Production, Processing and Utilization of Aromatic Plants

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Introduction

Humankind has been using plant secondary metabolites for over thousands of years as dyes flavors, fragrances (rose oil, lavender oil), stimulants, hallucinogens, insecticides, and for animal and human poisons.

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.

Aromatic plants

Aromatic plants are plants possess odoriferous oil in either of their organs or sometimes even in the whole plant. This kind 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 are 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 aromatic plants are multipurpose plants. For this reason, they are important to produce valuable aromatic substances, which can be used as food, fodder, construction material, ethno botanical, source of fuel, social and cultural values, environmental protection and services, etc.

The commonly used terms associated with aromatic plants are herbs, spices, and essential oils. Herbs are aromatic plants from temperate regions that contain phytonutrients and used for flavoring foods and beverages. Culinary herbs refer to these herbs used in minor quantities to flavor food and beverages. The term ‘spice’, is also used an aromatic plant 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.

**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. Sometimes they are called volatile oil or ethereal oil. The term essential, represent the very essence of odor and flavor. Essential oils often classified as secondary plant products or metabolites; 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.

Mostly, essential oils are aromatic substances produced from aromatic plants with original aroma and flavor of the odoriferous plants. They are colorless or slightly yellow complex mixtures of odorous and volatile compounds. They occur in various site of plant anatomy, in some cases they are found through out the plant organ and they could be 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 and, root or the whole part of the single plant species could be sources of essential oil.

Essential oils can be produced through different method of extraction. Steam and hydro distillation, effleurage, maceration, solvent extraction, or mechanical pressing are listed as techniques used for the extraction of essential oils from different raw materials of aromatic plants.

Chemically, essential oils are mostly tropanes, multiple isoprenoid units, aromatics, heterocyclics, and terpenes. The most abundant types of chemical compounds in essential oils are terpinoids and phenyl propanoids. Terpinoids in essential oils consists of monoterpenoids (C$_{10}$ compounds) and sesquiterpenoids which are (C$_{15}$ compounds) 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, for example, rose oil and, peppermint oil etc. Similarly, each type of essential oil of a given plant species or plant part is different from the others. As result, oil to exhibits 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 its use or application.

**Producing Essential Oils from Aromatic Plants**

Several 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 leaves of eucalyptus; and glands of lavender florets or the modified leaf hairs of mint. 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 essential oils are well known. For example, limonene is synthesized from geranyl pyrophosphate in the oil glands of *Mentha spp*. Oxygenated derivatives of limonene that make up the remainder of mentha oil are synthesized from limonene by microsomal preparations from oil glands, which show cytochrome p-450-type mixed function oxygenase activity.

The role of essential oils, in plants is 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, giving 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 their 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.

**Importance of Essential Oils**

The role of essential oils 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, and textile processing products such as artificial leather and fabric coatings, dyes, linoleum, textile oils and eater proofing materials are crucial.

**Food processing and flavoring industries**

Essential oils have a great role in the food industries, sweet meals factories like biscuits, cakes, icings, mincemeat, pies and sandwich fillings. Canning factories use them for flavoring and processing of fish, meat, sauces and soup. Chewing gum, condiment, factories and confectionery factories also use them.

**Beverage industries**

Essential oils are also used in the alcoholic beverage and soft drink industries 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**
Aromatic plants are 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 and antiseptics. Similarly, they are important in dental preparations such as tooth a paste and mouth washes.

**Bio pesticides and pesticides**
Essential oils can be used directly as pesticides and as a source of active ingredient for preparation of pesticides or as additive to improve or to make already prepared pesticides ready to use. Aromatic plant material is also used as ethno botanicals or traditional/herbal medicine Cultural application and household food and drink sweetening and flavoring.

**Producing Essential Oils from Aromatic Plants**

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.

**Capital Requirement**

The production essential oil is simple and relatively cheaper than other agro based industries. Large or medium-scale distillation units can be run by farmer groups, cooperatives, or other local institutions and involve a number of small-scale farmers as a supplier of raw material.

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Rural Development

As it requires low capital and technology and agricultural based investment, many countries have involved in production from the cultivation of selected (market oriented) aromatic plant species, as an alternative approaches of integrated rural development projects.

High Value Low Volume

High Value Low Volume (HVLV) products are held to be desirable products for developing countries including Ethiopia. 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 rarely produce products of high volume to achieve economies of scale throughout the entire supply chain 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. That means the proportion of price to volume is very high. Therefore, 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 huge effort on value addition of the product is required. The following processing could be used as methods. Increase product quality without further change. This can be achieved by minimizing adulteration and impurity, using special packaging system which improves the appearance and easy handling and helps the oil to keep its quality for a longer time.

Further processing of the oil, to win different compounds, which make up the crude oil 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 methods of separating active constitutes of crude material, fractional distillation can be mentioned as appropriate technology for volatile essential oil.
Higher Export Potential

The growing awareness of 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 products have very low or no-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 over the years.

The growth in trade is an indicator of wide opportunity in the sector. Therefore, countries interested to participate in this sector can generate hard currency. As the global market shows increment, the competition is so low, so that joining this market is easy for developing countries like Ethiopia.

Environmental and Ecological Benefits

As most of aromatic crops are perennial and have diversified morphological and physiological charters, they have enormous environmental and ecological benefits. Among these benefits of aromatic plant based essential oil production, the following can be considered as main examples.

Suitable soil and water conservation
As most of them are perennial and need not intensive tillage; they maintain the vegetation cover of the land and improve the physical and biological condition of the soil.

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 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
If it is properly planned, managed and monitored.

Utilization of Aromatic Plants

Sketching the overall production process aromatic plants and essential oil is important. This helps to describe 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 discussed. Each of these possesses a number of activities which determine for the overall output of the production cycle. By adjusting 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.

Choice of Crop

Factors such as location, climate, soils, grower experience and preferences, finance, markets trends, and specialization such as organically produced crops could influence the choice. The crop must meet the specifications of the destined market like International Standard Specifications or Private 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.

Site Selection

During site selection it is important to consider the following important aspects.
Production processing and utilization of aromatic plants

**Size of land area**
Small scale or large scale production

**Location**
Distance To market, or processing facilities.

**Climate**
Suitability for a particular crop.

**Topography**
Suitable landscape for machinery.

**Soils and drainage**
Good quality horticultural or arable cropping soils with good drainage.

**Shelter**
Exposure to hot, dry winds over the harvest period can severely reduce essential oils yield. Tall crops such as citrodora, lominat, and valerian can suffer extensive damage of wind sufficient shelter is not provided.

**Weeds**
Identification of weeds and assessment of possible control strategies should to be made.

**Water availability**
Irrigation is necessary for all crops in most environments, particularly during crop establishment. Therefore, irrigation system should be installed primarily.

**Crop structures**
During site selection suitability of building for drying plant, pack house or distillation unit should be considered.
Establishment and Management

Establishment

The starting activity of crop establishment is availing vigorous, healthy and sufficient planting materials which are important for completion activities economically in accordance with the plan 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. Such as mint species, grasses, lominat, rosemary and, geranium.

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, labor availability, area size, speed and cost.

Weed control
Perennial weeds should be eliminated before planting the crop. Annual weeds can be controlled using appropriate selective herbicides or mechanical methods. Effective weed control should be made achieve acceptable crop yields and avoid contamination of the end product.

Management
There are some management activities before and after establishment.
Spacing
Deciding on optimum plant density per unit area is one of pre-cultivation activities.

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
Mostly, fertilization improves the yield. However, reaching on the proper type and amount of fertilizer is costly which should be known before or after the crop establishment.

Pest and disease control
The problem and solution should be known early. Specialist advice is important to identify pests and diseases.

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 preferable, particularly as the area increases. Purpose-built or modern machinery may be needed for some crops. Manual harvesting is also advisable for small scale production in areas where cheap labor 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.

Processing
Processing of aromatic plants contributes a considerable effect on quality and quantity of essential oil to be produced. Proper processing enables to acquire a highly demanded product. Distillation equipment and process, drying or wilting period and condition, packaging and storage and other related activities are important.

Distillation/Extraction
Production methods of essential oils are different, such as steam distillation, hydro distillation, cold pressing, enfleurage, solvent extraction, turbo distillation extraction, hydro diffusion extraction and carbon dioxide extraction. Commonly, the essence is extracted from the plant using 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 a small amount of this precious oil, several pounds may be needed to produce a single ounce.

Steam Distillation
Steam distillation is the most common method of extracting essential oils. Many old distillers use 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 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 should be 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. Sometimes, floral water is preferable to pure essential oil, such as when treating a sensitive individual or a child, or when a more diluted treatment is required.

**Hydro Distillation**

Hydro distillation is a method in which the plant material to be distilled with the boiling water. Heat is important. The emerging vapor containing the volatile essential oil was led to a condenser and collected in the oil separate unit. This method differs from stem distillation so that; the material to be distilled comes with the boiling water in case of hydro distillation as opposed to the stem in stem distillation.

**Cold Pressing**

Cold-pressed expression, or scarification is another method. 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 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.
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 long process called effleurage is 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. Everyday, for 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 effleurage mixture separates the essential oil from the fatty substance, then the alcohol evaporates and the essential oil remains.

Solvent Extraction
Products used in flavor and fragrance industries can be extracted from plants using a solvent extraction system. This system requires technical expertise and significant capital. This method is used to get higher yield 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.

Solvent extraction has also disadvantages. Residues of the solvent may remain in the absolute and 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.

Turbo Distillation Extraction
Turbo distillation is suitable for 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.

**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 steam distillation. This method is also less harsh than steam distillation and the resulting essential oils smell much more than the original plant.

**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.

**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 its technique play an important role in the quality of the product. At Wondo Genet, it was found that chopping size and wilting duration had an impact on the over all distillation process for lemon grass, palmarosa and nardus grasses.
Market specifications require excellent communication. Generally, essential oils should be stored in a cool, dry place away from sunlight and insect infestation. In addition, essential oils should be bottled in glass or non-reactive metal containers. Specialists’ advice is important for appropriate equipment and methods to optimize drying efficiency and minimize loss of critical plant components.

Aromatic Plants and Essential Oil Production

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 around 50 years back. These activities started at Wondo Genet by French investors. At that time, geranium, citronella grass, lemon grass and citrodora are the major crops cultivated and processed. Essential oils used to be exported to European countries until the owners left the country. After this, production, processing and export were discontinued for ten years until the government realized its importance. After, the production of the commodities was reinitiated and started to distil essential oils for local consumptions for soap factories.

Demand and Supply

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. An average of 1736.5 t of essential oils and related products are imported per year with an average of about 37 million Birr. Because of 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 14,500 kg of flavors of different alcoholic drinks, by 4.2 million Birr. Although there is no 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 amount. This makes the total amount of imported essence
21,750 kg and the total money spent by liquor factory is estimated at about 6 million birr.

Essential oils imported from 2001 to 2004 are presented in table 1. It indicates that Ethiopia spend more than 50 million birr by importing more than 200,000 kg of essential oils during four years. This huge amount of money is an indicator that the demand oil 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 good. 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 save huge amount of money.

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 1 t/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 involving. Tabor herbs Private Company, Ariti Essential Oil Company, Bishoftu Medicinal Aromatic Agricultural Project (BIMAAP), and Abyssinia Essential Oils plc are some of them.

**Prioritized Aromatic Plants for Research**

From the existing species, (lemmon grass, palmarosa, citriodora, lemmon verbena, japanese mint, spear mint, piper mint, citronella grass) are prioritized research commodities.

**Cymbopogon spp**

The genus Cymbopogon comprises about 140 species. Some of the species yield essential oils and among them, the following are considered as economically important.
**Cymbopogon winterianus**
It is commonly known as *Java citronella*. It is from Poaceae family, which yields essential oil known as Citronella Java oil. It has fibrous root; culms stout, over 2m, 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 30m long decompound panicle.

*Java Citronella* flower can not produce viable seeds; therefore, the appropriate way to perptuate java is vegetative propagation. There fore planting is done by splitting the clumps into slips. Each slip contains 1-3 tillers, to be used as a propagule.

Mostly, 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 that care should be taken not to plant in areas where there is vulnerable to water-logging (even for short period). Hence, it is better to plant on ridges in areas where there is a problem of water logging.

It grows well under various 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 is available.

Fertilization may be required for improving the growth and yield of the crop. Fertilization of 80-120 kg N ha$^{-1}$ and 40 kg ha$^{-1}$ 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 varies between 2000 and 2500mm, well distributed throughout the year, irrigation is not necessary. However, in water deficit area, additional irrigation is crucial. Oil of citronella, is found in all parts 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* is expected to yield a fresh biomass of 15-20 tones/ha in first harvest, 20-25 t ha$^{-1}$ at second and third harvests. Out of which, 1.0 – 1.2 % is accounted for citronella oil. Under optimum conditions, essential oil yield between 200 and 250 kg ha$^{-1}$ per year can be obtained.

The oil is used extensively as a source of important perfumery chemicals like citronellal, citronellol and geraniol, which have 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.

**Cymbopogon citratus**

It is one of the prioritized aromatic grasses in research and development direction of Wondo Genet 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, 30-60cm long and linear lanceolate to almost subulate when enrolled.

Like any other tropical plant specious, the grass requires between 2000 and 2500 mm annual rainfall and average temperature of 23 and 27°C. It 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 using slips. During lemon grass cultivation, some specific requirements, such as adequate sunshine, occasionally heavy rain, warm temperature and sufficient humidity.

The production of essential oil is to earn higher revenue by adding the value. The value adding can be achieved by maximizing the crude essential oil per ha and the proportion of specific active constituent are the most economical ways.

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 of P₂O₅, K₂O and N at time of planting and 60 kg N/ha as top dressing in 3-4 splits is recommended.

First harvest possibly riches 6 months after planting. Subsequent harvests can be done 40-50 days. 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⁻¹ 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. The name lemon grass has been given because of the typical strong lemon-like odor of the plant. Due to high citral content of the essential oil in the leaves, it 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 is also used as a perfumery for various grades of soaps and cosmetics. The oil is also suitable as a fumigant against flies and mosquitoes.

For essential oil production, lemon grass is largely cultivated in west India, Guatemala and Brazil, for the supply of either in domestic and 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
Production processing and utilization of aromatic plants
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.

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

It is a tropical plant that grows in warm and humid area. Areas which are affected with severe frost are not suitable, because of the frost kill the grass and reduce the oil yield. A well-drained loamy soil having irrigation facility with an annual rainfall of 1500 mm are good 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 the fertility. Fertile soils don’t need any replenishment at least for the first two years. In deficient soils, a mixture of 20 kg of N, 50 kg P₂O₅ and 40 kg K₂O / ha is used as a basal dose at the time of planting. About 60 kg N/ha⁻¹ is applied in three split doses during the 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. 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 can be harvested when it produces flowers. Usually harvest is once obtained in the first year. In subsequent years, 2-3 harvest can be obtained depending on climatic condition of the area. It could stay productive for about 8 years under proper management.
Despite essential oils found in all parts of the grass; the major portion is accumulated in flower heads. So, harvesting is recommended when the crop is at full flowering. 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 with alkali. It also serves as a source of a very high grade geraniol. Geraniol has high value 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.

**Mentha spp**

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

**Mentha arvensis**

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

It grows in different climatic conditions of all tropical and subtropical regions; with adequate irrigation facilities. For better yield, adequate and regular rain fall during growth period and good sunshine during harvesting are required. Low altitude tropical or semi tropical areas are not considered as favorable.
Soils having good water holding capacity, free of water logging and a pH range between 6 and 7.5 are recommended. As it grows and spread through numerous underground runners (suckers or rhizomes), it requires a deep moist soil which is week ventilated and lose enough in texture so that the growth of roots will not be impeded.

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 160 kg N/ha. In addition, supplementary irrigation is required in moisture streets area to keep the soil moist.

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

Under proper management, it can give more than 48 t of fresh herb per ha and on an average 20-25 t of green herbs per ha 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. It 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-pastes, candies, chewing gums and mouth washes, etc. This is also used as an ingredient in medicinal preparations like ointments, pain balms, cough syrups, cough lozenges and tablets. It is 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.

**Mentha piperita**

It is commonly known as pepper mint. It is a perennial, glabrous herb with a height up to 90cm. Its stem is erected, 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 also grows 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 with pH greater than 8.5 is not recommended for commercial cultivation. Neutral to slightly acidic, well drained soils are considered as best growing media.

It was also 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\textsuperscript{-1}. 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 underground vegetative parts called stolen. Best time for planting is on the commencement of main rainy season. The stolen is 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.

It will be ready for harvesting after 100-120 days of 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.

Peppermint oil is recovered by stem distillation of the dry foliage and it is characterized with strong pepper-like pungent odor. Because of its low menthol content (35-50%), it is 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 as a flavorings agent and is constituent of medicinal preparations, such as cough syrups and certain brands of tooth-pastes and mouth-washes. Likewise, the oil is mainly used for flavoring of chewing gum, candy, confectionery, cigarettes, tobacco, cosmetics and high grade liquors (alcoholic beverage).

**Mentha spicata**

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 branches. Leaves are
sessile, smooth, and 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. This plant has similar biophysical requirement with peppermint for its commercial cultivation.

It is propagated by runners and underground vegetative parts called stolens. Best time for planting is the end of dry season. The stolens are cut into small pieces 10cm long and planted in shallow furrows of 7-10 cm deep at a distance of 45-60cm apart. After transplanting, it 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.

**Eucalyptus spp**

It is from Myrtaceae family. The genus eucalyptus comprises more than 700 species, which are native to Australian mainland, Tasmania and Papua New Guinea. Many of them are found in 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 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 Research Center in its research directions.

**Eucalyptus citrodora**

It is named as a 'Citron Scented Gum locally, 'Shito Bahir Zaf. 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 also grows in poor and gravel soil
an altitude of 600m in rain fed areas. A spacing of 1 to 1.5m between rows and 75cm to 1m between plants is best.

The available information about the fertilizer requirement of eucalyptus in general and *E. citrodora* in particular is very little. Nitrogen fertilizer contributes positively to the production of leaves which increase oil production per unit area. The fertilizer has not been 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 /ha are suggested to be applied at the time of planting as basal dose. Application of three top dressing each of 20 kg N /ha is recommended after every harvest.

The first harvest can be taken from six up to eight months. At this stage, herbage as well as essential oil yield is minor. But coppicing the plants is very necessary, since it promotes vigorous sprouting of side branching. Fresh shoots sprout in four weeks after coppicing, which are again ready for coppicing after 4-5 months. This process results in regular increase in yield of herbage which almost stabilized after plants are 3 years old. The first coppicing is at 30-45 cm and the subsequent once 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 is the first year is about 7 t, during the second year about 30 t and about 40 t 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. From non irrigated areas, only two harvests with nearly 37 t of green herb per ha per year is possible. The 0.5 to 4.8 % oil can be obtained depending on climatic conditions and other necessary production and processing technologies. The leaf oil is rich in citronellal (65-89%).

*Eucalyptus globulus*

It is commonly known as Tasmanians 'Blue Gum' and locally 'Nech Bahir Zaf'. Highland exotic spices in Ethiopia, It is highland tree species and is growing rarely in altitude less than 1300m. It is big tree to 55m with blue gray bark. Its young 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 leaves per year. The leaves are used for the essential oil production. The oil yield of *Eucalyptus globulus* in summer is 0.8 %, where as 0.7 % in winter. In Ethiopia, it varies between 1.1-1.5% on fresh weight basis. The top leaves of the trees have highest yield. 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, from 60%-73%. It's a clear thin with a cooling, fresh, medicinal, woody and earthly aroma, which can be used as antiseptic, antiviral, expectorant, antispasmodic, anti-catateral, anti rheumatic, balsamic, depurative, divertive, parasiticide, germicide, secretomotory, rubefacient, stimulant, vulnerary, deodorant and vermifuge. Even though the above applications are facts, it is commonly applied for respiratory disorders and rheumatism.

**Other Shrubs**

*Rosemary (Rosmarinus officinalis)*

It is from Lamiaceae family and locally known as”Yesga Metbesha”. It is dense evergreen shrub, which grows up to 1m height with 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.

It grows wild on the shores of the Mediterranean and 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 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 help them to be free from being leggy and promotes 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 and 2.5 % on dry weight basis. All parts of the plant contain an essential oil for aroma and flavor. The oil is recovered by steam distillation is used for flavoring of food product. The oil obtained from the flowering top has good quality, truly representing the odor of the leaves, but the yield is too small for commercial production. The oil is composed of borneol, cineole, camphor, bornyl acetate and α-pinene, camphene, terpinol and verbenone.

**Lemmon Verbena (Aloysia triphylla)**

It is a perennial shrub from verbenaceae family and it is locally known as Lominat. There is shortage of information about the crop. It has got its name from its whorls of three (tri) leaves (phyla) at each node. It is believed that, the plant is most probably originated from Argentina and Chile.

It is a rapidly growing plant up to 4.6m elegant shrub under tropical conditions. Flowers are small, white, single and inconspicuous. It can be exploited in flavorings, tea, fragrances, and ornamental and folk medicine preparations. The leaves are the most important part of the plant, which can be used to add lemony taste. Leaves make tea tasty either by it or with other herbs. It can be steeped in milk and added to puddings, ice creams or any baked goods 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 adequate 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 lower than 6 degrees, at which point it becomes herbaceous (dies back to the ground). In cold areas, planting should be done early in such a way 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 when weeds are small. Proper cultivation, field selection, and rotations can reduce or eliminate the need for chemical weed control. Field selection, 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.

Harvest timing and equipment are also important for obtaining quality product. At Wondo Genet, harvesting is done when the lower leaves start to turn yellow. Often, considerable hand labor is required in production and harvest, 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. Results at Wondo Genet Research Center indicated that leaves of *Lemon verbena* have 0.37% essential oil content on dry weight basis.

**Aromatic Plants at Wondo Genet Research Center**

From the existing plants in the center, aromatic plants share the largest proportion (37.5%). The existing aromatic plants have international quality standards. (Table 1)
<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>Aframomum korrerima</td>
<td>False cardamom</td>
<td>Korerima</td>
<td>Zingebraceae</td>
<td>Fruit</td>
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</tr>
<tr>
<td>Aloysia triphlla</td>
<td>Lemon Verbena</td>
<td>Lominat</td>
<td>Verbenaceae</td>
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<td>Spice, essential oil</td>
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<td>Anethum graveolens</td>
<td>Dill</td>
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<td>Seeds, leaves</td>
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<td>Artemisia abyssinica</td>
<td>Chinese worm wood</td>
<td>Arti</td>
<td>Asteracea</td>
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<tr>
<td>Artemisia rehan</td>
<td>Wormwood</td>
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<tr>
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<td>Kerefa</td>
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<td>Lemon grass</td>
<td>Lomi-sar</td>
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<td>Palmarosa</td>
<td>Tej-sar</td>
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<td>Key-bahir-zaf</td>
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<td></td>
<td>Apiaceae</td>
<td>Root</td>
<td>Essential oil</td>
<td></td>
</tr>
<tr>
<td>Vetivaria zezanoid</td>
<td>Vetivar</td>
<td>Cyperaceae</td>
<td>Root</td>
<td>Essential oil</td>
<td></td>
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</tbody>
</table>

[31]