A DRAFT TRAINING MANUAL ON PRODUCTION, PROCESSING, UTILIZATION AND MARKETING ASPECTS OF AROMATIC PLANTS: Based on Experiences of Wondo Genet Agricultural Research Center and Other Countries

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Part I

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Among the most important problems related to production, processing, marketing and utilization technologies of aromatic plants in Ethiopia is the level of awareness and attention given to the development of this sector. The problem is compounded with relatively weak institutional arrangement framework; limited knowledge and lack of established markets for the development of this sector. From the experience of developed countries, the rapid progress in this sector was achieved through provision of training resources.

The role of training in the development and promotion of aromatic plants is vital. It is directly related to the effectiveness of the economy in providing the requirement of trained manpower for the development process. Development requires intensive utilization of trained manpower.

It is very clear that, awareness about aromatic plants and their products/essential oils is as good as nil in every aspect in majority of Ethiopian people's. It is for this basic fact that this training manual is prepared for helping targeted groups to provide basic information about aromatic plants and their products. This material can be used in industries, agricultural sectors, entrepreneurs and others who have interest to have basic tips about aromatic plants and essential oils.
The objective of this training material is to provide basic information about the production, processing, utilization and marketing aspects of the business based on the experiences of Wondo Genet Agricultural Research Center as well as relevant secondary sources.

This manual is commended for use in industries, agricultural sectors, entrepreneurs and others where this sector is given emphasis. It is believed that, this material can be used as an additional and easily understandable item to the existing materials in this area.

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1. Introduction

The cultivation and utilization of aromatic plants have played an important role in the history of civilization, exploration and commerce. Their uses can be dated back to the history of Queen of Sheba, who visited king Solomon mentioned in the Holy Bible. Plants with strong aromas and flavors have attracted the attention of man for many years, probably at first for fragrances and perfumes, flavoring and condiments, food preservatives, curatives and aphrodisiacs.

Humankind has been using plant secondary metabolites for over thousands of years as dyes (anato extracts), flavours (vanillin), fragrances (rose oil, lavender oil), stimulants (caffeine, nicotine), hallucinogens (cocaine), insecticides (pyrethrin), as well as for animal and human poisons (coniine, strychnine).

In recent years, there has been a tremendous growth of interest in plant based perfumery products, cosmetics and aroma compounds used in food flavors and fragrances, drugs, pharmaceuticals and natural colors in the world.

There is a definite trend to adopt plant based products due to the cumulative derogatory effects resulting from the use of antibiotic and synthetics. The availability of plant based material is mainly from the natural sources like forests and wastelands except for a
few cultivated crops. There is a need to introduce these plants into
the cropping system of the country. Besides meeting the demands
of the industry, the activity will also help to maintain the standards
on quality, potency and chemical composition. The majority of
these natural benefits can be achieved through the use of aromatic
plants and essential oils in fragrances, flavorings, condiments, food
preservatives, curatives and aphrodisiacs preparations.

1.1 Aromatic Plants

Aromatic plants can be defined as plants which possess odoriferous
oil in either of their organs or sometimes even in the whole plant.
Such type of plant can be found from simple form of the plant
kingdom such as fungi and algae to the higher plants like
angiosperm and gymnosperms. The most commonly known and
utilized aromatic pants can be grasses (Cymbopogon martini, C.
winterianus, C. citratus), herbs (Mentha piperata, M. arvensis, M.
spicata, M. longifolia), shrubs (Aloysia triphylla, Rosmarinus
officinalis) or trees (Eucalyptus citrodora) with annual (Artemisia
spp., Trachispermum ammi, Coriandrum sativum, Matricaria
chamamole) or perennial (Cymbopogon spp., Mentha spp.,
Eucalyptus spp.) growth habits.

Usually they are considered as multipurpose plants. Due to this,
you are important to produce valuable aromatic substances, which
can be used as food, fodder, construction material, ethno
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botanical, source of fuel, social and cultural values, environmental protection and services, and so on.

The commonly used terms associated with aromatic plants includes herbs, spices and essential oils. Herbs are aromatic plants from temperate regions that contain phytonutrients and are used for flavoring foods and beverages. People also use the term culinary herb, which refers to herbs used in minor quantities to flavor food and beverages. When people in North America and Europe use the term 'spice', they mean an aromatic plant that comes from tropical regions. In most instances, spices are dried seeds, leaves, stems, roots or other plant parts from which none of the flavoring or bioactive components has been extracted. Aromatic plants that have a strong aroma may or may not be used for commercial production of essential oils.

The most commonly known aromatic plants used for commercial extraction of essential oils in the world include: ajowan, allspice, amarys, angelica, anise, artemisia, basil, bergamot, bajuput, calendula, camphor, caraway, cardamom, carrot seed, cassia, catnip, cedarwood, celery seed, chamomile, cilantro, cinnamon, citronella, citrus, clary sage, clove, coriander, cornmint, cumin, dill, eucalyptus, fennel, frankincense, geranium, garlic, ginger, grapefruit, hyssop, jasmine, lavender, lemon, lemon balm, lemongrass, lime, litsea cubeba, lovage root, marjoram, melissa, menthol, myrrh, ninde, nutmeg, orange, oregano, parsley,
patchouli, pennyroyal, peppermint, pine, rose, rosemary, rosewood, sage, sandalwood, sassafras, scotch, spearmint, star anise, tangerine, tarragon, tea tree, thyme, vanilla, wormwood, and yarrow.

1.2 Essential Oils

Essential oil is a generic name for plant constitutes which are volatile, oily liquids sometimes semi-liquid or solid substances with aromatic or odoriferous scent. Some times they are called as 'volatile oil' or 'ethereal oil'. The term essential do not mean that they are 'Need or Necessity' but sought to represent the very essence of odor and flavor. They are often classified as secondary plant products, and as a result many may be led to believe that they are of only secondary importance. Secondary metabolites found in a smaller range of plants as opposed to the primary metabolites, such as sugars and fats, which are found in all plants. Some useful essential are found only in a particular genus or species.

Most of the time essential oils are characterized as an aromatic substances produced from aromatic plants having the original aroma and flavor of the odoriferous plants named essential oils. They are colorless or slightly yellow complex mixtures of odorous and volatile compounds which are deposited by plants in sub cuticular space of glandular hairs, in cell organelles, in execratory cavities and canals. They occur in various site of plant anatomy, in some case they are
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found throughout the plant organ and in other case are restricted to specific organ or product of the plant. Either of the different part such as flowers, seeds, leaves, twigs, herbs, woods, barks, resinoids, sap, fruits, seeds, root or the whole part of the single plant species can be a potential sources of essential oil.

Essential oils can be produced from such plant biomass through different method of extraction. Steam and hydro distillation, effleurage (i.e. extraction using fat), maceration, solvent extraction, or mechanical pressing can be listed as techniques used for the extraction of essential oils from different raw materials of aromatic plants.

Chemically essential oils are for the most part tropanes, multiple isoprenoid units, aromatics, heterocyclics, and terpenes. The most abundant types of chemical compounds that are present in essential oils are terpinoids and phenyl propanoids. Terpinoids in essential oils consists of monoterpenoids which are C\textsubscript{10} compounds and sesquiterpenoids which are C\textsubscript{15} compounds, together with their oxygenated derivatives such as alcholes, esters, aldehydes, ketones, ethers and acids.

Mostly, essential oils bear the name of the plant species from which it is derived, e.g., rose oil, peppermint oil etc. Similarly, each type of essential oil of a given plant species (sometimes even oil from a different part of a single plant) is different from the others. So oil
from particular plant species or part is composed of particular chemical compounds or active constitutes which tends the oil to exhibit a peculiar fragrance and physicochemical characteristics. The type and extent of the active constitute present in a given oil usually determine the physicochemical property of that oil, which ultimately determines the use and application of that oil.

### 1.3 Where, How and Why Aromatic Plants Produce Essential Oils

Several specialized structures have been described as essential oil sources by microscopic studies. The most commons are cavities, ducts, glands or hairs. Cluster of cells (cavities or ducts) just below the epidermis in skins of citrus fruit or the leaves of eucalyptus; and glands of lavender florets or the modified leaf hairs of mint and geranium are identified as sites of essential oil synthesis.

Aromatic plants have their own mechanisms to synthesize aromatic substances. The secretory cells of plants that produce the volatile oils trap the photo-electromagnetic energy of the sun and with the help of glucose convert it in to biochemical energy in the form of aromatic molecules.

The genetics and biochemistry of the biosynthesis of the essential oils is reasonably well understood in some cases. For example, limonene is synthesized from geranyl pyrophosphate in the oil glands of *Mentha spp*. Further, the various oxygenated derivatives of limonene that make up the remainder of Mentha oil are
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synthesized from limonene by microsomal preparations from oil glands, which show cytochrome p-450-type mixed function oxygenase activity.

There is much speculation about the "role" of essential oils in plants. Do plants derive any benefit from their presence? Certainly several apparently "useful" effects have been described. They are the regenerating and oxygenating defense properties of plants. Their oxygenating molecules effectively transport nutrients and a myriad of other powerful chemical constituents to the cells, bringing life to the plants, destroying infections, staving off infections, aiding in growth, and stimulating healing. Moreover, they have an important role in plants as an attraction of pollinating insects by attractive volatile aromas; reduction of competition from other plant species (allelopathy) by chemical inhibition of seed germination and establishment, protection against insects by an anesthetic effect, protection against infectious micro flora by fungicidal and bactericidal properties, and against browsing animals by adverse taste and effects on the nervous system. This indicates that, they are not directly produced for performing normal physiological processes like growth, reproduction, and other processes carried out in response to primary the synthesis of plant metabolites. Apart from their magnificent purposes to aromatic plants themselves, essential oils have got tremendous importance for human beings.
1.4 Importance of Essential Oils

Normally, essential oils have a myriad of uses which start from simple household consumption to sophisticated industrial application. The variety of uses and application for essential oils and their individual components is so wide that only the broadest categories can be mentioned here. These are;

- **Industries application:** their roles in heavy industries like petroleum, mining, paint, varnish paper and printing like carbon papers, drinking cups, writing paper, paper bags and food wrappings, printing and writing inks, industrial tapes, inking pads etc, and textile processing products such as artificial leather and fabric coatings, dyes, linoleum, textile oils, eater proofing materials etc are indispensable.

- **Food processing and flavoring industries:** aromatic plants and their products have a great share in the food industries, sweet meals factories like biscuits, cakes, icings, mincemeat, pies, sandwich fillings etc, canning factories use them to flavoring and processing of fish, meat, sauces, soup etc), chewing gum factories (chewing gums, coated gums), condiment factories (catsup, chilly sauces, pickled fish, salad dressing, table sauces), confectionery factories (chocolates, hard candies, soft center candies, etc),

- **Beverage industries:** they are being used in the alcoholic beverage industry (bitters, cordials, rums, whiskies, wines etc) and soft drink industry (carbonated beverages, cola
drinks, fountain syrups, ginger ales, root beers, soda fountain supplies etc), as a primary inputs, flavoring or additives.

- **Pharmaceutical application**: the anti-oxidant, antiseptic, antiviral, parasitiside, secretomotory, rubefacient, stimulant, vulnerary, germicidal and other characters of most essential oils have caused them to be important sources of active and crude raw material for preparation of drugs and other pharmaceutical products.

- **Perfumery and cosmetics industries**: the perfumery industries and essential oils have a close association with the history of civilized man. Archeological findings revealed recently that Ancient Egypt, Persia, China and India were utilizing essential oils for perfumery and cosmetics products. Since then to the present times, aromatic plants stayed the predominate sources of the fragrance in perfumery and cosmetic products like creams, lipsticks, lotions, other beauty products.

- **Toiletries and dental products**: essential oils are a key raw material for toiletry products such as baby preparations, bath preparations, laundry soaps, room sprays, deodorants, antiseptics etc. Similarly, they are important in dental preparations such as tooth a paste, mouth washes etc.

- **Bio pesticides and pesticides**: essential oils can be used directly as pesticides or they can possibly be used as a source of active ingredient for preparation of pesticides or as
additive to improve or to make already prepared pesticides ready to use.

- **Aromatherapy:** they are also largely used in aromatherapy industry. The aromatherapy industry is a great user of essential oils. Aromatherapy is the demand equivalent of the supply side of essential oil production. That is, it is relatively small in terms of volume but has a large number of participating businesses. For example, in the USA some 25,000 aromatherapy companies are estimated to be operating, largely by mail order via the internet.

In addition to the above mentioned importance of the oil in diversified industries, the aromatic plant material itself has a number of uses, for instances,

- Ethno botanicals or traditional/herbal medicine
- Cultural application
- Household food and drink sweetening and flavoring either as fresh or dried spice.

### 1.5 Benefits from Utilization of Aromatic Plants for Essential Oil Production

Aromatic plants are found in almost every geographical climate ranging from pines of the cold region to frankincense trees of arid tropical areas. So in a country like Ethiopia, which has been endowed with diverse agro-ecologies, will have sufficient habitat for the evolvement of indigenous aromatic plant species, variety
development and as well as for the adaptation of exotic aromatic plant species. Hence forth, utilization of such potentials of a country should be considered during decision making process in selecting and implementing national, regional and local agricultural projects.

The most common benefits of aromatic plants utilization for essential oil production can be valued in terms of capital requirement, rural development, their high value and low volume properties, export potentials, economical and environmental benefits.

1.5.1 Low Capital Requirement

The whole production chain of essential oil production is simple and relatively inexpensive than other agro based industries. Large or medium scale distillation unit can be run by farmer groups, cooperatives, or other local level institutions and can also involve a number of small scale farmers as a supplier of raw material. Even small scale distillation still can be owned by individual farmers.

1.5.2 Rural Development

As it requires low capital and technology and as it is being agricultural based investment, many countries have involved in essential oil production from the cultivation of selected (market oriented) aromatic plant species, as an alternative approaches of
integrated rural development projects. South Africa and Cambodia can be taken as an example of such projects.

South Africa has a considerably large involvement in the essential oil industry as one of the rural development projects and as well as national economic development. Currently the country has 100 local producers, dozen of are commercial producers and two development projects, which have being a consistent supply of the both domestic and foreign market. The number of operational distillation units is estimated between 30 and 40, many of which are too small for large scale production, are serving the local producer in producing essential oil. Locally produced essential oils are generally sold to two or three of the local companies that have been able to penetrate the international export market. Low volumes of smaller quantities of oil are sold into the growing local aromatherapy market. This indicate the contribution of essential oil industry for the development of the rural areas through creating employments, generating new or additional income, utilizing the potentials of different area and so on.

Cambodia is also a country which are being engaged in producing essential oil and planed to enter international markets. Cambodia prepared to capture a market share with lemon grass, citronella and E. citrodora oils, valued at around USD 0.5 million / year in export earnings in 5-8 years. At this scale of output, the benefits in the rural sector would equate to bringing over 700 ha of land into
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productive use and creating about 3,800 new job opportunities, especially for women and in more remote areas that encounter problems in marketing perishable or low-value / high-volume products.

1.5.3 High Value Low Volume (HVLV)

In most writings on potential export opportunities for developing countries, frequent reference is made to the need to have products that are having high priced and low volume. When we are thinking of aromatic plants, the higher the price and the lower the volume refers directly to essential oils. Due to the properties of generating premium price through the sell of small volume of oil, essential oils are commonly termed as High Value Low Volume (HVLV) products.

HVLV products are held to be desirable products for developing countries including Ethiopia for two reasons. One, the high value ensures high income, always a desirable objective in these countries. Two, the low volume requirement is held to be an equally desirable attribute because developing countries can rarely produce products of high enough volume to achieve economies of scale throughout the entire supply chain that allows them to compete internationally. Low volume encapsulates the small scale nature of most production in developing countries whereas the high value allows the product to absorb financially what would otherwise be crippling supply chain costs.
Essential oils are the epitome of HVLV. As instance, report of FAO estimate in 2004 showed that 190, 428 tones of essential oil worth US$1.6 billion. This indicates that the proportion of price to volume is very high. Therefore, it is safe to say that high value can be obtained through the sale of low volume of essential oil. Despite the allure of essential oils being an ideal HVLV, by no means all essential oils are HVLV. To achieve additional higher end prices, a great deal of effort on value addition of the product is required. The following processing can be suggested as possible methods to appreciate the value of end product.

- Increase in the quality of the end product without further change in nature. This can be achieved by minimizing adulteration and impurity, using special packaging system which improves the appearance and easy handling, helps the oil to keep its quality for a longer time and so on.

- Further processing of the oil to win different compounds which makes up the crude oil. This helps to recover at least one of the major components of the oil with higher market value. Chemically, this can be achieved using different methods. Among those method of separating active constitutes of crude material, fractional distillation can be mentioned as appropriate technology for volatile essential oil.
1.5.4 Higher Export Potential

The growing awareness of the people toward clean environment, organic product and extended side effects of synthetic products have resulted in shift of demand from synthetic to natural product even to organic production. These types of product have very low or non-side effects to human being and their production process have minimized impact on the environment as well. For these reasons, the global demand for essential oils is significantly increasing with time (Fig 1). The estimated total trade in essential oils is over US$ 1.6 billion with exports rising nearly 60 percent in the six years from 1999 to 2004, growth must be considered strongly.

The growth in total trade is an indicator of wide opportunity to be involved in the sector. Therefore, countries interested to participate in this sector can generate hard currency in selling of essential oil to international market. Beside that, as the global market shows increment, the competition is so low, so that joining this market will not be difficult for developing countries like Ethiopia.
Figure 1 Total trade value of essential oil in the global market 1999 - 2004 (Source: ITC, 2004)

1.5.5 Environmental and Ecological Benefits

As most of aromatic crops are perennial and have diversified morphological and physiological charters, cultivating them have a lot of environmental and ecological benefits. Among many both quantifiable and unquantifiable benefits of aromatic plant based essential oil production, the following can be considered as main examples;

- **Excellent for soil and water conservation**: as most of them are perennial and needs not intensive tillage, they maintain the vegetation cover of the land and improve the physical and biological condition of the soil
- **The spent left after the distillation can be used to enrich the soil**: as the oil is the main product of such project, the
biomass that is used to obtain the oil will be left after the oil is extracted from it. This by product is most of the time can be used as mulch to the cultivated land, by doing this one can achieve either economical utilization of the soil moisture, weed suppression, improvement of soil biological, physical and chemical condition, reduced soil erosion or all.

- Environmentally friendly: the whole production chain starting from cultivation up to packaging the final product can possibly kept as environmentally friendly as possible with out affecting the profitability of the project, if it is properly planned, managed and monitored by genuine owners, experts and officials.

There are also other potential benefits achieved through the utilization aromatic plants though not covered in this manual. These can be designed during planning by targeting to be benefited from international convention and memorandum of understanding on carbon trading, biodiversity conservation, clean environment development and so on. Actually such benefits are totally depend on the mode of management that we practiced to grow the crop (organic farming vs inorganic and the like), the nature of the crop we are cultivating (wild vs planted crop, in situ vs exitu) or type of plant species (tree crop vs herbs, exotic vs indigenous). Moreover, such benefits also depend on sustainability and impact of the project on society and environment.
Therefore, it is important to understand the utilization of aromatic plants and sustainable biophysical, socio-economical, and political merits of any given country in such away that always bring such benefits. These can be achieved if the determining factors for successful utilization of aromatic plants and other resources are kept optimum.
2 Aspects for Economical Utilization of Aromatic Plants and Products

Sketching the overall production chain of aromatic plants and essential oil production is important. This helps to describe the determining factors that affect the successful utilization of aromatic plants for essential oil production. In this manual, brief information on production requirements from site selection to financial analysis were covered. Each of these posses a number of activities which are responsible for the overall output of the production cycle. By calibrating such production requirements, one can manage the effects of these factors on overall successes of the project on utilization of aromatic plant. Detailed information about these determining factors is presented below.

2.1 Choice of Crop

Choice will be influenced by factors such as location, climate, soils, grower experience and preferences, finance, markets and market trends, and specialization such as organically produced crops. The crop must meet the specifications of the destined market like International Standard Specifications or Individual Company ‘in-house’ Specifications. These specifications are generally determined by chemical analysis and physical assessment, olfactory evaluation and appearance. It is important to understand that the chemical composition of a crop can be affected by such things as
plant cultivar, environment, crop management, time of harvest, processing and post-harvest handling.

2.2 Site Selection

During site selection it is important to consider the following important aspects.

- **Size of land area**: small scale or large scale production.
- **Location**: distance to market or processing facilities.
- **Climate**: suitability for a particular crop, for example, basil requires a frost-free site; mint species and lemon grass prefer lowland rust free area.
- **Topography**: suitable terrain for machinery.
- **Soils and drainage**: good quality horticultural or arable cropping soils with good drainage are necessary for aromatic plants.
- **Shelter**: is a requirement for aromatic plants. Exposure to hot, dry winds over the harvest period can severely reduce essential oil yield. Tall-growing crops such as citrodora, lominat and valerian can suffer extensive damage if sufficient wind shelter is not provided.
- **Weeds**: identification of weeds present and assessment of possible control strategies needs to be made available.
- **Water availability**: irrigation is necessary for all crops in most environments, particularly during crop establishment. Therefore, irrigation system should be installed primarily or accessible for its installation.
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- Crop structures: during site selection suitability of building of drying plant, pack house or distillation unit should be considered.

2.3 Crop Establishment and Management

2.3.1 Crop Establishment

The starting activities of crop establishment is availing vigorous, healthy and sufficient planting material which assure the completion of the current activities (crop establishment) economically in accordance with the plan and availing timely and enable the activity timely. Hence, it is important to consider the following aspects during crop establishment.

- **Planting material**: source of seed for some species is limited. Vegetative propagation will be required for some species. E.g. Mint species, Grasses, Lominat, Rosemary, Geranium etc.
- **Pre-plant requirements**: soil test should be taken to determine soil acidity (pH) and nutrient levels. Appropriate applications of fertilizer and lime can then be recommended. The site should be free of weeds and well cultivated to give an even seed bed for direct seeding or transplanting of crops.
- **Planting**: the method of establishment used depends on the crop grown, labor availability, size of area to be planted, speed, cost etc.
- **Weed control**: perennial weeds should be eliminated before establishing the crop. Annual weeds can be controlled using appropriate selective herbicides or mechanical methods.
Effective weed control is vital to achieve acceptable crop yields and avoid contamination of the end product.

2.3.2 Crop Management

There are some management decision and or activities which need to be conducted both before and after establishment of the crop.

- **Spacing**: Among these, a determination of optimum plant density per unit area is one of pre-cultivation decision which is important for achieving a better yield and for well being of the standing crop.

- **Irrigation**: application rates and timing may require specialist advice. Otherwise, recommendations from research results should be considered for efficient utilization of the available resources or economical production of the desired product.

- **Fertilization**: most of the time fertilization improves the yield. However, reaching on the proper type and amount of fertilizer is a costly process which should be uncovered before or after the crop establishment.

- **Pest and disease control**: it is essential to be aware of the potential problems and remedy early. Specialist advice will be needed to identify pests and diseases affecting a crop.
2.4 Harvesting and Yield

- **Time of harvest**: often requires extractions and chemical analysis to define the best time to harvest.
- **Harvest method**: to be cost effective, mechanical harvesting is usually required, particularly as the area of crop grown increases. Purpose-built or specially modified machinery may be needed for some crops. Manual harvesting is also advisable for small scale production system in areas where cheap labor source is available.
- **Yields**: crop yield varies considerably depending on grower experience, the cultivar grown, environmental conditions and processing methods, and will, to a large extent, determine the economic viability of a crop production venture.

2.5 Processing

Processing of aromatic plants contributes a considerable effect both on quality and quantity of essential oil to be produced. Planning for proper processing will lead to acquire a product that is highly demanded by the market. In doing this, it is important to think of distillation equipment and process, drying or wilting period and condition, packaging and storage and other related activities.

2.5.1 Distillation/Extraction Methods

The different methods used for production of essential oils include steam distillation, hydro distillation, cold pressing, enfleurage,
solvent extraction, turbo distillation extraction, hydro diffusion extraction and carbon dioxide extraction. Most commonly, the essence is extracted from the plant using a technique called distillation. One type of distillation places the plants or flowers on a screen. Steam is passed through the area and becomes "charged" with the essence. The steam then passes through an area where it cools and condenses. This mixture of water and essential oil is separated and bottled. Since plants contain such a small amount of this precious oil, several hundred pounds may be needed to produce a single ounce.

2.5.1.1 Steam Distillation

Steam distillation is the most common method of extracting essential oils. The basic still design for steam distillation is shown in Figure 1. Many old-time distillers favor this method for most oils, and say that none of the newer methods produces better quality oils. Steam distillation is done in a still. Fresh or sometimes dried botanical material is placed in the plant chamber of the still, and pressurized steam is generated in a separate chamber and circulated through the plant material.

The heat of the steam forces the tiny intercellular pockets that hold the essential oils to open and release them. The temperature of the steam must be high enough to open the pouches, yet not so high that it destroys the plants or burns the essential oils. As they are released, tiny droplets of essential oil evaporate together with the
steam molecules and travel through a tube into the still's condensation chamber. As the steam cools, it condenses into water. The essential oil forms a film on the surface of the water.

To separate the essential oil from the water, the film is then decanted or skimmed off the top. The remaining water, a byproduct of distillation, is called floral water, distillate, or hydrosol. It retains many of the therapeutic properties of the plant, making it valuable in skin care for facial mists and toners. In certain situations, floral water may be preferable to pure essential oil, such as when treating a sensitive individual or a child, or when a more diluted treatment is required.

The still design, capacity, water purity levels and flow rates, operating temperatures and length of distillation are important aspects that can affect the composition and quality of the oil. Technical assistance to optimize extraction efficiency is necessary.
2.5.1.2 Hydro Distillation

Hydro distillation is a method in which the plant material to be distilled comes in direct contact with the boiling water. Heat was provided through heating sources. The emerging vapor containing the volatile essential oil was led to a condenser for condensation and collected in the oil separate unit. This method differs from stem distillation in that the material going to be distilled comes in direct contact with the boiling water in case of hydro distillation as opposed to the stem in stem distillation.
2.5.1.3 Cold Pressing

Another method of extracting essential oils is cold-pressed expression, or scarification. It is used to obtain citrus fruit oils such as bergamot, grapefruit, lemon, lime, mandarin, orange, and tangerine oils. In this process, fruit rolls over a trough with sharp projections that penetrate the peel. This pierces the tiny pouches containing the essential oil. Then the whole fruit is pressed to squeeze the juice from the pulp and to release the essential oil from the pouches. The essential oil rises to the surface of the juice and is separated from the juice by centrifugation.

2.5.1.4 Enfleurage

Some flowers, such as jasmine or tuberose, have such low contents of essential oil or are so delicate that heating them would destroy the blossoms before releasing the essential oils. In such cases, an expensive and lengthy process called enfleurage is sometimes used to remove the essential oils. Flower petals are placed on trays of odorless vegetable or animal fat, which will absorb the flowers' essential oils. Every day or every few hours, after the vegetable or fat has absorbed as much of the essential oil as possible, the depleted petals are removed and replaced with fresh ones. This procedure continues until the fat or oil becomes saturated with the essential oil. Adding alcohol to this enfleurage mixture separates the essential oil from the fatty substance. Afterwards, the alcohol evaporates and only the essential oil remains.
2.5.1.5 Solvent Extraction

Products used in the flavor and fragrance industry can be extracted from plants using a solvent extraction system. A high degree of technical expertise and significant capital investment are needed to set up such a system.

This method is used on delicate plants to yield higher amount of essential oil at a lower cost. In this process, a chemical solvent such as hexane is used to saturate the plant material and pull out the aromatic compounds. This renders a substance called a concrete. The concrete can then be dissolved in alcohol to remove the solvent. When the alcohol evaporates, the remainder is an absolute.

Although more cost-efficient than enfleurage, solvent extraction has disadvantages. Residues of the solvent may remain in the absolute and can cause side effects. While absolutes or concretes may be fine for fragrances or perfumes, they are not especially desirable for skin care applications. Some trees, such as benzoin, frankincense and myrrh exude aromatic 'tears', or sap that is too thick to use easily in aromatherapy. In these cases, a resin or essential oil can be extracted from the tears with alcohol or a solvent such as hexane. This renders a resin or an essential oil that is easier to use. However, only those oils or resin extracted with alcohol should be used for aromatherapy purposes.
2.5.1.6 Turbo Distillation Extraction
Turbo distillation is suitable for hard-to-extract or coarse plant material, such as bark, roots, and seeds. In this process, the plants soak in water and steam is circulated through this plant and water mixture. Throughout the entire process, the same water is continually recycled through the plant material. This method allows faster extraction of essential oils from hard-to-extract plant materials.

2.5.1.7 Hydro diffusion Extraction
In the hydro diffusion process, steam at atmospheric pressure is dispersed through the plant material from the top of the plant chamber. In this way the steam can saturate the plants more evenly and in less time than with steam distillation. This method is also less harsh than steam distillation and the resulting essential oils smell much more like the original plant.

2.5.1.8 Carbon Dioxide Extraction
Supercritical carbon dioxide extraction uses carbon dioxide under extremely high pressure to extract essential oils. Plants are placed in a stainless steel tank and pressure inside the tank builds as carbon dioxide is injected into the tank. Under high pressure, the carbon dioxide turns into a liquid and acts as a solvent to extract the essential oils from the plants. When the pressure is decreased, the carbon dioxide returns to a gaseous state, leaving no residues behind.
Many carbon dioxide extractions have fresher, cleaner, and crisper aromas than steam-distilled essential oils, and they smell more similar to the living plants. Scientific studies show that carbon dioxide extraction produces essential oils that are very potent and have great therapeutic benefits. This extraction method uses lower temperatures than steam distillation, making it gentler on the plants. It produces higher yields and makes some materials, especially gums and resins, easier to handle. Many essential oils that cannot be extracted by steam distillation are obtainable with this process.

2.5.2 Post Extraction Treatment

To effectively dry large quantities of aromatic plant materials, a drying shed equipped with a forced-air drier or a freeze drier will be necessary to store plant material before processing. Volumes, drying temperature, length of drying and drying technique play an important role in the quality of the end product. At Wondo Genet, it was found that chopping size and wilting duration had an impact on the overall distillation process for lemon grass, palmarosa and nardus grasses.

The type of packaging and how to meet consumer demand and market specifications requires excellent communication with the market. Generally essential oils should be stored in a cool, dry place away from sunlight and protected from insect infestation. In
addition, essential oils should be bottled in glass or non reactive metal containers.

Specialist advice will be required to recommend appropriate equipment and methods to optimize drying efficiency and minimize loss of critical plant components.

2.6 Market Research, Marketing and Financial Analysis

Market research is important to get the desired benefit from aromatic plants and their products. To achieve the target, undertaking analysis of market place, identification of products that the market wants, timing of supply, volumes required and prices are also important. In addition, commercial test samples to assess market acceptability are very crucial to enter in marketing of this business sector.

For running effective marketing, it is important to begin by targeting specific smaller markets interested in the likely quantity of product to be supplied. Supply will be a major problem if large markets are sought initially with the strong likelihood of losing the contract if the product cannot be supplied in full. Equally, personal contact with potential buyers is important.

Financial analysis including capital requirements (plant material, irrigation, harvesting and processing equipments), development and running costs (expert advice, travel costs and direct expenses
involved with growing and processing the crop) and market trends and prices need to be established. Once all possible financial data have been compiled, gross margins and other financial indicators can be developed with the help of specialist advisers to indicate the potential profitability of an enterprise.
3 Current Situation of Global Essential Oil Production and Marketing

3.1 Global Essential Oil Production

Aromatic plants or essential oil bearing plants are found in almost every geographic climate ranging from pines of the cold regions to the species found near equatorial climates. Currently around 64 countries were considered as major producers of essential oils around the world comprising a total of 74 aromatic plant species. The lists of major essential oil producing countries world wide along with plants used for production of essential oils are summarized in table 1. Of them, Brazil, China, USA, Egypt, India, Mexico, Guatemala and Indonesia are the leading producers of essential oils. This is primarily due to their large population and internal consumption of essential oils, their investment in scientific and technical training, their strong economic position and well developed export businesses.

Table 1. List of countries with their essential oil bearing plants

<table>
<thead>
<tr>
<th>No</th>
<th>Country Name</th>
<th>Name of Aromatic Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Algeria</td>
<td>Thyme</td>
</tr>
<tr>
<td>2</td>
<td>Argentina</td>
<td>Bergamot, Grapefruit, Lemon, Tarragon, Spearmint</td>
</tr>
<tr>
<td>3</td>
<td>Australia</td>
<td>Eucalyptus, Lavender, Lemon, Orange, Peppermint, Sandalwood, Spearmint, Tea Tree</td>
</tr>
<tr>
<td>No</td>
<td>Country Name</td>
<td>Name of Aromatic Plants</td>
</tr>
<tr>
<td>----</td>
<td>--------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>4</td>
<td>Austria</td>
<td>Eucalyptus</td>
</tr>
<tr>
<td>5</td>
<td>Belgium</td>
<td>Angelica, Catnip</td>
</tr>
<tr>
<td>6</td>
<td>Brazil</td>
<td>Bergamot, Citrus, Clove, Corn mint, Eucalyptus, Grapefruit, Lemon, Lemongrass, Lime, Orange, Patchouli, Rosewood, Sassafras, Spearmint, Tangerine, Wormwood</td>
</tr>
<tr>
<td>7</td>
<td>Bulgaria</td>
<td>Clary sage, Coriander, Dill, Lavender, Rose, Sage, Spearmint, Wormwood, Yarrow</td>
</tr>
<tr>
<td>8</td>
<td>Canada</td>
<td>Angelica, Coriander, Pine, Scotch spearmint</td>
</tr>
<tr>
<td>9</td>
<td>Ceylon</td>
<td>Cinnamon Leaf</td>
</tr>
<tr>
<td>10</td>
<td>China</td>
<td>Anise, Artemisia, Camphor, Cassia, Cedarwood, Citronella, Cornmint, Eucalyptus, Frankincense, Ginger, Jasmine, Lavender, Lemongrass, Lime, Litsea cubeba, Lovage root, Menthol, Patchouli, Peppermint, Rose, Rosemary, Sassafras, Scotch spearmint, Spearmint, Star Anise</td>
</tr>
<tr>
<td>11</td>
<td>Cuba</td>
<td>Lime</td>
</tr>
<tr>
<td>12</td>
<td>Dominican R</td>
<td>Orange</td>
</tr>
<tr>
<td>13</td>
<td>Egypt</td>
<td>Basil, Caraway, Coriander, Dill, Garlic, Jasmine, Sage, Spearmint</td>
</tr>
<tr>
<td>14</td>
<td>Ethiopia</td>
<td>Myrrh</td>
</tr>
</tbody>
</table>
### Table 3. Cont'd

<table>
<thead>
<tr>
<th>No</th>
<th>Country</th>
<th>Name of Aromatic Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>France</td>
<td>Angelica, Anise, Artemisia, Basil, Clary sage, Fennel, Hyssop, Jasmine, Lavender, Rose, Rosemary, Spearmint, Tarragon, Thyme</td>
</tr>
<tr>
<td>16</td>
<td>Germany</td>
<td>Angelica, Artemisia, Basil, Chamomile, Thyme</td>
</tr>
<tr>
<td>17</td>
<td>Ghana</td>
<td>Lime</td>
</tr>
<tr>
<td>18</td>
<td>Greece</td>
<td>Lemon, Thyme</td>
</tr>
<tr>
<td>19</td>
<td>Guatemala</td>
<td>Cardamom, Lemongrass</td>
</tr>
<tr>
<td>20</td>
<td>Haiti</td>
<td>Amarys, Lemongrass, Lime</td>
</tr>
<tr>
<td>21</td>
<td>Hungary</td>
<td>Angelica, Artemisia, Basil, Caraway, Carrot seed, Dill, Hyssop, Lovage root, Marjoram, Parsley, Spearmint, Tarragon, Wormwood, Yarrow,</td>
</tr>
<tr>
<td>22</td>
<td>India</td>
<td>Ajowan, Angelica, Artemisia, Caraway, Celery seed, Cinnamon Bark, Citronella, Coriander, Corn mint, Cumin, Frankincense, Ginger, Lemongrass, Menthol, Patchouli, Rose, Sandalwood</td>
</tr>
<tr>
<td>23</td>
<td>Indonesia</td>
<td>Basil, Cajuput, Cassia, Clove, Ginger, Nutmeg</td>
</tr>
<tr>
<td>24</td>
<td>Iran</td>
<td>Caraway, Cumin, Tarragon</td>
</tr>
<tr>
<td>25</td>
<td>Ireland</td>
<td>Lemon Balm</td>
</tr>
<tr>
<td>26</td>
<td>Israel</td>
<td>Basil, Grapefruit, Orange, Tarragon, Thyme</td>
</tr>
<tr>
<td>27</td>
<td>Italy</td>
<td>Bergamot, Clary Sage, Garlic, Jasmine, Lemon, Orange, Peppermint, Tarragon</td>
</tr>
<tr>
<td>28</td>
<td>Ivory Coast</td>
<td>Bergamot, Lime</td>
</tr>
<tr>
<td>No</td>
<td>Country</td>
<td>Name of Aromatic Plants</td>
</tr>
<tr>
<td>----</td>
<td>---------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>29</td>
<td>Jamaica</td>
<td>Allspice, Lime</td>
</tr>
<tr>
<td>30</td>
<td>Japan</td>
<td>Artemisia, Corn mint, Jasmine, Peppermint, Spearmint</td>
</tr>
<tr>
<td>31</td>
<td>Java</td>
<td>Ginger</td>
</tr>
<tr>
<td>32</td>
<td>Kenya</td>
<td>Frankincense, Myrrh</td>
</tr>
<tr>
<td>33</td>
<td>Korea</td>
<td>Spearmint</td>
</tr>
<tr>
<td>34</td>
<td>Madagascar</td>
<td>Clove, Vanilla</td>
</tr>
<tr>
<td>35</td>
<td>Malawi</td>
<td>Ninde</td>
</tr>
<tr>
<td>36</td>
<td>Malaysia</td>
<td>Patchouli</td>
</tr>
<tr>
<td>37</td>
<td>Mexico</td>
<td>Citrus, Garlic, Lime, Vanilla</td>
</tr>
<tr>
<td>38</td>
<td>Morocco</td>
<td>Artemisia, Basil, Caraway, Chamomile, Clary Sage, Coriander, Hyssop, Jasmine, Pennyroyal, Rosemary, Spearmint, Thyme, Wormwood</td>
</tr>
<tr>
<td>39</td>
<td>Nepal</td>
<td>Lemongrass</td>
</tr>
<tr>
<td>40</td>
<td>Netherlands</td>
<td>Angelica, Caraway, Coriander</td>
</tr>
<tr>
<td>41</td>
<td>New Zealand</td>
<td>Spearmint</td>
</tr>
<tr>
<td>42</td>
<td>North Korea</td>
<td>Corn mint, Star Anise</td>
</tr>
<tr>
<td>43</td>
<td>Paraguay</td>
<td>Corn mint, Eucalyptus, Spearmint</td>
</tr>
<tr>
<td>44</td>
<td>Peru</td>
<td>Lemon</td>
</tr>
<tr>
<td>45</td>
<td>Philippines</td>
<td>Cajuput</td>
</tr>
<tr>
<td>46</td>
<td>Poland</td>
<td>Caraway, Coriander</td>
</tr>
<tr>
<td>47</td>
<td>Portugal</td>
<td>Eucalyptus, Lavender, Rosemary, Thyme</td>
</tr>
</tbody>
</table>
### Table 5. cont’d

<table>
<thead>
<tr>
<th>No</th>
<th>Country</th>
<th>Name of Aromatic Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Romania</td>
<td>Coriander, Spearmint</td>
</tr>
<tr>
<td>49</td>
<td>Russia</td>
<td>Bergamot, Caraway, Clary Sage, Coriander, Dill, Lavender, Lemongrass, Rose, Rosemary, Sage, Spearmint, Star Anise, Tangerine, Wormwood</td>
</tr>
<tr>
<td>50</td>
<td>Saudi Arabia</td>
<td>Frankincense</td>
</tr>
<tr>
<td>51</td>
<td>Somalia</td>
<td>Frankincense</td>
</tr>
<tr>
<td>52</td>
<td>South Africa</td>
<td>Calendula, Coriander, Eucalyptus, Tangerine</td>
</tr>
<tr>
<td>53</td>
<td>Spain</td>
<td>Anise, Bergamot, Clary Sage, Cumin, Eucalyptus, Fennel, Lavender, Lemon, Marjoram, Rosemary, Tangerine, Thyme</td>
</tr>
<tr>
<td>54</td>
<td>Sri Lanka</td>
<td>Cinnamon Bark, Clove, Lemongrass, Nutmeg</td>
</tr>
<tr>
<td>55</td>
<td>Taiwan</td>
<td>Cassia, Corn mint, Spearmint</td>
</tr>
<tr>
<td>56</td>
<td>Tanzania</td>
<td>Clove</td>
</tr>
<tr>
<td>57</td>
<td>Thailand</td>
<td>Corn mint</td>
</tr>
<tr>
<td>58</td>
<td>Tunisia</td>
<td>Rosemary</td>
</tr>
<tr>
<td>59</td>
<td>Turkey</td>
<td>Jasmine, Rose</td>
</tr>
<tr>
<td>60</td>
<td>UK</td>
<td>Angelica, Chamomile, Clary Sage, Coriander, Lavender, Rosemary, Sage, Spearmint</td>
</tr>
<tr>
<td>61</td>
<td>USA</td>
<td>Angelica, Basil, Cedarwood, Chamomile, Cilantro, Citrus, Coriander, Dill, Fennel, Grapefruit, Lemon, Lemon Balm, Melissa, Orange, Oregano, Pennyroyal, Peppermint, Pine, Rosemary, Sage, Sassafras, Scotch spearmint, Spearmint, Tangerine, Thyme, Wormwood</td>
</tr>
</tbody>
</table>
3.2 Global Essential Oil Market

3.2.1 Total Market

Information concerning market data on essential oils is hardly available. This is because production is essentially concentrates on the province of small scale producers who have a history of very poor record keeping. In addition, production of a number of sources of the raw material used in essential oil occurs in developing countries where nationally statistical systems are weak. This is particularly true for material that is harvested from plants that are semi-domesticated and wild-harvested. Even in developed countries production data for a number of essential oils are under-reported. This is because most statistical systems need a certain minimum sized industry to start recording and that size is usually well above that of most essential oils supplied to the.

As a result, it is followed the approach that demand is best measured by reference to international trade data. Information collected from trade data has the advantage of having to be accompanied by a formal documentation process. Again, the
documented process associated with developed countries is considered more reliable than that of developing countries. It is from the international trade data that some general estimates of price behavior was developed for essential oils.

The estimated total trade of essential oils is over US$1.6 billion in 2004. The 20 most utilized essential oils world wide are orange, corn mint, eucalyptus (cineole-type), citronella, peppermint, lemon, eucalyptus (citronellal-type), clove leaf, cedar wood (U.S.), litsea cubeba, sassafras, lime, spearmint, cedar wood (Chinese), lavender, sassafras (Chinese), camphor, coriander, grape fruit and patchouli consecutively in a decreasing order.

The top ten essential oils importers and exporters were summarized in table 2. The past experience form 1994 to 2004 indicates the overall world export of essential oils is increasing (Fig 1). The growth is an indicator that the world population is moving in to an era with increasing demand for “organically” grown plant products with minimal use of manufactured chemicals both in agriculture and other purpose. Hence, these secondary products are assuming a growing importance and growth must be considered strong.
Table 7. The world’s ten largest importers and exporters of essential oils by value in 2004.

<table>
<thead>
<tr>
<th>Importer</th>
<th>Value of Exports</th>
<th>Exporter</th>
<th>Value of Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>US$ 316 m</td>
<td>United States</td>
<td>US$329 m</td>
</tr>
<tr>
<td>France</td>
<td>US$ 198 m</td>
<td>France</td>
<td>US$ 213 m</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>US$ 164 m</td>
<td>United Kingdom</td>
<td>US$109 m</td>
</tr>
<tr>
<td>Japan</td>
<td>US$ 130 m</td>
<td>Brazil</td>
<td>US$ 98 m</td>
</tr>
<tr>
<td>Germany</td>
<td>US$ 121 m</td>
<td>India</td>
<td>US$ 96 m</td>
</tr>
<tr>
<td>China</td>
<td>US$ 90 m</td>
<td>China</td>
<td>US$ 89 m</td>
</tr>
<tr>
<td>Switzerland</td>
<td>US$ 90 m</td>
<td>Germany</td>
<td>US$ 58 m</td>
</tr>
<tr>
<td>Ireland</td>
<td>US$ 63 m</td>
<td>Italy</td>
<td>US$ 51 m</td>
</tr>
<tr>
<td>Spain</td>
<td>US$ 53 m</td>
<td>Indonesia</td>
<td>US$ 46 m</td>
</tr>
<tr>
<td>Mexico</td>
<td>US$ 53 m</td>
<td>Spain</td>
<td>US$ 43 m</td>
</tr>
</tbody>
</table>

Source: FAOSTAT, 2004 (FAOSTAT is the statistical data source of FAO)

3.2.1.1 Import

Similar to the total trade of essential oil, global import value has shown increasing trend and essential oil market become attractive and less competitive. The list of importers showed in table 2 pose no real surprises. This is because the size of the United States food manufacturing industry would see a ready home for essential oils for use in flavoring. Likewise, a quick trawl of the internet will show that most of the sites offering deals in the aromatherapy and fragrance industry. China is on interest, showing that not only is
Training Manual on Aromatic Plants

China a major producer but also a major market. As currently wealth is growing in China, it is more likely that the country will become a larger player in essential oils business sector.

3.2.1.2 Export

Essential oil exports from the United States and Brazil are dominated by the citrus-based oils. United States is also a major producer and exporter of the mint oils. Whilst France and the United Kingdom are the second and third largest exporters of all essential oils, a great deal of their essential oil exports are re-exports of refined essential oils and value-added essential oil products. This is because the two countries, but especially the United Kingdom, do not have the climatic capability of producing the high volume essential oils. The same is true for Germany. This suggests that India and China are probably the world's most diverse exporters of raw essential oils.

The data presented in table 2 shows that, with the possible exception of Indonesia, none of the top ten exporters could be considered a developing country. This implies that the bulk of the world's exports of essential oils are not derived from raw plant material from the developing countries but rather are either basic essential oils that have been refined and/or value added to higher level products or are the result of being by-products from another industry, vide the citrus-based oils.
4 Aromatic Plants and Essential Oil Production in Ethiopian Context

4.1 Essential Oil Production in Ethiopia

Ethiopia is endowed with different bioclimatic zones that allowed for the cultivation and utilization of aromatic plants and their products. The start of production and development activities on aromatic plants was started dated back to around 50 years. These activities have been started at Wondo Genet by French investors.

During that time, Geranium, Citronella grass, lemon grass and citrodora are the major crops being cultivated and processed. The processed products specifically essential oils have been exported to European countries until the owners left out of the country. After this, production, processing and export of these commodities were discontinued for ten years until the government realized its importance in the economic sector. Then after, the production of the commodities was reinitiated and started to distil essential oils for local consumptions to be utilized in soap factories.

4.2 Essential Oil Demand and Supply of Ethiopia

In Ethiopia a considerable amount of plant-derived chemicals and their derivatives are imported by an alcohol, soft drink, soap, detergent, cosmetic, pharmaceutical, food, textile, paint, pulp and leather industry to the country. An average of 1736.5 tones of
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essential oils and related products is imported per year with an average value of about 37 million Birr.

With the newly emerging private alcohol and beverage factories, the amount of alcohol and soft drink essences imported to the country has increased. For instance, the government-owned National Alcohol and Liquor Factory alone imported 14,500kg of flavors of different alcoholic drinks, spending about 4.2 million Birr. Although there is no statistical data about the amount of essence imported by private liquor factories, based on the pure alcohol amount they buy from National Alcohol and Liquor Factory, it is estimated that they import half of the above-mentioned amount. This makes the total amount of imported essence 21,750 kg and the total money spent by liquor factory is estimated to be about 6 million Birr.

The overall import summary of essential oils from 2001 to 2004 is presented in table 3. It indicates that Ethiopia paid out a total of more than 50 million ETB by importing more than 200 thousand kg of essential oils during the mentioned four years. This huge amount of money is an indicator that the demand for essential oils is very high in the country. Despite the sector is lucrative, the number of participants in production and processing of essential oils in the country to fill up this demand is as good as nil. This might be due to lack of information and technologies about the production and processing of essential oils or awareness about this sector.
Therefore, much is expected from technology generating bodies and government officials in such a way that local and international producers and processors of aromatic plants to be involved in the sector and thereby save huge amount of money that the country spends for importation of processed products.

Table 8. Import of essential oils from 2001-2004 in amount and value in Ethiopia

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity in Kg</th>
<th>ETB</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>577,811.00</td>
<td>12,186,544.00</td>
</tr>
<tr>
<td>2002</td>
<td>520,442.00</td>
<td>10,295,234.00</td>
</tr>
<tr>
<td>2003</td>
<td>787,589.00</td>
<td>18,151,438.00</td>
</tr>
<tr>
<td>2004</td>
<td>464,284.00</td>
<td>9,613,714.00</td>
</tr>
<tr>
<td>Total</td>
<td>2,350,126.00</td>
<td>50,246,930.00</td>
</tr>
<tr>
<td>Average</td>
<td>587,531.50</td>
<td>12,561,732.50</td>
</tr>
</tbody>
</table>

So far, local production of essential oils and other related plant extracts has hardly established. Few years ago, the pilot scale production of essential oils by the Essential Oils Factory with a capacity of about 1 ton/year, which had changed itself to the only research center engaged on aromatic and other oil bearing plants. Recently, new investors on such sector are coming to appear. Tabor herbs Privet Company, Ariti Essential Oil Company, Bishoftu Medicinal Aromatic Agricultural Project (BIMAAP) and Abyssinia Essential Oils plc can be listed as example that starts investing on aromatic plants.
5 Aromatic Plant Research at Wondo Genet Research Center

5.1 Current Research Directions on Aromatic Plants

Currently Wondo Genet Agricultural Research Center has developed two projects that help to diversify, develop and promote the production, processing and utilization of aromatic plants. Understanding the infancy of this sector and presence of diverse agro ecologies in the country, the center planned to introduce technologies of aromatic plants available world wide. Selection of aromatic plants for high biomass and essential oil yield within the range of international standard and tolerant to disease following local collection is also the strategic focus of the center. For this, wider adaptability testing of aromatic plants will be practiced intensively and implemented soon. As survey, identification and loss assessment of disease and pests of aromatic plants were not carried out in the country; effort will be made to devise solutions for the gaps in the coming five years.

Essential oils content varies with environment, part used, harvesting stage and time of the day. This will be explicitly determined for prioritized aromatic plants. Moreover, the major constraints for post harvest processing technologies such as appropriate drying, extraction, packaging, storage and handling methods for prioritized aromatic plant species are the strategic focus of the center. Determination and isolation of active
compounds from the essential oils that are highly demanded in a niche market particularly in cosmetic and other industries will help to generate foreign currency. Therefore, fractional distillation of the essential oils and formulations were considered as future directions.

Information on value chain and economics of essential oils is lacking. This calls for research activities that are helpful for understanding of economic studies in production, processing, impact, marketing and policy issues. The plan was developed to address the gap in collaboration with other research staffs of the institute. Information and proven technology on aromatic plants were considered and planned to disseminate using conferences, workshops, exhibitions, posters and field days. With this, the technology generated in research will reach to users.

5.2 Lists of Aromatic Plants at Wondo Genet Agricultural Research Center

From the existing aromatic and medicinal plants maintained in the center, aromatic plants share the largest proportion (37.5%). The existing aromatic plants have the international yield and quality standards. Their botanical, common and local names together with use and part used are presented in table 4.
Table 4. Summary of aromatic plants present in Wondo Genet Agricultural Research Center

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Local name</th>
<th>Family</th>
<th>Parts used</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aframomum korrerima</em></td>
<td>False</td>
<td>Korerima</td>
<td>Zingebraceae</td>
<td>Fruit</td>
<td>Spice, food flavor, essential oil</td>
</tr>
<tr>
<td><em>Aloysia triphlla</em></td>
<td>Lemon</td>
<td>Lominat</td>
<td>Verbenaceae</td>
<td>Leaves, flowers</td>
<td>Spice, essential oil</td>
</tr>
<tr>
<td><em>Artemisia graveolens</em></td>
<td>Dill</td>
<td></td>
<td>Apiaceae</td>
<td>Seeds, leaves</td>
<td>Spice, Food flavoring</td>
</tr>
<tr>
<td><em>Artemisia abyssinica</em></td>
<td>Chinese worm wood</td>
<td>Chigugn</td>
<td>Asteracea</td>
<td>Leaves</td>
<td>Medicinal, flavor</td>
</tr>
<tr>
<td><em>Artimisia anua</em></td>
<td>Chinese worm wood</td>
<td></td>
<td>Asteracea</td>
<td>Leaves</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td><em>Artemisia rehan</em></td>
<td>worm-wood</td>
<td>Ariti</td>
<td>Asteracea</td>
<td>Leaves</td>
<td>Flavor, medicinal</td>
</tr>
<tr>
<td><em>Cinnamomum zeylanicu</em></td>
<td>cinnamon</td>
<td>Kerefa</td>
<td>Lauraceae</td>
<td>Bark, leaves</td>
<td>Spice, food flavor, essential oil</td>
</tr>
<tr>
<td><em>Coriandrum sativum</em></td>
<td>Coriander</td>
<td>Dimblal</td>
<td>Apiaceae</td>
<td>Seed, leaves</td>
<td>Spice, essential oil</td>
</tr>
<tr>
<td>Botanical name</td>
<td>Common name</td>
<td>Local name</td>
<td>Family</td>
<td>Parts used</td>
<td>Purpose</td>
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</tr>
<tr>
<td><em>Cymbopogon citratus</em></td>
<td>Lemon grass</td>
<td>Lomi-sar</td>
<td>Gramineae</td>
<td>Aerial</td>
<td>medicinal, Flavor, essential oil, medicinal</td>
</tr>
<tr>
<td><em>Cymbopogon martini</em></td>
<td>Palmarosa</td>
<td>Tej-sar</td>
<td>Gramineae</td>
<td>Aerial</td>
<td>Essential oil, flavor, medicinal</td>
</tr>
<tr>
<td><em>Cymbopogon nardus</em></td>
<td>Citronella grass</td>
<td>Yenardos-sar</td>
<td>Gramineae</td>
<td>Aerial</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td><em>Cymbopogon sp.I</em></td>
<td></td>
<td></td>
<td>Gramineae</td>
<td>Aerial</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Cymbopogon sp.II</em></td>
<td></td>
<td></td>
<td>Gramineae</td>
<td>Aerial</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Eucalyptus camaldulensis</em></td>
<td></td>
<td>key-bahir-zaf</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Eucalyptus citrodora</em></td>
<td>Lemon-scented gum</td>
<td>Ye'shito-bahir-zaf</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Eucalyptus globulus</em></td>
<td>White</td>
<td>Nech-bahir-</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Essential oil, medicinal</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Local name</th>
<th>Family</th>
<th>Parts used</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eucalyptus grandis</em></td>
<td>eucalypt</td>
<td>zaf</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Eucalyptus robusta</em></td>
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<td>key-bahir-zaf</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Feoniculum vulgare</em></td>
<td>Fennel</td>
<td>Inslal</td>
<td>Apiaceae</td>
<td>Leaves, seeds</td>
<td>Flavor, medicinal, essential oil</td>
</tr>
<tr>
<td><em>Jasamunum chandifloram</em></td>
<td>Jasmine</td>
<td>Tembelel</td>
<td>Oleaceae</td>
<td>Flower</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Lantana camara</em></td>
<td>-</td>
<td>Yewef kollo</td>
<td>Verbenacea</td>
<td>Leaves</td>
<td>Medicinal, essential oil</td>
</tr>
<tr>
<td><em>Lavandula officinalis</em></td>
<td>Lavander</td>
<td>-</td>
<td>Labiatae</td>
<td>Leaves, flowers</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td><em>Marjorana hortensis</em></td>
<td>Majoram</td>
<td>-</td>
<td>Labiatae</td>
<td>Aerial</td>
<td>Essential oil, food flavor, medicinal</td>
</tr>
<tr>
<td><em>Matricaria comomella</em></td>
<td>Comomella</td>
<td>-</td>
<td>Compositae</td>
<td>Flower</td>
<td>Essential oil, flavor, medicinal</td>
</tr>
<tr>
<td><em>Mentha arvensis</em></td>
<td>Japanese mint</td>
<td>-</td>
<td>Lamiaceae; Labiatae</td>
<td>Aerial</td>
<td>Essential oil, food flavor, Medicinal</td>
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</table>

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<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
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<th>Family</th>
<th>Parts used</th>
<th>Purpose</th>
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</thead>
<tbody>
<tr>
<td>Mentha logifolia</td>
<td>-</td>
<td>Semahal</td>
<td>Labiatae</td>
<td>Aerial</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td>Mentha piperita</td>
<td>Pepper mint</td>
<td>Nana</td>
<td>Lamiaceae;</td>
<td>Aerial</td>
<td>Essential oil, food flavor, medicinal</td>
</tr>
<tr>
<td>Mentha sp. I</td>
<td>-</td>
<td>-</td>
<td>Labiatae</td>
<td>Aerial</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td>Mentha sp. II</td>
<td>-</td>
<td>-</td>
<td>Labiatae</td>
<td>Aerial</td>
<td>Essential oil, medicinal</td>
</tr>
<tr>
<td>Mentha spicata</td>
<td>Spear mint</td>
<td>Menta</td>
<td>Lamiaceae;</td>
<td>Aerial</td>
<td>Essential oil, food flavor, medicinal</td>
</tr>
<tr>
<td>Nigella sativa</td>
<td>Black cumin</td>
<td>Tikur Azmud</td>
<td>Ranunculacea</td>
<td>Seed</td>
<td>Spice, food flavoring, medicinal essential oil</td>
</tr>
<tr>
<td>Ocimum basilicum</td>
<td>Basil</td>
<td>Besobila</td>
<td>Labiatae</td>
<td>Leaves, flowers</td>
<td>Spice, food flavoring, medicinal essential oil</td>
</tr>
<tr>
<td>Ocimum basilicum var. Thgrstifolium</td>
<td>Basil</td>
<td>Ajuban</td>
<td>Labiatae</td>
<td>Flower, leaves</td>
<td>Spice, food flavoring, medicinal Essential oil</td>
</tr>
<tr>
<td>Pelargonium</td>
<td>Geranium</td>
<td></td>
<td>Geraniaceae</td>
<td>Flowers, leaves</td>
<td>Essential oil</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
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<th>Parts used</th>
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</tr>
</thead>
<tbody>
<tr>
<td><em>Rosmarinus officinalis</em></td>
<td>Rosemary</td>
<td>Ye'siga metebesha</td>
<td>Labiatae</td>
<td>Leaves, flowers</td>
<td>Spice, food flavoring, medicinal</td>
</tr>
<tr>
<td><em>Ruta calpenesis</em></td>
<td>Rue</td>
<td>Tenadam</td>
<td>Rutaceae</td>
<td>Aerial</td>
<td>Medicinal, spice, food flavor</td>
</tr>
<tr>
<td><em>Salvia officinalis</em></td>
<td>Sadge</td>
<td>-</td>
<td>Labiatae</td>
<td>Leaves</td>
<td>Medicinal, essential oil</td>
</tr>
<tr>
<td><em>Schinus molle</em></td>
<td>Pepper tree</td>
<td>Qundoberber</td>
<td>Anacardiacea</td>
<td>Seed, leaves</td>
<td>Medicinal, essential oil</td>
</tr>
<tr>
<td><em>Tagitus minuta</em></td>
<td>-</td>
<td>Gimme</td>
<td>Astraceae</td>
<td>Aerial</td>
<td>Essential oil</td>
</tr>
<tr>
<td><em>Thymus vulgaries</em></td>
<td>Thylum</td>
<td>Tosgn</td>
<td>Labiatae</td>
<td>Aerial</td>
<td>Essential oil Medicinal</td>
</tr>
<tr>
<td><em>Trachyspemum amini</em></td>
<td>Bishop's weed</td>
<td>Nech Azmud</td>
<td>Apiaceae</td>
<td>Seed</td>
<td>Spice Essential oil</td>
</tr>
<tr>
<td><em>Vetivaria zezanoid</em></td>
<td>Vetivar</td>
<td>Vetivar</td>
<td>Cyperaceae</td>
<td>Root</td>
<td>Essential oil</td>
</tr>
</tbody>
</table>
5.3 Description of Prioritized Aromatic Plants

From the existing species of aromatic plants maintained at Wondo Genet Agricultural Research Center, nine of them (lemmon grass, palmarosa, citriodora, lemmon verbena, japanese mint, spear mint, piper mint, citronella grass) were prioritized to be included in the research and development directions of the center.

5.3.1 Cymbopogon spp

The genus Cymbopogon comprises about 140 species. Some of the species yield essential oils and among the essential oil yielding species, the following are considered as economically important.

5.3.1.1 Cymbopogon winterianus

It is commonly known as Java citronella. It is a tufted aromatic perennial herb belongs to the family Poaceae, which yields essential oil known as Citronella Java oil. It has fibrous root; culms stout, erect over 2m tall, terete, smooth and shining, leafy glabrous at the nods. The leaves are linear blades, gradually tapering to a long membranous acuminate tip, up to 1m length and 1.5 cm width. Inflorescence is a very large (30m long) decompound panicle.
Java Citronella flower can’t produce viable seeds; therefore, the appropriate way to perpetuate Java is vegetative propagation. So planting is done by splitting the clumps into slips. Each slip contains 1-3 tillers, which can be used as a propagule.

Most commonly, it is planted in 60 cm plant and row spacing. But in case of fertile and conducive soils, planting to a plant and row spacing of 90 cm is also recommended. Planting can be done at any time with the abundant of moisture. But the plant is sensitive to water logging, so care should be taken not to plant in areas vulnerable to water logging (even for short period). Hence, it is better to plant on ridges in areas where water logging is problematic.

It grows well under varying soil conditions, but optimum growth and yield is obtained in sandy loam. In addition, it flourishes well under tropical and sub tropical environment where abundant moisture and long sunshine hours for ground is readily available.

Fertilization may be required for improving the growth and yield of
the crop grown on infertile or depleted soils. Fertilization of 80-120 kg N/ha and 40 kg/ha each for P and K is recommended for infertile site; however, the rate might be reduced for fertile area. Nitrogen is applied four times in splits. The first at one month after transplanting and the remaining three will be applied after each harvest in three months interval.

The plant requires adequate moisture for growth and yield of leaves. In the area, where annual rainfall is about 2000-2500mm, well distributed throughout the year, irrigation is not necessary. However, in water deficit area, additional irrigation is crucial for economical production of Java Citronella.

Regarding oil of citronella, it is found in all part of the plant though the maximum amount and the best quality is found in the leaves. According to Indian experience, harvesting starts six months after planting and succeeding harvest can be done with three months interval. Both early and late harvesting of the leaves has an adverse effect on the quality of the oil. The plantation will remain productive for 5-6 years though maximum yield is obtained during the second and third years. By considering the extremes of growing conditions, Java Citronella plantation is expected to yield a fresh biomass of 15-20 tones/ha in first harvest, 20-25 tones/ha in second and third harvests. Out of which, 1.0 - 1.2 % is accounted for citronella oil. Under optimum conditions, essential oil yield between 200-250 kg/ha/year can be obtained.
The oil is used extensively as a source of important perfumery chemicals like citronellal, citronellol and geraniol, which find extensive use in soap, perfumery, cosmetics and flavoring industries for the production of soap, soap flakes, detergents, household cleansers, technical products, insecticides, insect repellent, etc., throughout the world.

5.3.1.2 *Cymbopogon citratus*

It is one of the prioritized aromatic grasses in research and development direction of Wondo Genet Agricultural Research Center. It is locally known as lemon grass and of course is among the major aromatic plants that has been imported and being cultivated for essential oil production since the establishment of the center. It is described as a tall perennial aromatic grass belonging to the family of Poaceae. There is another aromatic grass spices (*C. flexuosus*), which is known with a common name of lemon grass. The two can be differentiated as East Indian lemon grass (*C. flexuosus*) and West Indian lemon grass (*C. citratus*).

*C. citratus* is a grass with rhizomes from which leaves are produced. The leaf blade is linear, long-attenuated toward the base and tapering upward, with a dimension of 90 X 18 cm, and glabrous.
Regarding the inflorescence, it has spatheate panicle, decompound to sub decompound, losses, 30-60 cm long and linear lanceolate to almost subulate when enrolled.

Like any tropical other plant spices, the grass prefers an annual rainfall range between 2000 and 2500 mm and average temperature range of 23-27°C. It is a hardy plant and is resistant to drought. It grows best on well drained sandy loam soil. Planting is done in a row spacing of 90 cm and 60 cm plant spacing using slips. During cultivation of lemon grass, effective production can be achieved if the provision of some specific requirements of the crop such as availability of long sunshine hour, occasionally heavy rain, warmer temperature and sufficient atmospheric humidity are assured throughout the production cycle.

As the ultimate aim of essential oil production is earning higher revenue by adding the value on the primary products from the cultivation of aromatic plants. By turn, the value addition on essential oil can be achieved in a number of ways; among them maximizing the crude essential oil per hectare and also the proportion of specific active constituent are the most economical ways. These parameters of lemon grass can possibly be achieved through fertilization.

Application of ammonium nitrate, urea and Indole acetic acid enhance the vegetative growth and essential oil yield and quality.
Indole acetic acid produce maximum increase of 0.17% volatile oil and 5.9% increase in the content of the major active compound, i.e. citral. 30 kg each of P₂O₅, K₂O and N at time of planting and 60 kg N/ha as top dressing in 3-4 splits is recommended for obtaining optimum yield.

First harvest possibly riches 6 months after planting. Subsequent harvests can be done 40-50 days interval after harvest. Under normal conditions, three harvestings are possible during the first year and 4 in the subsequent years. Oil content and herbage yield is lowest in the first year and highest in the third and fourth years. Essential oil yield between 75 and 100kg/ha can be obtained. The essential oil content varies between 0.2 and 0.4%.

Oil of lemon grass is one of the most important essential oils produced in the world. The name lemon grass has been given because of the typical strong lemon-like odor of the plant. This is due to high citral content of the essential oil present in the leaves, which is used as a basic row material for synthesis of B-ionones. B-ionones are important row materials used for the synthesis of a number of useful aromatic compounds and Vitamin-A. Citral itself is used as a perfumery for various grades of soaps and cosmetics. The
oil is also suitable as a fumigant or repellent against flies and mosquitoes

Lemon grass has been largely cultivated in west India, Guatemala, Brazil etc, for essential oil production for the supply of either in domestic or export market or both. It has been cultivated and used as a dry spice for flavoring foods and tea in India. Moreover, the spent lemongrass which is left over after distillation has been reported to be suitable for making paper, as clean burning fuel for distillation of aromatic biomass and as an excellent source of green manure to enrich soil when applied directly as mulch or after transforming the herbage as compost or ash.

5.3.1.3 Cymbopogon martini

It is commonly known as Palmarosa and ‘Tej Sar’ locally. It is a perennial grass that can grow up to 3 m. It is susceptible to frost so that most of the time the aerial part dies in winter. Leaves are linear lanceolate to lanceolate, cordate or amplexicaul, 8-50 cm long and 1-3 cm wide.

Palmarosa is a tropical plant and grows in warm and humid area. Areas which are affected with severe frost are not suitable, this is because the frost kills the grass and reduces the oil yield. A well-drained loamy soil having irrigation facility and receiving an annual rainfall of about 1500 mm are ideal conditions for cultivation of
palmarosa. Although the grass grows best in soil with neutral pH, it can survive and gives economical yield in the alkaline soil of pH 9.

As the grass is perennial the soil needs replenishment and fertilization in different stage of development depending on fertility status of the area. Rich soils need no replenishment at least for the first two years. In deficient soils, a mixture of consisting 20kg of N, 50 kg of P₂O₅ and 40 kg of K₂O per hectare is used as a basal dose at the time of planting. About 60 kg N/ha is applied in three split doses during the growing season. The mixture of NPK should be repeated at the time of appearance of fresh leaves each year.

Palmarosa is propagated with seeds or through slips even if vegetative propagation is not suitable for commercial planting. Healthy and vigorous slips are used for planting commonly with 60 cm plant and row spacing.

It will be ready for harvest when it produces flowers. Usually one harvest is obtained in the first year. In subsequent years, 2-3 harvesting can be obtained depending on climatic condition of the
area. It will stay productive for about 8 years under proper management.

Despite essential oil is distributed in all part of the grass; major portion of essential oil is accumulated in flower heads. So, harvesting is recommended when the crop is at full flowering for obtaining maximum yield of essential oil. Palmarosa oil, which is rich in geraniol content, can be obtained by both hydro-distillation and steam distillation, though, the later gives better yield and quality.

The oil is used in perfumery, particularly in flavorings of tobacco and for blending of soaps. This is primarily due to the lasting rose-notes it imparts to the blend. In soap and perfumes, it has a special importance by virtue of geraniol being stable in contact with alkali. It also serves as a source of a very high grade geraniol. Geraniol is highly valued as a perfume and as a starting material for a large number of synthetic aroma chemicals like geranyl esters, which impart permanent rose-like odors.

5.3.2 *Mentha* spp.

Mints are perennial herbs that belongs to the family Lamiaceae; Labiatae. They have quadrangular stem. The herb yields essential oil up on distillation. Among the various species of mint Japanese mint (*Mentha arvensis* Linn. subsp. haplocalyx Briqet var. piperascens Holmes), Peppermint (*Mentha piperita* L), Spearmint (*Mentha
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*spicata* L.) and Bergamot mint (*Mentha citrata* Ehrh.) have a considerable economic importance. Except Bergamot mint, the first three are found in Ethiopia.

### 5.3.2.1 *Mentha arvensis* L.

It is commonly known as Japanese mint. It has rootstock creeping along or just under the ground surface. Its branches are rigged, pubescent, 60 - 90cm long. The leaves are lanceolate to oblong, 3.7-10 cm long, sharply toothed, sessile or shortly petiolated and hairy. Flowers are arranged in cyme, which are usually sessile or rarely peduncilate and are purplish and minute.

It can be grown in wide range of climatic conditions of all tropical and subtropical regions, provided adequate irrigation facilities are available. For proper production, it requires adequate and regular rain fall during growth period and good sunshine during harvesting. Low altitude tropical or semi tropical areas are not considered as favorable for economical cultivation.

Soils having good water holding capacity, free of water logging and a pH range between 6 and 7.5 are recommended for its cultivation.
As it grows and spread through numerous underground runners (suckers or rhizomes), the plant requires a deep moist soil which is weak ventilated and lose enough in texture so that the growth of roots will not be impeded.

In the other side, it was found that the proper use of fertilizers stimulates plant growth, affects maturity of the plants, increase biomass and oil yield. The fresh herbage and essential oil yield increases up to application of 160 kg N/ha. In addition, supplementary irrigation is required in moisture streets area, to keep the soil moist and thereby to enhance the development of the plant effectively.

It is propagated by means of underground vegetative parts named as stolens. Best time for planting is the end of dry season. The stolens are cut into small pieces about 10cm long and planted in shallow furrows of about 7-10 cm deep at a distance of 45-60cm apart. First harvest will be obtained after 100-120 days of planting.

Under good management, it can give as high as 48 tones of fresh herb per hectare and on an average 20-25 tones of green herbs per hectare can be obtained in three cutting of a given year. Out of which 0.4-0.6% is accounted for its essential oil.

The essential oil is obtained by distilling fresh or dry herb. Its essential oil is considered as a primary source of menthol, which
varies between 65-80% depending on climatic conditions. Compared to temperate climate, menthol content is high in tropical climates. Menthol is used as a flavorings agent in tooth-passes, candies, chewing gums and mouthwashes, etc. This is also used as an ingredient in a number of medicinal preparations like ointments, pain balms, cough syrups, cough lozenges and tablets as well as a large number of other medicinal preparations. It also used as a flavoring agent in a number of beverages and other items like tobacco, cigarettes, confectionery, betel nut flavoring, etc. In addition, essential oil and menthol are also used in flavoring mouth fresheners, aerosols, polishes, lipsticks and hair lotions.

5.3.2.2 *Mentha piperita* L.

It is commonly known as pepper mint. It is a perennial, glabrous herb attaining a height up to 90cm. Its stem is erect, branched, quadrangular, and naked or rarely covered by trichomes. Leaves are opposite, petiolated, ovate to oblong, lanceolate, 2.5-7.5 cm long and serrate.

The natural habitat of the crop is temperate climate, but under conditions of assuring irrigation. It is possible to grow in higher
altitudes of tropical and subtropical areas. Though, the crop can be raised under a fairly wide range of soil texture. However, waterlogged and clayey soil having pH over 8.5 is not recommended for commercial cultivation. Neutral to slightly acidic, well drained soils are considered as best growing media.

On the other hand, it was found that the proper use of fertilizers stimulates plant growth, affects maturity of the plants, increase biomass and oil yield. The fresh herbage and essential oil yield increases up to application of 160 kg N/ha. In addition, supplementary irrigation is required in moisture streets area to keep the soil moist for enhancing the development of the plant effectively.

It is propagated by means of underground vegetative parts called stolens. Best time for planting is on the commencement of main rainy season. The stolens are cut into small pieces about 10cm long and planted in shallow furrows of about 7-10 cm deep at a distance of 45-60cm apart.

The crop will be ready for harvesting after 100-120 days of
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planting. Second harvest will be ready 80 days after first harvest and third harvest will be ready after 80 days from second harvest. Average herbage yield of the crop is 41.8, 30.8 and 23.5 tones/ha on first, second and third harvests, respectively.

The oil of peppermint is recovered by stem distillation of the dry foliage and it is characterized with strong pepper-like pungent odor. Because of its low mentol content (35-50%), pepper mint is generally not used as a source of menthol. However, the oil has a sweeter aroma and taste due to the presence of some minor constituents. Therefore, the oil is used directly as a flavorings agent and is constituent of medicinal preparations, especially cough syrups and certain brands of tooth-pastes, mouth-washes, etc. Likewise, the oil is mainly used for flavoring of chewing gum, candy, confectionery, cigarettes, tobacco, cosmetics and high grade liquors (alcoholic beverage).

5.3.2.3 *Mentha spicata* L.

It is commonly known as spear mint. It is perennial herb that is cultivated as commercial crop for its volatile oil. It has erect 30-60 cm tall branches. Leaves are sessile, smooth, lanceolate to ovate lanceolate, sharply serrate and 6.5 cm long. Flowers are sharply pointed, long and narrow from
which the name spearmint is attributed to the plant. This plant has similar biophysical requirement with peppermint for its commercial cultivation.

It is propagated by means of runners and underground vegetative parts called stolens. Best time for planting is the end of dry season. The stolens are cut into small pieces about 10cm long and planted in shallow furrows of about 7-10 cm deep at a distance of 45-60cm apart. After transplanting, the crop will be ready for harvesting with in 100-120 days. Biomass and essential oil content of spear mint is similar to piper mint.

The oil is extracted through stem distillation and is used mostly as a flavor in tooth-pastes and as a food flavor in pickles and spices, chewing gums and confectionery, sups and sauces.

5.3.1 Eucalyptus spp

It belongs to the family Myrtaceae. The genus eucalyptus comprises more than 700 species, which are native to Australian mainland, Tasmania and Papua New Guinea. Many of them have been now introduced to various tropical and sub tropical countries.

It is one of the most important exotic tree species grown in Ethiopia. The planting rate of Eucalyptus spp is increasing due to the high demand for its wood especially for fuel, poles, construction material and other domestic consumption. However, countries like
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Thailand, Morocco, India, Spain, Portugal and Brazil use *E. citrodora* and *E. globules* for their essential oil to be used in various perfumery, pharmaceutical and industrial applications. Similarly these two eucalyptus species are among the priority crops of Wondo Genet Agricultural Research Center in its future research directions.

5.3.1.1 *Eucalyptus citrodora* Hook.

It is named as a 'Citron Scented Gum' commonly and 'Shito Bahir Zaf' locally. It is a tall tree growing a height ranging between 25 to 40m with a crown of leaves and branches at the top. It is fast growing species with a good adaptable nature. It prefers tropical and sub tropical climate. It has been also found growing in poor and gravel soil up to an altitude of 600m in rain fed areas. A spacing of 1-1.5m between rows and 75cm-1m between plants is best for raising a commercial crop.

The available information about the fertilizer requirement of eucalyptus in general and *E. citrodora* in particular is very scanty.
Beemnet et al.

Nitrogen fertilizer contributes positively to ward the production of leaves which ultimately increase oil production per unit area. The fertilizer has not found to bear with the percentage of oil in leaves yet. In irrigated areas, about 20 kg N, 30 kg P and 30 kg K per hectare are suggested to be applied at the time of planting as basal dose. Application of three top dressing each of 20 kg N per ha is recommended after every harvest.

The first harvest can be taken from six up to eight months old plantations. At this stage, herbage as well as essential oil yield is rather negligible. But coppicing the plants is very necessary, since it promotes vigorous sprouting of side branching. Fresh shoots sprout in about four weeks after coppicing, which are again ready for coppicing after 4-5 months. This processes results in regular increase in yield of herbs which almost stabilized after plants are 3 years old. The first coppicing is then at about 30-45 cm above ground and the subsequent ones are done at 75 cm up to 90 cm above ground. Usually three harvests can be taken annually from the irrigated plantations corresponding with the maximum oil contents of leaves.

The yield of green herb per ha during the first year is about 7 tonnes, during the second year about 30 tonnes and about 40 tones during third year in irrigated areas. This yield is almost stabilized after this age and a plantation is expected to remain economical for about ten years if properly maintained. From unirrigated areas, only
two harvests with nearly 37 tonnes of green herb per ha per year is possible.

The oil content ranging from 0.5 to 4.8 % can be obtained depending on climatic conditions as well as other necessary production and processing technologies. The leaf oil is rich in citronellal (65-89%) content and is highly esteemed in the perfume industries.

5.3.1.2 *Eucalyptus globulus* Labill.

It is commonly known as Tasmanians 'Blue Gum' and named as 'Nech Bahir Zaf' locally. It is one of the dominant highland exotic spices in Ethiopia. It is highland tree species and is growing rarely in altitude less than 1300m. It is big tree which attain up to 55m with blue gray bark. Its juvenilia leaves are opposite while the adult leaves are alternate. It grows well in loam soil with adequate moisture. It has straight boles which can be used for construction material, pole and fuel wood.

A 6-8 years old tree yield 30 to 60 kg of leaves per year. The leaves are used for the production of essential oil. The oil yield of eucalyptus globulus in summer is about 0.8 %, where as 0.7 % in
winter. In Ethiopia, it varies between 1.1-1.5% on fresh weight basis. The highest yield of oil comes from the top leaves of the trees. This oil has better solubility in alcohol and higher cineole content than the oil from the lower leaves.

Essential oil from *E. globulus* is categorized as medicinal Eucalyptus oil, commonly known as eucalyptol. The major constituent of the essential oil is 1, 8 cineol or Eucalyptol, which ranges from 60%-73%. It is a clear thin with a cooling, fresh, medicinal, woody and earthly aroma, which can be used as antiseptic, antiviral, expectorant, antispasmodic, anti-catitaler, antirheumatic, balsamic, depurative, divertive, parasiticide, germicide, secretomotory, rubefacient, stimulant, vulnerary, deodorant and vermifuge. Even though the above applications are facts, it is most commonly applied for respiratory disorder (pulmonary tuberculoses, infection of lungs, bronchitis, asthma, sinus and so on) and rheumatism.
5.3.2 Other Shrubs

5.3.2.1 Rosemary (*Rosmarinus officinalis* L.)

It is belongs to the family Lamiaceae and locally known it ‘Yesga Metbesha Qitel’. It is dense evergreen shrub, which grows up to 1m in height with a characteristic aromatic smell with lavender-like leaves. The plant has an erect stem divided into numerous long and slender branches bearing many sessile opposite leaves. The leaves are smooth, green, woolly, whitish and glandular beneath, 2 to 4cm long, almost cylindrical and folded inward. The flowers are situated in little cluster towards the ends of the branches. The flowers are situated in little clusters towards the ends of the branches.

It grows wild on the shores of the Mediterranean and in Spain, Portugal, Morocco and Algeria. It requires light and dry soil. It is susceptible to frost. It is best propagated by cuttings. The cuttings should be 15 cm long and from half of the length, leaves should be
removed. The cutting is put in the nursery beds of sandy soil to a depth of about 10 cm. The plant is also propagated through seed. In the field, plants are spaced 45 cm in rows, 120 cm apart.

Frequent cutting of the bushes after two or three years keeps them free from becoming leggy and promotes the formation of numerous shoots from which the oil is obtained. Information on biomass yield of rosemary is scanty. But, the plant has an oil content range between 1.5-2.5% on dry weight basis.

All parts of the plant contain an essential oil which is responsible for the characteristic aroma and flavor of the plant. The oil is recovered by steam distillation and is used mainly for flavoring of food product. The oil obtained from the flowering top is of the finest quality, truly representing the odor of the leaves, but the yield is too small for commercial production. Chemically the oil is composed of borneol, cineole, camphor, bornyl acetate and α-pinene, camphene, terpinol and verbenone.

5.3.2.2 *Lemmon Verbena* (*Aloysia triphylla*) (*L*.Hér.) *Britton*

It is a perennial shrub that belongs to the family verbenaceae and it is locally named as Lominat. Information in every aspect of the crop is scanty internationally as well as locally. It has got its name because of its whorls of three (tri) leaves (phylla) at each node. It is believed that, the plant is most probably originated from Argentina and Chile.
It is a rapidly growing elegant shrub that can reach to a height of 4.6m under tropical conditions. Flowers are small, white, single and inconspicuous. Their airy feel is an elegant crowning point for the open form of the plant.

It can be exploited in flavorings, tea, fragrances, and ornamental and folk medicine preparations. The leaves are the most economical part of the plant, which can be used anywhere that any one who wants to add a lemony taste. Leaves make tasty tea both by itself and in combination with other herbs. It can be steeped in milk and added to puddings, ice creams or any baked goodies calling for milk, lemon flavoring for drinks, salads and jellies. Likewise, essential oil is used in fragrance industries. The fragrant flowers are also used in tea and culinary concoctions.

It can be grown from seeds or stem cuttings. If cutting is the option for its propagation, it is advisable to use semi hardwood cuttings in summer, softwood cuttings in spring and division in
late fall to early spring. Main field planting requires a spacing of 0.3 to 0.6m between plants and rows. It is adapted to wide range of soil types and performs best in warm moist conditions with plenty of sunlight. In frost free areas, it is an evergreen perennial. When exposed to frost, it becomes deciduous. Mature plants well mulched in the field can survive brief temperatures as low as 6 degrees, at which point it becomes herbaceous (dies back to the ground). Cold area planting should be done at the earliest possible time in such away that it can become well established deep in the soil and develop the largest caliper trunk that helps to withstand the frost.

Pruning will induce the formation of more lateral branches bearing more leaves. Cultivation is recommended to be practiced as often as necessary when weeds are small. Proper cultivation, field selection and rotations can reduce or eliminate the need for chemical weed control. Proper rotations and field selection can minimize problems associated with insects. Proper rotations, field selection, sanitation, spacing, fertilizer and irrigation practices can reduce the risk of many diseases. Fields can be tested for presence of harmful nematodes. Using seed from reputable sources reduces risk from "seed-borne" diseases.
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Harvest timing and equipment are also important for obtaining quality product. At Wondo Genet, harvesting is done at a time when the lower leaves of a branch start to turn to yellow. Often, considerable hand labor is required in production and harvest operations, particularly when the marketable leafy portions need separation from stem and other unnecessary substances, or when only the floral parts are required. Portable or stationary still distillation units are required when essential oil is the desirable product. The harvested product often requires immediate special handling such as drying, separation of leaves, and temporary packaging storage to best preserve its color, aroma, flavor, the integrity of its appearance and sanitary condition.

Information on herbage as well as essential oil yield is not available. Preliminary laboratory results at Wondo Genet Agricultural Research Center indicated that leaves of lemon verbena has 0.37% essential oil content on dry weight basis.
6 Recommended Readings


Training Manual on Aromatic Plants


Evans E. Undated. Herbs Plant Fact Sheets. NC State University College of agriculture and life science. (erv_evans@ncsu.edu)


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University, Science Faculty Biology Department, National Herbarium, February 1997; Unpublished. Some essential oil producing plants in Ethiopia. P. Box 3434, Addis Ababa, Ethiopia, 14P.


7 Additional Web Sites

http://www.iucn.org/places/medoffice/nabp/web/documents/Essential%20oils%20study%20-%20UK.pdf#search=%22%22essential%20oil%22%20production%20countries%22
http://www.dpi.vic.gov.au/dpi/nreninf.nsf/9e58661e880ba9e44a256c640023eb2e/e7d168a90a1398f8ca256f10008018fd/$FILE/ATH9GX2/Ag0656.pdf
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