	Spares for gas chromatograph and mass spectrometer to be held in stock
6.	Instrument needed for measuring optical rotation
7.	Instrument needed for measuring boiling point
8.	Instrument needed to measure refractive index.
9.	Range of columns for gas chromatography to separate on basis of chirality and determination of enantiomers.
10.	Range of glassware
11.	Syringes for injecting samples for analysis.
12.	Small items such as septums for the capillary columns.
13.	Range of chemicals including solvents.
14.	Small cold press, with cooling, to extract fixed oils.
15.	Cooling mantle for existing distillation apparatus.
16.	Standards of aromatic oils as used in other accredited laboratories.
	Services and other operating costs
17.	Transport to make collections of plant samples. The laboratory may need its own transport.
18.	Rental of laboratory space: an agreement will have to be reached with the University.
19.	Costs related to international accreditation e.g. ISO, HACCP, Organic etc
20.	Costs related to maintenance of laboratory equipment
	Costs related to building human capital
21.	Fees/salaries of at least two chemists to be trained in the field of aromatic oil analysis. Two current staff members are ready to be trained to MSc level.
22.	Subscription to few of the most important international journals in the field of aromatic oils.
23.	Purchase of a few of the most important books in the field of aromatic oils to start building a library.
24.	Travel in Southern Africa e.g. to establish contact at the University of Stellenbosch
25.	Travel internationally to at least one prominent international conference per year.
26.	Costs related to inviting international experts to provide training to UEM staff. As an example we refer here to establishing a relationship with ASSNAP and Rutgers University

- Build a capacity in the areas of:
  - aromatic plant propagation and cultivation;
  - an ability to conduct research and development;
  - establish an experimental farming capacity;
  - collection of data to expand the current information base on Mozambique's indigenous flora, particularly aromatic plants;
  - establishing a Botanical Gardens specifically aimed at aromatic plants;
  - education and training of people whose knowledge and skills will be required by a growing aromatic plant industry in Mozambique.

It is proposed that the Centres of Expertise focusing on the abovementioned areas be created at the Institute of Agronomic Research (INIA – Instituto Nacional de Investigação Agronōmica) and the Department of Biological Sciences at the University Eduardo Mondlane (UAM). Both these institutions have already done groundbreaking work in all the abovementioned areas and have now certain core capacities in place.

Discussions with Dr[a] Samira Izidine from INIA have confirmed the fact of the existing capacity at the Institute but also the need for further investment into capacity building. For example, the existing capacity in plant propagation, particularly using tissue culture, with the accompanying excellent laboratory facilities, provides the base from which large-scale propagation of aromatic plants could be achieved. The propagation of plants should feed into a nursery where plants could be readied for distribution to commercial nurseries throughout the country.

We have frequently recommended in our Report that Mozambique should not attempt the beneficiation of any indigenous aromatic plant until such time that the full extent of the science of its propagation and cultivation is well understood and could be applied to initiate and maintain the cultivation any particular indigenous species with commercial potential. We propose that the capacity be created to at INIA and UEM to achieve this objective.

Together with Dr[a] Samira Izidine we have identified the following activity areas, which will require investment into capacity building:

	Requirements
1.	That adequate land at INIA be identified for the development into a nursery for the cultivation of aromatic plants.
2.	Additional structures and spaces will have to be created for the nursery, intended for the cultivation of both indigenous and commercial plants, including: ▪ greenhouses ▪ growing areas under shade ▪ open growing areas ▪ an area for filling of bags and containers with growth medium ▪ an area for planting of propagation material including cuttings, seeds and material from tissue culture.
3.	The capacity of the tissue culture laboratory will have to expand as the need to propagate aromatic plants gain momentum.
4.	An operation to prepare growth medium on a large scale will have to be established.
5.	People have to be provided with the necessary skills in all the activity areas mentioned. Training has cost implications.
6.	A section must be created for cultivation of plants intended for organic farming. This section will have to be certified together with other organic initiatives throughout the country, with accompanying costs.
7.	The capacity must be created at INIA to determine the genetic structure of any aromatic plant intended for commercialization, to monitor and maintain its integrity, and to safeguard valuable germplasms as a national asset.
8.	To establish a large scale commercial wholesale nursery, which will sell aromatic plants to other commercial nurseries. There will be costs associated to rental from INIA for spaces and services used.
9.	Establish a Botanical Garden specifically aimed at aromatic plants, particularly Mozambique's Indigenous plants. This will have cost implications, especially the preparation of land and the equipment needed such as a small tractor.
10.	Additional people will require financial resources for salaries and fees.
11	It will be necessary to build an international network involving experts from other countries and institutions. We refer again to the contacts, which could be established with ASSNAP, Rutgers University, the University of Stellenbosch and others. All these interaction will have cost implications.

Discussions with Dr Salomão Bandeira and his colleagues, Dr[a] Filomena Barbosa and Dr[a] Anna Senkoro, have highlighted the possibilities presented by the Department of Biological Sciences at UEM.

Although the primary function of a university is to deliver human capital, Dr Bandeira and his team have developed substantial research capacity, which could be invaluable to a future aromatic plant initiative in Mozambique.

The existence of an inventory of indigenous plants and the taxonomic ability to expand this inventory, with a focus on aromatic plants, will be an important contribution to establishing an industry in aromatic plants.

The comment was made that the development of human capital must be market related, particularly in the case of Mozambique with its lack if people with directed knowledge and skills. This realization emphasizes the importance that UAM and the Department of Biological Sciences should also direct activities at the needs of a growing aromatic oils industry and the various sectors therein. These activities should, on the one hand, progressively grow as the needs of the industry expand, for example, as the need for knowledgeable and skilled people, becomes better known. But, on the other hand, the institution should also play a more entrepreneurial role by guiding the industry into the technologies involved in commercializing aromatic plants and products, through, for example the establishment and operation of an experimental farm, not only for the purposes of research and education and training, but also of demonstrating the commercial viability of ventures into aromatic oils. Such an experimental farm must be operated for commercial gain, as it will be the best demonstration that, when correctly done, the production of aromatic oils is a viable business.

It will not make sense to start producing people qualified in a variety of aspects of aromatic plant beneficiation if the market in Mozambique is not ready for them. They will merely disappear over the borders of the country to places where their skills are in demand. It is advisable to plan the education and training of people, at both undergraduate and postgraduate level, to coincide with the increasing demand for their skills – the proposed plan to establish sizeable production capacity will allow for the employment of a considerable number of the qualified horticulturalists and other technologists from the UEM. Education and training schedule could be expanded as the market grows in terms of, say, income generated by the sales and exports of aromatic oils. Assuming there are currently about 50 students in total at the undergraduate level, over the period from the first year to year of graduation with a B-degree, the expansion schedule can work something as follows:

- If the "national strategic plan for the beneficiation of aromatic plants" projects that sales (local end exports) of, say, US$ 1 million could be achieved by the end of the first year from a certain date, the commitment and resources must be in place to:

- Lecture 10 hours per month at the undergraduate level on subjects directed at the production of aromatic oils, from propagation, to cultivation and extraction, including Good Agricultural and Good Management Practices, which will then require some practical work in nature and on the experimental farm;

- Get at least one postgraduate student started on a project in the field of aromatic plants and oils. The experimental farm will be invaluable for the practical work of the student(s).

▪ If the "national strategic plan" projects that sales of, say, US$ 3 million, could be achieved at the end of the second year, the commitments and resources must be in place to:

- Lecture 20 hours per month at the undergraduate level on the important and relevant subjects;
- At least two postgraduate students must now be working towards their postgraduate degrees.

▪ If the " national strategic plan " projects that sales of, say, US$ 7 million, could be achieved at the end of the third year, the commitments and resources must be in place to:

- Lecture 30 hours per month at the undergraduate level on the important and relevant subjects;
- At least three postgraduate students must be working towards their postgraduate degrees.

▪ If the "national strategic plan" projects that sales of, say, US$ 10 million, could be achieved by the end of the fourth year, the commitments and resources must be in place to:

- Lecture 40 hours per month on the important and relevant subjects at the undergraduate level;
- At least four postgraduate students will be working towards their degrees. At least three postgraduate students should have completed their studies and should be employed in the aromatic oil industry in Mozambique.

▪ By the time the "national strategic plan" projects that US$ 100 million sales per year could be achieved in a given year, the commitments and resources must be in place to:

- Offer undergraduate degrees majoring in subjects on the important aspects of aromatic oil production, graduating 10 or more graduates per year;
- Graduate at least five students with postgraduate degrees per year.

We have identified a number of activity areas, which will require investment in terms of monetary and physical resources:

	Requirements
1.	It will be good strategy to start with the education and training of a few students, at undergraduate level in aspects of aromatic plant cultivation and beneficiation as suggested above.
2.	A start must be made with the education and training of students at the postgraduate level in fields of importance to the future Mozambican industry in aromatic plants, as suggested above.
3.	Develop an experimental farm, on or close to the campus of the UEM. The farm will also serve as a demonstration farm to show that production of aromatic oils is a viable business opportunity. Ultimately, more than 200 hectares of land will be needed. The experimental farm will require the following inputs: ▪ A full-time and qualified horticulturalist will have to be appointed to oversee the establishment of the farm and manage it later on; ▪ Equipment to develop the farm will have to be acquired including a tractor, ploughs, etc. ▪ Infrastructure, including buildings for storage and operations of the distillation plants will have to be erected; ▪ A building, which could serve as a laboratory and seminar room will be needed. This facility will not only be used for the education and training of UEM students, but also to offer courses to farmers and producers of aromatic oil from across Mozambique; ▪ An industrial size distillation plant will have to be acquired; ▪ A nursery, where plants will be propagated and readied for cultivation, will be needed. This will require covered spaces including a greenhouse and shaded structures. This nursery should collaborate closely with the nursery at INIA.
4.	A facility, which could be operated as a separate entrepreneurial venture, to refine the oils produced across the country, before being dispatched to the markets of the world, could be established at the experimental farm. This facility should collaborate closely with the Accredited Quality Assurance and Control Laboratory in the Chemistry Department at UEM;
5.	Build capacity within the ranks of the academic and research staff at UEM within the broad field of aromatic oils. For more details see our proposal on the role which could be played by ASSNAP, the University of Stellenbosch and Rutgers University in the USA.
6.	The UEM should also consider establishing courses, which could lead to qualifications in perfumery, formulations of cosmetics and other fields, which could support the development of capacity in end-product manufacturing.
7.	The experimental farm should operate on the principles of entrepreneurship. A separate company should be formed wherein the staff of UEM, directly involved in its operations, should have an interest. There could also be a place for private investors. The UEM could maintain a majority stake. It is important to demonstrate that entrepreneurial principles work.
8.	Sophisticated technologies, such as super critical extraction , could, in future also be established within the framework of the experimental farm.

How are all these proposed actions and creation of capacities to be realized? It will require funding during all the stages of implementation of the range of projects referred to above, as well as the commitment of a number of people who can influence the process. A case must be presented to funding organizations that the building of capacity as presented above will be critical to initiate the process to grow an industry in aromatic oils of substance in Mozambique.

An ideal situation will be if funding could go hand-in-hand with organizations that are geared to build the capacities required. One such organization is ASSNAP – Agribusiness in Sustainable Natural African Plant Products. ASSNAP has indicated their willingness to become involved in capacity building projects, based in Maputo, Mozambique.

Background on ASSNAP

- ASSNAP (Agribusiness in Sustainable Natural African Plant Products) is based in Stellenbosch, South Africa, but operates in many countries in Africa.
- ASNAPP's mandate is to promote and support agribusiness development, with a focus on strengthening farm-agribusiness linkages, accelerating income and employment generation, improving food security, and increasing competitiveness through high-quality natural plant products. By tapping global demand for high-value products, ASNAPP strives to unlock the true value of Africa's "green gold" to the benefit of resource-limited producers. Through enterprise development models and integrated interventions, ASSNAP provides a sound technology base for socially conscious and environmentally sensitive plant production. Application of services leads to improved farming practices, access to cost-effective support services, development of new high-quality products for export, natural resource protection, improved infrastructure and skills capacity, opportunities for value addition at local level, and sustainable agribusiness and job creation.
- ASSNAP is already involved in projects in South Africa, Ghana, Rwanda, Zambia, Senegal and Malawi.
- ASSNAP has launched a brand MPUNTU, which is already used for a wide range of products. MPUNTU, an Akan expression of Ghana representing " progress in development " as the brand, forms the proud signature of ASSNAP's commitment towards sustainable development, encompassing the very essence of broad-based economic, social and environmental growth, as well as quality of life for present and future generations. The brand depicts that the livelihoods of rural poor communities form the central position of ASSNAP's university-led public-private partnership.
- With this brand and the product range it represents, ASSNAP demonstrates its total commitment to help move producers up the value chain, empower agri-entrepreneurs to take a much more prominent position in the global arena, and to serve as impetus to a truly natural Africa Renaissance.
- ASSNAP is closely associated with Rutgers, the State University of New Jersey in the USA. Rutgers University is strongly positioned to provide the technical inputs necessary to execute ASSNAP's stated mission.
- Prof. Jim Simon, leading the group at Rutgers University has now been appointed Extraordinary Professor at the University of Stellenbosch, which not only provides another link with the University of Stellenbosch, but also places the expertise provided by Rutgers within closer reach.
- ASSNAP gets involved in a project on the basis that the merits of a project will result in funding from a network of funding organizations.

ASSNAP is willing to consider involvement in a capacity building project in Maputo, specifically to create the necessary capacity within the Centres of Expertise detailed in this Report. It will require that the "business plan" to establish these Centres present such a strong business case that funding organizations will provide the necessary funding.

1.3 Negotiate market access

With the capacity in place to ensure that international quality assurance and control criteria will be adhered to in Mozambique; that pilot and commercial projects will have the technological support of well-resourced Centres of Expertise, that international norms dictating the sustainable beneficiation of bio-diversity are adhered to and that adequate cultivation and processing capacity to supply, not only quality but also quantity to market demand, is developing on an ongoing basis, it will possible to negotiate market access through recognized and trustworthy organizations in marketing and trading of aromatic oils.

As Mozambique's aromatic industry grows in recognition, markets will open up for its oils, and marketers and traders will queue to gain access to its supply.

2. Future Imperatives: Prospects and Initiatives

2.1 Implement a pilot project at Maniça

The MBB Associate in Mozambique, Andre van Aardt, is an experienced banana farmer, farming just outside Maniça. He has access to land and availability of other inputs, such as water to consider planting many other crops. He also has a very close relationship with the leadership and members of the community in the area, who are already involved in the banana operation. The idea is to expand the banana operation to market organic bananas. We have inspected the land and found it very suitable to grow a number of crops for the extraction of essential oils. We are now planning to find the necessary funding to establish such an operation. We haven't decided on the crop(s), but will do so after the necessary soil analysis and determination of available plant material.

2.2 Implement a pilot project at Bobole, Marraquene.

Mr Paul Hallowes of Kwezi Trading Mocambique Lda, is farming at Bobole, just outside Marraquene. He also has the capacity to expand his operation, with water freely available and a very close working relationship with the community. Similarly, we have inspected his land, and also found it suitable. He has a young plantation of Eucalyptus trees, indicating the possibility of expanding that operation. He also has a pilot planting of *Jathropa curcas*, with the view to become involved in a larger operation producing bio-diesel, which could also be expanded. We have a letter from Mr Hallowes, attached as **Annexure B**, supporting his proposition.

2.3 Expand the castor oil pilot project outside Nampula

We have already referred to the castor oil pilot project, run by Ms Judite Pinto, outside Nampula Town, in Nampula Province. She is operating under her company, Ricino Moçambique, Lda. She currently has a planting of 3 ha on a total of 1 000 ha, allocated to her. She would like to expand the castor oil planting to 500 ha. We have discussed with her the possibility to enter into some sort of partnership, and raise the necessary funding to expand her operation, as planned. This process must start as soon as possible.

2.4 Develop an experimental farm at the UEM

We view the development of an experimental farm at the University Eduardo Mondlane, as of critical importance. It will add so much momentum to many other plans if a commercially successful aromatic oil operation could be run, within Maputo, and within the research oriented environment of the university. We have not discussed any detail with the university but, with the active participation of Dr Salomao Bandeira and his colleagues at the Department of Biological Sciences, intend to do so as soon as possible.

2.5 Develop pilot projects in Niassa, Cabo Delgado and Nampula Provinces

The need to focus on these provinces has been referred to before. We have identified a number of possible pilot projects, which will be ideally suitable to these provinces and would like to proceed as soon as avenues of funding have been established.

2.6 Establish avenues of funding and investment: start presenting the business cases of various pilot projects.

This process of identifying funding organizations and also private sector investors, must get underway. We have contact with a number of individuals, companies and organizations that will be interested in getting involved in specific projects. We attach **Annexure A**, as a typical approach to an organization providing finance. In such a document reference has to be made to specific projects, but we also have to indicate that we taking these initiatives with the sanctioning of the authorities in Mozambique. We therefore repeat our request that we be given a formal mandate to start working with this Report, derive projects plans from it and start presenting these to interested organizations and investors.

SECTION 15:
FINANCIAL MODELING

1. Introduction

The financial aspects of any operation, including the production of an aromatic or essential oil, and whether on a national scale or a small rural farm, needs careful and continuous consideration. In the end it is net cash in the bank, which is the measure of the success of any business.

Furthermore, the capital requirements of a new venture, especially in a developing country such as Mozambique need careful consideration. As mentioned before, it is unlikely that any of the proposed pilot projects will be able to get off the ground without some form of grant funding. The financial modelling needed to determine the capital required per project, as well as the projected requirements for the first stage of the establishment of an aromatic oil industry, will be important.

There are a number of starting points from where financial models needed to detail project viability could be constructed. Such models will also help the aromatic oil entrepreneur to get a grip on his or her fledgling business. One is to start with the realization of yield.

2. Yield – the ideal partner of quality

At the end of the extraction process, and the oil is safely in the right container, the net weight of the oil divided by the weight of the mass of plant material (wet or dry – it is important) which delivered that oil, expressed as a weight to weight (w/w) percentage (sometimes, the volume to weight ratio, v/w, is used, but as oils are sold per kilogram, let's stick with w/w), is the yield. Actually, even better still, the sum should be made after the oil has been purified and all the unwanted stuff removed - that is the real yield! If the yield looks good, we may just be in business!

What sort of yields are we talking about? Firstly, each plant, and parts of a plant, will under ideal conditions deliver an optimum yield expressed as mass of oil per mass plant material used to make the extraction.

Estimated Production Yields of Selected Raw Materials Suitable to Produce Essential Oils			
Raw Materials	**Species**	**Parts Used**	**% Yield**
Anise	Pimpinella anisum	Seed	1,5 – 4,0
Coriander	Coriandrum officinalis	Seed	1
Garlic	Allium sativum	Root bulbs	0,1
Geranium	Pelargonium species	Leaves	0,3 – 2,0
Ginger	Zingiber officinale	Rhizome	3
Lavender	Lavendula angustifolia	Flower tops	0,5 – 1,0
Lemongrass	Cymbopogon flexuosus	Leaves	1
Orange flowers	Citrus species	Blossoms	0,1
Parsley	Petroselenium crispum	Seeds	6
Parsley	Petroselenium crispum	Leaves	0,5
Peppermint	Mentha x piperita	Leaves and tops	1,0- - 2,5

Rose	Rosa species	Flowers	0,006
Rosemary	Rosmarinus officinalis	Leaves	2
Vetiver	Vetiveria zizanioides	Root	0,9
Source: USDA presented by Ramu Govindasamy at the ASSNAP Conference, Stellenbosch, Feb 27 – March 1, 2006			

But, each species, each plant, even a different part of a plant, delivers a different yield. In the end, each producer will have to determine the typical highs and lows in yield (and WHY??) of his or her own crops. Then decide on a target yield and find out what are the conditions (there are many, that is the bad news), which will deliver that yield, together with its partner, QUALITY, each and every time. Good luck!

With this important information now up our sleeves, how much money can we expect to make? This concerns another important yield factor: yield of saleable product per hectare. Let's look at examples of income calculations from a few other countries.

Estimated Average Production Cost and Income of Selected Essential Oils per Hectare (all amounts in US Dollars)				
Crop	**Mint Oil**		**Lavender**	
Country	**USA**	**UK**	**France**	**UK**
Period	**2 – 4 Years**	**2 – 4 Years**	**2 – 15 Years**	**2 – 15 Years**
Assumption	500 hectares under production	40 hectares under production	40 hectares under production	40 hectares under production
Fixed Cost	842.65	1,064.04	272.95	707.95
Variable Cost	932.52	1,203.09	824.68	1.191.27
Total Cost	1,775.32	2,267.13	1,107.63	1,899.23
Average Yield (per hectare)	75 kg	75 kg	30 kg	50 kg
Market Price	30.28	30.28	60.90	60.90
Total Income	2,270.70	2,270.70	1,827.00	3,045.00
Total Gross Margin	1,338.18	1,067.61	1,002.32	1,853.73
Total Net Margin (Pre Tax)	495.38	3,57	729.37	1,145.78
Source: ADAS Consulting Ltd, 2002				

It is quite remarkable what a high yield, with a good price (largely determined by quality) and the containment of costs can do to the bottom line!

It is of value to take a perspective, at a national level, on the sort of value, which could be generated, in this case the USA and from Peppermint and Spearmint. This model demonstrates the profitability of an operation once good quality and a high yield achieve a fair price in the market, in this case representing two products in the USA.

United States Peppermint and Spearmint Value of Production during 2003 – 2004				
	Peppermint		**Spearmint**	
Year	2003	2004	2003	2004
Total Hectares	3,213,000	3,144,000	6,390	6,110
Total Production (MT)	3,173,000	3,242,000	807	792
Yield/hectare (Kg)	98.8	103.1	126.1	129.6
Price ($US/kg)	26.40	26.18	20.44	20.86
Total Value ($US million)	84.20	85.20	16.50	16.55
Source: NASS, USDA				

A case closer to home that of three oils produced in Malawi.

Malawi's Estimated Essential Oil Production (per Hectare)					
Plantation	**Average Raw Material (MT)**	**% of Oil Yield**	**Average Production per Hectare (liter)**	**Price (NY Spot Price, 2005)**	**Total Value Per Hectare.**
Eucalyptus	32	1%	365	$6,35	$2 318
Lemongrass	23	0,4%	107	$13,90	$1 487
Citronella	23	1%	260	$5,60	$1,456
Source: Africabiz and USDA					

Models like these are necessary to determine profitability of a crop, a business, and for an industry as a whole to determine profitability and overall viability.

3. Financial models to determine capital requirements.

The first approach will be to try and get an overall view of the sort of capital Mozambique will need to get the first round of pilot projects of the ground. At the moment, the figures have to be based on assumptions and guestimates, but the value of such an exercise will be to develop usable models. In the following table an attempt is made to get a feel for the capital amount, in US$ to fund some of the pilot projects referred to under the Recommendations, and also elsewhere in the Report.

Proposed Capacity Building and Pilot Projects					
Project Title		**Actions Required**	**US$'1000 Approx. Year**		
			1.	**2.**	**3.**
1.	Lab@UEM: Quality Control	Actions as detailed in Report	150	100	50
2.	Capacity@Biology@UEM	Actions as detailed in Report	100	100	100
3.	Experimental farm @UEM	Actions as detailed in Report	400	300	200
4.	Capacity@INIA: Nursery etc	Actions as detailed in report	300	200	100
5.	Pilot project@Maniça	Establishment and risk alleviation	80	30	20
6.	Pilot project @Bobole	Establishment and risk alleviation	80	30	20
7.	Pilot project:castor oil@Nampula	Expansion and risk alleviation	150	100	50
8.	Pilot project beneficiating marula	Establishment and risk alleviation	400	300	200
9.	Pilot project beneficiating baobab	Establishment and risk alleviation	400	300	200
10.	Pilot project beneficiating *Citrus*	Establishment and risk alleviation	600	400	200
11.	Pilot project beneficiating Linum	Establishment and risk alleviation	400	200	100

12.	Pilot project: crop integration	Establishment and risk alleviation	300	200	100
13.	Pilot project Niassa Province	Establishment and risk alleviation	500	400	300
14.	Pilot project in Cabo Delgado	Establishment and risk alleviation	500	400	300
15.	Pilot project in Nampula Province	Establishment and risk alleviation	500	400	300
16.	Pilot project e.g. *Cannabis sativa*	Establishment and risk alleviation	300	200	100
Total			**5 160**	**3 660**	**2 340**

Each pilot project will require it own business plan wherein the capital cost requirements will be quantified in much more detail. However, it is valuable to have an initial, rough-cut impression of the order of magnitude of the capital required. These figures above are based on experience and instinct derived from developing many projects of this nature.

4. Business plans – a blueprint - for each project

In the tables here above a reference is made to important financial elements, which will ultimately determine the viability of each project. These elements include those, which will determine revenue (quality, yield, volume and price), the costs involved (costs of sales or raw materials needed, other variable costs and then fixed costs including cost of labour). Lastly reference was made to the amounts of capital, which will be required to get projects off the ground. Capital has its own cost (interest, expectations of return, etc), which, if possible, should be kept as low as possible. To achieve this goal, capital which is not as exposed to risk should be sourced – grant funding.

All these factors will have to be incorporated in the business plan for each project. The stronger the business case, as presented in the business plan, the better the chance to obtain the most suitable type of capital.

As stated before, we are confident that the content and message of this Report will enable us to raise the required capital from a number of sources, to get these proposed projects of the ground. To enable us to do that, our position will be strengthened if we could be given a formal mandate to do so by the most appropriate authority in Mozambique.

SECTION 16
CONCLUSION

Mozambique, as a country, has undoubted and vast potential to become one of the world's leading producers or aromatic oils, including essential oils. The country can also gain a leading position as a producer of organic oils. The country must gain and maintain an image as a green country, a country, which cares about its natural resources, its unique biodiversity, but also a country, which can produce oils of the highest quality. Mozambique is starting this journey towards becoming a recognized producer of aromatic oils ostensibly far behind the leading producers of the world. This is true but, herein lies a strength – Mozambique has the opportunity to set out on this journey with a well-designed map, and avoid the pitfalls, dead-ends and worthless destinations which others had to experience. These experiences of other countries could be traced through the history of aromatic oils, and even in modern times mistakes are made because, often, basic principles are ignored. One such basic principle is quality.

Quality is a multi-dimensional principle by which industries (and smaller ventures) in aromatic oil will stand or fall. Markets will always be there, markets will most probably continue to grow. The most certain way to win market share is through quality, as is the most certain way to loose it, through poor quality. If this Report can achieve one major goal it must be to convince all the current and future participants in Mozambique's aromatic oil industry that there must be no compromise on the quality of the products which will leave the shores, in whatever form, of this country.

We believe this Report sets the stage for the quest towards quality. A lot of work has to be done, it will require investment of many kinds into the resources needed to achieve quality and maintain it into the future. We have highlighted many of the inputs, which will be needed. We have emphasized an entry strategy based on the implementation of a number of pilot projects – we advocate an approach based on caution – as we have cautioned against the indiscriminate harvesting of any plant species from nature, we also caution against a rushed approach. If there was any hope that the beneficiation of Mozambique's indigenous aromatic plants will present a "quick-fix" solution to the problems of rural poverty and others, which beset the economy of Mozambique, it is based on a misconception. It will not happen overnight. Any attempt to make it happen overnight will end in disaster.

The road to success is going to be a slow and arduous one, taking one painstaking step after the other. We believe this Report provides the framework within which to chart this road. The format and content of the Report addresses all the main elements needed for understanding the field and designing strategies at a national level and the level of a small enterprise. The Report does not claim comprehensiveness – to achieve that is a life's task.

Our own resources will be at the disposal of Mozambique, as a country, but also the individual entrepreneurs wishing to claim a stake in its future aromatic oil industry. The pilot project approach will require various resources including funding, which we believe could be mobilized if well substantiated business plans could be produced, which will also require financial support. With a formal mandate to do so we are ready to set in motion a process of sourcing such funding and putting it into use on a project-by-project basis.

We are looking forward to a continued relationship with Mozambique, a country we have grown to love.

SECTION 17:
GLOSSARY:[92]

Absolute. Highly concentrated, alcohol-soluble, usually liquid; normally obtained by solvent extracting plant material, oils or concretes. Absolutes are considered most accurately to reflect the taste and odour of the original material.

Adulteration. Any material added to a whole, genuine oil, which alters its original composition or odour. The word is normally used to designate materials added for fraudulent purposes. Legitimate adulteration is normally defined i.e. fixative added, refined, enhanced, etc.

Aroma. An intangible concept described by Arctander as odour plus flavour.

Annual. A plant that completes its life cycle in a year.

Bark The external group of tissues, from the cambium outwards of a woody stem or root.

Biosystematics A field of taxonomy which emphasizes breeding behaviour and chromosome characteristics

Boiling point. Components of essential oils have varying boiling points: low boiling point compounds will distil over first, those with higher boiling-points progressively later. Control of distillate content is thus possible by varying distillation temperature or duration.

Brix Number Percentage of total soluble solids using a Brix hydrometer calibrated at 20ºC.

Bud An undeveloped shoot, largely meristematic tissue, generally protected by modified scale leaves.

Bulb A modified bud, usually underground, a short, flattened or disk-shaped underground stem, with many fleshy scale-leaves, filled with stored food.

Carnuncle A spongy outgrowth of the seed coat, especially prominent in the castor bean seed.

Chemotaxonomy Use of chemical analysis of plants or plant parts, especially essential oils, to assist in classification. It is particularly useful where there are no (or minor) visual botanical differences.

92 Taken from: Essential Oil Crops by EA Weis, Published by CAB International. 1997, and other sources.

Clay Soil particles less than 2 microns in diameter, composed mainly of aluminium (Al), Oxygen (O) and silicon (Si).

Complete flower A flower bearing four whorls of floral leaves: sepals, petals, stamens and carpels.

Compound leaf A leaf whose blade is divided into several distinct leaflets.

Concrete Concentrated solvent-extracted solid or waxy material; main use is a raw material for production of absolutes.

Constituent Specific component of an oil accurately defined.

Crude Oil Oil from generally unspecialized stills, which may contain water, impurities and solids. It is usually reprocessed (refined) prior to shipment. Oil is frequently so described when delivered in bulk, commonly for use as raw material for an isolate.

Cuticle Waxy layer on outer wall of epidermal cells.

Cutin A waxy substance which is but slightly permeable to water, water vapour, and gases.

Deciduous Referring to trees and shrubs that loose their leaves during autumn.

Distillate Liquid produced by distillation; may be crude from primitive stills or refined from modern stills.

Ecology The study of plant life in relation to the environment.

Ecosystem An inclusive term for a living community and all the factors of its non-living environment.

Ecotype A genetic variant within a species, which is adapted to a particular environment, yet remains interfertile with all other members of the species.

Emulsion A suspension of fine particles of a liquid in a liquid.

Essence A general and ambiguous term for a concentrated perfume or flavouring material.

Essential Oil The commonly used term for a volatile oil normally secreted in special glands in various plant parts, and not found in living cells. Obtained by distillation, extraction or expression. Most essential oils are terpenoids, some benzene derivatives. Not to be confused with fixed or vegetable oils.

Exocarp Outermost layer of the fruit wall

Extracts Any concentrated material normally obtained by solvent extracting natural raw materials. The term is widely misused.

Fixed Oils Non-volatile, fatty, generally vegetable, frequently contained in seeds (oilseeds, for example). Usually obtained by pressure extraction.

Genotype Refers to the genetic make-up of the plant. Genotypic changes are genetically fixed and are passed on to the offspring.

Genus A group of structurally or phylogenetically related species.

Herb A seed plant that does not develop woody tissues.

Herbaceous Referring to plants having the characteristics of herbs.

Herbarium A collection of dried and pressed plant specimens.

Humus Decomposing organic matter in the soil.

Hybrid The offspring of two plants (or animals) differing in at least one Mendelian character; or the offspring of plants (or animals) differing in many characters.

Isolates Obtained by fractionating oils including citral, phellandrene, vetiverol, safrole, etc. Isolates have specific uses and an essential oil may be solely used as a source of isolates.

Loam A particular soil texture class, referring to a soil giving 30 – 50% sand, 30 – 40% silt, and 10 – 25% clay.

Macronutrients An essential element required by plants in relatively large quantities. (N, P, K, Ca, Mg, S)

Micronutrients An essential element required by plants in relatively small quantities (B, Mn, Fe, Cu, Zn, Mo)

Nut A dry, indehiscent, hard, one-seeded fruit, generally produced from a compound ovary

Odour There is no accurate description of this term. It commonly attempts to explain what an individual perceives via their nose as the scent of any material. A highly esoteric language is used to describe odour by technicians and perfumers (see odour groupings as suggested by Arctander).[93]

93 Arctander, S. (1960) Perfume and Flavour Materials of Natural Origin.

Optical Rotation Angle through which the plane of polarization of light is rotated when polarized light passes through a layer of liquid. Unless otherwise specified, measurement is by sodium light in a 1 mm layer of liquid at 20ºC. Oils may be dextrorotatory (+) or laevorotatory (-) according to whether the plane of polarization is turned to the left or right.

Oxidation A general term indicating the changes in oil composition or odour when exposed to air; most are undesirable, thus oil should be stored in full, airtight containers.

Perennial A plant that lives from year to year.

Petal One of the flower parts, usually conspicuously coloured.

Phenotype Refers to the appearance of the plant. Phenotypic changes are temporary; could be a plastic response to a harsh environment.

Photosensitive Reacts to light. Many oils are affected by light, resulting in decomposition of, or undesirable reactions between constituents. Thus oil should generally be stored in opaque containers.

Population A group of closely related, interbreeding organisms, such as a group of trees of the same species.

Refractive Index The ratio of the velocity of light in a vacuum to its velocity in a substance. It varies with the wavelength of light used.

Sand Soil particles between 50 and 2000 microns in diameter.

Shoot A young branch that shoots out from the main stock of a tree, as the young main portion of a plant growing above ground.

Silt Soil particles between 2 and 50 microns in diameter.

Soil The uppermost stratum of the earth's crust, which has been modified by weathering and organic activity into (typically) three horizons: an upper A horizon which is leached, a middle B horizon, in which the leached material accumulates, and a lower C horizon which is unweathered parent material.

Soil texture Refers to the amounts of sand, silt and clay in soil, or a sandy loam, loam or clay texture.

Solubility Maximum quantity of an oil which can be dissolved in a stated volume (v/v) or weight (w/w) of alcohol of given concentration; 70%, 90%, etc normally at 20ºC, or as specified.

Solvent Hexane, petroleum ether, acetone or methanol used to extract essential oil or other derivatives from plant materials or their extracts. There are legal requirements in many countries regarding their use and residues in products for human consumption.

Species A class of individuals usually interbreeding freely and having many characteristics in common.

Stem The main body of the portion above ground of a tree, shrub, herb or other plant; the ascending axis, whether above or below ground, of a plant, in contradistinction to the descending axis or root.

Taxonomy The science dealing with the describing, naming and classifying of plants.

Trait A distinctive definable characteristic; a mark of individuality.

Tuber A much-enlarged, short, fleshy underground stem.

Turgor pressure The pressure within the cell resulting from the absorption of water into the vacuole and the imbibition of water by the protoplasm.

Supercritical Fluid Extraction Method of extraction using a liquid gas, frequently carbon dioxide

Terpenoids Volatile aromatic hydrocarbons, including monoterpenes, sesquiterpenes, diterpenes and higher polymers. A wider use of the term would include terpene hydrocarbons, alcohols, ketones and camphors. Terpenes are of great importance in essential oil composition and their presence or absence has a marked effect on odour and usage. Whole oils may be processed to remove all or some terpenes, and described as terpeneless oils. Terpenoid distribution is now considered of major value in taxonomy (chemotaxonomy).

Unavailable water Water held by the soil so strongly that root hairs cannot readily absorb it.

Variety A subdivision of a species due to naturally occurring or selectively bred populations of plants that differ from the species in minor characteristics.

Vascular Referring to any plant tissue or region consisting of or giving rise to conducting tissue e.g. bundle, cambium, ray.

Vegetation The plant cover that clothes a region; it is formed of the species that make up the flora, but is characterized by the abundance and life form (tree, shrub, herb, evergreen, deciduous plant etc.) of certain of them.

Viscosity Rate of flow of a liquid. Measured in cgs units the absolute unit of viscosity is the poise. Absolute viscosity of water at 20,2ºC is 1000 centipoises (one hundredth of a poise).

Water potential Refers to the difference between the activity of water molecules in pure distilled water at atmospheric pressure and 30^0C (standard conditions) and the activity of water molecules in any other system; the activity of these water molecules may be greater (positive) or less (negative) than the activity of the water molecules under standard conditions.

Weed Generally a herbaceous plant or shrub, not valued for its use or beauty, growing where unwanted, and regarded as using ground or hindering the growth of more desirable plants.

Whole Oil Specifically an oil free of all impurities, water and additives and true to the original material; is often misused.

Wild-type In genetics, the gene normally occurring in the wild population, usually dominant.

SECTION 18.
DETAILS OF USEFUL CONTACTS

1.

MEMBERS OF THE TEAM WHO UNDERTOOK THIS STUDY		
1.	Dr Louis de Lange	louis.delange@sudoreco.com
2.	Mr Mathys de Wet	mjdewet@mbbsouth.co.za www.mbb.co.za
3.	Mr Ian Mclean	imclean@telkomsa.net
4.	Dr Mariana Smith	naturalbotanicals@mweb.co.za
5.	Mr André van Aardt	porcosesphinos@yahoo.com

2.

USEFULL ORGANISATIONS TO KNOW ABOUT		
1.	Agribusiness in Sustainable Natural African Plant Products - ASSNAP	info@asnapp.org www.asnapp.org
2.	Commercial Products From the Wild Group CP-Wild	info@cpwild.co.za www.cpwild.co.za
3.	PhytoTrade Africa	info@sanprota.com www.phytotradeafrica.com
4.	Southern Alliance for Indigenous Resources (SAFIRE)	felix@safire.co.zw www.safireweb.org
5.	IUCN World Conservation Union South Africa Country Office	Anthea.stephens@iucn.org www.iucnsa.org.za
6.	SA Essential Oil Producers Association (SAEOPA)	www.saeopa.co.za
INTERNATIONAL		
1.	International Federation of Essential Oils and Aroma Trades (IFEAT)	www.ifeat.org
2.	Flavour and Extract Manufacturers Association (FEMA)	www.femaflavor.org
3.	Research Institute for Fragrance Materials (RIFM)	www.rifm.org
4.	S&D Aroma (United Kingdom)	www.sdaroma.com
5.	S&D Botanicals (South Africa)	imclean@telkomsa.net
6.	AFNOR	www.afnor.fr
7.	International Trade Centre (ITC)	www.intracen.org
8.	Food and Agriculture Organization of the United Nations (FAO)	www.fao.org
9.	Organic Monitor	www.organicmonitor.com
10.	Ecocert	www.ecocert.de
11.	USDA National Organic Program	www.ams.usda.gov/nop
12.	Independent Inspectors	www.ioia.net
13.	DEFRA	www.defra.gov.uk
14.	Japanese Agricultural Standards (JAS)	www.maff.go.jp
15.	Canadian Organic Standards	www.pwgsc.gc.ca/cgsb
16.	EU Organic Standards	www.europa.eu.int/eur-lex/en
17.	Internaitonal Organisation for Standardisation	www.iso.org
18.	Natural Resources Institute (NRI)	www.nri.org
19.	Herb Research Foundation	www.herbs.org

20.	Consultative Group on International Agricultural Research	www.cgiar.org
21.	Fair Trade labelling Organisation International	www.fairtrade.net
22.	International Fair Trade Association	www.ifat.org
23.	Traidcraft	www.traidcraft.co.uk
24.	TransFair International	www.transfair.org
25.	Danish Import Promotion Office for Products from Developing Countries	www.dipo.dk
26.	Organic Trade Association (OTA)	www.ota.com
27.	Organic BioFach Fair	www.biofach.de
28.	Organic Products Europe	www.naturalproducts.co.uk
29.	All Things Organic (ATO)	www.atoexpo.com
30.	World Perfumery Congress	www@worldperfumerycongress.com
31.	Symposium International d'Aromatherapie	congress@ville-grasse.fr
32.	Genetic Resources Action International (GRAIN)	www.grain.org
33.	Indigenous Peoples Council on Biocolonialism	www.ipcb.org
34.	Internaitonal Centre for Trade and Sustainable Development	www.ictsd.org
35.	International Institute for Environment and Development	www.iied.org
36.	Science and Development Netword	www.scidev.net
37.	Third World Netword	www.twnside.org.sg
38.	Forest Stewardship Council	www.fsc.org
39.	International Federation of Organic Agriculture Movements	www.ifoam.org
40.	People and Plants International	www.peopleandplants.org
41.	Scientific Certification Systems	www.scscertified.com
42.	Socal Accountability International	www.sa-intl.org
43.	Soil Association Certification	www.soilassociation.org
44.	TRAFFIC	www.traffic.org
45.	Convention of Biological Diversity	www.biodiv.org

3.

AROMATIC OIL EXTRACTION EQUIPMENT MANUFACTURERS IN RSA		
1.	Saturn Stainless Industries	s.s.i@iafrica.com
2.	Dennes Engineering	donnash@dennes.co.za
3.	Essential Distillation Equipment	www.edesa.co.za sandor@cornergate.com
4.	Grotto Defrancheshi (Pty) Ltd	www.grotto.co.za

-o0o-