A R O M A T I C P L A N T S

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I. IMPORTANCE AND SCOPE

Aromatic plants possess odorous volatile substances which occur as essential oil, gum exudate, balsam and oleoresin in one or more parts, namely, root, wood, bark, stem, foliage, flower and fruit. The characteristic aroma is due to a variety of complex chemical compounds. The term *essential oil* is concomitant to fragrance or perfumes because these fragrances are *oily* in nature and they represent the *essence* or the active constituents of the plants. They are called *volatile or ethereal oils* as they evaporate when exposed to air at ordinary temperatures. Essential oils are highly concentrated, low volume, high value products.

The world of essential oils has since then come out from the narrow field of definition to a wide variety of applications in flavours, disinfectants, oral hygiene, tobacco, pharmaceuticals and in almost all spheres of human activity. In the world wide flavour and fragrance market, essential oils constitute about 17 per cent. The estimate of world production of essential oils varies from 40,000 to 60,000 tonnes per annum. The demand for spice oils is placed at 2,000 tonnes per annum.

Out of a total of about 1500 species of aromatic plants which serve as a source of raw materials for the perfumery, information on the chemistry and properties of essential oils of only about 500 species is known in some detail at present. Of these, about 50 species find use as commercial source of essential oils and aroma chemicals, though the number of those having regular and large scale utilization hardly exceeds two dozens.

Essential oils and aroma chemicals constitute a major group of industrial products. These oils form indispensable ingredients of the necessities in many spheres of human activity. They are adjuncts of cosmetics, soaps, pharmaceuticals, perfumery, confectionery, ice-creams, aerated waters disinfectants, tobacco, agarbathis and a host of related products. However, with the recent advances in organic chemistry, the synthetics have outnumbered the naturals in a ratio of about 200:1 due to limitations in the availability of the latter in sufficient quantities at a steady price over a period of time. Naturals are seen as good and safe. The concern for nature and the love for all things which are basic and natural has been spearheading to a green movement of everything natural and nature-based consumer products all over the world. A future shock is awaiting the industry as the already dwindling world resources of coal and petroleum on one side and the philosophy of going back to the nature is gaining acceptance internationally on the other side. This will revert the dependence of the industry on the petrochemicals to the perennial source of naturals. Thus, because of a large spectrum of usage in the everyday life of man, the essential oil and aroma industry has a bright future.

In today's world of consumer boom, the role of essential oils has increased many folds. Apart from the hitherto known applications of essential oils, more and more areas are opening up which will benefit the industry. Use of essential oils in therapeutics is becoming popular in Japan and European countries. Aromatherapy involves the use of essential oils and aromatics derived from plants to cure diseases. Some of the essential oils are reported to be in many ways better than antibiotics due to their safety and wide spectrum of activity. Synergistic activity of essential oils needs further probe. Application of essential oils in agriculture as antifeedants, repellents, botanical insecticides, natural herbicides and growth boosters are still open to fascinating realms of research. Production of secondary metabolites in bioreactors under controlled conditions using cell and tissue culture offers exciting frontiers of future research.

II. MAJOR AROMATIC PLANTS

Out of a total of about 1500 species of aromatic plants known, only a little over 300 species have been studied in some detail. Of the 50 species which find use as commercial source of essential oils and aroma-chemicals, the number of those having regular and large scale utilization hardly exceeds two dozens. The important aromatic plants of the world are listed below, classified according to the botanical family, genus and species.

Botanical classification of aromatic plants
(Guenther, 1952, modified)

DIVISION : EMBRYOPHYTA
Subdivision: I. Gymnospermae
Class : Coniferae

Family Genus (species names given in parentheses)

Podocarpaceae Dacrydium (franklini)
Pinaceae Picea (abies, alba, canadensis, excelsa, glauca, jezoensis, mariana, nigra, obovata, vulgaris)
Tsuga (canadensis, douglasii, heterophylla)
Pseudotsuga (douglasii, glauca, mucronata, taxifolia)
Abies (alba, balsamea, balsamifera, douglasii, excelsa, mayriana, mucronata, pectinata, picea, sachalinensis, sibirica)
Cedrus (atlantica, deodara, libani, libanotica)
Pinus (albicaulis, aristata, attenuata, ayacahuite, balfouriana, balsamea, banksiana, caribaea, cembra, clausa, contorta, coulteri, echinata, edulis, flexilis, glabra, jeffreyi, lambertiana, longifolia, monophylla, montana, monticola, mugo.)
Taxodiaceae Sciadopitys (verticillata)
Cryptomeria (japonica)
Cupressaceae Callitropsis (araucarioides)
Thujopsis (dolabrata)
Thuja (plicata)
Cupressus (fastigiata, glauca, Japonica, lambertiana, lawsoniana lusitanica, macrocarpa, pendula, sempervirens, sinensis, torulosa)
Chamaecyparis (lawsoniana, obtusa, taiwanensis, thyoides)
Juniperus (communis, mexicana, oxycedrus, phoenicea, procera, sabina,thurifera, virginiana)

Subdivision: II. Angiospermae
Class : 1. Monocotyledonae

Graminae Elyonurus (latiflorus, tripsacoides)
(Poaceae) Vetiveria (zizanioides)
Cymbopogon (afronardus, caesius, citratus, clandestinus, coloratus, confertiflorus, densiflorus, exaltatus, flexuosus, georingii, giganteus, jwarancusa, rectus, martinii, nardus, nervatus, polyneuros, procerus, proximus, schoenanthus, senaarensis, stipulatus ,virgatus, winterianus)
Andropogon (aciculatus, connatus, fragrans, intermedius, kuntzeanus, muricatus, nardoides, odoratus, versicolor)
Cyperaceae Cyperus (rotundus)
Palmae Cocos (nucifera)
(Palmaceae)
Araceae Acorus (calamus)
Liliaceae Allium (cepa, sativum)
Lilium (candidum)
Hyacinthus (non-scriptus, orientalis)
Convallaria (majalis)
Amaryllidaceae Narcissus (jonquilla, poeticus, tagetta)
Polyanthes (tuberosa)
Irridaceae Crocus (sativus)
Iris (florentina, germanica, pallida) Zingiberaceae Hedychium (flavum)
Kaempferia (galanga, rotunda)
Curcuma (amada, aromatica, caesia, domestica, longa, xanthorrhiza, zedoaria, zerumbet)
Alpinia (alleghas, galanga, officinarum, calcarata, khulanjan, malaccensis, nutans)
Zingiber (mioga, nigrum, officinale)

Amomum (angustifolium, aromaticum, cardamom, globosum, hirsutum, korarima, melegueta)

Elettaria (cardamomum)

Class : 2. Dicotyledonae

Piperaceae *Piper (acutifolium, angustifolium, asperifolium, camphoriferum, clusii, crassipes, cubeba, guineense, lineatum, longum, lowong, mollicomum, molissimum, nigrum, officinarum, ribesioides)*

Betulaceae *Betula (alba, brea, dulce, lenta, papyrifera, pendula, pubescens)*

Moraceae *Humulus (americanus, lupulus)*

Santalaceae *Osyris (tenuifolia)*

Santalum (album, lanceolatum, preissianum, spicatum, zygnorum)

Fusanus (spicatus)

Aristolochiaceae Asarum (canadense, europaeum)

Chenopodiaceae Chenopodium (ambrosioides)

Caryophyllaceae Dianthus (caryophyllus)

Ranunculaceae *Nigella (damascena)*

Magnoliaceae *Magnolia (grandiflora)*

Michelia (champaca, longifolia, excelsa, figo, kisopa, nilagirica, rheedi)

Illicium (anisatum, japonicum, religiosum, verum)

Anonaceae *Cananga (odorata)*

Myristicaceae *Myristica (argentea, fragrans, malabarica, succedanea)*

Lauraceae *Cinnamomum (aromaticum, infers, glanduliferum, camphora, cassia, culilawan, kanahirai, loureirii, micranthum, obtusifolium, xanthoneuron, zeylanicum, tamala)*

Ocotea (caudata, cymbarum, parviflora, pretiosa, sassafras)

Sassafras (albidum)

Cryptocaria (massoia)

Laurus (nobilis)

Umbellularia (californica)

Aniba (parviflora, rosaeodora)

Cruciferae *Cochlearia (armoracia)*

Brassica (alba, juncea, napus, nigra)

Raphanus (sativus)

Resedaceae *Reseda (odorata)*

Saxifragaceae *Philadelphus (coronarius)*

Hamamelidaceae *Hamamelis (virginiana)*

Liquidambar (orientalis, styraciflua)

Rosaceae *Spiraea (ulmaria)*

Rosa (alba, canina, centiflolia, damascena, gallica, indica, glandulifera, moschata, pubescens)

Prunus (amygdalus, laurocerasus)

Leguminosae *Acacia (cavenia, dealbata, decurrens, farnesiana, floribunda)*

Copaifera (coriacea, glycycarpa, guianensis, martii, multijuga, officinalis, reticulata)

Myroxylon (balsamum, pereirae)

Lupinus (luteus)

Genista (sibirica, tinctoria)

Spartium (junceum)

Wistaria (sinensis)

Hardwickia (mannii)

Myrocarpus (fastigiatus, frondosus,)

Geraniaceae *Geranium (lugubre, macrorrhizum)*

Pelargonium (capitatum, fragrans, graveolens, odoratissimum, radula, roseum, terebinthinaceum)

Zygophyllaceae Bulnesia (sarmienti)

Rutaceae *Xanthoxylum (piperitum)*

Ruta (angustifolia, bracteosa, graveolens, montana)

Pilocarpus (jaborandi, microphyllus, racemosus, spicatus)

Cusparia (trifoliata)

	Boronia (megastigma)
	Barosma (betulina, crenulata, serratifolia)
	Amyris (balsamifera)
	Clausena (anisata, anisum-olens, excavata,)
	Citrus (acida, aurantifolia, decumana, aurantium, deliciosa, limetta, limon, medica, nobilis, paradisi, reticulata, sinesis, unshiu)
Burseraceae	*Boswellia (carterii)*
	Bursera (aloexylon, delpechiana, fragroides, glabrifolia)
	Commiphora (abyssinica, erythraea, myrrha, schimperi)
	Canarium (luzonicum)
Euphorbiaceae	*Croton (eluteria)*
Anacardiaceae	*Pistacia (lentiscus)*
	Schinus (molle)
Tiliaceae	*Tilea (cordata, platyphyllos, tomentosa,)*
Malvaceae	*Hibiscus (abelmoschus)*
Dipterocarpaceae	*Dryobalanops (aromatica, camphora)*
	Dipterocarpus (tuberculatus, turbinatus)
Cistaceae	*Cistus (ladaniferus)*
Violaceae	*Viola (odorata)*
Myrtaceae	*Myrtus (aeris, caryophyllata, communis, pimenta)*
	Pimenta (acris, citrifolia, officinalis, racemosa)
	Eugenia (acris, caryophyllata, pimenta,)
	Leptospermum (citratum, flavescens)
	Melaleuca (alternifolia, bracteata, cajeputi, leucodendron, linariifolia, maideni minor, smithii, trichyostachya, viridiflora)
	Eucalyptus (amygdalina, australiana, bicostata, citriodora, cneorifolia, dives, dumosa, elaeophora, fruticetorum, globulus, leucoxylon, lindleyana, macarthuri, maculosa, numerosa, phellandra, polybractea, radiata, sideroxylon, smithii, viridis)
Umbelliferae	*Coriandrum (sativum)*
(Apiaceae)	*Cuminum (cyminum)*
	Apium (graveolens, petroselinum)
	Petroselinum (hortense, sativum)
	Carum (ajowan, bulbocastanum, carvi, copticum, petroselinum, verticillatum)
	Pimpinella (anisum, diversifolia, saxifragra)
	Foeniculum (vulgare,)
	Anethum (graveolens, sowa)
	Oenanthe (phellandrium)
	Levisticum (officinale)
	Angelica (archangelica, atropurpurea, glabra, levisticum
	Ferula (alliacea, asafoetida, badra-kema, ceratophylla, foetida, galbaniflua, rubricaulis, suaveolens, sumbul)
	Peucedanum (ostruthium)
	Daucus (carota)
	Crithmum (maritimum)
Ericaceae	*Gaultheria (procumbens)*
Primulaceae	*Cyclamen (europaeum)*
Oleaceae	*Syringa (vulgaris)*
	Jasminum (officinale, grandiflorum, auriculatum, sambac, undulatum)
Verbenaceae	*Lippia/Aloysia (citriodora)*
Labiatae	*Rosmarinus (flexuosus, lavandulaceus, laxiflorus, officinalis, tournefortii)*
(Lamiaceae)	
	Lavandula (barmanni, dentata, hybrida, intermedia, latifolia, officinalis, pedunculata, spica, stoechas, vera, viridis)
	Nepeta (cataria, liniaris, spicata)
	Salvia (carnosa, espanola, hiemalis, hispanorum, lavandulaefolia, leucophylla moscatel, officinalis, sclarea, triloba, verbenaea)
	Monarda (citriodora, fistulosa, menthaefolia, pectinata, punctata)

Melissa (officinalis)
Hedeoma (pulegioides)
Satureia (hortensis, montana)
Hyssopus (officinalis)
Origanum (compactum, elongatum, fort-queri, grossi, majorana, virens, vulgare)
Marjorana (silvestre, hortensis)
Thymus (capitatus, cephalotus, hiemalis, hirtus, loscossi, mastichina, serpyllum, virginicus, vulgaris, zygis)
Mentha (aquatica, arvensis, cablin, canadensis, citrata, japonica, longifolia piperita, pulegium, rotundifolia, spicata, sylvestris, verticillata, viridis)

Perilla (citriodora, frutescens, nankinensis, ocymoides)
Pogostemon (cablin, heyneanus, hortensis, patchouli)
Ocimum (americanum, basilicum, canum, carnosum, gratissimum, kilimandscharicum, album, anisatum, menthaefolium, micranthum, minimum, nakurense, pilosum, sanctum, suave, viride.)
Mosla/Orthodon (angustifolia, chinesis, formosana, hadai, japonica, lanceolata, lysimachiiflora, punctata, thymolifera)
Pycnanthemum (incanum, lanceolatum, muticum, pilosum)
Coridothymus (capitatus) Myoporaceae Eremophila (mitchelli)
Rubiaceae Gardenia (citriodora, florida, grandiflora, longistyla, resinifera, floribunda, latifolia)
Leptactina (senegambica)
Caprifoliaceae Lonicera (caprifolium, gigantea, japonica)
Valerianaceae Valeriana (celfica, officinalis, wallichii, brunoniana, hardwickii)
Compositae Solidago (odora)
(Asteraceae) Erigeron (canadensis)
Blumea (balsamifera, lacera, ampletectens, densiflora, aurita, glabra)
Helichrysum (angustifolium, arenarium, italicum, stoechas)
Inula (helenium)
Tagetes (glandulifera, minuta, erecta, patula)
Santolina (chamaecyparissus)
Anthemis (nobilis)
Achillea (millefolium, moschata)
Matricaria (chamomilla, inodora)
Artemisia (absinthium, cina, dracuculus, maritima, pallens, pontica, tridentata, vulgaris, vestita, scoparia, parviflora)
Arnica (montana)
Saussurea (lappa)
Tanacetum (vulgare)

III. EXTRACTION AND UTILIZATION OF AROMA PRINCIPLES

Plants owe their fragrance to the presence of traces of essential oils in different parts. Numerous fragrance materials are present in roots, stems, barks, leaves, flowers, fruits and heartwoods. Gums, balsams and oleoresins are also valuable raw materials for perfumes by virtue of their tenacious but soft odour. Several processes like hydrodistillation, steam distillation, hydrodiffusion, enfleurage, maceration, expression and solvent extraction are available for the extraction of aroma principles. Application of these processes, either singly or in combination, depends upon the nature of the material and of the essential oil or absolute intended to be recovered.

1. Distillation

The bulk of essential oils are produced by distillation. There are three systems of distillation- hydro, hydro-steam and steam distillation.

Hydrodistillation system, though the oldest, is still being widely practised for oil extraction. The plant material is in direct contact with boiling water in a crude metallic distillation outfit. Orange blossom and rose petal oil units employ this method.

Hydro-steam distillation is employed where the perfumery material is vulnerable to direct steam. Consequently, the plant material is supported on a perforated grid or screen inserted at some distance above the bottom of the still. The lower part of the still contains water upto a level just below the grid.

In a *steam distillation system*, live steam under pressure (upto 7 kg/cm^2) is injected through steam tubes below the charge and the pressure within the distillation vessel is controlled according to the nature of the material being distilled. This method is efficient and gives higher yields. However, it is not generally employed to delicate flowers.

In all these distillation processes, steam is employed to carry the volatile odorous oil along with its vapours which are subsequently condensed to liquefy the oil and water vapours. The three methods differ in the intensity of steam employed for the purpose. Steam of different intensities is needed depending upon the volatility of the fragrant components in the plant material as well as on the thermostability or thermolability of these components. To get maximum extraction the plant materials are subjected to comminution. However, flowers and leaves by virtue of their having desired thinness of the cell walls are not comminuted.

There have been occasional improvements in the design of the still and the improved versions are employed for distilling lemongrass, palmarosa, vetiver, celery seed, linaloe berries, geranium, patchouli, cedars and others.

Free water in the oil is completely drained off by decantation and the remaining traces of water are removed by adding anhydrous sodium sulphate at the rate of 20-30 g/l. The anhydrous sodium sulphate can be left in the oil for 4-5 hours after which the oil is filtered to remove the sodium sulphate and other sediments. Rectification of distillate is effected by fractional hydrodistillation at reduced pressure for improving their colour and odour. Bad odours and impurities are removed in the fore-runs and hind-runs during rectification.

The major odoriferous constituents of most of the essential oils are oxygenated compounds like alcohols, aldehydes, esters, ethers, ketones, lactones, phenols and phenol ethers. Terpenes and sesquiterpenes are usually present along with these compounds and their separation is beneficial. This is done through fractional distillation in vacuum or by solvent extraction. Usually the terpeneless oil is extracted with dilute alcohol or similar solvents
to remove waxes and sesquiterpenes.

2. Absolute flower oils

Absolute flower oils are obtained by maceration, expression, enfleurage and extraction with volatile solvents.

Maceration: In maceration, the oil cells of the fragrant flowers are ruptured by immersion in a hot fat or oil at 60-70 C which in turn absorbs the essential oils. Fat is separated from spent flowers and reused for absorbing fragrance from the next batch of fresh flowers. The fat retained by flowers is recovered by hydraulic pressing. The resultant perfumed pomade is frequently marketed as such but is often extracted with strong alcohol to yield extracts. These alcoholic absolutes are the absolutes of pomade in market parlance.

Extraction with volatile solvents: This yields concretes and alcohol soluble absolutes having a near natural odour thereby making the enfleurage and maceration process obsolete.

This process is presently employed regularly for the extraction of aromatic substances from flowers, leaves and mosses. The extraction is effected at room temperature using perfumery grade solvents like petroleum ether of boiling point 60 to 80 C or benzene by the following two systems.

a) Stationary system consisting of vertical cylinders with perforated metal grids arranged horizontally around a central vertical shaft. Fresh flowers are loaded on grids. Extraction is effected by three successive washings, distilling the total perfume rich solvent for their respective recoveries.

b) Rotary system fabricated from a tinned iron drum rotating on a horizontal axis. Four perforated metallic partitions make four compartments to hold charges of fresh flowers. The lowest part of the drum contains the solvent. On rotating the drum, the rising compartment drips the liquid through its perforations to the bottom. Each batch of flowers receives three washings. The extract is pumped to a vacuum still for distilling off the solvent at temperatures lower than 60 C. Solvent recovery is 88-93%. The concentrate is cooled, filtered and further concentrated in vacuum.

The concrete is exhausted with warm alcohol thereby separating the wax and preparing the absolute. The clarified alcoholic concentrate is chilled at temperatures of -20 to -30 C facilitating additional separation of wax. The filtered clear solution is used as such but is also further concentrated under vacuum to a viscous consistency. The solvent should be selected such that it should completely and quickly dissolve the odoriferous principles of the plant materials and should not dissolve inert principles of plant materials like waxes, pigments, and albuminous compounds and also be inert to flower oil

constituents. The boiling point should not be too high or too low, it must be uniform. The solvent should be cheaper, noninflammable and immiscible with water.

Expression: This method is employed when the essential oils are thermosensitive. It is used for isolating essential oils from lemon and orange peels. In expression method there are two processes.

a) The Ecuelle process, where the whole lemons are rolled in hollow vessels covered inside with spikes to puncture oil cells permitting the essential oil to ooze out into a collecting vessel for filtering to obtain a clear oil.

b) The sponge process, where the fruit is cut across the shorter axis and the peel separated, steeped in water followed by hand pressing between sponges. The oil soaked sponges are squeezed to release the oil.

Enfleurage: Enfleurage is the process of extraction of fragrance by absorbing it from flowers in contact with cold fats. This process is adopted for fragrant flowers of jasmine and tuberose which continue to manifest their characteristic fragrance even in plucked condition. Solvents lack this virtue of arresting the manifested fragrance.

The fats should be saturated and odourless to prevent entrance of fat odours. Refined lard or beef suet are preferred. The fat is thinly layered on both sides of a glass plate supported on a rectangular wooden frame or chassis. Fresh fragrant flowers are lightly layered on
the fat coated chasses. Several chasses are placed one above the other sandwiching the flowers between two layers of fat. Spent flowers are removed (defleurage) and fresh charge is made. Reversing of the glass slab is called *patage*. Patage is done several times to obtain maximum perfume absorption. Furrows are created with combs to increase absorption surface. The process of defleurage, fresh charging and patage is continued to obtain fat of the desired perfume strength.

3. Supercritical Fluid Extraction (SCFE)

This is emerging as a versatile and important tool to separate components that are susceptible to thermal degradation. It is employed for the extraction of flavours, fragrances and perfumes from a wide variety of natural products. This method of extraction is superior and faster than distillation. Higher diffusiveness and lower viscosities of supercritical fluids enable better penetration and faster equilibration. Besides, the solvent power is manipulable, free from surface tension and wetting properties and easily adoptable to isolate highly thermolabile compounds. Carbon dioxide is the favourite solvent by virtue of its cheapness, nontoxicity, noncorrosiveness, non-flammability, easy to handle, needing mild processing conditions during extraction, good solvent power for alcohols, aldehydes, esters and ketones.

In this process, volatility as well as solubility are employed. Temperature and pressure variations are manipulated to utmost advantage. After extraction, solvent is separated from the extract phase by varying the operating conditions and is recycled after makeup.

Liquid carbon dioxide is completely miscible with the components of essential oils like aldehydes, ketones, esters and alcohols. At the same time, proteins, starches, mineral salts and water are insoluble in liquid carbon dioxide. The essential oils obtained by liquid carbon dioxide extraction are superior to that obtained through steam distillation and solvent extraction. Extraction of several natural products such as pyrethrins from chrysanthemum flower, essential oils from anise, caraway, clove star anise, cinnamon and ginger are increasingly done by this process.

4. Natural Aroma Products

Production of essential oils has been developing into a very profitable agroindustry during the last few years. It has provided diversification in the agricultural sector and is gaining popularity on the rural front also. Due to the availability of essential oils more freely in the market, not only their direct uses as attars, floral and aromatic waters, perfumery grade alcohol and in flavour encapsulation, but also the end uses have been widening. Accordingly, the essential oils are today used in soaps, perfumery, cosmetics, agarbathis, disinfectants, deodorants, mosquito repellents, flavouring of foods and pharmaceuticals and a range of allied products.

i) Attars are flower distillates collected over sandalwood oil. Accordingly, there are attars of jasmine, kewada, rose, champaca, khus, maulsari (*Mimussops elengi* L.) kadamba (*Anthocephalus cadamba* Miq.), mango, agar (*Aquilaria agallocha* Roxb.), henna (*Lawsonia inermis* L.), kishar (*Crocus sativus* L.), harshringar or parijatak (*Nyctanthes arbor-tristis* L.), kuth (*Saussurea lappa* Clark), surangi (*Ochrocarpus longifolius* Benth. & Hook. f.) and others. Attars are prepared by washing sandalwood oil with one middle and tail distillate from a previous batch in order to remove lower terpenes from the oil as well as sweetening the attar into a mellow and fragrant note. The vapours from the water-distillation still are condensed and absorbed in the aforesaid washed sandalwood oil. The base oil is then charged to the forerunnings of a fresh batch of perfumery plant materials, while tail runnings are employed for the preparation of a new batch of base oil. Distillation with fresh charges is repeated till the required concentration of natural oil in the base oil is obtained. Attars being more stable have longer shelf life. The

quantum of flower oil in the product determines the quality and price of attar. Attars are used for perfuming tobacco, soaps, agarbathis and hair oils. Alcoholic solution of attars are now available.

ii) Floral and aromatic waters are prepared by distilling fragrant materials with water. A specific quantity of the fragrant materials is distilled with a specified volume of water for a specific period and a predetermined volume of the distillate is collected as per individual formulas of the manufacturers. These waters are prepared and marketed as single, double or triple distilled water. These are employed for perfume wafting at sacred places and during social functions. It is also added in traces to cold clean drinking waters.

iii) Agarbathis are the Indian version of Chinese joss sticks and *dhoop* is of incense. Both are burnt slowly to obtain a fragrant smoke. These too have their religious, aesthetic and secular uses. Some industrial houses procure raw agarbathis, add perfumes, pack and market them.

iv) Perfumery grade alcohol is required as diluent and solvent for the production of high class perfumes and flavours, for which the olfactory quality of alcohol is a basic and essential requirement. It must be free from higher alcohols and aldehydes. Such alcohols are technically denoted as *Extra Neutral Alcohol* and commercially called *silent spirit* which is manufactured from rectified spirit of 90 to 95 % purity obtained from molasses or grains by double or triple fractionation.

v) Flavour encapsulation systems like spray drying, spray cooling, spray chilling, gelatin encapsulation, and cold encapsulation are now increasingly being used by the industry. Spray drying converts a liquid into powder in one step process. The liquid to be dried (feed) is atomized in a stainless steel drying chamber by a nozzle or a rotating disc into a spray which instantly comes into contact with the drying air. Due to rapid evaporation, the temperature of the droplets can be kept far below the drying air temperature and is normally 15 -20 C below the outlet air temperature. The flavour to be encapsulated is specifically formulated to have highest strength and added to the encapsulating medium like gum acacia and modern carriers from modified starches. Carrier choice depends upon emulsification properties, low viscosity in solution at high solid content, flavour retention ability, hygroscopicity, blend flavour compatibility in finished products and stability during storage.

IV. PHYSICO-CHEMICAL PROPERTIES OF ESSENTIAL OILS

Essential oils have several common physical properties like characteristic fragrances and high refractive indices. They are mostly optically active and immiscible with water but sufficiently soluble to impart their characteristic fragrance to water. Factually, the aromatic waters are dependable on this slight solubility. Essential oils are however soluble in ether, alcohol and organic solvents.

In the laboratory, essential oils are distilled out using Clevenger's apparatus and the physical properties are studied in the case of specific gravity by specific gravity bottle, refractive index by refractometer and optical rotation by polarimeter. Fragrance investigations are generally carried out by the following techniques.

i) direct solvent extraction ii) steam distillation at atmospheric or reduced pressure followed by solvent extraction.
iii) simultaneous distillation and extraction
iv) high vacuum and molecular distillation
v) use of porous polymers, activated charcoal, etc.
vi) supercritical fluid extraction
vii) separation of fragrant complex into individual components achieved through the use of column chromatography, gas liquid chromatography (GLC), thin layer chromatography (TLC), high pressure liquid chromatography (HPLC), ion exchange chromatography and permeation chromatography
viii)identification of the constituents through ultraviolet, infrared, NMR and mass spectroscopy
ix) radioactive carbon determination of natural and synthetic aroma compounds on the basis of their ^{14}C contents.
x) chemiluminescence or detecting whether the test material has been derived from species besides food aromas.

The most widely used technique is the combined gas chromatography with data systems. Liquid chromatography with mass spectrometry is particularly useful for analysis of low vapour pressure and high molecular weight samples which defy resolution by the gas chromatography cum mass

spectrometry. The liquid chromatography cum mass spectrometry is now commercially available. This has enabled to do quick analysis of even small amounts of substances.

Essential oils differ from fixed oils. The former can be distilled from their natural source, do not consist of glyceryl esters of fatty acids, do not leave a permanent oily spot on paper and are unsaponifiable with alkalies. Unlike fixed oils, essential oils do not become rancid. Instead, they get oxidized and resinified on exposure to light and air.

Practically all volatile oils are complex mixtures varying widely in their composition. The chemical constituents compose of oxides, esters, aldehydes, ketones, ethers, alcohols, and hydrocarbons. Only a few possess a single component in a very high percentage, viz, santalol in sandalwood oil, citral in lemongrass oil and eugenol in cinnamon leaf oil. The diverse types of organic compounds can however, be separated by various techniques as given below.

i) low temperature for crystallizing the stearoptenes
ii) fractional distillation
iii) fractional crystallization from polar solvents and
iv) removal by chemical action: free acid group is removed from the oil by sodium carbonate (Na_2CO_3), basic compounds with hydrochloric acid (HCl), phenols with sodium hydroxide (NaOH) and aldehydes with sodium bisulphite ($NaHSO_3$).

V. STORAGE OF ESSENTIAL OILS

Essential oils are colourless or lightly coloured and free flowing when they are fresh. On long storage they become darker in colour and highly viscous due to oxidation and resinification. To prevent this, they are stored in a cool and dry place in tightly stoppered amber glass bottles. Exclusion of air by completely filling the container with oil prolongs its storage life. The quality of the oil is also spoiled during prolonged storage. This deterioration in quality of the oil is attributed to a number of chemical reactions such as oxidation, resinification, polymerization, hydrolysis of esters and interaction of functional groups. These processes are activated by heat, presence of oxygen or air and moisture. These reactions are considered to be catalyzed by light in some cases and possibly by metals. The high terpene containing oils like citrus, pine needle and turpentine are particularly prone to spoilage by oxidation and resinification. Light is less harmful than moisture. Essential oils containing a high percentage of esters, viz, oil of bergamot and lavender turn acidic after improper storage, due to partial hydrolysis of esters. The aldehyde content of lemongrass oil gradually diminishes, yet much more slowly than if the isolated aldehyde (citral) is stored as such, perhaps due to the presence of some antioxidants. Fatty oils can be preserved by adding antioxidants like hydroquinone. Alcohol containing essential oils like sandal and geranium are quite stable and withstand prolonged storage. Others like patchouli and vetiver improve considerably on aging hence are made to age before use in perfume compounds.

Essential oils should be freed from metallic impurities and moisture followed by its clarification. Then they should be stored in well filled, tightly closed containers at low temperatures and protected from light. Bottles of hard and dark coloured glass are well suitable for small quantities of oil. But large quantities are generally stored in aluminium containers ormetal drums with tin lining. A stream of carbon dioxide or nitrogen gas blown inside the container before it is sealed will replace the air above the oil and thereby assure added protection against oxidation.

Prior to storing, the oil should be carefully clarified and any moisture should be removed because the presence of moisture is one of the main factors in the spoilage of an essential oil. Smaller lots can be dehydrated with the help of anhydrous sodium sulphate (Na_2SO_4). After the addition of anhydrous sodium sulphate, the container is shaken thoroughly, kept aside for 24 hours and filtered. Calcium chloride ($CaCl_2$) must never be used for dehydration as this forms complex salts with certain alcohols. Large commercial lots are not always easy to clarify. To viscous oil lots like vetiver, sufficient quantity of common salt should be added and the mixture stirred for a while and allowed to stand until the supernatant oil has become clear which is drawn off. The lower cloudy layer is filtered clear. If filtration through plain filter paper does not give a clear oil then kieselghur or specially prepared filtering clay should be used. Care should be exercised in the selection of the filtering medium as some media like activated carbon may react chemically with certain constituents of the oil and affect its quality. Bulk lots of oil may be filtered through filter presses.

Centrifuging in high speed centrifuges at more than 15,000 rpm is an excellent means of clarifying essential oils. It helps to remove not only moisture but also waxy materials in the oil.

High phenol containing essential oils like those of cloves and bay, when freshly distilled are in crude form and are dark coloured due to the presence of metallic impurities. To get rid of these, sufficient quantity of tartaric acid powder is added to the oil lot and stirred to settle the same. The supernatant clear layer is carefully drawn off, while the lower layer is filtered until clear. The contents are thoroughly mixed and allowed to separate. The upper oily layer when sufficiently clear is withdrawn off as such.

The middle and lower layers are further clarified by filtration. Super centrifuges are of great help here also. If this too fails to eliminate the undesired oil colour, the oil lot is redistilled or rectified.

TROPICAL AROMATIC CROPS

Hot humid tropics offers an invaluable array of plant species which yields essential oils of fragrance and flavours. Some are commercially cultivated while others have potential for large scale planting. The major crops, along with their agrotechnology are briefly described hereunder. For the sake of practical convenience the crops are classified under the following four broad groups.

a) Aromatic grasses: Lemongrass, palmarosa, citronella, vetiver

b) Aromatic herbs and shrubs: Mints, ocimums, patchouli, rosemary, clarysage, thyme, celery, coriander, cumin, fennel, ajowan, davana, chamomile, geranium, cardamom, ginger, kacholam.

c) Aromatic trees: Sandalwood, eucalyptus, clove, camphor, cinnamon, nutmeg, linaloe.

d) Aromatic flowers: Rose, jasmine, tuberose, marigold, champaca.

A. AROMATIC GRASSES

1. LEMONGRASS Cymbopogon flexuosus Graminae

Importance

Lemongrass is a tropical perennial grass which yields an aromatic oil containing 70-90% citral. The name *lemongrass* is given to this crop because of typical strong *lemon-like odour* of the plant which is predominantly due to the high citral content in the essential oil present in the leaves. Lemongrass oil of commerce is popularly known as *Cochin oil* in the world trade as 90% of it is coming from Cochin port. Kerala has the monopoly in the production of lemongrass oil. The annual world production of lemongrass oil is around 1000 tonnes.

Lemongrass oil is one of the most important essential oils being widely used for the isolation of citral which can be converted into ionones having the odour of violets. They are used in flavours, cosmetics and perfumes. ß-ionone is used for the commercial synthesis of vitamin A. In some Far Eastern countries like Java, Japan, China and India the leaves are used for flavouring foods, drinks and tea and for scenting bathwater. The oil is used as a repellent against flies and mosquitoes. The spent grass is an excellent fuel, manure and mulch and forms raw material for the production of silage, mushroom and paper boards. The crop is also cultivated along the bunds as a live mulch. The well ramified root system of the plant helps in soil and water conservation.

Origin and distribution

Three types of lemongrass are known, viz, East Indian, West Indian and Jammu lemongrass. *East Indian lemongrass* is the genuine and commercial type. It is indigenous to India. It grows wild in India and is cultivated as well in the states of Kerala, Assam, Maharashtra and Uttar Pradesh. It is distributed over other countries like Guatemala and China. *West Indian or American lemongrass* is believed to have originated either in Malaysia or in Sri Lanka. It is widely distributed throughout the tropics and is grown in the West Indies, Guatemala, Brazil, Congo, Tanzania, India, Thailand, Bangladesh, Madagascar and China. *Jammu lemongrass* is mostly confined to North Indian states such as Jammu and Kashmir, Sikkim, Assam, Bengal and Madhya Pradesh.

Botany

Lemongrass belongs to the family Graminae (Poaceae) and the genus *Cymbopogon*. Three species are generally identified.

i) *Cymbopogon flexuosus* (Nees ex Steud.) Wats., (2n=20,40).

It is known as *East Indian, Cochin or Malabar grass*. Under this species two varieties are identified based on the stem colour.

a) *C. flexuosus var. flexuosus*| The Red grass, locally known as "Chumannapullu". The stem is reddish or purplish in colour. It is recognized as the *true lemongrass* and is commercially cultivated. The oil yield is poor but the citral content of the oil is high (75-90%).
b) *C. flexuosus var. albescens*: The white grass, locally known as "Vellapullu", is characterized by the white colour of the stem. The plant is normally seen wild. The oil is poor in solubility. The oil yield is high but poor in citral content (60-75%).

Cymbopogon flexuosus is a tufted robust perennial grass, 2 m tall. It flowers freely. Leaves linear, lanceolate 125x1.7 cm. Panicles very large, drooping, lax, greyish-green, rarely with a purplish tinge, with the raceme pairs in dense masses, spreading, 100-135 cm long, slightly hairy, lower glumes of the sessile spikelets 3-4, 4-5 mm long, 1 mm wide with 1-3 definite or obscure intracranial nerves, shallowly concave with one to two depressions.

ii) *Cymbopogon citratus* (DC.) Stapf. (2n=40,60)

It is known as *West Indian or American lemongrass. C. citratus* is a stemless perennial grass with numerous stiff tillers arising from short rhizomatous rootstock, making large tussocks. It seldom flowers in cultivation. Leaf blade narrow, linear, glaucous, drooping, 50-100 x 0.5-1.5 cm with scabrous margins. Ligule truncate, 0.2-0.8 cm long. Inflorescence rarely produced, a large loose panicle; spathe bracts long and narrow, sessile spikelets, awnless, linear-lanceolate.

iii) *Cymbopogon pendulus* (Nees ex Steud.) Wats.

It is known as *Jammu lemongrass*. It is white stemmed and dwarf in stature. The plant is frost resistant and suited to Sub-Himalayan areas of Northern India.

Agrotechnolgy

Lemongrass requires a warm humid climate with plenty of sunshine and rainfall ranging from 2500-3000 mm, uniformly distributed over the year. The grass prefers an average temperature of 23-30 C. The plant is hardy and tolerant to drought. This crop is well suited for rainfed agriculture. It grows well at altitudes between 100 and 1200 m above MSL. It is generally grown on poor soils along hill slopes, though it flourishes on a wide variety of soils ranging from rich loam to poor laterite. The grass grows best on well drained sandy loam soil.

It is propagated through seeds and root divisions or slips. Clonal propagation is better as seed propagation leads to considerable genetic heterogeneity resulting in gradual deterioration of yield and oil quality. Improved varieties such as 'Sugandhi' or 'OD-19' (developed at Aromatic and Medicinal Plants Research Station, Odakkali), 'LS-48' and 'Pragati' (developed at CIMAP, Lucknow) are available for cultivation.

Fresh seeds are to be used for sowing as they are short viable and the viability is drastically reduced after six months of storage. Seed rate is 3-4 kg/ha for transplanting and 25-30 kg/ha for broadcast sowing. For transplanting, seeds are sown in a well prepared nursery during April-May. Seeds germinate in 5-7 days. Seedlings are transplanted when 45-60 days, old at a distance of 20-50 cm in rows, 20-75 cm apart depending on the soil fertility and tillering nature of the variety. In areas receiving high rainfall, planting on ridges or beds is recommended. Ridges or beds are taken across the slope on hilly areas. Lemongrass is a soil exhausting crop. Spent-lemongrass in the form of compost at 10 tonnes/ha and wood ash at 2 tonnes/ha, which are obtained as byproducts of grass distillation, supply sufficient amount of nitrogen and potash to the crop. Inorganic fertilizers are recommended at 30 kg/ha each of N, P_2O_5 and K_20 as basal dose at the time of planting. 60 kg N/ha can be applied as top dressing in 3-4 splits after every harvest during a year. 4-6 irrigations are essential for getting optimum yield in areas where rainfall is restricted or not well distributed. Crop-weed competition period is the first 25-30 days after planting or harvest. Generally, 2-3 weeding are necessary during a year. Among herbicides diuron at 1.5 kg/ha and oxyfluorfen at 1.5 kg ai/ha are effective for weed control. Spraying Paraquat at 2-2.5 l/ha in 500 l of water immediately after cutting the grass for distillation is an excellent method of weed control. Burning of stubbles in summer is practised in some areas to ward off pests, diseases and weeds. Earthing up of plants after weeding and fertilizer application is beneficial as the roots have a tendency to grow above the soil.

A stem borer, *Chilotrea* species bores into the stem and remains there feeding on the shoot. It is recognized by the drying up of the central shoot followed by the death of the whole shoot. The stem borer attack can be controlled by timely application of any systemic insecticide. *Helminthosporium cymbopogi* and *H. sacchari* cause leaf spot diseases in lemongrass which can be controlled by fungicide application. *Tolyposporium christensenii* causes a long smut in Kerala and completely destroys the inflorescence, for which no effective control measure is available at present.

The first cutting of grass is taken about 3 months after planting, thereafter every 6-8 weeks. Harvesting is done with the help of sickles, the plants being cut close to the base about 10 cm above ground level.

Generally, 3 harvests are possible during the first year and 4-5 during subsequent years. The plantation remains economical for 4-6 years. The fresh grass yield ranges from 3 to 10 tonnes/cut/ha depending on soil fertility, agroclimatic conditions and management. The grass yield is the lowest in the first year and highest in the third or fourth year of planting.

Postharvest technology

The essential oil is produced by distillation of the grass with water. For obtaining good quality oil, steam distillation in stainless steel units is preferred, with a steam pressure of 18-32 kg/cm^2 in the boiler. The grass is distilled either fresh or after wilting. Wilting of grass for 2 days and chopping to 3 cm size gave about 30% more oil and citral. The oil yield and content in the grass depend upon several factors such as fertility of the soil, climatic conditions, age of the grass, time of cutting, the state of the grass distilled (whether fresh or dry), distillation method, etc. On an average the oil recovery is 0.2-0.4% and the oil yield is 100-125 kg/ha/year.

Physico-chemical properties of oil

The physico-chemical properties of *Cymbopogon flexuosus* red and white types, *C. pendulus* and *C. citratus* are given in the following table.

Physico-chemical properties of lemongrass oils

Property	*C. flexuosus*		*C. pendulus*	*C. citratus*
	Red grass	white grass		
Specific gravity at 30 C	0.881	0.931	0.915	0.898
Refractive index at 30 C	1.482	1.498	1.489	1.491
Optical rotation at 30 C	-3 to 1	-	-0.36	-0.62
Total aldehydes	80-89%	76.4%	75-80%	74.96%
Solubility in 70% alcohol	2.8 vol.	Insoluble	-	-

East Indian lemongrass oil is more soluble in alcohol than others and hence it is more preferred for direct use in perfumery. *C. flexuosus* oil contains 75-85% of aldehydes consisting largely of citral. Other constituents in the oil are linalool, geraniol, citronellol, nerol, 1,8-cineole, citronellal, linalyl acetate, geranyl acetate, -pinene, limonene, caryophyllene, ß-pinene, ß-thujene, myrcene, ß-ocimene, terpinolene, methyl heptanone and terpineol. The essential oil of *C. citratus* contains approximately -pinene 0.13%, ß-pinene 0.19%, delta-3-carene 0.16%, myrcene 12.75%, dipentene 0.23%, ß-phellandrene 0.07%, ß-cymene 0.20% methyl heptanone 2.62%, citronellal 0.73%, ß-elemene 1.33%, ß-caryophyllene 0.18%, citronellyl acetate 0.96%, geranyl acetate 3.00%, citral b 0.18%, citral a 41.82%, geraniol 1.85%, elemol 1.20% and ß-caryophyllene oxide 0.61%. The average composition of *C. pendulus* oil is reported to be -pinene 0.19%, camphene 0.01%, ß-pinine 0.16%, car-3-ene 0.04%, myrcene 0.04%, dipentene 0.35%, phellandrene 0.30%, p-cymene 0.36%, methyl heptanone 1.05%, citronellal 0.49%, linalool 3.07%, ß-elemene 0.70%, ß-caryophyllene 2.15%, citronellyl acetate 0.72%, geraniol acetate 3.58%, citral b 32.27%, citral a 43.29%, geraniol 2.60%, elemol 2.29% and ß-caryophyllene oxide 1.56%.

2. PALMAROSA Cymbopogon martinii Graminae

Importance

Palmarosa is a tall perennial grass, the flowering tops and foliage of which contain a sweet-smelling oil of *rose-like odour*. Two types of palmarosa grasses have been recognized, viz,*Rosha or Russo grass and Gingergrass*. Rosha grass yields a superior oil which is used in perfumery, particularly for flavouring tobacco and blending soaps due to the lasting rose note it imparts to the blend. In soap perfumes, it has a special importance by virtue of geraniol, being stable to alkali. It is a source of 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 have a permanent rose-like odour. It is also used as an adulterant of Turkish attar of roses. Gingergrass oil is poor in quality and is mainly used as a cheap perfume in countries bordering the Red Sea.

Origin and distribution

The exact location of origin of the crop is not clearly known. It grows wild in India, particularly in Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Uttar Pradesh and Orissa. Palmarosa oil has been distilled in India for more than 50 years, mostly from wild growths. The plant was successfully introduced into Java, The Seychelles, Guatemala and Brazil where commercial production was undertaken to a limited extent. About 60-70 tonnes of palmarosa oil is produced in India annually both from cultivated and natural sources.

Botany Palmarosa grass belongs to the family Graminae (Poaceae) and the species *Cymbopogon martinii* (Roxb.) Wats. It is a perennial grass growing to 2-3 m in height. In this species, the following two varieties are recognized which are morphologically very similar but differ considerably in their habitat and also in the essential oils.

i) Cymbopogon martinii var. motia (2n=40)

It is known as *Palmarosa, Rosha or Russa grass*. Its leaves are lanceolate, 50 cm long, 1-3 cm broad. Panicles 10-30 cm long, turning reddish, often very bright when mature. Racemes 15-19 mm long, in pairs, each consisting of many pairs of spikelets. In each pair, one is sessile and hermaphrodite and the other is pedicelled and male. Sessile spikelets 3.5 mm long. Glumes 3.3-4.0 mm long. Awns 11.4-14.0 mm long. Lower glume of fertile spikelet deeply channeled.

ii) *C. martinii var. sofia* (2n=20)

It is known as *Gingergrass*. Morphologically it resembles motia grass, but the oil is inferior.

Jamrosa is an interspecific hybrid between *Cymbopogon nardus var. confertiflorus* and *C. jwarancusa*. Its oil contains 75-80% geraniol and 15-20% geranyl acetate. The oil has more terpenic, limy or grassy by-odours in contrast to the sweet, rosy odour of palmarosa oil.

Agrotechnology

Palmarosa grass is a tropical plant and it grows in warm humid areas. It is susceptible to frost and hence frost-prone areas are not suitable for its cultivation. Although it grows best on soils having neutral pH, it can survive and give economic yields on alkaline soils of pH upto 9. Motia grass prefers well drained soils and it grows in separate clumps on open dry hill sides with a rainfall of 800-900 mm. It cannot tolerate stagnant water. Sofia grass grows densely and abundantly at lower altitudes in moist and poorly drained soils in areas of higher rainfall.

It is propagated best through seeds and also through slips. 'IW 31245', 'IW 3629', 'IW 3244' and 'Trishna' are improved varieties available for cultivation. Seeds are sown on nursery beds prepared in May. About 5 kg seeds are adequate to give seedlings for planting one hectare. As the seeds are very small and light, they are usually mixed with fine sand or soil in the ratio of 1:10 for even distribution and ease of sowing. The beds are watered lightly and regularly. Germination starts in two weeks time. In about 4-6 weeks, seedlings are ready for transplanting. The field is prepared well before the onset of monsoon and the seedlings are transplanted during June-July. Healthy and established seedlings, about 15 cm tall are carefully removed from the nursery and transplanted in rows, 20-60 cm apart with the plants spaced at 20-60 cm. Spacing can be increased on fertile soils. Farm yard manure is given at 10 tonnes/ha before planting. Fertilizers at 20 kg N, 50 kg P_2O_5 and 40 kg K_20/ha are given at planting as a basal dose. About 40 kg N/ha is applied in two splits during the growing season. The NPK application should be repeated each year at the time of appearance of fresh leaves. Application of micronutrients like iron (as $FeSO_4$) and manganese (as $MnSO_4$) improves the growth, herbage and oil yield. Palmarosa plantations are to be irrigated at 10-14 days interval during the summer period. The plantation should be kept weed free by regular weeding and hoeing. Diuron at 1.5 kg ai/ha and oxyfluorfen at 0.5 kg ai/ha have been recommended to control weeds in palmarosa. No serious insect pests have been reported in this crop. *Curvularia trifolii* (Kauff.) Boed causes leaf blight. Yellowing of leaves and necrosis are the symptoms. *Dreschlera cymmartinii* sp. nov. also infects palmarosa. Application of a suitable fungicide can be resorted to, if the attacks are severe.

The optimum stage of harvest is the initial seed setting stage. This stage will be reached about 10-15 days after flowering. The grass is cut at a height of about 10 cm from the ground level and the whole plant is used for distillation. During the first year one or two cuttings can be obtained depending upon the climatic conditions. After the first harvest, subsequent harvests can be made at 70-80 days interval and 3-4 cuttings can be taken a year. The plantation remains productive for 4-6 years. The yield of grass and oil starts decreasing from the third or fourth year onwards. The grass yield is 6-10 tonnes/cut/ha.

Postharvest technology

The harvested herbage is allowed to wilt in shade for 24-48 hours for draining off the excess moisture from the leaves. This reduces the bulk and cost of distillation. The oil can be obtained either by

hydrodistillation or by steam distillation. Steam distillation yields more of better quality oil. The distillation unit should be clean, rust free and free of any other odour. The oil content and yield depend upon the climatic conditions, harvesting time, maturity of grass, extent of wilting and the distillation process. The oil yield is low in the first year and it increases with the age but gradually decreases after fourth year. All parts of the plant contain essential oil, the maximum being present in flowers and the least in the stalks. On an average, the oil content in various parts are: whole plant 0.10-0.40%, stalks 0.01-0.03%, flowering tops 0.45-0.52% and leaves 0.16-0.25%. The average annual oil yield is 100-125 kg/ha though an yield of 250 kg/ha is not uncommon.

Physico-chemical properties of oil

The physico-chemical properties of the two oils are as follows:

Property	Roshagrass	Gingergrass
Specific gravity at 15 C	0.887-0.900	0.900-0.955
Optical rotation	-2 to 3	-30 to 54
Refractive index at 20 C	1.468-1.476	1.479-1.493
Acid value	upto 1.8	upto 2
Ester value after acetylation	9-36	120-200
Total alcohols calculated as geraniol	80-95%	36.3-64.7%
Solubility in 70% alcohol	1-3 vol.	2-3 vol.

Pale yellow rosha grass oil has a sweet, floral rosy odour and various undertones and top notes according to the quality and age of the oil. The yellowish-brown ginger grass oil has a peculiar fatty-sweet odour leaving a slightly woody and rosy dry out note, sometimes referred to as an "ensilage" odour.

Motia oil contains upto 95% of geraniol for which it is the best natural source. The chemical composition of motia oil has been reported as limonene 0.1%, p-cymene 0.1%, methyl heptanone 0.1%, 2-nonanol 0.1%, linalool 2.4%, citronellol 6.4%, farnesene 0.6%, ß-terpineol 1.0%, ß-humulene 0.6%, -terpineol 0.4%, geraniol 81.7%, geranyl acetate 5.7% and farnesol 0.4%.

3. CITRONELLA Cymbopogon nardus Graminae

Importance

Citronella is a tufted perennial grass, the leaves of which on distillation give an yellowish-brown essential oil with *citrus odour*. Two types of citronella are identified, viz, *Ceylon and Java citronella*, the former gives inferior quality oil while the latter yields a superior oil of commercial importance. Java oil serves as a starting material for the extraction of geraniol and citronellal which can be converted into aroma chemicals such as citronellol, hydroxy citronellol, synthetic menthol and esters of geraniol. These find extensive use in soap, perfumery, cosmetic and flavouring industries throughout the world. Soaps, soap flakes, detergents, household cleansers, insecticides and other technical products are often perfumed exclusively with this oil. Citronellol is used in many perfumery blends of the soap and cosmetic industries when rosaceous notes are required. Hydroxy citronellol is a key ingredient in compounding and in floralizing perfume materials. Citronellol esters like formate and acetate are used in a wide range of fragrances. The oil is also used in the manufacture of deodorants, mosquito repellent creams and allied products. The oil of Ceylon citronella is employed chiefly for perfuming low priced technical preparations such as detergents, sprays, polishes and insect repellents. The spent grass can be used as a source of raw material for cellulose pulp and paper production by using sulphate, sulphite and cold caustic soda.

Origin and distribution Both Ceylon and Java citronella have probably originated from *Mana gras*s of Sri Lanka which according to Finnemore occurs in two wild forms, viz, *Cymbopogon nardus var. linnaei (typicus)* and *C. nardus var. confertiflorus*. The Java citronella which is called *Mahapengiri* in Sri Lanka is the result of a selection from the Ceylon citronella and the name *Cymbopogon winterianus* is given to this selected variety to commemorate Mr. Winter, a prominent citronella oil distiller of Sri Lanka who first cultivated and distilled *Mahapengiri* type of citronella grass in Sri Lanka.

Mahapengiri was introduced in Java in 1889 and by 1919 Java surpassed Sri Lanka in production of this oil. Java citronella oil has higher alcohol content of 80-85% as compared to Ceylon type which has 60-70% alcohol content. The Java type of oil is preferred in international trade and then the Java type came to be known as *Java citronella*, while the inferior Ceylon variety is referred to as *Ceylon citronella*.

The citronella grass has now been widely distributed throughout the tropics comprising Sri Lanka, Java, Central America, Guatemala, Taiwan, Brazil, East Africa, Congo, Malagasy Republic, The Seychelles, India and West Indies. In India it is cultivated in the States of Assam, West Bengal, Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Gujarat, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland and Tripura. The production of Java citronella far exceeds most other essential oils. The world production of citronella oil is about 7000 tonnes/year; the major producers being Taiwan, China, Indonesia and Guatemala. The chief importing countries are USA, UK, West Germany, Japan and Hong Kong.

Botany

Citronella grass belongs to the family Graminae (Poaceae) and the species *Cymbopogon nardus* (L.) Rendle with 2n=20. Two varieties are recognized in this species.

i) *Cymbopogon nardus var. lenabatu*

It is known as *Ceylon citronella*. It is the older form and less important than Java type. Ceylon type is cultivated in Sri Lanka. It is hardier and can be grown on poor soils. The leaves which aresmaller than that of Java type yield an inferior oil with a lower citronellal content. The plant is a robust, stoloniferous perennial grass, 0.5-1.0 m high, leaves broad, panicles large and mostly compound, spikelets awnless, lanceolate and flattened on back.

ii) *Cymbopogon nardus var. mahapengiri*

This is sometimes recognized as a distinct species, *C. winterianus* Jowitt. It is known as *Java citronella*. Java citronella is a tufted aromatic perennial grass with fibrous roots. Plants are over 2 m in height. Clumps are stout, erect, terete, leafy and glabrous at the nodes. Leaf blades linear, with long acuminate tip and serrate margins. Ligules are scarious. Inflorescence is a very large compound panicle. Racemes 20 mm long, one sessile and the other pedicelled with the two lower spikelets, homogeneous, male or neuter, the remaining pairs in both racemes heterogeneous. Ovary superior with one carpel, uni-locular. Stigma bifid, lateral and leathery. Ovule single and erect.

Agrotechnology

Java citronella is more extensively and commercially cultivated than Ceylon type, though the former is less hardy compared to the latter. Citronella grows well under tropical and subtropical conditions. It requires abundant sunshine and moisture for good growth. Even though it grows upto 1000 m above MSL its growth is restricted, resulting in low yields, when grown above an altitude of 400 m. Annual rainfall of 2000-2500 mm and high atmospheric humidity are ideal for better growth of the plant and quality of the oil. Citronella grows well under varying soil conditions but optimum growth and yield is obtained in sandy loam soil with abundant organic matter. Heavy clay and sandy soils do not support good growth. It grows best on soils with a pH around 6.0 though a pH range of 5.8-8.0 is suitable. The crop is very

sensitive to water-logging. Citronella grass is propagated only vegetatively by slips which are obtained by dividing well grown clumps. Clumps are separated in a manner that each slip contains 1-3 tillers. Roots and leaves are trimmed off before planting. About 50 slips are obtained from an year old healthy clump. 'Jorlab C2', 'RRL JOR-3-1970', 'CIMAP/Bio-13' and 'CIMAP/73-1' are the improved high oil yielding varieties available for cultivation. With the onset of monsoon, the land is brought to fine tilth by ploughing and harrowing. Ridges and furrows or beds are made. The slips obtained from healthy vigorously growing plants are planted during June-July at 60-90 cm spacing and 10 cm deep. Delay in planting results in drying of slips and poor establishment and plant population. Farm yard manure is applied at 10 tonnes/ha before planting. A fertilizer dose of 200 kg N, 80 kg P_2O_5 and 40-80 kg K_20 is recommended per hectare per annum for optimum growth and yield. Better results are obtained by applying N in 4 equal split doses at an interval of about 3 months. P and K are applied fully as basal. Irrigation is required within 24 hours of planting if there is no rain. Supplemental irrigation is not required in areas with 2000-2500 mm rainfall, well distributed over the year. However, in drier months irrigation may be provided for better yield. Depending on weather and soil conditions, 8-10 irrigations are required in dry areas during the rain free period. The field is to be kept weed free till a complete cover of the crop is obtained. Weeding in the interrow spaces can economically be achieved using cultivators between the rows. Earthing up is done after about 4 months of planting and again after every harvest as the citronella rootstock has a tendency to work out of soil by itself.

Termite attack on planted slips as well as on the live clumps can be controlled by soil application of aldrin or heptachlor at 25 kg/ha. Leaf blight disease is caused by *Curvularia andropogonis* (Zimm.)

Boedijn. in the beginning of monsoon. It appears as small brownish spots which enlarge into long patches along the tips and margins of the leaves. Another fungus *Colletotrichum graminicola* (Ces.) Wilson has been found to affect the crop in Karnataka. These diseases can be controlled by prophylactic spraying of Dithane M-45 or Dithane Z-78 at 2g/l at an interval of 10-15 days during the disease prone period.

The crop is ready for the first harvest after about 9 months of planting and subsequently at an interval of 3 months. Harvesting is done by sickle above the first node at 20-45 cm above the ground. Generally leaf blades are cut and sheath are left out. Flowering should be discouraged as it causes aging and reduces the life span of the plantation. Harvesting can be done 4 times a year. Generally the Java crop once planted yields profitable returns for 4-5 years and needs replanting only afterwards. Ceylon citronella remains productive for 10-15 years. Uprooting of the plantation after its life span and rotation with any legume species is recommended. Horse gram, cowpea and sunhemp are good rotational crops.

Post harvest technology

The harvested grass is wilted in shade for a short time and steam distilled within 24 hours. The oil yield varies with the season, soil fertility and distillation efficiency. On an average, 0.8-1.2% of oil is recovered from the grass and the oil yield is about 100 kg/ha during the first year and 150 kg/ha during subsequent years. Yields of 200-250 kg/ha/yr can be obtained under favourable conditions with good management.

Physico-chemical properties of the oil

The physico-chemical properties of the oil have been reported as below.

Specific gravity at 15 C	0.887-0.895
Optical rotation	-0 35'to -5 6'
Refractive index	1.4685 - 1.4728
Total geraniol	82.3 - 89.4%
Aldehydes and cintronellal	28.8 - 43.9%
Solubility in 80% alcohol	1-2 vol.

Guenther reported that Java citronella oil contained citronellal 32-45%, geraniol 12-18%, citronellol 11-15%, geranyl acetate 3.8%, citronellyl acetate 2-4%, limonene 2-5%, elemol and other sesquiterpene alcohols 2-5%, ß-elemene and -cadinene 2-5%, and traces of cubebene, calamenene, bourbonene, bisabolene, eugenol, methyl eugenol, isopulegol, nerol, linalool, geraniol, methyl heptanone, myrcene and -pinene. Good quality citronella oils contain more than 38% of citronellal, 16% of geraniol and 12% of citronellol.

4. VETIVER Vetiveria zizanioides Graminae

Importance

Vetiver, Vetivert, Khus or Khuskhus is a densely tufted, wiry, glabrous perennial grass. Its leaves are odourless but the spongy, much branched fine roots contain a fragrant oil, which is a perfume by itself. Vetiver oil enjoys world wide reputation as one of the finest aromatic oils. It is used in perfumery and as a fixative for more volatile constituents for scenting soaps and in the preparation of cosmetics. It is also used for the extraction of vetiverol, vetiverone and vetiveryl acetate which are widely used aroma chemicals. The aromatic roots of vetiver have been used since ancient times. They are cleaned, dried and used for making mats, fans, screens, pillows and sachet bags. Roots are often put with clothes because of their scent and in the belief that they keep out insects. Young leaves are used as fodder and they make good bedding material for horses and cattle. Leaves are also used for thatching purposes. Stem and inflorescence peduncles are used for making brooms and fancy baskets. Leaves made into pulp are suitable for making straw boards. The plant has gained much recognition as one of the best soil binders and is being used to check soil erosion. The grass is widely being used throughout the tropics for planting on the contour as an antierosion measure, for protective partitions in terraced fields and as a border for roads and gardens.

Origin and distribution

Vetiver is believed to have originated either in India or in Sri Lanka. It has been widely distributed in the tropics. Prior to second world war, Java was the principal producer of vetiver oil,
but Haiti, Reunion and India are now the main producers, with subsidiary production in Congo, Angola, Brazil and Guatemala. The world production of essential oil is around 300 tonnes/annum. The crop is also cultivated in Indonesia, Malaysia, Philippines, Japan, Angola, Belgian Congo, Dominican Republic, Argentina, British Guiana, Jamaica, Mauritius and Honduras. In India it is cultivated in the states of Rajastan, Uttar Pradesh, Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. **Botany**

Vetiver belongs to the family Graminae (Poaceae).It was earlier named as *Andropogon muricatus* Retz. Later it was recognized as *Vetiveria zizanioides* (L.) Nash with chromosome number 2n=20. Vetiver grows in large clumps from a much branched spongy rootstock with erect culms, 0.5-1.5 m high.

Leaf blades stiff, long, narrow, upto 75 cm long, 8 mm or less in width, glabrous, but rough on the edges. Panicles 15-30 cm long, very narrow; branches 2.5-5.0 cm long, whorled; spikelets in pairs, narrow, acute, appressed, awnless; one sessile and hermaphrodite, somewhat flattened laterally, with short sharp spines, 3 stamens and 2 plumose stigmas; the other spikelet pedicelled and staminate. Some cultivars seldom flower.

Agrotechnology

Khus prefers tropical and subtropical climate for its proper growth, development and essential oil yield. It grows luxuriantly in places upto an altitude of 600 m, with an annual rainfall of 1000-2000 mm, temperature ranging from 21 to 44 C and with moderately humid climate. In places of scanty rainfall, which are otherwise suitable, it can be grown as an irrigated crop. The plant is sufficiently hardy and grows on almost all types of soils. Light soils, however, should be avoided as the roots obtained produces very low percentage of oil. Red lateritic soils with abundant organic matter are considered ideal as the roots produced in such soils are thick and contain more essential oil. Heavy soils make harvesting of the roots difficult, with a loss of the finer roots
which contain most of the oil. It can be grown even on saline and alkaline soils with a pH range of 8.5-10.0, being suitable otherwise.

The grass is capable of both vegetative and sexual reproduction in nature. However, under cultivation, it is generally multiplied vegetatively through slips. While preparing the slips for planting, fibrous roots and leaves should be trimmed off. 'Pusa hybrid-7', 'hybrid-8', 'CIMAP/KS-2', 'Sugantha' and 'ODV-3' are improved varieties available for commercial cultivation. With the onset of monsoon land is prepared. Farm yard manure or compost is applied at 10-15 tonnes/ha and slips collected from good healthy and disease free clumps are planted during the months of June-July vertically about 10 cm deep at a spacing of 30-60 cm. Late planted crop yields coarse roots which yield inferior quality oil. Normally, vetiver crop is not fertilized on fertile soils. On poor soils N, P_20_5 and K_2O may be applied each at 25-50 kg/ha. It is beneficial to apply N in 2-3 split doses. In areas where rainfall is good and well distributed over the year and humidity is high, supplemental irrigation is not necessary. In other areas 8-10 irrigations are required to get optimum yield. 2-3 weedings at an interval of about a month are needed during the initial period of plant growth. Once the plantation is established very well, weed problem is not very severe because of the thick and dense shoot cover. Earthing up after weeding is also beneficial to the crop. Leaf blight caused by *Curvularia trifolii* and *Fusarium* disease, affect the growth and yield of the crop, which can be controlled by repeated spraying of copper fungicides and drenching with copper oxichloride or 1% Bordeaux mixture. Roots are harvested after 15-24 months of planting. Harvesting can be done even earlier. Although the young roots give a higher yield of oil, this will be of low specific gravity and lacking in the valuable high boiling constituents. If the roots stay in the ground for over two years, the yield of oil diminishes considerably and the oil becomes very viscous with a dark colour but of a high quality. In general, the crop is harvested after 18 months during the dry season from December to February by digging out the bush along with its roots manually. The length of the roots varies from 10-35 cm according to the condition of growth, soil, climate, etc of the locality. The roots are separated from the plants, washed to remove the adhering soil and dried under shade for 1-2 days which improves the olfactory quality of the essential oil. Prolonged drying in the sun reduces the oil yield. The root yield is 3-5 tonnes/ha.

Postharvest technology

The roots can be crushed and powdered before distillation. Both fresh and dry roots can be distilled. Usually steam distillation is resorted to. As the most valuable quality constituents are contained in the high boiling fractions, the roots must be distilled for a prolonged period ranging from 24 to 48 hours. But it has also been reported that 78% of the oil was recovered in 16 hours time. The oil obtained from stored roots is more viscous and possesses a slightly better aroma than that obtained from freshly harvested roots. To obtain maximum oil yield and to shorten the time of distillation, the roots should be distilled when fresh. The oil recovery from fresh roots is 0.3-0.8% and from dried roots is 0.5-3.0% depending upon the duration of distillation. On an average 15-25 kg oil is obtained per hectare per crop.

Physico-chemical properties of the oil

Vetiver oil is light brown to deep brown in colour with a characteristic aroma and persistent odour of sweet woody note. Aging for a period of six months improves the odour of the oil substantially; the harsh, green and earthy odour characteristics of the freshly distilled oil disappears and develops into a fuller, heavier and sweeter odour. Other properties are:

Specific gravity at 30 C	0.9882 - 1.0219
Refractive index at 30 C	1.514 - 1.519
Optical rotation	-53.4 to -101.8

Acid value	6.6 - 40.9
Ester value	10.1 - 24.1
Ester value after acetylation	162.1 - 185.7
Carbonyls	55.4 - 82.9%

The oil contains more than 150 complex compounds including elemol 0.4-2.3%, 10-epi-eudesmol 1.1-2.2%, ß-eudesmol 5.5-8.5%, vetiverol + cyclocopacamphenol 6.1-7.5%, vetiselinenol 11-20%, khusimol 13-28%, ß-vetivone 2-5%, -vetivone 1.5-5.8%, among others.

B. AROMATIC HERBS AND SHRUBS

1. MINTS *Mentha spp.* *Labiatae*

Importance

Mints are aromatic perennial herbs with quadrangular stem and bearing leaves with essential oil present in glands located in the subcuticular region. Among the various types of mints, only *Japanese mint* is cultivated in the tropics or subtropics with a cooler climate. It is generally cultivated as a primary source of menthol, which is widely used for flavouring toothpastes, candies, beverages, confectionery, chewing gums, pan parag, and mouth washes and for scenting shaving creams, tobacco, cigarettes, aerosols, polishes, hair lotions and lipsticks. It is employed as a soothing ingredient in cosmetic preparations, colognes, deodorants, aftershave lotions and perfume bases. It is also employed in a number of medicinal preparations like ointments, pain balms, cough syrups, cough lozenges and tablets.

Origin and distribution

The origin of Japanese mint is not clearly known. It is widely distributed over a number of countries such as Brazil, China, Paraguay, Argentina, Japan, Thailand, Angola, India, Bolivia, Peru, Korea and Taiwan. In India, it is chiefly grown in the northern states of Jammu and Kashmir, Punjab and Haryana. The world production of Japanese mint oil is about 4000 tonnes per annum and the major producers are Brazil and China.

Botany

Mints are a group of plants belonging to the family Labiatae (Lamiaceae) and the genus *Mentha*. Four major mints are recognized in this genus.

1. *Mentha arvensis* L. Japanese mint
2. *M. piperita* L. Pepper mint
3. *M. spicata* L. Spear mint
4. *M. citrata* Ehrh. Bergamot mint or Lemon mint

In some cases, Japanese mint is specifically recognized as *Mentha arvensis* L. subsp. *haplocalyx* Briquet var. *piperascens* Holmes.

In the strict sense, mints are temperate crops. However, Japanese mint can be grown in subtropical and even tropical areas with cooler climate. It is a downy perennial herb with rootstock creeping along or just under the ground surface. Red, purple and green varieties are known. Branches rigid, pubescent, 60-100 cm tall; leaves lanceolate to oblong, 3.7-10 cm long, sharply toothed, sessile or shortly petiolated and hairy; flowers arranged in cyme which are usually sessile or rarely pedunculate, purplish, minute; calyx 2.5-3.0 mm long, narrowly deltoid, acuminate; corolla white to purple, 4-5 mm long.

Agrotechnology

Mints grow well over a wide range of climatic conditions. Japanese mint grows well under subtropical conditions while others prefer temperate climate. Adequate and regular rainfall during the growing period and good sunshine during harvesting are ideal for its cultivation. Medium deep soil rich in humus is best suited for the cultivation of Japanese mint. The soil should have a pH range of 6-7.5 with good water holding capacity but waterlogging is detrimental.

Japanese mint is propagated through stolons. 'CIMAP/MAS-1' and 'Hybrid-77' are improved varieties. Seed rate is 400 kg/ha. A hectare of well established mint provides enough planting materials for 10 hectares. Stolons are planted either on flat land or ridges. In plains, they are planted in shallow furrows of 7-10 cm deep at a spacing of 45-60 cm after incorporating compost or farm yard manure at 10-12 tonnes/ha. Inorganic fertilizers upto 160 kg N and 50 kg each of P_2O_5 and K_2O/ha are applied; nitrogen being applied in 2-3 split doses. Irrigation enhances growth and improves the yield. The field should be kept weed free, particularly during the initial stages of growth till proper establishment and coverage of the ground area (Singh and Singh, 1989). Termite attack observed during the dry months can be controlled by the soil application of 3% heptachlor at 50 kg/ha. Hairy caterpillars cause rapid defoliation. Cut worms, semi-loopers and red pumpkin beetle also attack the crop. These insect
pests can be controlled by 5% DDVP, 2% methyl parathion dust or any other suitable insecticide. Nematode attack has also been reported for which application of Fenamiphos at 10-12 kg/ha is effective. Mentha rust is caused by *Puccinia menthae* which results in severe leaf shedding. Powdery mildew caused by *Erysiphe cichoracearum* can be controlled by wettable sulphur application. *Macrophomina phaseoli* and *Thielavia basicola* cause stolon rot which is effectively controlled by the application of maneb or PCNB.

Japanese mint is first harvested after about 4 months of planting when the lower leaves start turning yellow. Subsequently two more harvests can be taken generally at an interval of 80 days. The fresh herb yield ranges from 25 to 50 tonnes/ha obtained in 3 cuttings annually (Dutta and Chatterjee, 1961)

Postharvest technology

The harvested herb may be wilted in shade for a few hours for draining off the excess moisture thereby reducing the bulk. Both fresh and dry herb are employed for distillation. Steam distillation is usually preferred and the duration of distillation is 1.5-2 hours generally. Fresh herb contains 0.4 to 0.6% oil. On an average, 100-150 kg oil/ha is obtained annually.

Physico-chemical properties of oil

The physico-chemical properties of the oil of Japanese mint are reported as:

Specific gravity at 20 C	0.8997-0.9011
Optical rotation at 25 C	-37 11' to 37 29'
Refractive index at 25 C	1.4590-1.4595
Ester menthol	4.74-5.01%
Total menthol	78.24-82.78%
Acetylated menthol	6.01-6.36%
Menthone	11.85-13.75%
Terpenes	4.1-6.61%
Acid value	1.1-2.1
Ester value	17-18
Solubility in 70% alcohol	2-3 vol.

The chemical constituents in Japanese mint oil are reported to be l-menthone, d and l iso-menthone, methyl acetate, camphene, -pinene, caryophyllene, esters of formic, iso-valeric and caproic acids, ethyl carbinol, hexanol l-limonene, ß-pinene, cineole, 3-octanol, linalool, menthofuran, neo-menthol, pulegone, piperitone and piperitone oxide (Handa *et al*, 1964; Gupta, 1993).

2. OCIMUMS Ocimum spp. Labiatae

Ocimums are an important group of aromatic and medicinal plants which yield many essential oils and aroma chemicals and find diverse uses in the perfumery and cosmetic industries as well as in indigenous systems of medicine. Ocimum species with oil rich in camphor, citral, geraniol, linalool, linalyl acetate methyl chavicol, eugenol and thymol are important and can be harnessed for successful utilization by the industry. Among the various *Ocimum* species *Ocimum basilicum* L. is commercially and extensively cultivated for essential oil production. Its oil is employed for flavouring of food stuffs, confectionery, condiments and in toiletry products such as mouth washes and dental creams. It is also used in the flavouring of foods such as spiced meats, sausages, tomato pastes, various kinds of sauces, fancy vinegars, pickles, ketchups and beverages. In the perfumery industry, the oil is used for compounding certain popular perfumes notably jasmine blends. It is recognized as a febrifuge and antimalarial plant. The juice obtained from the leaves gives relief to irritation of throat ear ache and ringworm infections. Seeds are used internally for the treatment of constipation and piles.

Origin and distribution

Ocimums are well represented in the warmer parts of both the hemispheres from sea level to 1800 m. The main centres of diversity are Africa, South America and Asia. The different species are well distributed over the tropical countries in these continents. Of the 160 species of *Ocimum*, *O. basilicum* is the most important species and
is known to have been cultivated for at least 3000 years by Europeans and Asians for folklore and religious rituals and got established wherever they migrated with extreme variations in the population. It is grown and distilled for oil in France, Italy, Bulgaria, Egypt, Hungary, South America, Comoro Islands, Malagasy Republic, Thailand, India, Haiti and Guatemala.

Botany

Ocimums belong to the family Labiatae (Lamiaceae) and the genus *Ocimum.* Owing to a high degree of polymorphism exhibited by the species as also abundant cross pollination, a large number of species, subspecies, varieties and strains have come into existence which make the botanical nomenclature extremely difficult (Krishnan, 1981). In view of the great diversity, the various species have been classified into two broad groups, viz, *basilicum* and *sanctum* groups, based on the geographical sources, morphological and cytological features and chemical constituents, as detailed in the following table.

Classification of different *Ocimum* species (Atal and Kapur, 1982)

Species	Habit	Cytology	Major constituents of oil
Basilicum group (Basic No. X=12)			
O. canum Sims. (Hoary basil)	Herb	2n=24,26	Linalool or camphor
O. basilicum L. (Sweet/French basil)	Herb	2n=48	Methyl chavicol, methyl cinnamate, eugenol, linalool
O. americanum L.	Herb	2n=72	Methyl chavicol, citral
O. kilimandscharicum Guerke (Camphor basil)	Perennial under shrub	2n=76	Camphor
Sanctum group (Basic No. X=8)			
O. sanctum L. (Holy/Sacred basil)	Bi or triennial shrub	2n=32	Eugenol
O. gratissimum L.	Perennial woody shrub	2n=40	Eugenol
O. viride Willd.	Perennial woody shrub	2n=40	Thymol
O. suave Willd.	Perennial shrub	2n=64	---
O. carnosumck	Perennial woody shrub	2n=48	---
O. micranthum	Perennial woody shrub	2n=48	Elimicin,eugenol, methyl isoeugenol

The additional distinguishing features between the two groups are that in basilicum group, bracts are petiolate, flowers more conspicuous and seeds black and ellipsoid which become mucilaginous when wetted whereas in sanctum group, the bracts are sessile, flowers less conspicuous and seeds brownish, globose to ellipsoid but do not become mucilaginous when wetted.

Sweet or French basil is an erect, almost glabrous herb, reaching a height of 30-90 cm. Leaves ovate to lanceolate, 3.75-5 cm long; flowers 0.72- 1.25 cm long, borne on long terminal racemose inflorescence; calyx 5-toothed; corolla 0.72-1.25 cm long, white to purplish, 2-lipped tube; stamens 4, protruding; ovary bicarpellary, syncarpous, bilocular; stigma bifid; fruit nutlets.

Clocimum is a hybrid strain of *Ocimum gratissimum var. clocimum* obtained by crossing *O. gratissimum* race 1 and *O. gratissimum* race 2, developed at the Regional Research Laboratory, Jammu, India. The name *clocimum* means *clove scented ocimum* and its odour is similar to that of clove oil. Clocimum oil contains 70-75% eugenol and 10-15% myrcene.

Agrotechnology

The crop comes up well under tropical climate upto an altitude of 1800 m. The growth is poor in areas which receive heavy and continuous rainfall. Frost is harmful to the plant and hence frost prone areas are to be avoided. Basil can be cultivated on a wide variety of soils, though moderately fertile well drained loamy or sandy loam soils are considered ideal for its cultivation. Basil is tolerant to higher concentration of copper and zinc but is susceptible to cobalt and nickel.

The plant is propagated through seeds. Seedlings are first raised in the nursery and then transplanted in the field. The seed rate is about 125 g/ha for transplanting. Seeds start germinating 3 days after sowing and germination is over in 7-10 days. When 6-10 cm tall the seedlings are transplanted in the field at 40-60 cm spacing in rows. At the time of planting, 10-15 tonnes of compost or farm yard manure is to be applied. A medium fertilizer dose of 40:40:40 kg/ha of N, P_2O_5 and K_2O is recommended for economic yield though good response has been received upto 120:100:100 kg/ha. Irrigation is required once a week when it is raised as a summer crop. The field should be kept weed free for the first 20-25 days, till the crop canopy completely covers the ground. Weeding is usually carried out once or twice.

A number of diseases are reported in basil crop. *Corynespora cassicola* (Berk. and Curt.) Wie. causes leafspot disease which appears as small water soaked spots turning brown. *Elsinoe arxii* sp. nov. causes scab disease. The symptoms are little defoliation with pluckering, clipping of the leaves and distortion of the tender twigs. Blight caused by *Alternaria species* and *Colletotrichum capsici* (Sy.) Butler & Bisby can be controlled by spraying 0.2% zineb or maneb. Wilt is caused by *Fusarium oxysporum* at all stages of growth. But the attack is more pronounced in rainy season. This is controlled by dipping the seedlings in a solution of organo mercurial fungicide.

Basil is harvested when the plant is in full bloom and lower leaves start turning yellowish. The crop comes to full bloom 9-12 weeks after planting. For high quality oil, only the flowering tops are harvested. 4-5 crops are obtained per year.In some areas it is possible to get four floral harvests. The first harvest is done when the plants are in full bloom and the subsequent ones after every 15-20 days. The last harvest comprises the whole plant. Floral harvests yield 3-4 tonnes of flowers and the final harvest of the whole plant is 13-15 tonnes of herb per hectare. While harvesting the whole herb, plants are cut not less than 15 cm from the ground for enabling regeneration of the crop.

Postharvest technology

The essential oil in young inflorescence or the whole plant is extracted by hydrodistillation or steam distillation. Corresponding to the part employed, two grades of oil are obtained, ie, *flower oil and herb oil*. The flower oil has a superior note and is more expensive. Steam distillation is preferred for large plantation as it takes less time and gives better recovery of oil, while hydrodistillation carried on in a direct fire still is cheaper and more handy for small plantations. Distillation is carried out for 1-1.5 hours. The young inflorescence contains 0.3-0.5% oil and the whole herb 0.10-0.25%. Generally, an yield of 30-40 kg of flower oil and 20-25 kg whole plant oil is obtained per hectare.

Physico-chemical properties of the oil

Dhingra *et al* (1955) has reported the following properties for sweet basil oil.

Refractive index at 20 C 1.528
Optical rotation -6.8
Specific gravity at 24 C 0.9676
Acid value 2.25

The chemical composition of basil oil is reported as -pinene 0.1-0.4%, camphene 0.02-0.1%, ß-pinene 0.07-0.8%, myrcene 0.12-0.8%, limonene 2.0-9.3%, cis-ocimene 0.1-0.6%, p-cymene 0.05-0.15%, cis-3-hexenol 0.02-0.08%, fenchyl acetate 0.1-0.5%, camphor 0.37-0.75%, linalool 40-54%, fenchyl alcohol 2-9%, methyl chavicol 23-26%, -terpineol 0.8-1.9%, citronellol 0.65-3.7%, geraniol 0.03-0.30%, methyl cinnamate 0.05-0.34% and eugenol 5-12% (Sharma *et al*, 1987).

3. PATCHOULI Pogostemon patchouli Labiatae

Importance

Patchouli is an erect, branched, pubescent aromatic herb, the essential oil of which is one of the best fixatives for heavy perfumes

which imparts strength, character, alluring notes and lasting qualities. In fact, it is a perfume by itself and is highly valued in perfumes, soaps, cosmetics and flavour industries. The oil is extensively used as a flavour ingredient in major food products, including alcoholic and non-alcoholic beverages, frozen dairy desserts, candy, packed foods, gelatin, meat and meat products. It blends well with the oils of sandal wood, geranium, vetiver, cedarwood, clove, lavender, bergamot and many others. The oil gives one of the finest attars when blended with sandal wood oil. Tenacity of odour is one of the great virtues of patchouli oil and is one of the reasons for its versatile use. The oil possesses antibacterial and insect repellent activity. In Chinese medicine, patchouli leaves are used as decoction with other drugs to treat nausea, diarrhoea, cold and headaches. The dried leaves are used for scenting wardrobes. The leaves and tops are added in bath water for their antirheumatic action. It is also used as a masking agent for alcoholic breath.

Origin and distribution

Patchouli is a native of the Philippines. It grows wild in Malaysia, Indonesia, Singapore, China and India where they are also cultivated for the essential oil. In India, it is met with in the Southern Peninsula, notably in the Western Ghats, the Nilgiris, Central India and subtropical Himalayas. World production of patchouli oil is 500-550 tonnes per annum and the largest producer is Malaysia.

Botany

Patchouli *Pogostemon patchouli* Pellet. var. *suavis* Hook. f. which is synonymous to *Pogostemon cablin* Benth comes under the family Labiatae (Lamiaceae). The plant is herbaceous, erect, branched, pubescent, 0.5-1.0 m high and aromatic when crushed. Leaves ovate to oblong, upto 10 cm x 10 cm, serrate with dotted glands beneath; petiole upto 8cm; stem swollen on the nodes; spikes terminal or axillary, dense, sometimes interrupted, 2.5-14 cm long; flowers small, irregular, bisexual, hypogynous; calyx 5-6.5 mm;

corolla lobes obtuse, 6-9 mm, white to purple, blotched on all segments; filaments violet; bracts as long as calyx.

Agrotechnology

Patchouli prefers warm humid climate with a fairly heavy and evenly distributed rainfall of 2500-3000 mm per annum, a temperature of 24-28 C and an average atmospheric humidity of 75%. It grows successfully upto an altitude of 1000 m above MSL. The crop grows well under irrigation in less rainfall areas, and in partially shaded conditions. It is relatively a hardy plant and adopts itself to a wide range of soil conditions. A well drained deep loamy soil rich in humus and nutrients, with a loose friable structure and with no impervious hard layer at the bottom is ideal. A pH range of 5.5-6.2 is suitable. Patchouli is a shade loving plant. It is generally grown as an intercrop in orchard crops like fruit trees, coconut or arecanut.

The plant is propagated vegetatively by stem cuttings having 4-5 nodes and 15-20 cm length. Improved varieties commonly cultivated are 'Johore', 'Singapore' and 'Indonesia'. Cuttings are prepared from the apical region of healthy stocks. The basal 2-3 pairs of leaves are carefully removed and the cut ends are treated with IBA, IAA or NAA at 500, 1000 or 1500 ppm respectively for better rooting. Cuttings are planted 3.5 cm apart in nursery beds, seed pans or polythene bags. It is important to provide aeration, partial shade and regular watering in order to get early and good rooting. Rooting occurs in 4-5 weeks and they are ready for transplanting in 8-10 weeks. Before transplanting, the field is prepared well and laid into beds of convenient size. These beds are incorporated with organic manure at 12-15 tonnes/ha and N, P_2O5 and K_2O at 25:50:50 kg/ha and leveled. Rooted cuttings are transplanted at 40-60 cm spacing and irrigated if there is no rain. After 2 months, 25 kg N is applied. Subsequently, 50 kg N/ha is applied in two split doses; the first dose just after the harvest and the other about two months later. Totally 150 kg N/ha/year is applied to the crop. Constant watering, regular weeding and light cultivation after every harvest are essential for proper growth and yield of the crop (Kumar *et al*, 1986; Farooqi and Khan, 1991).

The crop is highly susceptible to root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood. An integrated approach consisting of crop rotation, application of neem oil cake, carbofuran and systemic nematicide proved effective. Phytosanitory measures are to be adopted from the nursery stage itself. This is done by passing steam through the seed pans or poly bags for about an hour. Nematicides like carbofuran and carbofenthion are also effective in controlling the nematode problem. Leaf blight caused by *Cercospora* sp. is controlled by spraying 0.5% solution of zineb. Yellow mosaic disease is transmitted by white fly, *Bemisia tabacci* (Gen.). Caterpillar and leaf webber attacks can be controlled by spraying methyl parathion (Sarwar, 1969; Sarwar and Khan, 1972)

The crop is harvested when the foliage becomes pale green to light brown and the stand emits a characteristic patchouli odour. The first harvest of the leaves is taken after about 5 months of planting. Subsequent harvests can be taken after every 3-4 months depending on the local conditions and management practices. Harvesting is done in the cool hours of the morning to avoid loss of essential oil. Young shoots of 25-50 cm length which contain at least 3 pairs of mature leaves are cut. In practice, a few shoots are always left unplucked to ensure better growth for next harvest. The crop stands for 3-4 years.

Postharvest technology

The harvested herb is dried in shade allowing free air circulation for about 3 days. Proper drying is very important for the quality of oil. During drying, the material should be frequently turned over for promoting uniform drying and for preventing fermentation. Completely dried material can be pressed into bales and stored in a cool dry place for sometime. The dried herbage is steam distilled for its oil. Interchange of high and low pressures (1.4 to 3.5 kg/cm^2) produces better yield as more cell walls rupture in this process. Duration of distillation is 6-8 hours. Prolonged distillation gives higher yield and better quality of oil. But if it is distilled for too long, the oil will have a disagreeable odour. The oil yield varies from 2.5 to 3.5% on shade dry basis. On an average, from one hectare we get 8000 kg fresh leaves annually which on shade drying yield 1600 kg and on distillation give 40 kg of oil. Patchouli resinoid is also prepared occasionally by extracting the leaves with volatile solvents such as benzene. Such extraction gives 4.5-5.8% of resinoid which contains 70-80% of alcohol soluble absolute.

Physico-chemical properties of the oil

The essential oil of patchouli is reported to have the following properties.

Specific gravity at 15 C	0.967-0.972
Refractive index at 20 C	1.509-1.510
Optical rotation	49 40'-55 41'
Acid value	5.0
Saponification value	5.6
Ester value after acetylation	16.8-21.5

Solubility in 90% alcohol 6.5-7.0

The odour of patchouli oil improves on aging; oil preserved well for some months possesses a fine and fuller odour than fresh oil and is highly esteemed by perfumers.

Patchouli oil has the following approximate composition as reported by Mukherjee and co-workers (1981): ß-elemene 1%, caryophyllene 20%, -guaiene 15%, -bulnesene 25%, -guaiene oxide 1%, -bulnesene oxide 4%, caryophyllene oxide 2%, nor-patchoulinol 0.5%, patchouli alcohol 30% and pogostol 1%.

4. ROSEMARY Rosmarinus officinalis Labiatae

Importance

Rosemary is a dense evergreen undershrub with lavender-like leaves, and a characteristic aroma. Its essential oil is used almost wholly in the perfumery industry in the production of soaps, detergents, household sprays and other such products. It is an excellent fixative material. The oil contributes a strong, fresh odour, which blends well with various other oil odours and also serves to mask the unpleasant smells of certain other ingredients. It is used in shampoo, toilet soaps and medicine. Rosemary oil is known to have antimicrobial activity. It can kill 90-100% of mosquito and larvae of *Culex quinquefasciatus*. It is carminative and mildly irritant. It is used in formulations of compounded oils for flavouring meat, sauces, condiment and other food products, It is used as a culinary herb. A distilled water is obtained from flowers which is used as an eyewash (Graf and Hoppe, 1964).

Origin and distribution.

Rosemary is a Mediterranean plant. It is indigenous to South Europe, Asia Minor and North Africa, It grows wild on the Mediterranean shores and in Spain, Portugal, Morocco and Algeria, It is also cultivated in Spain, Tunisia, Yugoslavia, France, Italy, North Africa and India. It is grown in Nilgiris in India. The world production of Rosemary oil is 250-300 tonnes/year. U.S.A and Europe are the major markets.

Botany

Rosemary *Rosmarinus officinalis* L. belongs to the family Labiatae (Lamiaceae). It is an evergreen dense highly branched herb or undershrub growing upto 1 m in height. The long slender branches bear many sessile opposite leaves, smooth and green, woolly whitish and glandular beneath, 2-4 cm long, almost cylindrical and folded inwards; flowers situated in small clusters towards the ends of the branches; calyx is 2-lipped, with an upper single broad oval lobe and a lower
two segmented triangular lobe; corolla is two lipped with two violet stamens and a long style projecting from it; fruit is an oval 4-sectioned cremocarp.

Agrotechnology

The plant rosemary comes up well in Mediterranean climate. It is susceptible to frost injury. In cooler areas it can be cultivated in summer season. It requires light dry soil, preferably lying over chalk. Neutral to alkaline pH is suitable. The plant is propagated through seeds and vegetatively by cuttings, the latter being generally adopted. The cuttings should be 15 cm long and leaves removed from the basal half portion. The cuttings are put in nursery beds of sandy soil at a depth of about 10 cm. The main field is prepared well incorporating 10-15 tonnes/ha of organic manures. The rooted cuttings are transplanted in rows, 120 cm apart with a plant to plant spacing of 30-40 cm. Fertilizers are applied at 100:40:40 N, P_2O_5 and K_2O/ha, N being applied in 4-5 split doses during each year. Irrigation is needed when the soil is depleted of water during non-rainy period. The field of rosemary is kept weed free by regular weeding and hoeing. Intercultivation keeps the soil loose and clean from weeds and promotes proper plant growth and development. *Phytocoris rosmarini* sp. nov. and *Ortholylus ribesi* sp. nov. are reported to infest rosemary crop. The shoots are cut for distillation when they have reached their maximum size but before they have become woody. The hard wood imparts an undesirable turpentine odour to the essential oil. Harvesting is usually done during May-June. Frequent cutting of the bushes after 2-3 years keeps them free from becoming leggy and promotes the formation of numerous young shoots.

Postharvest technology.

Freshly harvested twigs and leaves are steam distilled to obtain the essential oil of rosemary. Steam distillation at 2-3 times atmospheric pressure gives an oil yield of 1.0-1.5% of freshly harvested plants and 1.5-2.5 % of dried leaves.

Physico-chemical properties of oil

The essential oil of rosemary is reported to have the following properties.

Specific gravity at 15 C 0.894-0.913
Refractive index at 20 C 1.466-1.468
Optical rotation 0 43'to 13 10'
Esters as bornyl acetate 1.8-7.0%

Total alcohol as borneol 8.4-14.3%

The essential oil contains chemical components as -pinene 7-24%, camphene 3-9%, ß-pinene 0.6-1.5%, sabinene trace, myrcene 2-19%, -phellandrene 0.1-1.8%, -terpinene 0.5-1.5%, limonene 3.3-5.4%, 1, 8-cineole 15-20%, -terpinene 0.2-1.8%, p-cymene 2-3.7%, terpinolene 0.1-0.6%, camphor 0.1-0.6%, copaene 0.1-0.3%, linalool 14-17%, terpinen-4-ol 0.9-1.8%, caryophyllene 0.9-2.9%, -terpineol 1.8-3%, thymol 0.1-0.7% and carvacrol 0.1-2% (Boelens, 1985).

5. CLARYSAGE Salvia sclarea Labiatae

Importance

Clarysage is a perennial herbaceous plant with a widely branched deep root system; the flowering tops, leaves and derivatives of which
are extensively used in the flavour industry for the formulation of liquors and soft beverages. The plant was used in middle ages for *clearing the vision* and for this reason it received its popular name *clarysage or clary-eye* (Guenther, 1949). The essential oil is used in perfumery because of its coriander-like notes. It is used as a flavour in liquors and as a modifier in spice compounds. The oil is also used in preparations of non-alcoholic and alcoholic beverages, ice-creams, candy and baked goods.

Origin and distribution

The nativity of the plant is not well understood. It is grown extensively in Russia, U.S.A., Bulgaria, Yugoslavia, France, Switzerland and Morocco. In India, all areas in Kashmir valley especially the uplands and dry dunes in hilly tracts of Himachal Pradesh and Uttar pradesh are suitable for its cultivation. The major consumers are U.S.A, UK, Italy, Canada, France and Japan.

Botany

The plant clarysage belongs to the family Labiatae (Lamiaceae) and the genus *Salvia*. Sage oils are obtained from different species of *Salvia*. Inferior Spanish and Dalmatian materials are obtained from *Salvia officinalis* L., whereas a superior and more expensive oil is obtained from *Salvia sclarea* L. The latter is commonly cultivated. *Salvia sclarea* is 60-90 cm tall herb with a widely branched deep root system. Stem is branched, 4-ribbed with numerous epidermal glands on younger parts; leaves petiolate, opposite, broadly oval toothed and thinly hairy above; flowers many, blue to purple, in 15-80 cm long peduncle, bisexual and zygomorphic; calyx gamosepalous, inferior; corolla bilipped, upper 3-lobbed, lower 2-lobbed; stamens two, inserted in corolla tube; ovary bicarpellary, syncarpous; superior; stigma bilobbed; placentation axile. Honey discs are present at the base of the ovary and 138 kg/ha of honey has been reported to be recovered from these honey discs. Anisophylly has been observed in clarysage. *Xylocopa violacea* has been reported as the only effective pollinator of clarysage in Yugoslavia. The cells of the pericarp and skin of the fruit contain oil drops. The fruits differ in size,
weight, colour, swelling intensity and mucilization.

Agrotechnology

Clarysage is tolerant to cold and drought and adaptable to a wide variety of situations. Higher altitude with ample sunshine and few good showers in spring results in good yield of oil having superior quality. The plant is generally grown on poor soils. Slightly acidic soils of pH 4.0-5.5 are better.

It is propagated through seeds. Few high yielding hybrid varieties have been developed in Bulgaria . 'Zarya' is a medium early variety with 0.24% oil and 78% linanyl acetate in the oil. 'Lazur'' is cold resistant with 0.23% oil and 73% linalyl acetate. A new biennial variety with 0.31% oil and 81.5% linalyl acetate has also been developed (Illieva, 1979). The seeds can be directly sown in the field or transplanted either in November or March-April depending upon the weather conditions. Seed rate is 3-4 kg/ha for transplanting. Seedlings appear in 10-15 days and are transplanted when 30-35 days old, at 1 m row spacing after incorporating 10-12 tonnes of organic manure in the field for optimum growth of the plants. 100-120 kg N and 30 kg each of P_2O_5 and K_2O are recommended per hectare . N may be applied in 4 equal splits. One or two irrigations may be given in case of a drought situation. One or two weeding should be done during March-April. Pre-emergence application of fluometuron or diuron at 2 kg/ha and post-emergence application of preforan or introchlor at 3 kg/ha have been recommended for weed control. 2-3 hoeings should be done before the flowering season.

An aphid *Acyrtosiphon salviae* has been found in colonies on clarysage which can be controlled by a mild insecticide. Rootknot nematode *Meloidogyne incognita* infests the plant heavily. The fungus *Rhizoctonia solani* causes rot disease. All the above ground portions have been found infected. Under humid and wet condition, the whole plant collapses within 2-3 days. Drenching with copper oxychloride or Bordeaux mixture is recommended for rot disease.

The flowering tops and leaves are harvested twice a year during July and September. Excessive stalk growth is removed as it contains
no significant amount of oil. After harvest, a hoeing is given. Plants remain productive for 5-6 years and thereafter yields decline and new plantation is started in a different location.

Postharvest technology The harvested herb is to be distilled immediately with a view to avoid evaporation loss of essential oil. Distillation is carried out for a period 2-3 hours using live steam from a separate steam boiler. An average, recovery of 0.15% is obtained on poor soils whereas 0.2-0.3% is achieved with improved varieties and good management when the yield of oil will be 40-50 kg/ha.

Physico-chemical properties of oil

The oil of clarysage is an yellow liquid with a characteristic herbaceous odour, wine like taste and the following properties.

Specific gravity at 20 C	0.8930-0.8990
Refractive index at 20 C	1.4675-1.4710
Optical rotation at 21 C	-15 12' to -29 3'
Acid value	0.61-1.20
Ester value	104.50-129.60
Ester content calculated as linalyl acetate	26.50-45.34%
Saponification value	105.18-129.60
Total alcohol content calculated as $C_{10}H_{18}O$	60.20-68.01%
Solubility in 85% alcohol	0.6-1.20 vol.

The chemical constituents of the oil are reported to be and ß-ocimene, p-cymene, terpinolene, cis-3-hexen-1-ol, linalool (the major constituent) and its acetate, terpinen-4-ol, caryophyllene, -terpineol, citronellol, nerol, geraniol, and their acetates, trans ß-terpineol ß-gurjunene, caryophyllene oxide, tricyclene, camphene, 1, 8-cineole, methyl heptanone, camphor, ß-thujone, ß-humulene, -thujone, delta-cadinene and citral a and b (Tajuddin *et al*, 1982; Sharma *et al*, 1985).

6. THYME Thymus vulgaris Labiatae

Importance

Thyme is an ever green perennial herb the essential oil of which
has a powerful fresh odour masking other unpleasant smells. This plant is extensively used as a pot herb in cooking, perfumery and in liquor distillery. Thyme oil finds its major use in the perfumery industry in soap and detergent work. Thymol has a powerful medicinal odour and finds more applications in flavours than in perfumes. Owing to the presence of thymol the oil shows germicidal properties and is effective against a variety of pathogenic bacteria. It is employed in dental preparations, oral hygiene products, vermifuges and antigastro-intestinal products. In aromatherapy, garden thyme is regarded as one of the most important elements because of its antiseptic properties. The essence is effective in treating whooping cough as well as parasitic infestations. The dried leaves and floral tops constitutes the thyme of commerce known as *Thymi Herba* in pharmacy. Dried flowers and leaves are used to preserve linen from insects and to impart characteristic smell.

Origin and distribution.

Thyme is believed to be a native of the Mediterranean region. It grows wild in almost all the countries bordering Mediterranean area, Asia and Central Europe. It is extensively cultivated in Germany, France, Spain, England and various other neighbouring countries both for seasoning and for its volatile oil. Thyme production is both geographically widespread and easily undertaken. The world production of thyme oil is 20-30 tonnes per annum. Spain is the largest producer followed by France, Morocco, Turkey and Mediterranean countries.

Botany

Thyme belongs to the family Labiatae (Lamiaceae) and genus *Thymus*. There are many species of thyme. *Thymus serpyllum* L. and *T. satureioides* Coss. & Bal. are some wild species. Commercial supplies are derived from *T. zygis* L. (*white thyme*) and *T. vulgaris* L. (*garden thyme*). The demand for garden thyme is more and hence commonly cultivated. The plant *T. vulgaris* is an evergreen perennial aromatic herb 20-30 cm high. Roots are fairly robust and stem very much branched. The sessile leaves vary in shape from elliptic to linear or diamond-shaped towards the apex; young leaves are slightly woolly;
flowers, united in spikes at the top of the branches, have a bilabiate, tube-like calyx and corolla, lower lip of corolla 3-lobed; fruit consists of a smooth, dark coloured, 4-sectioned nutlet found in the remains of the calyx tube.

Agrotechnology

The plant grows best in a warm humid climate at an elevation of 1500-4000 m from MSL. Light loamy fertile and calcareous soils are suitable. On heavy wet soils, the leaves become less aromatic.

Thyme is propagated by divisions of the old plant cuttings, layering or by seeds. Cuttings and layers are prepared during summer months. Seeds are sown on well prepared nursery beds. Seedlings are very small and remain inconspicuous for several weeks after germination. Planting of rooted cuttings, layers or transplanting of seedlings is done during late summer at a spacing of 30-45 cm between plants and 60 cm between rows. In autumn, a light dressing of farm yard manure is given. Fertilizers are applied at 100:40:40 kg N, P_2O_5 and K_2O/ha. Top dressing of N in the spring promotes the formation of numerous leafy shoots. Irrigation is given when warranted. The field is to be kept weed free. Not much pests and diseases are reported in this crop. About 15 cm long shoots, in the early flowering stage, are harvested during May-June. The lower portions of the stem, together with any yellow or brown leaves are rejected.

Postharvest technology

The harvested herb is transported to the drier immediately. Alternatively, on a smaller scale, the herb can be tied in small bunches and hung on to dry in the sun or in a well ventilated shed or room. The dried flowering tops are steam distilled to get the thyme oil. On an average, the oil recovery is 2%.

Physico-chemical properties of the oil

Thyme oil is reported to have the following properties (Guenther, 1948).

Specific gravity at 25 C 0.891
Optical rotation at 20 C -3 12'
Refractive index at 20 C 1.4909
Phenol content 28.0%
Solubilityin 80% alcohol 7 vol.

The chemical composition of the oil is reported as: camphene + pinene 0.15%, p-cymene 15-50%, linalool 3-13%, linalyl acetate 0-6%, borneol 2-8%, carvacrol 0-20%, thymol 5-60%, -thujene 0.5%, ß-pinene 4.6-4.7%, myrcene 0.4-0.9%, delta-3-carene 0.1%, -phellandrene 0.1-0.2%, limonene + 1,8-cineole 35.7-44.4%, -terpinene 0.3%, trans-linalool oxide 0.5%, cis-linalool oxide 1.0-1.1%, camphor 11.6-16.3%, ß-terpineol 0.6-0.9%, -terpineol + borneol + bornyl acetate 7.8-8.9%, -terpinlyl acetate 0.7-1.4%, geranyl acetate 0.5% and geraniol 0.1-0.2%.

7. CELERY Apium graveolens Umbelliferae

Importance

Celery popularly known as *Karnauli or Ajmod* is an annual or biennial erect herb with jointed stems whose seed on distillation gives a pale-yellow essential oil which is used as an essence in flavour and pharmaceutical industry. Bulk of the demand comes from the canned soup industry. It is used in the flavouring of all kinds of prepared foods such as soups, meats, pickles, vegetable juices and in the preservation of meat sauces. In pharmacy, the oil is used in certain preparations having sedative effect. It is highly priced for fixative purposes and as an ingredient of novel perfumes. It has a powerful odour and imparts a pleasant warm note. The oil is used in compounding ayurvedic formulations. Fruits yield 17% of a fatty oil which is used as an antispasmodic and nerve stimulant. Seeds of celery are rich in vitamin B.

Origin and distribution

Celery is a native of northern hemisphere extending from Sweden to Egypt. It is cultivated in Algeria, Ethiopia India, Caucasus, Baluchistan, France, Holland, Hungary, China and U.S.A.. In India, it is grown in Punjab, Haryana and Uttar Pradesh.

Botany

Celery plant *Apium graveolens* L. comes under the family Umbelliferae (Apiaceae). Two varieties are recognized under the species.

(1) *Apium graveolens L.* var. *dulce* (Mill.) Pers. the leaves and flowering stems of which are used as appetizer and salad at table and as a flavouring agent in soups.

(2) *A. graveolens L.* var. *rapaceum* (Mill.) Gandich or *turnip-rooted celery*. This is smaller with dark green leaves, less developed stalks and swollen roots (5-6 cm in diameter) which are eaten after cooking.

Apium graveolens is an annual in the plains producing seeds in the very first year but in colder climates and on the hills it becomes biennial and produces seeds only in the second year. It is an erect herb of 60-90 cm height. Roots succulent and numerous. Stems branched, angular or fistular, conspicuously jointed. Leaves pinnate, deeply divided into three leaflets which are ovate to suborbicular and 3-lobbed; inflorescence compound umbel; flowers small, white; calyx teeth obsolete; petals 5, ovate, acute with tip inflexed; carpels semiterete, filiform; fruits schizocarp with two mericarps, aromatic and slightly bitter.

Agrotechnology

Celery prefers a moist, cool climate . It grows as an annual in the plains but as a biennial at higher elevations with cooler climate. It flourishes well on fertile, well drained, sandy and silt loam soils. Clayey soils are not suitable.

The plant is propagated through seeds. Seeds obtained from primary umbels are heavy and produce better seedlings in comparison to seeds obtained from quarternary umbels. On hills or higher elevations, seeds are sown during March-April, transplanted in May and harvested in November. In the plains, seeds are sown during September-October, transplanted in January and harvested in May. High temperature pretreatment of seeds increases germination rate (Biddington and Thomas, 1979). Healthy seedlings are obtained by incubating the seeds at 90% relative humidity and 15-20 C for 8-10 days. For transplanting one hectare, 1.5 kg seeds are sown in a nursery area of about 1000 m^2.

The main field is thoroughly prepared incorporating organic manures at 10-20 tonnes/ha according to availability and transplanting is done in moist soil at 30-40 cm spacing. Fertilizer application of 200 kg N and 40 kg P_20_5/ha is much remunerative. The crop needs plenty of water and the field is irrigated every 10-15 days during non-rainy period. The crop may lodge when strong winds blow after irrigation which may be prevented by providing wind breaks. The field is kept weed free by 2-3 hoeings, first 3 weeks after transplanting and subsequently at 2 weeks interval. A leaf miner, *Liriomyza trifolii* Burgess and a fungus *Septoria apicola* Speg. attack the crop. They can be controlled by suitable insecticide and fungicide respectively. The crop is harvested when the white flowers start turning reddish. The harvested crop is thrashed with sticks the next day and the seeds are taken. Average seed yield is 1-1.5 tonnes/ha.

Postharvest technology

Celery seed oil is obtained by the steam distillation of the seed. Usually, distillation is carried out for 18 hours. The oil is very light and hence separation from water is not a problem. The celery seed contains 2-3% of essential oil. From the chaff also an essential oil can be obtained, which of course, lacks the better aroma of the seed oil. Celery chaff oil and synthetic d-limonene are common adulterants of celery seed oil which are difficult to detect.

Physico-chemical properties of the oil

Celery seed oil is a light pale-yellow coloured liquid with persistent characteristic odour of the plant. The other properties of the oil reported by Guenther (1950) are:

Specific gravity at 15 C	0.866-0.898
Refractive index at 20 C	1.478-1.486
Optical rotation	51 to 82
Acid value	upto 4.0
Ester value	16.0-55.0
Ester value after acetylation	43.0-67.0
Solubility in 90% alcohol	6-8 vol.

Lawrence (1980) reported the composition of celery seed oil as limonene 80.0%, -p-dimethyl styrene 0.9%, n-pentyl benzene 1.0%, caryophyllene 0.5%, -selinene 0.5%, n-butyl phthalide 1.0% and sedanolide 0.5%. The other constituents reported are sabinene, ß-elemene, trans-1, 2-epoxy limone, linalool, iso valeric acid, cis and trans dihydro carvone, terpinen-4-ol, cis and trans p-menth-2, 8-dien-1-ol, -terpineol, carvone, cis and trans, carveol, trans anethole, trans-carvyl acetate, cis and trans-p-menth-1(7), 8-dien-2-ol, perillaldehyde and thymol (Gold and Wilson, 1963).

celery leaf oil is richer in mono and sesquiterpenes in comparison to celery seed oil.

8. CORIANDER Coriandrum sativum Umbelliferae

Importance

Coriander is an annual erect aromatic herb. The young green plant is a culinary herb and the mature fruit a spice. Practically, all parts of the plant contain essential oil. The seed oil and oleoresins are commercially extracted. The essential oil is used in the flavouring of processed food and to some extent in pharmaceutical products and perfumery formulations. Its major fraction linalool, which accounts for the characteristic aroma, serves as a starting material for the synthetic preparation of citral and ionones. The oleoresin has similar application as the essential oil in flavouring and perfumery. The spice is either used as whole or ground. The ground spice is an ingredient of curry powder and is extensively used as flavouring agent and for the manufacture of processed food. The whole spice is employed in pickling and flavouring of liquors and other alcoholic beverages like gin. The leaves are used raw in salad and are rich in vitamin A and C. The leaves and seeds are also used for the treatment of ailments like indigestion, dyspepsia, flatulence and piles.

Origin and distribution

Coriander plant is a native of the Mediterranean region. Its cultivation is geographically widespread in European, Asian and

African countries. In India, it is cultivated in majority of the states. The culinary herb is in great demand in Asia, Middle East, Central and South America. Coriander seed oil is chiefly produced in Eastern and Western European countries, Russia and in U.S.A. The annual world production of coriander seed oil is 90-100 tonnes. The oleoresin is prepared on a small scale in Russia and in some of the highly industrialized western countries.

Botany

The coriander plant *Coriandrum sativum* L. is grouped under the family Umbelliferae (Apiaceae). Two varieties are recognized under the species. (1) *Coriandrum sativum* L. var. *microcarpum* DC. which is small fruited and is produced in temperate regions such as Russia and European countries.
(2) *C. sativum* L. var. *vulgare* Alef. which is large fruited and is cultivated in the tropical and subtropical countries like Morocco and India.

Coriandrum sativum is a glabrous aromatic annual herb, 30-90 cm in height. Stem is profusely branched heterophyllous with quadrangular lamina. Leaves are adnate and pinnately compound; inflorescence terminal compound umbel; flowers on the periphery of the umbels are zygomorphic and the central ones are actinomorphic; calyx tubular, adnate to ovary at the base 5-lobed; corolla 5, spreading, clawed with a broadly ovate limb; stamens 5; ovary two celled; fruit schizocarp, green when young and brown on maturity.

Agrotechnology

Coriander requires a frost free cool climate. It can be cultivated either as a winter crop during October or May-June. The plant grows on a wide variety of soils ranging from heavy black cotton soils to silt loams, though well drained medium to heavy soils are the best. The crop can be successfully cultivated as a rainfed crop on medium to heavy soils with well distributed soil moisture and as an irrigated crop on rich silt loams.

It is propagated by seeds. 'Lucas' and 'Amber' are improved cultivars commonly used in Russia. Selections like' NP(D)92', 'NP(D)95', 'NP(D)172', 'NP(J)24', 'NP(K)45' and 'CIMPO S-33' are cultivated in India. Seeds are rubbed to separate one seeded mericarps before sowing. Sowing is done either by broadcasting or by using seed drills in rows 30 cm apart. The seed rate is 10-12 kg/ha for pure cropping and 4-5 kg/ha for mixed or intercropping with other crops. Seeds start germinating in 8-10 days of sowing. Manures at 10 tonnes of FYM and fertilizers at 100:40:40 N, P_2O_5 and K_2O/ha are generally applied. The crop is irrigated immediately after sowing to ensure even germination and later on at 7-10 days interval depending upon the soil and climatic conditions. The field is to be kept weed free by regular weeding and hoeing. Postemergence application of 5-6 kg of propanil brings about optimum control of weeds and improves the yield. Diseases such as wilt (*Fusarium oxysporum* Schlecht), tumour (*Protomyces macrosporus* Unger.), powdery mildew (*Erysiphe polygoni* DC.), stem rot (*Sclerotina sclerotiarum* (Lind.) de Bary) and root rot (*Rhizoctonia bataticola* Taub.) are reported in coriander. The crop matures in 90-110 days. To avoid shattering of the fruit, it is generally harvested when the fruits in the main umbel have turned brownish or half of the fruits have turned brown. Harvesting is done either by uprooting the whole plant or by cutting them with sickle manually. The plants are then tied into small bundles and stacked for drying, keeping the bundles upside down, and then threshed to separate the fruits. The yield is 400-600 kg/ha under rainfed farming and 1400-2000 kg/ha under irrigated condition.

Postharvest technology

The essential oil is obtained by the steam distillation of mature dry fruits (Dimiri, 1976). Generally, distillation is carried out for 9-10 hours. The larger fruit contains 0.1-0.35% oil whereas the small fruit contains 0.8-1.8% oil. Oil recoveries as high as 2.6% have also been reported . An oil yield of 30-40 kg/ha is obtained. The stalks and leaves yield 0.1-0.9% oil which is not commercially used because of the pronounced odour of decylaldehyde and other higher nonaliphatic aldehydes.

Coriander oil is often adulterated with sweet orange oil cedar wood oil, aniseed oil, turpentine or anethole.

Physico-chemical properties of oil

The colourless or pale yellow essential oil of coriander seed has the following properties.

Specific gravity at 20 C	0.868-0.870
Refractive index at 20 C	1.464-1.465
Optical rotation at 20 C	10.5 to 11.1
Acid value	1.0-1.3
Saponification value	7.4-11.4
Ester value	6.4-10.1
Total alcohols	63.1-75.5%

The range of reported chemical composition of the seed oil is -pinene 0.96-7.97%, ß-pinene 0.6-1.7%, -terpinene 1.06-2.20%, p-cymene and phellandrene 3.69-9.91%, linalool 59.55-72.61%,

borneol and decyl aldehyde 5.31-7.43%, camphene 0.91%, myrcene 5.44%, _terpinene 5.44%, terpinolene 0.09%, camphor 2.46%, terpinen-4-ol 0.25%, -terpineol 0.26%, carvone 0.15%, geranyl acetate 2.04%, geraniol 1.0%, trans-anethole 0.01%, -terpinene 0.09%, 1,8-cineole and nerolidol 0.1% (Chou, 1974; Gupta *et al*, 1977).

9. CUMIN Cuminum cyminum Umbelliferae

Importance

Cumin is a small slender glabrous annual herb. It is one of the most important condiments consumed all over the world. The seed is used as a spice for flavouring foods of various kinds like breads, cheese and curry powders. Cumin oil is preferred to the whole fruit in many types of flavouring preparations. The oil is also used in soap, perfumery and beverages. The absolute is superior to the oil for flavouring. Cumaldehyde, the chief constituent of cumin oil, is used in perfumery. The thymol free, distillation residue water is given to children as carminative and is useful in flatulence and gripping.

Origin and distribution

The cumin plant is native to Mediterranean region. It is widely grown is Egypt, Syria, Iran, Turkey, India and North Africa. In India, it is cultivated in Rajastan, Gujarat, Madhya Pradesh, Punjab, Uttar Pradesh and Tamil Nadu. Iran is the largest producer and supplier of cumin.

Botany

The cumin plant *Cuminum cyminum* L. belongs to the family Umbelliferae (Apiaceae). It is a glabrous annual herb 30-40 cm in height with much branched angular or striated stem. Leaves bluish- green, 2 or 3-partite, ultimate segment filiform, leaf base sheathing; flowers in compound umbel, with few rays and several bracts and bracteoles, small, white to rose, regular and bisexual; calyx 5, teeth like, subulate, unequal; petals 5, oblong to ovate; fruit greyish, tapering towards both ends and compressed laterally with ridges covered over by papillose hairs.

Agrotechnology

Cumin is usually cultivated as a winter crop. It prefers low atmospheric humidity during flowering and seed setting. It is grown on well drained, medium to heavy textured soils of medium to high fertility. The incidence of wilt disease is more in light textured soils.

The plant is propagated by seeds. 'S-404', 'MC-43', 'RS-1', 'UC-52', ' UC-91', 'NP(D)-1', 'NP(J) 126' and 'NP(J) 149' are some of the improved varieties available for cultivation. Seed rate is 20 kg/ha for broadcasting and 12-15 kg/ha for drilling or line sowing at 25-30 cm between rows. Seeds are sown in November on well prepared seed beds manured with 10-15 tonnes of organic manure and 30-40 kg each of N, P_2O_5 and K_2O/ha. The field is irrigated immediately after sowing. Thereafter, 4-5 irrigations are needed at an interval of 12-20 days depending upon weather and soil conditions. Weeding is carried out twice, 20 and 40 days after sowing. A top dressing of 30 kg N/ha is given after second weeding. Not many pests are reported in this crop. Aphids attacking cumin can be easily controlled by tobacco decoction or a mild insecticide like malathion. Fusarium wilt (*Fusarium oxysporum* and *F. cumini*), blight (*Alternaria burnsii*) and powdery mildew (*Erysiphe polygoni*) are also observed on the crop which can be controlled by the application of maneb, MBC and wettable sulphur respectively.

The fruits appear in tufts and mature in 80-100 days after sowing. The fruits are harvested before they shatter, by pulling the whole plants in the morning when they are wet. The uprooted plants are stacked for 2-3 days for drying in sun. The seeds are separated from the plants by winnowing. On an average a seed yield of 800-1500 kg/ha is obtained (Notwani, 1959).

Postharvest technology

The dried fruit or seed is crushed and distilled immediately to obtain the essential oil. Steam distillation is usually carried out.

The oil recovery ranges from 2.5 to 4.5% . Older seeds yield less oil. On an average, an oil yield of 25-30 kg/ha is obtained.

Cumin oil is often adulterated with synthetic aldehydes, the presence of which in small quantities cannot be detected by routine analysis, higher percentages affect the optical rotation.

Physico-chemical properties of oil

Cumin oil is colourless or pale yellow liquid which slowly turns black on keeping. The oil has the following properties (Rao, 1925).

Specific gravity at 15 C	0.8945
Refractive index at 25 C	1.4910
Optical rotation at 25 C	3.6

Aldehyde content (bisulphite method) 16%

Solubility in 80% alcohol at 20 C 11 vol.

Cumin oil is reported to contain -pinene 0.7-1.1%, ß-pinene 14.3-19.7%, p-cymene 2.7-6.0%, limonene 0.4-1.5%, -terpinene 11.5-16.3%, cuminaldehyde 20.0-22.4%, p - menth - 1, 3-dien-7-al 11.1-13.5%, p-menth-1,4 dien-7-al 23.6-24.3%, cuminyl alcohol 3.7-72.2%, myrcene 0.12%, sabinene 3.38%, ß-terpinene 0.68%, -terpinene 0.09%, ß-phellandrene 0.93%, 1,8-cineole 0.46%, trans-sabinene hydrate 0.29%, cis-sabinene hydrate 0.69%, bornyl acetate 0.12%, linalool 1.06%, caryophllene 0.48%, piperitol 0.81%, -terpineol 2.75%, perillaldehyde 1.12%, methyl cinnamate 0.46%, carveol 1.45%, caryophyllene oxide 1.45%, anisaldehyde 2.79%, benzyl cinnamate 4.47%, farnesol 2.98% and cinnamic acid 0.01% (Agarwal *et al*, 1979; Karim *et al*, 1979).

10. FENNEL Foeniculum vulgare Umbelliferae

Importance

Fennel is a stout glabrous biennial or perennial aromatic herb whose fruit has a fragrant odour and a pleasant taste. The fruits are used for flavouring soups, meat dishes, sauces, bread rolls, pastries, pickles, confectionery and liquors. The seeds yield essential oil which is used in perfumery, food, soap, liquor and drug industries. Medicinally, it is useful in infantile colic and flatulence. It also checks gripping and is used as vermicide against hook worms.

Origin and distribution

The plant is believed to be a native of Southern Europe and Asia. Bitter and sweet types of fennel are recognized. Wild growing bitter fennel is found in South Western Europe and North-West Africa. Sweet fennel does not grow wild, but is cultivated in France, Italy, Bulgaria, Morocco, India, Spain, Russia, Rumania, Germany, Hungary, Argentina and U.S.A. In India, fennel is cultivated in the states of Maharashtra, Gujarat, Karnataka, Punjab and Rajastan. Fennel oil is produced in West Germany, Spain, France, Hungary, India, and China. Spain and France are the major producers.

Botany

Fennel belongs to the family Umbelliferae (Apiaceae) and the species *Foeniculum vulgare* Miller. Two cultivated forms are observed.

(1) Bitter fennel: *Foeniculum vulgare* Mill. subsp. *capillaceum* (Gilib.) Holmboc var. *vulgare* Mill. which yields bitter fennel oil and is cultivated in Russia, Rumania, Germany, France, Italy Hungary, India, Japan, Argentina and U.S.A.

(2) Sweet fennel: *F. vulgare* Mill. subsp. *capillaceum* (Gilib.) Holmboc var. *dulce* Mill. which yields sweet fennel oil and is cultivated in France, Italy and Macedonia. Indian fennel is sometimes referred to as a distinct form, var. *panmorium* (Krishna & Badhwar).

Foeniculum vulgare is a medium to large sized stout, glabrous, biennial or perennial aromatic herb growing to 150-180 cm in height. Leaves 2-4, pinnate, ultimate segments linear, strongly scented; flowers small, yellow, arranged in terminal compound umbels; bracts none; bracteoles none or few, linear; calyx teeth absent; petals notched; fruits oblong, not flattened, 5-ridged, ridges prominent, furrows with oil glands; seeds flattened, inner face slightly hollow.

Agrotechnology

Fennel requires a fairly mild climate. It is mainly cultivated as a winter season crop upto an altitude of 1800 m throughout the subtropical and temperate regions. In many countries, it is grown as a garden crop in home yards. It grows on a variety of soils, but thrives best on rich loamy soils containing sufficient lime. Saline and waterlogged soils are not suitable. The plant is propagated by seeds and rarely by root divisions. Seeds are broadcast or drilled in rows 30-45 cm apart, during October-November in plains and during March-April in higher elevations. Seed rate is 8-10 kg/ha. The seedlings when 8-10 cm high may be thinned out to 20-30 cm in rows. The field should be supplied with 15-20 tonnes/ha of organic manure before planting and fertilizer application can be dispensed with at higher levels of organic manure application. When organic sources are limited inorganic fertilizers can be applied at 100:30:30 kg N, P_2O_5 and K_2O/ha. N is applied in 2-3 splits while P and K are applied as basal at the time of sowing. Irrigation is required immediately after sowing if there is no rain. Subsequently, irrigation is to be provided at 7-15 days interval depending upon the weather and soil conditions. Weeding is carried out twice, one and two months after sowing which is followed by topdressing of N. Thrips (*Heriothrips indicus*) may severely damage the crop which can be controlled by insecticide application. Blight (*Cercospora foeniculi* P. Magnus) and powdery mildew (*Leveillula tauria* (Lev.) Arnaud) are the common diseases of fennel, which are controlled by spraying maneb (2g/l) and wettable sulphur (3g/l), respectively.

The crop will be ready for harvest in 5-6 months time. Individual umbels are cut before they are fully ripe to avoid losses by shattering. The harvested crop is spread out in loose bundles to dry in the sun for 4-5

days. The dried fruits are then separated by thrashing and cleaned by winnowing. The average seed yield is 1000-1500 kg/ha.

Postharvest technology

The crushed fennel seeds, on steam distillation yield the essential oil. The oil content in seed varies considerably with the variety, being the lowest (0.7-2%) in fruits of Indian origin and highest (4-6%) in fruits obtained from Eastern Europe.

Physico-chemical properties of the oil

Fennel seed oil is a colourless or pale-yellow liquid with a characteristic odour. Indian oil smells less sweet and flavoury but tastes bitter, whereas the European oil is sweet. The other properties of the oil reported by Guenther (1950) are:

Specific gravity at 15 C 0.965-0.978
Refractive index at 20 C 1.528-1.539 Optical rotation 4 to 24
Congealing point 5 C to 14 C
Solubility in 80% alcohol 5-8 vol.
Solubility in 90% alcohol 0.5 Vol.

Chemically, Indian fennel oil contains over 70% anethole and 5% fenchone. Fenchone is mostly absent in European oils. The high percentage of anethole (upto 90%) and the relative absence of fenchone are responsible for its delicate odour and flavour. Other constituents of the volatile oil are d- -fenchone, methyl chavicol, d- -pinene, camphene, d- -phellandrene, dipentene, foeniculin (p-anolprenyl ether), anisaldehyde and anisic acid. The composition of the oil varies widely with the variety and the geographical location. The oil from wild growing bitter plants contains little anethole, the chief ingredient being d- -phellandrene (Trenkle, 1972; Mahindru, 1992).

11. AJOWAN Trachyspermum ammi Umbelliferae

Importance

Ajowan is a profusely branched winter annual herb, the seed oil of which is a major source of thymol, being present to the extent of 35-60%. Ajowan oil is aromatic, stimulant and carminative. It possesses antimicrobial activity (Dalme and Tipinis, 1980). Ajowan seeds are employed alone or in combination with other spices and condiments in pickles, confectionery and beverages. It is a good remedy for indigestion. A paste of the crushed fruit is applied externally for relieving colic pains. It is also used in lotions and ointments.

Origin and distribution

The plant is believed to have originated in Egypt. It is cultivated around the Mediterranean sea and in the South-West Asia extending from Iraq to India. It grows wild in North India.

Botany

Ajowan plant belongs to the family Umbelliferae (Apiaceae) and the species *Trachyspermum ammi* (L.) Sprague. It is a profusely branched annual herb, 60-90 cm tall. Stem is striated; Leaves pinnate, with a terminal and 7 pairs of lateral leaflets; inflorescence compound umbel with 16 umbellets, each containing upto 16 flowers; flowers actinomorphic, white, male and bisexual; corolla 5, petals bilobbed; stamens 5, alternating with the petals; ovary inferior; stigma knob-like; fruit aromatic, ovoid, cordate, cremocarp with a persistent stylopodium.

Agrotechnology

It is mainly grown as a winter crop in subtropical and temperate climate. It grows on any soil type but performs best in humus rich loamy soil. It is grown as a rainfed crop in heavy soils whereas it requires irrigation in light textured soils. It is generally propagated by seeds. The field is ploughed repeatedly during September-October, incorporating organic manures at 10-15 tonnes/ha. Seeds are sown broadcast or drilled in rows 45 cm apart in November. Seed rate is 3-4 kg/ha. Irrigation is given immediately after sowing and later at 7-10 days interval. The seeds germinate in 7-14 days. Broadcast crop may be thinned to a spacing of 30-45 cm. N, P_2O_5, K_2O and S are applied at 80,30,30,50 kg/ha, respectively for obtaining best yields. Weeding is generally done twice. Collar rot caused by *Sclerotium rolfsii* is observed in some pockets. Flowering starts in 2 months time. Harvesting is done in February-March when the flower heads turn brown. The harvested crop is dried, threshed and winnowed to separate the clean seeds.

Postharvest technology

The dried seeds are crushed and distilled to obtain the essential oil. Hydro or steam distillation is resorted to. Seeds lose the essential oil when stored for long time. On an average, the dry seeds contain 2-4% oil.

Physico-chemical properties of oil

The pale yellowish-brown ajowan seed oil has a characteristic thyme odour with sharp burning taste and the following properties (Guenther, 1950).

Specific gravity at 15 C 0.910-0.930
Refractive index at 20 C 1.498-1.504
Optical rotation 0 to 5
Content of phenols 45-57% Solubility in 80% alcohol 1-2.5 Vol.

The characteristic odour of ajowan oil is due to the high content of thymol. On standing, the major portion of thymol gets crystallized. The other major constituents are -pinene, p-cymene, dipentene, -terpinene and carvacrol. The following monoterpenes constitute the hydrocarbon portion of the oil: -pinene 1.8%, camphene 0.5%, ß-pinene 3.5%, myrcene 0.3%, delta-3-carene 0.5%, limonene 5.1%, -terpinene 34.9% and p-cymene (Nigam *et al*, 1963; Ashraf and Bhatty, 1975).

12. DAVANA Artemisia pallens Compositae

Importance

Davana is a delicate, erect, branched annual herb, the flowering top of which yields an essential oil which is extensively used in high grade fine perfumes. The oil is used for flavouring cakes, pastries, tobacco, beverages, sausages and preserved products. The leaves form an important component of garlands and bouquets (Narayana *et al*, 1978)

Origin and distribution

Davana is probably a native of South India. Though it is not systematically cultivated in its home country, she holds the key position in the production of davana oil. The annual production is about 2 tonnes. Karnataka, Tamil Nadu, Uttar Pradesh and Andhra Pradesh are the major producing states.

Botany

The plant davana *Artemisia pallens* Wall.ex DC., belongs to the family Compositae (Asteraceae). It is an erect branched annual herb 45-60 cm tall and covered with greyish white tomentum. Leaves alternate, exstipulate, petiolate, lobed; inflorescence capitulum, axillary, peduncled to sessile, heterogeneous with yellow glabrous florets; involucre two or more, seriate, ovate to elliptic-linear; inner florets 5-lobed, bisexual; stamens 5 with free epipetalous filaments; style bifid.

Agrotechnology

Davana is a delicate plant and hence cannot withstand heavy rains. It prefers light drizzles, bright sunshine, and a mild winter with no frost and heavy morning dew during the growing season. Cloudy weather and rains during flowering and seed ripening stages adversely affects the yield. The crop grown during November gives the maximum herb and oil yield. However, the crop can be grown round the year for use in garlands and bouquets. The plant grows on various types of soils ranging from sandy loam to medium black soils, but humus rich red loam soils are ideal (Thakur and Singh, 1979).

The plant is propagated by seeds. Seeds are short-viable and hence cannot be stored for long. Transplanting is generally practised in the crop. A nursery area of 500 m^2 sown with about 1.5 kg seeds is sufficient for planting one hectare. The seeds are mixed with fine sand, broadcast over the nursery bed, covered with a thin layer of sand and watered regularly. Seeds germinate in about 3-4 days. When the seedlings are 10-12 cm tall they are transplanted to the main field at 15 x 7.5 cm spacing. Before transplanting, 12-15 tonnes of well decomposed FYM and 40 kg/ha each of phosphate and potash are incorporated into the soil. N is applied at 120 kg/ha in 4 equal splits, 3 for the main crop and 1 for the ratoon crop at 15 days interval. The crop is irrigated weekly. Two weedings are carried out in the main crop and one in the ratoon crop. The crop is often subject to damping off at the tender early stage, particularly in the nursery. This disease, caused by *Rhizoctonia* species is common during cloudy and rainy period. Hence adjusting of sowing time is important for avoiding the disease. The crop is harvested during February-March when a large number of flower buds start opening. Flower to plant ratio at the time of harvest is reported to be important in davana. Harvesting is done by cutting the whole plant with sickle at a height of 10 cm from the ground. The herb yield is 8-10 tonnes/ha.

Postharvest technology

The harvested herb is dried in shade for 2-3 days. The dried herb is steam distilled for a period of 6-8 hours for extracting the essential oil. The flower heads contain 0.3-0.4% of oil and in general, an oil recovery of 0.2% is achieved from the whole plant. The oil yield is 12-15 kg/ha.

Physico-chemical properties of the oil

The best yield and quality of davana essential oil is obtained from plants grown in summer months. Sastry (1946) has reported the following properties for the oil.

Specific gravity at 20 C 0.9605

Refractive index at 20 C	1.4880
Optical rotation	35
Acid Value	2-4
Ester Value	52.9
Solubility in 70% alcohol	10 Vol.

Davana oil contains davanone, fenchyl alcohol, cinnamyl cinnamate, caryophyllene, cadinene, linalool, dehydro- - linalool, davanafuran, isodavanone, dihydrorosefuran, n-alkanes, hydroxy davanone, geraniol and nerol. Davanafurans are responsible for the characteristic odour of davana oil though they constitute only 0.8% of the oil (Gulati, 1980; Akhila and Tewari, 1986).

13. CHAMOMILE Matricaria chamomilla Compositae

Importance

German or Hungarian chamomile is a much branched erect spreading annual herb from which essential oil, infusions, tinctures and fluid extracts are prepared for diverse uses. The essential oil is used in alcoholic and non-alcoholic beverages, ice-creams, ice candy, baked goods and chewing gums as flavouring agent. It is used in high class perfumes in low concentrations. Medicinally, it acts as antispasmodic, expectorant, carminative, anthelmintic, sedative and diuretic. It also possesses antimicrobial activity. It is used in infant ailments such as teething troubles and stomach disorders. The infusion is a common beverage which is a mild sedative and digestive. The dried herb and the tinctures are used in bitter tonic beverages and elixirs.

Origin and distribution

Not much is known regarding the nativity of this plant. Chamomile is grown in Germany, Hungary, France, Russia and Yugoslavia. It has been introduced to India about 300 years ago during the Mughal period. Since then it has been grown in Punjab, Uttar Pradesh, Maharashtra and Jammu and Kashmir.

Botany

The Chamomile plant belongs to the family Compositae (Asteraceae) and three species of chamomile are recognized .

(1) *Matricaria chamomilla* L. known as *German or Hungarian Chamomile* and is the most common. It is cultivated in Europe, Germany, France, Hungary and Russia.

(2) *Anthemis nobilis* L. known as *Roman Chamomile*

(3) *Ormenis multicaulis* Braun Blanquet & Maire termed as *Moroccan Chamomile*.

Matricaria chamomilla is the most widely and commonly cultivated species. It is an annual herb, much branched, erect spreading, 60-90 cm tall and glabrous. Leaves pinnate; leaflets narrow and linear; inflorescence capitulum, 1.3-2.5 cm in diameter; flowers borne on hemispherical or conical hollow receptacles, surrounded by involucre of 2-3 rows of small imbricate bracts; ray florets 10-20, whitish or yellowish, later becoming reflexed, disc florets, numerous, yellow, tubular, dark brown or greyish yellow achenes with 3-5 faint ribs.

Agrotechnology

The plant is grown as a winter crop in plains and as a summer crop on hills. For good seed germination, the optimum temperature is 18-20 C. Temperature and light conditions have a greater effect on essential oil production. It grows on any type of soil, but comes up well on moist, moderately heavy soils rich in humus. The optimum soil pH is 7, though saline and alkaline soils having pH as high as 9.0 also support good growth .

The crop is raised through seeds. Seedlings are raised in nursery during September-October. Seed rate is about 1 kg/ha. The seedlings are transplanted when 6 weeks old at a spacing of 30-40 cm (Dutta and Singh, 1964). Adequate manuring is needed for good growth and yield of the crop. Application of 15-20 tonnes/ha of well-rotten farm yard manure and 80:40:20 kg N, P_2O_5 and K_2O/ha are recommended. On normal soils, 3-4 irrigations are sufficient during the entire growing season. Saline soils need frequent light irrigations. Generally, one or two weedings and hoeings are required for raising a good crop. Black bean aphids (*Aphis fabae*) is a serious pest. Flowers are attacked by an insect, *Nysius minor*, which causes them to shed. Another insect, *Antographis chryson* also attacks the plant and causes defoliation. These insect pests can be effectively controlled by spraying suitable insecticides.

The plants start flowering from February to April. The flowers are harvested at full bloom stage. Generally, 4-5 harvests can be taken at an interval of 10-15 days. The yield is 4000-7000 kg fresh flowers which gives 1000-1500 kg/ha on drying. Drying is done under shade between 22-24 C as the flowers are delicate. Fully dried flowers can be packed and stored in moisture free environment Chandra *et al*, 1970).

Postharvest technology

The dried flowers are steam distilled for 4 hours at a pressure of 7 atmosphere/cm^2 in the steam generator. The oil being very viscous, forms a deposit along the inner walls of the condenser. Hence the flow of cooling water is to be frequently stopped till the temperature rises sufficiently. The oil yield varies from 0.3 to 1.3% depending upon the location, strain and the conditions and fertility status of the soil. The oil content in the flowers is maximum when the temperature is 22-25 C during the flowering period. The average oil yield is 50-75 kg/ha (Sharma *et al*, 1983).

Physico-chemical properties of the oil

Chamomile oil is a viscous, intensely blue coloured liquid with a characteristic aroma and bitter tonic flavours. The colour changes to green and finally to brown on exposure to light. The other properties of the oil are reported to be:

Specific gravity at 15 C	0.9326-0.9459
Acid value	18.7-31.7
Ester value	1.9-12.1
Ester value after acetylation	66.3-115.7
Solubility in 90% alcohol	Soluble

The essential oil contains 1-15% of chamazulene, which is responsible for the blue colour of the oil; azulene, farnesene, -bisabolol oxide a and b and a dicyclo ether (Sharma *et al*, 1962; Chandra *et al*, 1979).

14. GERANIUM Pelargonium graveolens Geraniaceae

Importance

Geranium also known as *Rose geranium*, is a bushy pubescent aromatic perennial shrub which produces an essential oil having strong rose-like odour with a minty top note. Geranium oil blends well with all kinds of scents, floral and oriental bouquets and is extensively used in perfumery and cosmetic industries. It is widely used for scenting soaps due to its stability in the slightly alkaline medium. The oil is also used for the production of rhodinol used in the manufacture of perfume compounds (Kumar *et al*, 1985).

Origin and distribution

Geranium is a native of Cape Province in South Africa, where it grows in a state of nature but do not enjoy the position of a producer of its volatile oil. It is grown in France, Belgium, China, Spain, Morocco, Madagascar, Reunion Islands, Egypt, Congo, Russia and India for the production of geranium oil. In India, Maharashtra, Andhra Pradesh, Tamil Nadu, Jammu and Kashmir, Himachal Pradesh and Kerala are suitable for its cultivation. The world production of geranium oil is around 300 tonnes/year and the major producers are Reunion Islands, Egypt, China, Algeria, Morocco, India and Russia.

Botany

Geranium *Pelargonium graveolens* L'. Herit. belongs to the family Geraniaceae. It is a suffrutescent bushy aromatic perennial shrub with cylindrical stem. Leaves simple, alternate, stipulate, broadly cordate with palmatisect primary lobes and pinnatisect secondary lobes, pubescent and aromatic; inflorescence umbellate, bracteate; flowers pentamerous, basically bisexual, hypogynous; calyx free quinquincial; corolla pink, zygomorphic, polypetalous; stamens 10;
filaments subequal, united at the base; ovary superior, pentacarpellary, syncarpous, hairy; stigma 5 lobed.

Agrotechnology

A Mediterranean type of mild climate with a low humidity, warm winter, mild summer temperature and an annual rainfall of 1000-1500 mm is ideal for the crop. It grows successfully at an altitude of 1000- 2100 m. Well drained porous soils are suitable for its cultivation. Saline, alkaline and damp soils are unsuitable (Arumugam and Kumar, 1979).

There is no seed setting in geranium. The plant is propagated by stem and root cuttings. Terminal cuttings root earlier than middle and basal cuttings. IAA is better than IBA for inducing rooting. Rooted cuttings are raised in the nursery during November-January and transplanted after 2 months at 60 x 40 cm spacing in the main field after applying well decomposed FYM or Compost at 10-12 tonnes/ha. Inorganic fertilizers like phosphate and potash are applied at 40-60 kg/ha as basal while N is applied upto 200 kg/ha/year in six equal splits to cover the 3 harvests. Application of micronutrients such as Cu at 20 kg/ha/year and Mo at 3 kg/ha/year in 3-4 split doses is found to be beneficial (Dhakshinamoorthy *et al*, 1980). Irrigation is provided daily for the first 3-4 days, on alternate days till two weeks and weekly thereafter. The crop requires weeding 20 and 40 days after planting and hoeing after harvest. Attack of root-knot nematodes *Meloidogyne incognita* and *M. hapla* are common in this crop. These are controlled by applying Aldicarb at 20 kg/ha. *Fusarium oxysporum* and *Botryodiplodia theobromae* cause wilt disease for which the systemic fungicide benomyl is effective.

The crop is ready for harvest after 4 months from transplanting when the leaves begin to turn light green and exhibit a change from lemon like odour to that of rose. The green leafy shoots are harvested with a

sharp sickle. Three harvests can be taken per annum and the crop remains in the field for 4-6 years. The yield of fresh herbage/ha/year from the 3 harvests is about 15 tonnes.

Postharvest technology

The harvested herb is immediately taken up for distillation. Steam distillation gives better quality oil as compared to hydrodistillation. Distillation takes 3-4 hours. The volatile oil is present mostly in the leaf blades and there is practically no oil in the woody stem. In large scale distillations, the oil recovery varies from 0.1 to 0.15% on fresh weight basis and the average oil yield is 18-20 kg/ha/year. A maximum oil yield of 60 kg/ha has been reported. **Physico-chemical properties of oil**

Geranium oil possesses strong, somewhat rose-like odour which is reported to improve with age when properly stored. The other properties of the oil are reported to be:

Specific gravity at 15 C	0.888-0.8966
Refractive index at 20 C	1.461-1.471
Optical rotation	-7 40' to +13 15'
Acid value	1.50-3.22
Esters as geranyl tiglate	21-33%
Total alcohol as geraniol	55.6-67%
Ester value after acetylation	206-233
Solubility in 70% alcohol	2-3 vol.

The chemical composition of the essential oil is reported to be -pinene 0.28-0.86%, ß-pinene 0.04-0.16%, myrcene 0.06-0.19%, phellandrene + limonene 0.12-0.21%, cis and trans-ocimene 0.1-0.36%, cis and trans-rose oxide 1.0-2.50%, cis and trans-linalool oxide 0.36-0.92%, menthone 0.78-1.50%, iso-menthone 5.2-7.2%, linalool 3.96-12.90%, caryophyllene 0.74-1.04%, Guaia-6,9-diene 0.15-4.4%, citronellyl formate 1.92-7.55%, geranyl acetate 0.10-1.08%, citronellol 19.28-40-23%, nerol 0.67-1.24%, geraniol 6.45-18.4% and traces of over hundred compounds (Pesnelle *et al*, 1971; Tewari and Virmani, 1988).

15. CARDAMOM Elettaria cardamomum Zingiberaceae

Importance

Cardamom is a tall herbaceous perennial with branched subterranean rhizomes from which arise several erect leafy shoots and

erect or decumbent panicles. The dried capsules, the essential oil, oleoresin and tinctures are extensively used in the formulation of compounded mixtures for liquors beverages baked goods, canned foods, meats, sauces and condiments. Cardamoms are stimulant, carminative and flavouring agent. Dried cardamom fruits are used as a masticatory and in medicine. They are used for flavouring curries, cakes, bread and other culinary purposes. The essential oil is employed in perfumery and flavourings. The oleoresin has similar applications to essential oil in flavouring of processed foods but it is less used. The oil and oleoresins also find use in the preparation of aromatic, stimulant, stomachic and diuretic tinctures.

Origin and distribution

The plant has originated in India. Its natural habitat is the evergreen forests of Western Ghats. It is grown in India, Sri Lanka, Guatemala and Thailand. India is the largest producer of cardamom, with cultivation mainly confined to the southern states of Kerala, Karnataka and Tamil Nadu. About 80% of the cardamom in the international market comes from India. Sri Lanka which was the second largest exporter has now been overtaken by Guatemala.

Botany

The plant cardamom *Elettaria cardamomum* Maton belongs to the family Zingiberaceae. It has a chromosome number 2n=48. As the different races and varieties of cardamom are interfertile, the variability is so high that some confusion exists with regard to the systematics. Generally, two botanical varieties are recognized.

(1) *Elettaria cardamomum* Maton var. *major* Thw.: It is the wild cardamom of Sri Lanka and the southern half of the Western Ghats. It is a robust plant, 3 m tall, with pinkish pseudostems, broad leaves, and erect panicles; ovary and calyx subtomentose; fruits 2.5-5.0 cm long, drying to a dark brown colour, longer and seeds larger, more numerous and less aromatic than the var. *minor*.

(2) *E. cardamomum* Maton var. *minor* Watt. (syn. var. *cardamomum* Thw.; var. *minuscula* Burkill).: This includes most of the cultivated types. The panicle is longer, with more numerous flowers. Ovary and

calyx glabrous, fruits smaller than var. *major*, subglobose, yellowish when dried. Seeds more aromatic. Flowers bisexual; fruits trilocular capsule with 15-20 seeds per fruit. The flowers which open from the base of the panicle upwards over a long period, are said to be self-fertile. They are visited by bees which bring

about cross pollination. Several races such as Malabar, Mysore and Vazhukka are recognized under this variety.

Agrotechnology

Cardamom grows wild in the evergreen rain forests of the Western Ghats in India between 750 m and 1500 m and in Sri Lanka above 1000 m altitude. They occur in the preclimax stage of the forest. In cultivation, the crop requires an annual rainfall of 1500-4000 mm, a temperature of 10-35 C and an altitude of 600-1200 m with moderate shade and protection from wind. Cardamom is generally grown in forest loamy soils rich in available phosphorus and potassium, but well drained deep loamy soils abundant in humus is ideal.

The plant is propagated vegetatively by divisions of rhizomes or by seed; the former is often used for planting small areas. Clonal propagation by tissue culture permits large scale planting of high yielding selections but is not advisable where *Katte* and other virus diseases are prevalent (Nadyanda *et al*, 1983). In such areas seedling progenies are advisable as virus disease is not transmitted through seeds. Seed germination is often poor and irregular. Plants propagated vegetatively come to bearing one year earlier than the seedling propagated plants. For seedling propagation, ripe capsules of desired cultivar are collected from high yielding plants during September-October. 'ICRI-1', 'ICRI-2', and 'PV-1' are the improved varieties available for cultivation. Seeds are extracted by gently pressing the capsules and washing 3-4 times with water to remove the mucilaginous coating on the seeds. Seeds are dried in shade for 2-3 days and sown in the nursery within a fortnight as the seeds are short-viable. Seeds can be preserved for one month in the capsule form in polythene lined gunny bags.

The seeds are sown in primary nursery from where the young seedlings are transplanted 25-30 cm apart in a secondary nursery or in polybags during June-July where they are maintained for one year and the 18 month old seedlings are finally transplanted to the main field at 1.5-3 m spacing depending on the cultivar and soil conditions. Sixty gram seeds are sown on well prepared beds of 6 m^2, mulched with potha grass or straw and watered regularly. Seedlings will take 4-6 weeks to appear above ground. Shade trees like dadap, albizzia, jack, eucalyptus, red cedar and wild nutmeg are planted. Cardamom plantation is fertilized with N, P_2O_5 and K_2O at 75:75:150 kg/ha respectively. Fertilizers are applied in two split doses before and after the south west monsoon in a circular band 20 cm wide at 30-40 cm away from the base of the clumps and incorporated into the soil. Mulching is practised to conserve moisture, reduce weed growth and overcome dry situation. Sickle weeding is required frequently. Forking is necessary in hard soils. Trashing is carried out during June-July with the commencement of monsoon to prevent spread of diseases and expose panicles for pollination by honey bees. Maintaining four bee colonies/ha during the flowering season is recommended for increased fruit set and capsule production. Shade regulation is essential to provide optimum shade. Red cedar (*Toona ciliata* Roem.) is an ideal shade tree which sheds leaves during rainy season and thus provides natural shade regulation (KAU, 1993).

Cardamom thrips (*Sciothrips cardamomi*) and leaf eating caterpillars are common pests of cardamom which can be controlled by spraying 0.2% HCH or 0.03% Quinalphos. *Katte* or mosaic virus disease is transmitted by the aphid *Pentalonia nigronervosa*. *Azhukal* or capsule rot caused by *Phytophthora* species, clump rot or rhizome rot caused by *Pythium aphanidermatum*, leaf blotch caused by *Phaeodactylum venkatesanum* and *Chenthal* disease are frequently observed in cardamom plantations. Multifaceted approach consisting of field sanitation, use of tolerant cultivars, repeated drenching and spraying with 1% Bordeaux mixture, is to be resorted to for effective disease control.

cardamom plants normally start bearing capsules from the third year of planting. Picking is carried out at an interval of 30 days during September-February and the peak period of harvest is October-November. Cardamom capsules with green colour fetch a premium price. Hence emphasis has to be given on the preservation of green colour during curing and subsequent storage. A cardamom plantation gives economical yield for 10-15 years after which replanting has to be done.

Postharvest technology

Processing of capsules is done in specially built curing houses. The harvested capsules are washed in water to remove dust and soil particles. Then they are uniformly spread and dried on wire net trays for 36-42 hours at 50-60 C. The dried capsules are rubbed on wire mesh to remove the stalk and other waste particles. This is called *polishing*. The polished capsules are then graded according to size by passing through a series of 7 mm, 6.5 mm and 6 mm sizes. The graded produce is stored in polythene lined gunny bags to retain the green colour and to avoid exposure to moisture. The outturn of dried capsules is 20-25% of the harvested fruits. The average yield of dried capsules is 200-300 kg/ha/year.

The fruits are crushed and steam distilled for 4 hours to recover the essential oil. The oil content is 3.5-7% which is dependent on the cultivar, stage of harvest and conditions and duration of storage. Upto 11% oil is available in seeds while it rarely exceeds 1% in husks. Cardamom oleoresin with 52-58% of oil content is produced on a relatively smaller scale.

Physico-chemical properties of oil

Cardamom oil is a greenish-yellow liquid with a warm spicy aromatic odour somewhat pungent and faintly bitter at high concentration. Rao (1925) has reported the following properties for cardamom oil.

Specific gravity at 15 C 0.9264-0.9349
Refractive index at 25 C 1.4603-1.4620
Optical rotation at 25 C 15.1 to 44.0
Acid value 0.36-1.3
Saponification value 96.5-156.4

Cardamom capsules contain 20% water, 10% protein, 2% fat, 42% carbohydrate, 20% fibre and 6% ash. The aroma and therapeutic properties are due to a volatile oil constituting 3-8% in the seeds, whose main constituents are cineole, terpineol and limonene. Nigam *et al* (1965) reported the composition of the essential oil of *E. cardamomum* var. *minuscula* as: -pinene 1.9%, sabinene 4.5%, limonene 14%, cineole 30.7%, p-cymene 1.9%, methyl heptanone 0.8%, linalool 0.9%, linanyl acetate 1.2%, ß-terpineol 0.8%, -terpineol 3.7%, -terpinyl acetate 28.1%, borneol 0.1%, neryl acetate 0.3%, geraniol 0.7%, nerol 1.4%, nerolidol 0.3% and heptacosane 0.5%.

***16. GINGER Zingiber officinale Zingiberaceae* Importance**

Ginger is a slender perennial herb with robust branched rhizome borne horizontally near surface soil. There are 3 primary products of the ginger rhizomes, namely *fresh, preserved and dried ginger*. Fresh or green ginger is consumed as a vegetable. Immature ginger preserved in sugar syrup is mainly used as a desert. Crystallized ginger is used as a sweet meat. The dried rhizomes constitute the spice and is esteemed for its flavour, pungency and aroma. It is a constituent of curry powder. It is also used in the production of ginger beer, ginger oil and ginger wine. Pressed ginger is prepared by boiling tender fleshy peeled rhizomes after which they are boiled and sold in sugar syrup. Crystallized ginger is produced in the same way, but it is dried and dusted with sugar. The rhizome yields an essential oil, but this lacks the pungent principle. It is used in the manufacture of flavouring essences and in perfumery . An oleoresin is also extracted in which the full pungency of the spice is preserved. It is used for flavouring purposes and in medicines. Ginger is widely used in local medicines. Taken internally, it is a stimulating carminative and externally it is used as a rubefacient and counter irritant.

Origin and distribution

Ginger is believed to have originated in South Asia. It is widely grown in India, China, Sumatra, Africa, Mexico, Jamaica, Hong Kong,
Australia, Nigeria, Sierra Leone and Japan. The largest producer and exporter of ginger is India where it is chiefly produced in the states of Kerala and Assam. It is a plant of very ancient civilization and the spice has long been used in Asia. It is also one of the earliest known spices in Europe and is still in large demand.

Botany

Ginger belongs to the family Zingiberaceae and the species *Zingiber officinale* L. It is a slender perennial herb, upto 1 m tall, with robust branched rhizome bearing leafy shoots close together. Rhizome is thick, laterally compressed, palmately branched with small distichous scales and fine fibrous roots. Leafy shoots annual, erect, formed of long leaf sheaths, bearing 8-12 distichous leaves, lamina sessile, linear, lanceolate; ligule 5 mm long, glabrous and bilobbed; inflorescence arises direct from rootstock, spiciform, 15-25 cm long, spike cylindrical, conelike, bracts appressed, ovate or elliptic, one flower produced in the axil of each bract; calyx thin, tubular, 3-toothed, corolla tube 2-2.5 cm long with 3 yellowish lobes; filament of stamen short and broad, anther connective prolonged into a slender curved beak-like appendage; stigma protruding, just below the apex of the appendage; ovary 3-locular with many ovules per locule; fruits seldom produced, thin walled, 3-valved capsule with small black arillate seeds.

Agrotechnology

The plant requires a warm and humid climate. It thrives well from mean sea level to 1500 m. A well distributed rainfall of 1500-3000 mm during the growing season and dry spells during land preparation and harvesting are congenial. It prefers a rich soil with high humus content. Being an exhausting crop, ginger is not cultivated continuously in the same field but shifting cultivation or crop rotation is practised. The crop cannot withstand waterlogging and hence soils with good drainage are preferred for its cultivation.

Ginger is propagated vegetatively. The seed rhizome is 2.5-5 cm long having at least one good bud. They are preserved in covered pits. Smoking of seed rhizome is also practised to enhance germination

and ward off pests and diseases. Several clones have been recognized which differ in the fibre content of the rhizomes and yields. Rhizomes with less fibre which varies from 1.7-9.0% have a higher demand. Varieties preferred for green ginger are' Rio-de Janeiro', 'China' and 'Wyanad local' and for dry ginger are 'Maran', 'Wyanad', 'Manantody' and 'Valluvanad' (Kannan and Nair, 1965a). In Taiwan 'Ta-Kuang' and 'Chu-chiang' are cultivated. Land is prepared during April-May. A good tilth is required in order to produce good shaped rhizomes in hard soils they are often malformed. Rhizome seeds at the rate of 1000-1500 kg/ha are planted on raised beds at 20-30 cm spacing and 5-10 cm deep. Ginger benefits greatly from the application of organic manures. 25-30 tonnes/ha of cattle manure or compost is applied at planting. Fertilizers are applied at 75:50:50 kg N, P_2O_5 and K_2O/ha. Full dose of P and half of K may be applied as basal dose. Half dose of N may be applied 2 months after planting and the remaining quantity of N and K may be applied 4 months after planting . Mulching is an essential operation for high yield. Application of leaf mulch during planting and after each topdressing followed by earthing up, using a total of 20 tonnes of green leaves/ha favourably modifies the soil physico-chemical environment resulting in increased availability of nutrients and also controls the weeds. Irrigation is to be given when rainfall is limited . Rootknot nematode (*Meloidogyne incognita*) and shoot borer (*Dichocrosis punctiferalis*) attack the crop. Leaf spot caused by *Colletotrichum zingiberis* and *Phyllosticta zingiberi*, rhizome soft rot caused by *Pythium aphanidermatum* and bacterial wilt caused by *Pseudomonas solanacearum* are the common diseases of ginger.

For vegetable and preserved ginger, the crop can be harvested from 6 months. For making dry ginger, harvesting is done during December-January, 8-9 months after planting when the leaves become yellow and shoots start lodging. The yields vary greatly from 20-30 tonnes/ha fresh ginger which produces 20-30% of dried ginger. Yields as high as 40 tonnes/ha have been produced by irrigated crops.

Postharvest technology

For the production of dried ginger, the rhizomes are cleaned of dirt and roots and washed in water, carefully scraped and dried in the sun for 5-6 days. The scraped or peeled ginger is known as *uncoated ginger* and that with the epidermis still attached as *coated ginger*. The rhizomes are sometimes bleached by sulfur fumes or lime water. The dried rhizomes may be powdered to produce ground ginger. In the preparation of preserved ginger the rhizomes may be stored in brine until processed by controlled heat, cooking in syrup. Large light coloured brittle rhizomes with good aroma and little fibre fetch the highest price. The essential oil is generally obtained from unscraped powdered ginger. Steam distillation for 10-15 hours yields 1.0-2.7% oil. Ginger oleoresin is obtained by solvent extraction of powdered, dried ginger. The average yield is 4.5-6.5%. The oleoresin possesses the full aroma, flavours and pungency of ginger. It contains 20-25% essential oil and 25-30% pungent principles (Lewis, 1972).

Physico-chemical properties of oil The essential oil is a pale yellow liquid with a warm spicy sweet strongly aromatic odour and sharp pungent flavour. The oil has the following properties (CSIR, 1953).

Specific gravity at 30 C 0.868-0.880
Optical rotation at 20 C -28 to -45
Refractive index at 30 C 1.4840-1.4894
Saponification value 20

Fresh ginger contains approximately water 80%, protein 2.3%, fat 1%, carbohydrate 12.3%, fibre 2.4% and ash 1-2%. Dried ginger contains about 10% moisture and 1-3% of volatile oil of which the chief constituent is a sesquiterpene, called zingiberene ($C_{15}H_{24}$). The pungent principle of ginger is zingerone ($C_{11}H_{14}O_3$) which is present in the oleoresin. The essential oil contains approximately -pinene 0.4%, camphene 1.1%, ß-pinene 0.2%, myrcene 0.1%, limonene 1.2%, 1,8-cineole 1.3%, ß-phellandrene 1.3%, p-cymene 0.1%, methyl heptanone 0.1%, nonanal 0.1%, decanal 0.2%, neral 0.8%, geraniol 1.4%, 2-nonanol 0.2%, linalool 1.3%, bornyl acetate 0.1%, d-borneol 2.2%, geraniol 0.1%, -selinene 1.4%, ß-elemene 1.0%, ß-zingiberene 35.6%, ß-bisabolene 0.2%, arcurcume 17.0% and ß-farnesene 9.8% (Krishnamurthy *et al*, 1970; Kami *et al*, 1972; Akhila and Tewari, 1984).

17. KACHOLAM Kaempferia galanga Zingiberaceae

Importance

Kacholam, also known as *Sugandhavacha, Chandramulika or sidhul* is a rhizomatous perennial plant, the rhizomes of which yield an essential oil. The oil is utilized in the manufacture of perfumes and in curry flavouring. It is also employed in cosmetics, mouth washes, hair tonics and toiletries. The pungent, hot, sharp, bitter and aromatic rhizomes find an important place in indigenous medicine as stimulant, expectorant, diuretic and carminative. It promotes digestion and cures skin diseases,piles, phantom tumors, coughs, oedema, fever, epilepsy, spleenic disorders, wounds, asthma and rheumatism. The rhizomes are

used for protecting clothes against insects and are eaten along with betel and arecanuts as a masticatory. The rhizomes and leaves are attached to neck laces and added to bath water for perfume.

Origin and distribution.

The plant is supposed to have been originated in East Asia, most probably in Burma. It is widely distributed in Asia, Africa and Australia. It is grown in India, Burma, China, Nigeria, Mexico and other neighbouring countries. In India it is cultivated mainly in Kerala, Karnataka, Tamil Nadu and West Bengal.

Botany

Kacholam *Kaempferia galanga* L. belongs to the family Zingiberaceae. *Kaempferia sessilis* Koenig, *K. plantaginifolia* Salisb. and *Alpinia sessilis* Koenig, are its synonyms. It is a pentaploid with x=11.

The plant is a stemless perennial herb with tuberous, aromatic rootstock having fleshy cylindrical nonaromatic root fibres. Leaves are round to ovate, deltoid, acuminate, 10-12 ribbed, 6-12 cm long, 4.5-9.0 cm wide, horizontally spreading; inflorescence scape with 6-12 flowers, figatious, fragrant, open successively and seldom set fruits.

Agrotechnology

Kaempferia galanga requires a warm humid climate. It thrives well upto an elevation of 1500 m. A well distributed annual rainfall of 1500-2500 mm during the growing period and dry spells during land preparation and harvesting are ideal. Rich loamy soil with good drainage is suitable for the cultivation of the crop. Laterite soil with heavy application of organic matter is also suited. It cannot stand waterlogging.

The plant is propagated by division of rhizomes. For planting mother rhizomes are better than finger rhizomes (Rajagopalan and Gopalakrishnan, 1985). Seed rhizomes are stored in cool dry place or in pits dug under shade. Smoking of rhizomes prior to planting is beneficial for better germination and establishment of sprouts. With the receipt of pre-monsoon showers in May land is ploughed and beds of 1-2 m width, 25 cm height and convenient length are taken and sprouted seeds are planted at 15-30 cm spacing. Seed rate is 500-750 kg/ha. Kacholam responds well to organic manuring. Application of 30 tonnes/ha of FYM or compost and mulching with leaves or straw at 15-20 tonnes/ha are recommended. Application of 50-75 kg each of N, P_2O_5 and K_2O in 2-3 splits is beneficial (Rajagopalan *et al*, 1989). Weeding is to be done 45 and 90 days after planting which is to be followed by fertilizer application and earthing up. It is a shade loving plant. Growth is better in partial shade offering great potential for its cultivation as intercrop in coconut, arecanut, banana and other widely spaced perennial crops.

Insect pests are not commonly reported in this crop. Leaf spot and rhizome rot diseases occur particularly during the rainy months which could be controlled by drenching and spraying with 1% Bordeaux mixture.

The crop is harvested 6-7 months after planting when the leaves start drying up. The rhizomes are dug out, cleaned and washed to remove the adhering soil particles.

Postharvest technology

The clean rhizomes are sliced to circular pieces of uniform size and dried for 3-5 days. The sliced and dried rhizomes are marketed.

The yield, on an average, is 5-8 tonnes/ha of fresh rhizomes which on drying yields 1.5-2 tonnes/ha of dry rhizomes. The driage varies from 23 to 28%. The sliced and dried rhizomes on steam distillation for 3-5 hours yield 2-3% of essential oil. Frothing is noticed during distillation due to the presence of starch in the rhizome.

Physico-chemical properties of oil

The tuberous rhizome of kacholam contains an alkaloid, starch, gum, fatty matter with a fragrant liquid essential oil and a solid white crystalline substance and mineral matter. The rhizome possesses a camphoraceous odour with somewhat bitter aromatic taste resembling that of *Hedychium spicatum*. The essential oil has the following properties.

Specific gravity at 30 C	0.8792-0.8914
Optical rotation at 30 C	-2 36' to -4 30'
Refractive index at 30 C	1.4173 to 1.4855
Acid value	0.5-1.3
Saponification value	99.5-109.0

The essential oil is reported to contain over 54 components of which the major constituents are ethyl-trans-p-methoxy, cinnamate 16.5%, pentadecane 9%, 1,8-cineole 5.7%, -carene 3.3%, and borneol 2.7%. Terpenoid constituents amounted to 16.4% (Nerle and Torne,1984; Anon,1991; Wong *et al*, 1992).

VANILLA *Vanilla fragrance* *Orchidaceae*

Importance

Vanilla is a herbaceous orchid climber found in the tropics of both hemispheres. Its fruits, commercially known as beans, become aromatic on curing due to the development of an aromatic principle called vanillin. Vanilla is an important spice. It has been widely used by Aztecs both as a drink and as tributes to emperors and kings. Vanilla beans and derivatives are important in food flavouring, especially, confectionery, ice-creams, liquors and baked goods. Vanilla flavoured ice-creams, custards, milk shakes, cakes, puddings, chocolates, beverages and different confectioneries are very popular in the market. Extracts and tinctures are prepared from beans. The usual concentration of vanilla extract in various items are: non-alcoholic beverages 200 ppm, ice-cream 3000 ppm, candy 4000 ppm, baked goods 1900 ppm, icings 2000-4800 ppm, syrups 10-50 ppm and toppings 2700 ppm (Atal and Kapur, 1982). Vanilla essence made from extracts of the pod or vanilla sugar (castor sugar placed in a closed jar together with a vanilla pod thereby absorbing its aroma) is used for flavouring. Vanilla is also used in perfumery and to a smaller extent in medicine. Nowadays, synthetic vanillin, which is cheaper and more convenient, is often used instead of vanilla. The aroma of genuine vanilla, however, cannot be matched because it is the result of the natural balance of vanillin and small quantities of other aromatic components contained in the pods (Radhakrishnan *et al*, 1991; Kybal and Kaplicka, 1995; De, 1996).

Origin and Distribution

Vanilla is a native of the Atlantic coast from Mexico to Brazil. It was known to the Aztecs, who used it to flavour cocoa long before the discovery of America by Europeans. In the wild, its twining stems climb high onto the tops of trees, anchoring themselves by means of aerial roots. It is also raised in Mexico, India and other tropical countries for it can be pollinated by artificial means (Kybal and Kaplicka, 1995). It is grown on plantation scale in Java, Mauritius, Madagascar, Tahiti, Seychelles, Zanzibar, Brazil and Jamaica and other islands of the West Indies. Malagasy Republic grows 70-80% of the world's crop of vanilla followed by Reunion. The world production is reported to be 2000-3000 tonnes/annum. USA is the largest importer followed by France and West Germany. Vanilla was introduced to India in 1835, presumably by the British East India Company at Kuttalam. Its cultivation is now restricted to Wynad of Kerala and Nilgiris of Tamil Nadu (De, 1996; Purseglove, 1975; Kumar *et al*, 1997).

Botany

Vanilla is an orchid, belonging to the family Orchidaceae. The genus *Vanilla* comprises over 100 species of stout, scandant, terrestrial or epiphytic herbs. But only three are important source of vanillin. They are:

1. *Vanilla frangrance* (Salisb.) Ames syn. *V. Planifolia* Andrews. This produces short thick pods.
2. *Vanilla pompona* Schiede (F.). It is known as West Indian vanilla. It is cultivated in Trinidad and Central America. It has the largest pods.
3. *V. tahitensis* J.W. Moore (F & B). It is called Tahitian Vanilla. It is found in Hawaii. It is fleshy, herbaceous, perennial vine.

Vanilla fragrance is the most popular and commercially cultivated species. It is a climber grown as wild in the forests, aerial roots are seen in nods by means of which the plant clings and climbs. Leaves are opposite, sessile, oblong and 10-23 cm long. Racemose inflorescences emerge from leaf axils about 8 cm long, generally unbranched bearing 20-25 flowers. It takes 50-60 days from bud initiation to the appearance of fully developed flowers. Synchronous flowering is lacking. Each flower remains open for a single day. Blooming period continues for 14-30 days in an inflorescence. In a vine 7-15 inflorescences are produced. Flowers are large pale green, bisexual and zygomorphic. Sepals and petals look alike and are referred to as perianth. The lower petal is short, broad and is modified into a labellum which envelopes a central structure called the column (gynostemium). The column bears a single stamen with two pollen masses (pollinia) covered by a hood. Below it is the stigma covered by a flap like rostellum, which prevents natural pollination. Ovary is slender and 4-5 cm long. Flowers bloom from the base upward. Pollen fertility is 72-87%. Flowers are pollinated through melapone bees and humming birds. Over 70% of flowers develop into fruits. Fruits are capsules or pods and commercially known as beans. They are pendulous, cylindrical, three angled and up to 21cm long. Fruits mature in 10-12 months. Seeds are black in colour (De, 1996; Kuruvilla *et al*, 1996).

Agrotechnology

Vanilla prefers humid moist tropical climate having temperature range of 25-32 ^{o}C. It grows well at an elevation of 700 – 1500 m with an annual rain fall of 2500 mm well distributed for a period of 9 months and a dry period for 3 months. It is adaptable to a wide range of soil types provided there is plenty of organic matter and proper drainage. It prefers a pH range of 6-6.5.

Vanilla is generally propagated by stem cuttings. Vines of 60-120 cm long are selected as planting material. The vines are coiled and buried inside the soil. Plants raised from lengthy cuttings commence early flowering whereas the plants raised from short cuttings take three to four years for bearing. Therefore, cutting with less than 5-6 internodes and 60 cm length may not be used for planting. As the availability of planting materials is a limiting factor, recently tissue cultured planting materials are made available by some private companies and spices board.

Vanilla requires support for growing. It flourishes well in partial shade. Vines may be trained on trellises or trees having low branching with a rough and small leaves. Trees like *Jatropha, Plumeria alba, Casuarina equisetifolia, Erythrina, Glyricida, Bauhinia* or Silver oak are now used for this purpose. The supports are planted at a spacing 2.5 to 3.0 m between rows and 2m within the row making a population of 1600 to 2000 per hectare. If limb cuttings are used for planting, they should have roughly 4-6 cm diameter and about 1.5 to 2 m length. The supporting saplings may be established 6 months before planting vanilla cutting. Vanilla is generally planted at a time when there is a slight wetting weather. While planting the cuttings, 3-4 basal leaves in the cutting should be removed and this defoliated portion is laid on the loose soil and covered with a thin layer of about 2-3 cm soil. The growing end is gently tied to the support for climbing by aerial roots. Artificial shade with any suitable material may be provided to the cuttings. It makes 4-8 weeks for the cutting to strike roots and to show initial signs of growth.

Once established, the vines have to be given constant attention. Any operation done in the plantation should not disturb the roots, which are mainly confined to the mulch and surface layer of the soil. When the support is grown up they are pruned early to introduce branching so as to give more shade and protection to the growing vines. If the trees are evergreen types they are to be pruned before the commencement of heavy rain to allow in more sunlight. The pruned vegetation is chopped and applied as mulch in the plantation. The decomposed mulch is the main source nutrients to vanilla. Animal sources of manure are not generally applied. Annually, vine may be fed with 40 to 60 g N, 20 to 30 g P_2O_5 and 60-100g K_2O. The above quantity may be given in two or three splits for efficient uptake. Part of the above fertilizers may also give through foliar spray since they respond well to it. If the vine is permitted to grow up on tree, it will rarely blossom, so long as it is growing upward. Hence the vines are allowed to grow up to 1.50 m and then tied horizontally on the branch of support and later coiled round them. This induces more flower production in this portion of the vine.

Anthracnose (*Calospora vanillae*) is the most serious disease. It attacks almost all parts. Root rot, *Fusarium betatis* var. *vanillae* is a limiting factor in certain areas. They can be controlled by spraying suitable fungicides. The bug, *Trioza litseae* is the major pest attacking the buds and flowers of vanilla, which is controlled by any systemic insecticide.

The vines commence flowering in the second or third year depending on the length of cutting used. Due to the peculiar structure of the flower described earlier artificial pollination by hand is the rule of fruit setting. The procedure involved is simple. It is done easily by children and women. Using a pointed bamboo splinter or pin anther is pressed against stigma with the help of thumb and thus smearing the pollen over it. Generally, 85-100% success is obtained by hand pollination. The stigma is highly receptive during morning hours. The ideal time for pollination is 6 am to 1 pm. Unfertilized flowers fall off within two or three days. Normally 5-6 flowers per inflorescence and a total of not more than 10-12 inflorescence per vine are pollinated. The excess flower buds are nipped off to permit the development of good pods. Pods take six weeks to attain full size from fertilization and 4 to 10 months to reach full maturity depending upon the locations. When immature, the bean is dark green in colour, but when ripe yellowing commences from its distal end. This is the optimum time for harvesting the bean. If left on the vine the bean turns yellow on the remaining portion and start splitting, giving out a small quantity of oil, reddish brown in colour, called *the balsam of vanilla*. Eventually they become dry, brittle and finally become scentless.

The yield of vanilla varies depending upon the age of vines and the method of cultivation. Normally it starts yielding from the third year and the yield goes on increasing till the seventh or eighth years. Thereafter, it slowly declines till the vines are replanted after 14 to 15 years. Under reasonable level of management a middle aged plantation may yield 300-400 kg cured beans per hectare (George, 1981; Sasikumar *et al*, 1992; KAU, 1996; Kumar *et al*, 1997).

Postharvest Technology

Artificial methods are employed to cure vanilla. The aroma principle, vanillin is developed as a result of the enzyme (Beta Glucosidase) action on the glucosides contained in beans during the process of curing. Basically any curing method involves the following four stages.

1. Killing the vegetative life of the beans to allow the onset of enzymatic reaction.
2. Raising temperature to promote this action and to achieve rapid drying to prevent harmful fermentation.
3. Slow drying for the development of different fragrant substances
4. Conditioning the product by storing for few months.

The following are some of the curing methods

1) Peruvian process: Curing is done by hot water. In this process the pods are dipped in boiling water. The ends are tied and hung in the open. They are allowed to dry for 20 days. Later they are coated with castor oil and afterwards tied up in bundles.
2) Guiana process: The pods are collected and dried in the sun till they shrivel. Later they are wiped and rubbed with olive oil. The ends are tied up to prevent splitting and then bundled.
3) Mexican process: The harvested pods are kept under shade till they shrivel. Then they are subjected to sweating. This operation is carried for 2 days depending on the weather conditions. In warm weather, pods are spread over blankets and exposed to the sun. During midday the blanket is covered over and bundles are left in the open for rest of the day. They are wrapped in blanket in the night to maintain fermentation and sweating. The pods would be wrapped in blankets when they are hot to touch. This process is repeated for 7-12 days till they become dark brown in colour, soft and flexible. They are packed in tins and sealed. The Mexican process yields 4.15 to 4.40 % of vanillin content.

When the weather is cloudy, the pods are bundled in bales and wrapped with woolen cloth covered with banana leaves. They are subject to radiation of heat by maintaining the temperature of air-oven at 50^{o}C for 24 hours. Thereafter, they are dried to change the colour. Then they are spread in dry place and finally packed and sent to the market.

The most desirable beans will be 18 to 25 cm long, dark brown, highly aromatic, fleshy, free from mould, insects and blemishes. They are supple and small crystals of fragrant vanillin are visible on the surface. There are three grades, viz. Grade-1, which includes whole beans of minimum 11 cm length, and grade 2 and 3 will have a minimum of 8 cm length. Vanilla must be stored in air tight wrapper or container to preserve its aroma (Kybal and Kaplicka, 1995). One kilogram of processed produce is obtained from 240-260 beans. The moisture content of the beans after processing is 24%. The vanillin content is 2.41% during the curing process, the enzyme Beta glucosidase hydrolyses the glucoside into vanillin (Gopinath, 1994; KAU, 1996; Kumar *et al*, 1997).

The beans are cut into small pieces and are extracted with dilute alcohol which the gives the flavouring extract or vanilla essence. Vanilla is employed for food flavouring either in the powdered state or in the form of solvent extract. The various types of vanilla products employed in flavouring applications are:

a) Vanilla extract: This is a hydro alcoholic solution containing the extracted aroma and flavour. Principles of vanilla beans and may also contains added sweetening/thickening agents like sugar and glycerin. Vanilla extract may be prepared by direct extraction (maceration) or by dilution of concentrated vanilla extract or vanilla flavouring or vanilla oleoresin.
b) Vanilla flavouring: This is similar to vanilla extract but contains less than 35% ethyl alcohol by volume.
c) Vanilla tincture: This is prepared by maceration from one part vanilla beans by weight to ten parts of aqueous alcohol by volume. It contains added sugar. It differs from other two products mentioned above, in respect of its alcohol percentage, which is around 35%. It is mainly used for pharmaceutical purposes.

d) Vanilla Oleoresin: This is a semi solid concentrate obtained by complete removal of its solvent from a vanilla extract. Aqueous iso-propanol is frequently used instead of ethyl alcohol. Owing to unavoidable evaporation loses during solvent stripping step, this product is inferior in aroma.

e) Vanilla powder: This may be pure powered vanilla but is more usually a mixture of vanilla powder or vanilla Ole with sugar, food starch or gum acacia. The vanilla beans are grounded to give powder. Besides these, for perfumery applications a number of advent extracted products are employed, among which vanilla perfumery tincture may contain 90% alcohol. However due to high cost and known availability of natural vanillin most of the consuming countries including India now depends on low priced synthetic vanillin of very poor quality for making vanilla based products. As the world today is searching for harmless products there exists an urgent need to produce more natural vanillin for internal consumption and export (De, 1996).

Physico-chemical properties

The cured vanilla beans contain vanillin, organic acids, fixed oil, wax, gum, resins, tannins, pigments, sugar, cellulose and minerals. Vanillin content of cured seed is about 2.41%. The cured beans contain very little steam volatile (essential) oil. The fat content is 4.5 – 15%. The major components of fatty acids have been identified as oleic and palmitic acids. Sugar content is 7 – 20%, glucose and fructose being the major components. The essential oil contains aromatic carbonyls, alcohols, acids and esters. The vanillin content of a conventional, single fold vanillin extract, containing the soluble extractives of 1 part of beans by weight to 10 parts of solvent by volume is usually around 0.2%. The composition of all the three species of vanilla are similar in nature and may vary in percentage of their constituents (Atal and Kapur, 1992).

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C. AROMATIC TREES

1. SANDALWOOD *Santalum album* *Santalaceae*

Importance

The term sandalwood, in the world market, is frequently used for a variety of woods that yield oils similar in smell to that of the *East Indian Sandalwood* which is the *true sandalwood*. The East Indian Sandalwood is a small evergreen tree with slender drooping branches. The world famous *East Indian Sandalwood Oil* is extracted from the strongly scented heartwood of this tree. Sandalwood oil is used primarily in perfumery because of its outstanding fixative properties. It is used in preparing all types of perfume compositions especially Indian attars like Hina, Gulab, Kewda and Jasmine in which the natural essential oils from distillate of floral distillation is absorbed in sandalwood oil. With neem oil, it is used as contraceptive. It is used for healing wounds and blisters caused by the smallpox vaccination. Sandalwood is also one of the finest woods for carving. The wood is smooth with uniform fibres. Saw dust from heartwood is mostly used in incense for scenting cloths and cupboards.

Origin and distribution

Sandalwood tree is indigenous to the mountain districts of South India and Malayan Archipelago. Some plant historians believe that the tree is indigenous to South East Asia (Timor Islands) and was introduced into India by traders possibly before the Christian Era. In India, sandal is spread over 480 km from Dharwar in the north to the Nilgiris in the south and 400 km from Coorg in the west to Kuppam (Andhra Pradesh) in the east. About 90% of the world production of sandalwood oil is from India.

Botany

Sandalwood is a small evergreen tree growing to 18 m in height and 2.4 m in girth, with slender drooping branches. The sapwood is white and odourless while the heartwood is yellowish brown and strongly scented. Leaves 3.5-4 cm, elliptic, lanceolate glabrous and petiolate; inflorescence terminal or axillary, paniculate cyme; flowers bisexual, many, brownish purple; perianth campanulate; stamens 4, exerted, alternating with 4 rounded obtuse scales; fruit drupe, globose, 1.25 cm in diameter, purple black, endocarp hard and ribbed. Sandal tree is a plant parasite and its roots thrive on many types of host plants such as *Cassia siamea, Pongamia pinnata, Lantana acuminata, Cajanus cajan,* etc.

Agrotechnology

Warm tropical climate is best suited to sandalwood tree. It grows best between altitudes of 600 m and 1350 m above MSL though it may grow between 360 m and 1850 m altitude. Annual rainfall of 600-1600 mm is ideal for its growth. More than 1800 mm of rain is not very conducive to its growth. It grows well on laterite soils on the slopes of hills exposed to the sun.

The plant is propagated through seeds. Barring a few tissue culture attempts, vegetative propagation has not been very successful. Seeds are obtained from plants over 20 years old. Fresh seeds obtained from October fruiting are depulped, dried and sown on seed beds. Gibberellic acid is used to bring down the dormancy period and to induce quick and uniform germination. After germination, seeds are put in polybags of size 15 cm x 25 cm. A host plant is sown in the polybag when the seedling reaches 15 cm in height. The optimum stage for planting is when the seedlings are 25-50 cm high and the basal portion becomes darker. Pits of 30-50 cm cube are dug and the sandal seedlings along with the host seedlings are planted from May to October at 2.5-4.0 m spacing. Weeds are removed as and when necessary. In case the sandalwood seedlings are overtopped by the host plant the host is lopped to provide sufficient light to the seedlings. The heartwood formation is at its peak when the trees are 30-60 years and the trees attain a girth of 40-60 cm. Sandal spike disease is reported to be caused by mycoplasma-like organisms which causes severe reduction in leaf size and shortens internodes. As the roots are richest in oil, sandalwood tree is harvested by uprooting and not by cutting to avoid the loss of root system.

Postharvest technology

Sandalwood oil is obtained chiefly by steam distillation of the powdered wood soaked in water for about 48 hours. Distillation is carried out at a steam pressure of 1.4-2.8 kg/cm^2 for 48-72 hours. The oil content is about 10% in the roots and 1.5-2% in the chips which constitute a mixture of heartwood and sapwood. The yield from the heartwood varies with maturity and locality.

Physico-chemical properties of oil

Sandalwood oil has been reported to have a persistent woody odour and the following properties.

Specific gravity at 20 C	0.971-0.983
Optical rotation at 20 C	-15 58' to -20
Refractive index at 20 C	1.505 to 1.510
Alcohol calculated as santalol	more than 90%

Acetate calculated as santalyl acetate more than 20%
Solubility in 90% alcohol more than 1 vol.
Solubility in 70% alcohol 5 vol.

The major constituents of sandalwood oil are reported to be -santalol 60%, ß-santalol 30%, and ß santalene, and ß curcumene, ß-farnesene, santene, santenol, santenone, teresantalol, teresantalic acid, santalic acid, nor-tricyclockasantalol, borneol and isovaleraldehyde (Nigam *et al*, 1983).

2. EUCALYPTUS Eucalyptus spp. Myrtaceae

Importance

Eucalyptus is an essential oil yielding tree which has perfumery, industrial and medicinal uses. The essential oil is used in soap and cosmetic industries. It is an effective substitute for Java citronella oil and a source of citronellal for the manufacture of citronellol, hydroxy citronellal and menthol. The oil is used in germicides and disinfectants to improve the odour. It is used as an antiseptic especially in the treatment of infections of the upper respiratory tract and in certain types of skin diseases. It is used as a stimulating expectorant in chronic bronchitis and as a vermifuge against hookworm. It is internally administered or inhaled with steam for asthma and respiratory disorders. Eucalyptus wood is used as mine props, railway sleepers, for paper manufacture and in house construction (Penfold and Wallis, 1961).

Origin and distribution

Eucalyptus plant is indigenous to Australia. It is widely distributed over tropical and subtropical countries in Asia, Africa and America. It was introduced in 1948 at the Horticultural Research station, Ambalavayal, Kerala, India. It is grown in the states of Kerala, Tamil Nadu, Karnataka, Meghalaya and Uttar Pradesh. Annual world production of eucalyptus oil is around 2000 tonnes.

Botany

The genus *Eucalyptus*, belonging to the family Myrtaceae, comprises more than 700 species. Some of them possesses medicinal value or volatile oils having fragrances varying from camphor, thymol, peppermint to rose and lemongrass. *Eucalyptus citriodora* Hook. and *E. globulus* Labill. are the most common species. *E. citriodora* commonly known as *citron (lemon) scented gum or spotted gum* is a tall, graceful tree, 25-40 m high, with a crown of leaves and branches at the top. Bark smooth, white to pinkish. distinct cotyledonary, seedling, juvenile, intermediate and adult leaves are observed at various stages of the plant. Adult leaves alternate, lanceolate; inflorescence usually axillary, corymbose panicle, umbels 3-5 flowered on terete 5-7 mm long peduncles; flowers pedicellate; calyx tube hemispherical or cylindrical; anthers adnate; fruits ovoid, truncate, contracted at the edge, rim thin and valves opening downwards (Kapur *et al*, 1967).

E. globulus grows to a height of 55 m. Bark blue-grey; inflorescence axillary, usually solitary, but occasionally in 3-flowered umbels on a very short or rudimentary peduncle; flowers sessile, operculum, flattened, hemispherical; fruit sessile, globular to broadly conical, 4-ribbed and warty.

Agrotechnolgy

Eucalyptus plants prefer tropical and subtropical climate but grow satisfactorily in temperate regions as well. They are frost sensitive in early stages. *E. citriodora* grows in plains upto 600 m while *E. globulus* prefers an elevation of 1300-2700 m. The former grows well on poor gravelly soils in rainfed areas but can be grown on any soil whereas the latter is chiefly grown on moisture rich loamy soils (Kannan, 1958).

The plant is propagated by seeds only. Seeds can be sown directly in the field or seedlings can be raised in the nursery during February-September. Germination takes upto a fortnight depending upon atmospheric humidity and temperature. Cold stored seeds germinate in 2-4 days. Seedlings are maintained in the nursery for 2-3 months until they attain a height of 20-30 cm when they are transplanted to the mainfield at 70-100 cm spacing. 10-12 tonnes/ha of organic manure and 120:60:60 kg/ha of N, P_2O_5 and K_2O are applied. Weeding is required during the initial period until the plants are established well (Muralidharan and Nair, 1974).

Seedlings, leaves and stems of *E. citriodora* are severely damaged by blight caused by *Cylindrocladium scoparium* Morgan. Drying and defoliation are caused by *Physalospora latitans* Sace. *Fusarium orthoceros* attacks the seedlings at the hypocotyl level. These fungal diseases can be controlled by spraying and drenching with 1% Bordeaux mixture or copper oxichloride.

Harvesting is done when the weather is clear and oil content in leaves is maximum. Accordingly, harvesting leaves during February, April, July and October has been recommended (Kannan and Nair, 1965b; Nair *et al*, 1983). In Kerala, harvesting twice a year, in May and November, is practised. Plants can be pollarded to promote vigorous sprouting of side shoots. Fresh shoots sprout in about four weeks after

pollarding, which are ready for harvesting after 4-5 months. First pruning is done at 30-45 cm above ground and the subsequent ones at 75-90 cm above ground.

Postharvest technology

The harvested leaves are steam distilled for 2-3 hours soon after harvesting to avoid loss of oil through evaporation as well as deterioration of its quality during storage. Though oil recoveries as high as 5% has been reported, 1-2% yield is frequently achieved in *E. citriodora*. The highest oil yield is obtained from the top leaves. This oil has better solubility in alcohol and higher cineole content than the oil obtained from the lower leaves. A 6-8 years old tree yields 30-60 kg of leaves/year which gives 0.5-1 kg of oil.

Physico-chemical properties of oil

E. citriodora oil is colourless to light yellow with a grassy verbena odour. The oil has been reported to have the following properties.

Specific gravity at 15 C 0.8640-0.8770
Optical rotation -3 to +3
Refractive index at 20 C 1.4511-1.4570
Citronellal content 65-85%
Ester value 12-60
Ester value after acetylation 230-292
Solubility in 70% alcohol 1.3-1.5 vol.

The approximate composition of the oil is -pinene 0.1-1.9%, ß-pinene 0.4-1.9%, myrcene 0.1-0.6%, limonene 0.4-7.1%, 1,8 cineole 1.1-17.9%, p-cymene 0.3-0.9%, -terpinene 0.2-0.9%, terpinolene 0.1-0.8%, citronellal 26.7-82.6%, linalool 0.3-0.9%, iso-pulegol 4.7-29.8%, citronellol 5.1-13.4%, citronellyl acetate 0.41-0.7% and caryophyllene 0.3-3.9% (Nair, 1974).

E. globulus oil is colourless to light yellow with camphoraceous odour and the following properties.

Specific gravity at 20 C 0.9065-0.9155 Optical rotation -9 39' to +5 27'
Refractive index at 20 C 1.463-1.466
Acid value 0.18-1.04
Saponification value 8.90-12.0 Saponification value after acetylation 17.00-21.68

The major constituents of the oil are cineole (60-70%) caryophyllene, camphene, sabinene, myrcene, p-menthane, , ß and -terpinene, fenchone, and ß-thujone, citral, verbenone, iso-amyl alcohol, trans-pino carveol, borneol, myrtenol, eudesmol, thymol, bornyl acetate, caproic acid, piperitone and globulol (Nishimura and Clavin, 1979; Tewari and Akhila, 1985).

3. CLOVE Eugenia caryophyllus Myrtaceae

Importance

Clove is a small evergreen tree valued for spice and essential oils. In trade, cloves are the dried unopened flower buds of the plant which have been used in the Orient for over 2000 years as a spice, to check tooth decay and to counter halitosis. They are used as a table spice, in the preparation of curry powders, to flavour the betel quid in *panmasalas* and to season sausages and puddings. Clove buds, stems and leaves on steam distillation yield essential oils which are used in the manufacture of perfumes, soaps, in flavouring, medicine, dentistry and as a clearing agent in microscopy. The major constituent, eugenol is converted into iso-eugenol and a very high grade vanillin. In medicine, cloves are stimulative, antispasmodic and carminative. In dentistry, eugenol in combination with zinc oxide is used for temporary filling of cavities.

Origin and distribution

Clove plant is indigenous to Moluccas Islands in Indonesia. It is widely grown in Zanzibar, Mauritius, Madagascar, Reunion Islands, Seychelles, Sumatra, Indonesia, Sri Lanka, Brazil and India. In India, it is grown in Kerala and Tamil Nadu. Clove bud oil which has the maximum quality and price, is largely produced in Madagascar, Sri Lanka, Brazil and Indonesia. The annual production is around 50 tonnes. Stem oil is mainly produced in Zanzibar and Tanzania. Leaf oil is produced in Indonesia and Madagascar (Tidbury, 1949).

Botany

Clove plant *Eugenia caryophllus* (Sprengel) Bullock & Harrison belongs to the family Myrtaceae. *Caryophllus aromaticus* L., *Eugenia aromatica* Kuntze, *Eugenia caryophyllata* Thumb., and *Syzygium aromaticum* (L.) Merr. & Perr. are often used synonymously.

It is a small evergreen tree growing to a height of 15 m, conical in shape when young, later becoming cylindrical. Leaves are simple, opposite, exstipulate, glabrous and aromatic, petiole swollen, lamina

lanceolate; inflorescence terminal corymbose, trichotomous panicle; bracts and bracteoles narrow and acute; flowers bisexual with a fleshy hypanthium surmounted by sepals; calyx, 4-lobbed, fleshy, triangular; petals 4, imbricate, red tinged, rounded; stamens numerous, grouped in four; ovary 2-celled, multiovulate, inferior, embedded in the top of the hypanthium; fruits single seeded, oblong, fleshy, drupes, reddish purple in colour and are called *mother of cloves*. Flowers are visited by bees and are probably cross pollinated. Some botanists opine that the bisexual flowers and their structure ensure complete self-pollination.

Agrotechnology

Cloves grow best with insular, maritime climates in the tropics upto an elevation of 1000 m. Annual rainfall of 1500-3000 mm and a temperature of 25-32 C are ideal. Drier weather is desirable for harvesting and drying the produce. Well drained, deep, sandy, red or acid loams with high humus content are best suited. Waterlogging is fatal.

Cloves are propagated by seeds, though vegetative propagation through layering, approach grafting and budding has been met with occasional success. Fully ripened, freshly fallen fruits are collected, soaked in water and heaped under wet sacks for fermentation for 3 days. The seeds are then hulled with fingers, washed and sown in nursery at 15-20 cm spacing and watered regularly. Fresh seeds give a germination over 90%, but the seed viability diminishes sharply in storage. 1-1.5 years old seedlings can be transplanted to the mainfield at 6-7 m spacing in pits of 60-75 cm cube. Cattle manure or compost is applied at 15 kg/tree/year. A well grown tree, of 15 years or more, is applied with N, P_2O_5 and K_2O at 300:250:750 g/plant/year. Application of coconut meal, bone meal or fish meal at 2-5 kg/plant is beneficial. Irrigation is to be provided during summer months. Young plants are usually ring weeded. Mulching, partial shading and protection from heavy rains and winds are required during early stages of growth. Cloves can be intercropped in coconut, arecanut, nutmeg, coffee and banana plantations. Termites, the coccid-*Saissetia eugeniae* and shoot borer (*Sinoxylon* sp.) are the common pests of clove. Leaf spot, twig blight and flower bud shedding are caused by different fungal pathogens. Die back caused by *Cryptosporella eugeniae* and sudden death by *Valsa eugeniae* are other diseases of the plant. These diseases except, sudden death can be controlled by suitable fungicides.

The trees begin to flower in 6 years. Full bearing is achieved by about 20 years and the production continues for 80 years or more. Bearing between years shows much variation. Clove clusters are hand-picked when the buds reach full size and turn pink but before they open. They are spread thinly on mats and stirred frequently for uniform drying. Well dried cloves will snap cleanly with a sharp click across the thumb nail and weigh about one-third of the green weight. On an average, a clove tree yields 3.5-7.0 kg/year which depends upon the age, size and condition of the tree. Yields upto 80 kg/tree/year have also been recorded.

Postharvest technology

Various parts of the clove tree yield essential oil on distillation. The duration of distillation ranges from 8-24 hours depending upon the size of the still, nature and volume of steam and condition of cloves. Leaves and small twigs yield clove leaf oil. Clove stem oil is obtained from stems attached to the buds and flowers, whereas clove bud oil which has the highest quality and price is obtained from buds. The essential oil yield is 17-19% from clove buds, 6% from clove stems and 2-3% from clove leaves.

Physico-chemical properties of oil

The physico-chemical properties of clove oils obtained from various parts are reported to be as follows.

Property	Bud oil	Stem oil	Leaf oil
Specific gravity at 15 C	1.043-1.068	1.040-1.067	1.032-1.067
Refractive index at 20 C	1.529-1.537	1.531-1.538	1.533-1.539
Optical rotation	upto -1 35'	upto -1 30'	-0 49'to-1 53'
Solubility in 70% alcohol	1-2 vol	1-2 vol	1 volor more
Total phenol content	78-98%	83-95%	82-93%
Eugenol content	<85%	85-90%	85-90%
Eugenol acetate	>10%	<5%	<5%
Total sesquiterpene hydrocarbons	<5%	>5%	10%
Total oxygenated compounds (non phenolic)	<15%	5%	5%

Clove bud oil contains eugenol 80-90%, caryophellene 4-8%, -humulene 0.5%, -terpinyl acetate 0.1%, methyl eugenol 0.2%, humulene epoxide 0.2%, chavicol 0.3% and traces of several other compounds.

4. CAMPHOR Cinnamomum camphora Lauraceae

Importance

Camphor plant is an evergreen tree valued for the presence of camphor in its wood and leaves. Camphor is chiefly a pharmaceutical product though it is used in the preparation of artificial essential oils like lavender and lavendin. It is used as an incense and in balms of various kinds. It is employed as a masking agent in perfumery and sometimes used to achieve lift in perfume blends. Redistilled brown oil is used directly in soap perfumes for a masking effect. The oil is a source of safrole which is a starting material for the production of various perfumery chemicals.

Origin and distribution.

Camphor tree is a native of Japan, China and Taiwan. It is distributed over the tropical and subtropical countries of Asia, Africa and South America. It was introduced to India and is grown in Dehra Dun, Calcutta, Bangalore and the Nilgiris.

Botany

Camphor tree *Cinnamomum camphora* (L.) Presl. belongs to the family Lauraceae. It is a large handsome evergreen tree, 8-18 m tall. Leaves opposite or alternate, usually triple nerved, leathery, 5-7 cm long and aromatic. Leaves are shed every year during February-March, but simultaneously new leaves appear. Flowers small, bisexual, borne on axillary, lateral or sublateral cymes or panicles; perianth tube short, funnel shaped, enlarged in fruit, lobes 6, subequal, persistent and partly truncate; perfect stamens 9 or fewer with introse 4-celled anthers; ovary sessile, at the bottom of the perianth tube narrowed into thick style; fruit seated on the enlarged perianth tube.

Camphor is formed in the oil cells, distributed in all parts of the tree. These cells begin to form early in the growth of the plant organs and are filled with a yellow oil from which camphor is slowly deposited. The oil progressively becomes colourless and volatile and irregular masses of camphor appear. The formation of camphor is brought about by an enzyme present in the growing parts of the tree, particularly in the tissue within the cambium region. Each layer of wood, as it is formed, is enriched by camphor.

Agrotechnology

Camphor tree grows best at an altitude of 1350-1500 m with temperature not going below 33 C. In the Nilgiris it does well upto 2100 m above MSL. It withstands an annual rainfall of 1000 mm where it can be successfully cultivated. Fertile well drained sandy loam soils are best suited for the cultivation of camphor tree. Deeply
tilled clayey soils are also suitable, provided rendered porous by mixing leaf mould and sand supplemented with artificial fertilizers.

It is chiefly propagated through seeds and rarely through layers, branches, cuttings, root cuttings and root suckers. Fresh ripe fruits are collected either direct from the tree or soon after they fall. Removal of the pulpy seed coat and presoaking of the seeds in water for 24 hours enhances seed germination. Seeds are sown in nursery at a spacing of 6-8 cm in rows 25-30 cm apart and irrigated regularly. Seeds start germinating after 3 months of sowing. The nursery is maintained weed free. 12-16 months old seedlings are transplanted in the mainfield in 60 cm cube pits, 2-3 m apart. Application of organic manures and inorganic fertilizers has proved beneficial. Plants are trimmed to a height of 1.5-2 m and maintained as bushes to facilitate picking of leaves. Leaf blight disease in camphor is caused by *Glomerella singulata* which can be controlled by spraying difolatan and benlate. Leaves and twigs are harvested every year and distilled to produce camphor oil. Wood over 50 years of age are also used for distillation. Bushes are harvested 3-4 times a year.

Postharvest technology

Camphor oil is obtained by distilling leaves, twigs and wood. The crude camphor oil is separated in various fractions as white, brown and blue camphor oils. White camphor oil is generally not used as such in perfumes, but it serves as a starting material for the production of a number of perfumery chemicals such as cineole, terpineol, menthol, thymol, etc. There is little difference in total yield of camphor when two or four pickings are taken in a year. Tender leaves as well as plants grown in the open contain more camphor.

The yield of camphor and camphor oil is 50-80 kg/ha which varies widely with the part used and the geographical location.

Physico-chemical properties of oil

Camphor tree exhibits wide variability in different locations. Samples from Calcutta (India) recorded the following properties.

Property	Oil extracted from		
	Leaves	Branches	Trunk
Colour	Colourless	Light brown	Light brown
Specific gravity at 30 C	0.928	0.943	0.944
Optical rotation	30 6'	26 21'	28 48'
Refractive index at 30 C	1.479	1.471	1.473
Acid value	2.238	2.980	3.125
Ester value	12.148	3.965	4.396
Solubility	1:1 (90% alcohol)	1:2 (80% alcohol)	1:2 (80% alcohol)

The essential oil distilled from branches, wood and root is obtained as a semi solid mass. The yield is generally 1-1.2% and wide variability is reported with locations.

Leaf oil is reported to have the following constituents: sabinene 1.47%, -phellandrene 0.17%, -terpinene 0.24%, terpinolene 0.30%, furfural 0.16%, piperitone 2.4%, geranyl acetate 0.22%, cuminaldehyde 0.15%, safrole 13.4%, eugenol 0.12%, cinnamyl alcohol 0.18% and traces of more than twenty compounds (Baruah *et al*, 1975).

5. CINNAMON Cinnamomum verum Lauraceae

Importance

Cinnamon, also known as *true cinnamon or Ceylon cinnamon*, is an evergreen tree whose bark and leaves are strongly aromatic. The bark, exported as *quills*, is used as a spice or condiment, for flavouring cakes and sweets and in curry powders, incense, dentrifices and perfumes. Two types of essential oils are commercially extracted from cinnamon plants; bark oil from the bark of the tree and leaf oil from the leaves and tender twigs. Bark oil is used in expensive perfumes. It is used in flavouring confectionery, liquors and in pharmaceutical preparations, especially to mask the unpleasant taste. Leaf oil is used in the manufacture of cheaper types of perfumes used in soap, tooth pastes hair oil, etc. In the flavouring industry, it is used as a modifier. It is a cheap substitute of clove oil for seasoning. Eugenol, the main constituent of leaf oil is used for the synthesis of vanillin, the perfumery component of vanilla beans (Senanayake, 1977).

Origin and distribution

True cinnamon is believed to have originated in Sri Lanka. It reached Egypt and Europe by fifth century B.C. It was introduced into Java in 1825 and has since been cultivated in India, the Seychelles, Madagascar and Brazil. It is also cultivated in other tropical countries. In India it is confined to the lower elevation of Western Ghats in Cannanore, Calicut and Kottayam districts of kerala and the lower Nilgiris of Tamil Nadu. Sri Lanka is the largest producer and exporter of the quill and the oil of the best quality. The Seychelles is the second largest producer of the bark.

Botany

Cinnamon *Cinnamomum verum* Presl. is synonymous to *C. zeylanicum* Bl. with a chromosome number 2n=24. It belongs to the family Lauraceae. This evergreen tree is 8-17 m high in wild state, but in cultivation it is coppiced to develop as a bush. Leaf is stiff; petiole 1-2 cm long, grooved on upper surface; lamina ovate or elliptic, strongly 3-veined from the base. Leaf is reddish when young. The anthocyanin pigments present in the flushes are reported to be cyanidin glucoside, cyanidin xyloside and cyanidin galactoside. Inflorescence is axillary or terminal panicle at the ends of twigs with creamy white peduncle. Flowers very small, 3 mm in diameter, with foetid smell, each subtended by a small ovate hairy bract; sepals 6, campanulate, pubescent; stamens 9 in 3 whorls with glands at the base; filaments hairy; anthers 4-celled opening by 4 small valves; staminodes 3; ovary superior, 1-celled; fruit fleshy berry, black, 1-seeded, ovoid, 1.5-2 cm long with enlarged calyx at the base. In Sri Lanka the trees flower in January and fruits ripen 6 months later.

Agrotechnology

Wild cinnamon trees are confined to tropical evergreen rain forests upto 1800 m from MSL. The best cultivated cinnamon is grown at low altitudes in Sri Lanka with an average temperature of 30 C and 2000-2500 mm rainfall per annum. Sandy loam soils with admixture of humus or vegetative mould is the best for sweet and fragrant bark. Proximity to sea, humid conditions and saltish water are good for the crop.

It is propagated mainly by seed and rarely by cuttings of young 3-leaved shoots, layering of shoots and by the division of old rootstocks (Vadivel, *et al*, 1981). Seeds soon lose their viability and should be sown fresh after the removal of the pulp. Germination takes 2-3 weeks time. Seeds are sown thickly in nurseries in May-June. When 4 months old, seedlings are transplanted into poly bags or baskets. After a further 10-12 months they are planted in the main field at 2-3 m spacing when they have sufficiently hardened off.

Cattle manure or compost at 20 kg/tree/year may be applied. Inorganic fertilizers may be applied at 20:20:25 g N, P_2O_5 and K_2O/seedling in the first year which is gradually increased to 200:180:200 g/tree/year for grown up plants of 10 years or more. Regular weeding is done in the early stages of growth and the seedlings are irrigated till they are established, if there is long drought period. Plants are pruned when they are 2-3 years old at a height of 15 cm above ground level. Side shoots growing from the base are cut to encourage growth of more side shoots till the whole plant assumes the shape of a bush. Leaf spot and die back diseases caused by *Colletotrichum gloeosporioides*, grey blight caused by *Pestalotiopsis palmarum* and sooty mould caused by *Phragmocapinus betle* are the common diseases of cinnamon.

For the preparation of *quills*, the plants are harvested 3 years after planting when the shoots have grown 2-2.5 cm in diameter and 1.5-2 m in length. Harvesting is done in May or November. The correct time for cutting the shoots for peeling is determined by noting the sap circulation between the wood and the corky layer. Peelers can judge this by making a test cut on the stem with a sharp knife. If the bark separates readily the cutting is taken immediately in the early morning with sharp knife to prevent breaking and splitting of cut ends (Fazlullahkhan, 1967).

Postharvest technology

Leaves are removed, the brown skin is scraped off and the stems are cut into pieces of convenient length. The bark is split longitudinally and peeled off using peeling knife on the same day of harvest. The cylindrical pieces of bark (quills) are dried in sun for 2-5 days and packed in bundles for trade. The first harvest may yield 30-50 kg quills/ha/year. Better harvests are expected after 10 years when 170-200 kg of dried quills/ha/year are obtained.

The chips, featherings or trimmings of bark left after the collection of quills are used for distillation and the oil yield is 0.5-1% generally. For the extraction of leaf oil, the leaves and tender twigs are harvested in May and November. Wilting of the harvested leaves in shade for 24 hours increases the oil recovery. Steam distillation for 4-6 hours gives an oil yield of 0.5 to 0.7%.

Physico-chemical properties of oil

The cinnamon bark oil is light yellow in colour when freshly distilled. On storage it becomes reddish. It has specific gravity (15.5 C) 0.950 to 1.030, refractive index (20 C) 1.565 to 1.599, optical rotation (20 C) 0 to 8 and its solubility in 70% alcohol is 10 volumes. Bark oil contains cinnamic aldehyde (60-75%), eugenol (10%), benzaldehyde, methyl amyl ketone, phellandrene, pinene, cymene, nonylaldehyde, linalool, cumin aldehyde, caryophyllene and esters of butyric acid.

Leaf oil is heavier than water, yellow to yellowish brown in colour with a slight camphoraceous odour resembling that of clove oil due to the presence of 70-95% of eugenol. Leaf oil has specific gravity (15.5 C) 1.065, refractive index (20 C) 1.530 to 1.545, optical rotation (20 C) -1 to +3 , acid value 14.0-15.7, ester value 4.7-16.7 and its solubility in 70% alcohol is 10 volumes. Leaf oil contains approximately -pinene 0.2%, 1,8-cineole 1.65%, p-cymene 0.35%, -ylangene 0.25%, linalool 1.5%, caryophyllene 1.85%, -humulene 0.2%, -terpineol 0.15%, piperitone 0.1%, safrole 0.65%, cinnamaldehyde 1.3%, cinnamyl acetate 0.8%, eugenol 87%, acetoeugenol 1.0%, cinnamyl alcohol 0.60%, benzyl benzoate 2.68% and traces of over 15 compounds (Wijesekera *et al*, 1974).

The root bark oil, with 2-3% yield, is another variety of essential oil obtained from cinnamon. It is colourless, lighter than leaf oil with specific gravity 0.994 and optical rotation +50 and contains most of the terpenoids.

6. NUTMEG Myristica fragrans Myristicaceae

Importance

Nutmeg plant is a spreading dioecious evergreen tree which yields two spices, the dried seed called *nutmeg* and the dried aril called *mace*. Although the essential oils are similar in both spices, the flavours of them are distinctively different. Nutmeg is grated in small quantities to flavour milk dishes and confectionery. Mace is favoured for use with savoury dishes in pickles and ketchups. The pericarp is made into sweet meats and jellies. The seeds yield a solid fixed oil, *nutmeg butter*, which is used in ointments

and perfumery. Both butter and oil contain *myristicin* which is narcotic and poisonous, so that nutmegs and mace must be used sparingly as 4-5 g produces symptoms of poisoning in man.

Origin and distribution

Nutmeg is a native of the Eastern Islands of the Moluccas. It is widely grown in Java, India, Banda, Amboina, Mauritius, New Guinea, French Guiana, Penang, Malacca, Singapore, Indonesia, Grenada and Sumatra. Indonesia is the major producer with about 60% of the total world production followed by Grenada and New Guinea. In India it is grown in Kerala and Tamil Nadu.

Botany

Nutmeg *Myristica fragrans* Houtt. with a chromosome number 2n=42 belongs to the family Myristicaceae. It is an evergreen spreading tree, 5-15 m high with superficial root system. The plant is dioecious but occasional trees occur with male and female flowers on the same tree. Leaves alternate, exstipulate; petiole, 1 cm long; lamina glabrous, elliptic or lanceolate with 8-10 pairs of lateral veins; flowers unisexual but bisexual flowers have also been rarely observed; inflorescence axillary, umbellate, cymes with 1-10 flowers in males and 1-3 flowers in females; male flowers 5-7 mm long, stamens 8-12 with adnate anthers; female flowers upto 1 cm long; ovary sessile, 1-celled with very short 2-lipped stigma; fruits fleshy, drupes, drooping, yellow, smooth, 6-9 cm long with circumferential longitudinal ridge and persistent remains of stigma, when ripe succulent yellow pericarp splits into 2 halves exposing purplish brown, shiny seed surrounded by a much lacinate red aril, attached to the base of the seed; seeds broadly ovoid 2-3 cm long with convoluted dark brown perisperm and lighter coloured endosperm.

Agrotechnology

Nutmeg requires warm humid conditions with an annual rainfall of 1500 to 2500 mm and temperature of 25-33 C. It grows well from sea level to an elevation of 1300 m. Extreme dry climate as well as waterlogging are injurious to the crop. For the cultivation of nutmeg, river banks and hill valleys with sandy loam and red laterite soils are ideal. Partial shade appears to be beneficial in early growth stages.

Nutmeg is normally propagated by seeds. The seeds soon lose their viability and should be sown soon after collection. Seeds which rattle inside the shell will not germinate as they have dried out. Fresh seeds are sown in shaded nurseries. Germination takes 4-6 weeks. The sprouted seeds are transplanted into polythene bags which can be planted in the mainfield after 6-12 months. Seedling progeny will give about 50% of each sex, which is very difficult to distinguish until the trees flower 4-6 years after planting. It is customary to cut off the surplus males at this stage, leaving one male to 10 females. Vegetative propagation like budding and grafting is also followed with limited success to ensure female progeny (Nichols and Creickshank, 1964). Large seeds of uniform size, round shape, light brown colour with thick mace and low terpene content are selected for sowing. Fast growing trees like albizzia or erithrina may be planted in advance for providing required shade. Nutmeg seedlings are planted in the mainfield in pits of 90 cm cube dug at 8 m spacing and filled with top soil and compost or cattle manure at 10 kg/pit. Cattle manure application is gradually increased to 50 kg/tree of 15 years or more. Similarly, fertilizers are applied at 20:18:50 g N, P_2O_5 and K_2O/plant in the first year which is increased to 500:250:1000 g/plant/year in the fifteenth year or later. Regular weeding and irrigation are required for good growth, early bearing and higher yield.

The hard scale (*Saissetia nigra*) infesting the shoots can be controlled by spot spraying with quinalphos at 0.025%. Shot hole caused by *Colletotrichum gloeosporioides*, leaf blight and fruit rot by *Botryodiplodia theobromae*, leaf spot by *Alternaria citri* and sooty mould caused by *Phragmocapinus betle* are the common diseases of nutmeg, which can be controlled by spraying 1% Bordeaux mixture repeatedly.

Seedling trees begin bearing in 4-6 years. Budded and grafted plants start bearing early. Trees come to full bearing between 15 and 20 years and continue for more than 40 years. Fruits ripen about 6 months after flowering. Fruits are available throughout the year but the peak period of harvest is from December to May. Fruit split open when fully ripe which are collected and dehusked. The aril is removed flattened out and dried slowly in sun for 10-15 days. The nuts are dried for 4-8 weeks till the kernel rattles within the shell. A tree produces 1500-2000 or more fruits/year. Yields per hectare may vary from 1000-1500 kg of nutmegs and 200-250 kg of mace per annum. Mace to nutmeg ratio is about 7:200 on weight basis.

Postharvest technology

Essential oil is extracted from the seed, mace, leaves and also the bark, by steam distillation. For oil distillation, the economically viable and accepted materials are the rejections from spice trade. The oil yield ranges from 6 to 16% in nutmeg, 4 to 15% in mace, 0.14% in bark and 0.4 to 0.6% in leaves.

Nutmegs contains approximately water 9%, carbohydrate 27%, protein 6.5%, fixed oil 33%, and essential oils 4.5%. Mace has less fixed oils but more of essential oils. Nutmeg seeds contain 25-30% butter which contains 73% trimyristin and 13% essential oils. The seed essential oil contains 80% pinene

and camphene, 4% myristicin which is poisonous, dipentene, p-cymene, d-linalool, terpineol, geraniol, safrole, eugenol and isoeugenol. The seed oil is colourless to pale yellow and it has the characteristic nutmeg odour (Nair, 1978).

Mace essential oil is similar to nutmeg oil but it is fresher than the seed oil.

7. LINALOE Bursera delpechiana Burseraceae

Importance

Linaloe is a large dioecious tree whose wood as well as the berries and leaves yield essential oils which are used as the raw material for the extraction of linalool. Because of its stability to alkali the oil is particularly useful in the manufacture of scents, cosmetics and soaps; transparent soaps in particular. The berry oil resembles *Bois de Rose* and can be used as a fixative in perfuming lily, lavender, cananga and soaps.

Origin and distribution

Linaloe tree is a native of Mexico. In India its plantation was started in Bangalore about 50 years ago covering nearly 50 hectares by two Scotch men, the Anderson brothers. Now it is grown in the states of Maharashtra and Andhra Pradesh.

Botany

Linaloe plant *Bursera delpechiana* Poisson ex Engl. belongs to the family Burseraceae. This is a deciduous dioecious tree. The medium sized male tree has a longer trunk and grows to about 7.5 m. Female tree attains about 6 m height and has larger leaves measuring upto 18 cm in length. Leaves imparipinnate, serrate or nearly entire; flowers green, pentamerous; calyx small, lobes rounded; petals valvate in bud; stamens 10, nearly equal; ovary hairy surrounded by a broad crenate disk; fruits fleshy, berry, dark green, turning to reddish brown as they mature and fall off.

Agrotechnology

Linaloe plant requires a dry tropical climate with an annual rainfall of 500-1000 mm. It grows upto an altitude of 760 m. The tree is very hardy and it flourishes even on rocky soils. In deep sandy loam it attains good height with spreading branches. Well drained medium or light loamy soil with neutral pH is ideal for growing the crop. Waterlogging causes cracking of stems and finally wilting away to death.

The plant is propagated by stem cuttings and seeds. Stem cuttings are usually used as seeds do not germinate easily and germination is very poor. Cuttings of about 1 m length and 1-3 cm diameter are first planted in nursery or poly bags. About 90% recovery is obtained. The rooted cuttings are transplanted to the main field after 4-6 months in pits of 80 cm cube at a spacing of 6-7 m. The plants establish in the field very quickly. They start shedding leaves during November and are completely bare of foliage till late March when new flushes appear. They are very hardy and once established do not need much care. No serious pests and diseases are noticed.

Linaloe plant raised from cuttings set fruits the first year itself while those from seeds take about 5 years for fruit set. New flush of leaves along with flower buds appear in April. Berries start setting by May and mature by July-August when they are harvested, dried and dehusked. One kg of dried husk is obtained from 5-6 kg of fully mature berries.

Postharvest technology

Almost all parts of the linaloe tree contain aroma. Mexicans distill the wood while Indians use the outer husks of berries. The husk oil yield is much less, 1.8% as compared to 2.5-3.0% obtained from the wood in Mexico. The berries can be steam distilled either fresh or dry. Fresh berries take about 5 hours while dry ones 20-25 hours for distillation. The still should not be filled up to the brim as the husks swell during distillation. Fresh fruits yield 1.5-2.5% oil while dried husks yield 8-12% oil. The wood oil is distilled from the wood of 40-60 years old trees which yield 7-12% oil while younger trees yield 2.5-3% oil. The seed oil produced in India is known as *Mysore Linaloe oil or Indian Lavender oil* (Sastry, 1952). Leaf oil yield is 0.15-0.25%.

Physico-chemical properties of oil

The husk oil is a light coloured mobile liquid much lighter than water with specific gravity (20 C) 0.8952, refractive index (20 C) 1.4658, optical rotation (20 C) 1.5, acid value zero, saponification value 130, saponification value after acetylation 274 and it is soluble in 70% ethanol. The approximate composition of the oil is methyl heptanol 1.5%, linalool 47.7%, linalyl acetate 40.8%, sesquiterpene and other viscous substances 8%. Mexican oil contains 60-75% linalool. the leaf oil has a sweet wafting odour and it contains 65-70% linalyl acetate (Adams and Bhatnagar, 1975).

D. AROMATIC FLOWERS

1. ROSE Rosa damascena Rosaceae

Importance Rose is a perennial erect shrub with beautiful sweet scented flowers valued for worship, making garlands and preparation of rose oil, rose water, rose attar and rose otto. Rose oil is one of the oldest and most valuable perfumery raw materials. It imparts characteristic fragrant top notes to perfumes. The extracted absolute adds lasting notes. A mixture of distilled oil and extracted absolute combines the advantages of both the products. The distilled oil is employed in cases where solubility in dilute alcohol is important. The absolute is soluble only in high-proof alcohol and therefore used only in handkerchief perfumes or in cosmetics where solubility plays no role. In creams and powders cheap concrete is used. Bulgarian rose oil is used for flavouring certain types of tobacco, particularly snuff and chewing tobacco and in a number of fruit flavours. Limited quantities of otto are employed in flavouring soft drinks and alcoholic liquors. Rose water has been valued from ancient times for use in making syrups and medicinal preparations. At marriages and other social functions rose water is sprinkled on the guests. Rose jam of Unani medicine is used as a mild laxative and tonic. With the availability of cheap or synthetic substitutes like geraniol, the use of rose flower for perfumery purposes has declined.

Origin and distribution

Rose is indigenous to Europe. It is widely distributed in Europe and middle east countries especially Iran, Afghanistan and Turkey. It
is grown in Bulgaria, Russia, Egypt, France, India and Morocco. Bulgaria is the major producer of rose oil and the annual world production is 15-20 tonnes.

Botany

Roses belong to the family Rosaceae and the genus *Rosa*. Out of about 120 species of roses, three species are commercially used for the production of rose oil, namely, *Rosa damascena* Mill., *R. gallica* L. and *R. centifolia* L. Out of these, *R. damascena* is the most important species with a delicate fragrance and considerably larger percentage of oil. Most of the high grade rose oil is produced from this species (Pal, 1972).

Rosa damascena is a perennial erect or climbing shrub with a life span ranging upto 50 years. It grows upto 3 m, stems spiny, leaves pinnate, leaflets serrate, stipules adnate to the petiole. Flowers terminal, solitary or corymbose, pine red; bracts rarely persistent; calyx tube persistent, globose, ovoid or pitcher shaped, mouth contracted, lobes leafy, imbricate in bud, petals many, large, stamens many, inserted on the disc; carpels many, rarely few, in the bottom of the calyx tube; styles subterminal, free or connate above, stigma thickened, ovule 1, pendulous. Achenes cariaceous or bony, enclosed in the fleshy calyx tube.

Some of the other popular species of roses are:

(i) *R. foetida* Herrm. syn. *R.eglanteria* Mill. non L. is an erect bush of medium height with a few straight spines. The flowers emit a rich and heavy odour and are borne singly or in few-flowered groups.

(ii) *R. giganta* Collet syn. *R. odorata* Andrews Sweet var. *giganta* (Collet ex. Crepin) Rehd & Wills is a rampant climber with thick, hooked prickles, producing fragrant white or pale-yellow flowers borne usually singly.

(iii)*R. leschenaultiana* Wight & Arn. is a profuse climber with purplish branches bearing small hooked prickles. Flowers are large, pink, fragrant, borne in small clusters.

(iv) *R. moschata* Herrm. is a profuse climber, prickly with fragrant white flowers in terminal clusters.

Gulliot's La France is a hybrid tea rose. It has large flowers of silvery-pink rose colour with delicious fragrance.

Agrotechnology

Roses come up in almost all climates. The plant needs plenty of sunshine and protection from strong winds for proper growth. Humidity above 60% and a temperature of 15-20 C is congenial for plentiful harvest. A temperature of 0-5 C for a fortnight prior to blooming enhances the quality and quantity of flowers. At the time of flowering the temperature should be 25-30 C and the relative humidity 60%. The plant grows on a wide range of soils, but light and well drained soils are considered ideal. Acidic soils inhibit growth and reduce flower yield. Alkaline soils with pH range of 7-9 are quite suitable.

Rose is propagated vegetatively by cutting and budding. Cuttings taken from mature plants in January are planted at a spacing of 10 x 30 cm in a nursery or in poly bags. Treatment of cut ends with 200 ppm IBA induces profuse rooting. The rooted cuttings are ready for transplanting when they are about 9-12 months old. The rooted cuttings are planted in trenches, about 1 m deep and 0.5 m wide, spaced 1 m apart. The trenches are filled with well rotten FYM at 8-10 tonnes/ha. About 10,000 plants are required for planting one hectare of land. Rose is a soil exhausting crop. A good crop requires 200 kg N as calcium ammonium nitrate, 50 kg P_2O_5 as superphosphate and 30 kg K_2O as muriate of potash per hectare in 2-3 split doses annually. Rose plants need frequent irrigation during the period of vegetative growth, flowering and just after pruning. In a year, 10-12 irrigations may be required.

Plants are regularly pruned, once or twice a year, for getting higher yield of flowers. October-February is the best time for pruning. Plants should be pruned upto a height of 50 cm from the ground level. It takes 75-90 days for flowering after pruning. Weeding and hoeing should be done after pruning. Generally, 3 weedings and hoeings are required annually. Annual weeds can be controlled by herbicides like simazine or atrazine applied at 3 kg/ha in light soils
and 5 kg/ha in medium or heavy soils.

Insect pests of roses are *Macrosiphum rosae* (Aphidae), *Eulecanium caryli* (Coccidae) *Agrilus chrysoderes* (Buprestidae), *Podophylla fulho* (Scarabaedae) and *Rhynchites hungaricus* (Curculionidae) which can be controlled by suitable insecticides. Leaf spot is the main fungal disease which can be controlled by regular application of 1% Bordeaux mixture.

Rose plants flower during March-April in the plains and May-June on hills. The peak flowering period is about 45 days. Sporadic flowering may continue throughout the year. Flowers are harvested from 5 a. m. to 9 a. m. in the early morning, when they begin to open. The average yield of flowers is 2000-3000 kg/ha/year.

Postharvest technology Rose oil is extracted from the flowers by distillation for 2-3 hours or by extraction with volatile solvents (Kahol, 1985). The flowers can be stored in clean cold water for a period of 3 days without any loss in oil recovery or change in oil quality. The average oil yield is 0.03%. Water distillation is a popular method for obtaining rose water. *Rose attar* is obtained by water distillation of rose flowers and collecting the distillate over sandal wood oil. *Otto of rose* is prepared by the water distillation of rose flowers and redistilling the distillate 2-3 times till it gets saturated with the oil dissolved in it. Then it is chilled and the oil drops floating on the surface of water are removed. The yield of the oil comes to about 0.0045% (Gupta *et al*, 1955).

Physico-chemical properties of oil

Rose oil is a colourless liquid, but on aging develops an amber colour. It has specific gravity (30 C) 0.8845, refractive index (30 C) 1.4657, optical rotation 2.5 , Acid value 2-6, ester value 18.7 and total alcohol content 81.6%. The essential oil contains various alcohols, aldehydes, ketones, esters, phenols, terpenes and acids. The major components are citronellol 38%, paraffins 16%, geraniol 14%, nerol 7%, ß-phenyl ethanol 3%, eugenol methyl ester 3%, linalool 2%, ethanol 2% and farnesol 1% (Srivastava *et al*, 1979; Ranade, 1980).

2. JASMINE Jasminum grandiflorum Oleaceae

Importance

Jasmines are a group of shrubs which are commercially grown for their fragrant flowers and essential oil production. The bulk of the flowers is used as such in garlands and decorative bunches for religious offerings and a small quantity for the production of oils and attars. Jasmine concrete and absolute are used in high grade perfumes, ranking next to the rose in the order of importance. Jasmine oil blends with every floral scent and extensively used as an important perfumery item throughout the world. Almost all high quality perfumes contain at least a small amount of jasmine oil. The absolute, though expensive, also blends with any floral scent imparting smoothness and elegance to the perfume composition. **Origin and distribution**

The term Jasmine is probably derived from the Persian word *Yasmin* meaning *fragrance* which is adopted in Arabic as *Yasym* given to jasmine flowers. Of the many species of jasmine, the commercially cultivated species, namely *Jasminum grandiflorum* is a native of Kashmir, Afghanistan and Iran, *J. sambac* a native of South India and *J. auriculatam* is a native of South and Central India. A study by Veluswamy *et al* (1975) of ancient Tamil literature of "Sangam" period (500 B.C. to 200 A.D.) has revealed that all these three species have been mentioned in those ancient works and therefore South India, could well have been an important centre of origin of the *Jasminum* species. Jasmines are widely found in warm parts of Europe, Asia, Africa and the Pacific regions but almost absent in America. The annual production of jasmine concrete is more than 15 tonnes, the largest producer being Egypt, followed by Morocco, India, Italy, France and China.

Botany

Jasmines belong to the family Oleaceae and the genus *Jasminum.* Though more than 2000 species are known, three species, viz, *J. grandiflorum* L., *J. sambac* Ait. and *J. auriculatum* Vahl. are commercially cultivated and only *J. grandiflorum* L. is grown for use in perfume.

J. grandiflorum is a twining or nearly erect growing shrub; branches ribbed, drooping, annular; leaves opposite, imparipinnately compound, rachis flattened or winged; leaflets, 5-7, elliptic, round or oval; flowers borne on lax, axillary or terminal cymes longer than leaves, white, often tinged purple on the outside, fragrant; bracts ovate to spathulate, oblong, foliaceous; calyx glabrous, 5-lobbed, subulate; corolla

5-lobbed, star shaped, elliptic or obovate; corolla tube encloses 2 stamens borne on short slender filaments; ovary bicarpellary; fruit berry.

J. sambac Ait. is a dwarf spreading bushy shrub, 0.5-1.0 m high with attractive glabrous leaves producing attractive, white, sweet scented flowers in great profusion in the hot season.

J. auriculatum Vahl. is a twining scandent shrub growing to 5-7 m with small opposite leaves; flowers white and sweet smelling with calyx fine notched having round firm glandular process on the outside, light weight; around 26,000 flowers weighing a kilogram.

Agrotechnology

Jasmines are sun loving plants and prefer warm humid climate for successful growth. They perform well at elevations ranging from 600 to 1200 m. Areas having a warm summer and mild winter with sun almost throughout the year are considered the best. Jasmines can be grown on a wide range of soils, but well drained rich sandy loam to clay loam soils with a soil pH of 6.5-7.5 are best suited.

Layers and cuttings can be used for propagation. Improved varieties of *J. grandiflorum* ('Jaji mallige' and 'Ajjige') and *J. auriculatum* ('Vasantha mallige' 'Parimullai' and 'CO -1 mullai') are used for commercial cultivation. Cuttings for planting should be 20-25 cm long with 3-4 eyes and are dipped in seradix-B (or a solution of 4000 ppm of IBA) and planted under intermittent mist for rooting during January to March. Almost 90% rooting is achieved and the cuttings will be ready for transplanting in 4-5 months. Cuttings, are planted in pits dug upto 1 m in depth, and filled with top soil, cowdung and compost. Plants are spaced at 1 m in rows, 1.5 m apart. Irrigation is given if soil moisture is inadequate.

Jasmine plant needs 15-30 kg FYM, 60-120 g N, 120-240 g P_2O_5 and 120-240 g K_2O/plant/year which are given in 3-4 split doses. Pruning is needed to get high flower yield and to keep the bushes to manageable size. Plants pruned between 17th December and 7th June produce maximum number of branches and the highest yield of flowers. The shoots are cut at 30 cm height. Diseased leaves and dry shoots are also removed. After pruning, the soil around the plant should be stirred upto a depth of 15 cm and repeated every 2-3 months. The field should be kept clean by removing weeds as and when necessary (Chandra and Srivastava, 1977).

Red scale, mealy bug, jasmine bug, leaf eating caterpillar, white flies and mites are the common insect pests of jasmine. Red mite can be controlled by spraying trithion while others by any common insecticide. Black leaf spot, mildew and rootknot (nematode) are the diseases of this crop.

The plant flowers from the second year of planting. The flowering period ranges between April and May and from August to November. In Egypt the plant flowers almost 10 months in a year. Harvesting is done during early morning because the flowers contain maximum perfume at this time. Flowers gathered at noon and in the afternoon yield lesser flower oil than those collected very early in the day. Warm weather and ample sunshine yield a crop of heavily scented flowers than in cool or rainy weather. The annual yields of flowers have been reported to be 750-1000 kg/ha in India, 2000-4000 kg in France, 4500-5500 kg in Sicily and Italy and upto 6000 kg/ha in Morocco and Egypt. A jasmine plantation gives economic yield for 10-15 years after which the crop is removed and crop rotation is followed for some years before establishing a new jasmine plantation.

Postharvest technology

The essential oil in flowers is extracted through enfleurage which is widely used for production of jasmine attars in India (Sharma *et al*, 1980). In this method, seeds of sesame or til (*Sesamum indicum* L.) are first soaked in water with a view to remove their covering and then dried in the sun. The fresh jasmine flowers and the dehusked sesame seeds are spread in thin layers, one above the other, for 10-12 hours daily. The exhausted blossom is replaced by fresh flowers and this process is repeated for 5-7 days till all the dehusked seeds are saturated with the perfume. One kg seed can extract the perfume from 3 kg flowers. The perfumed seeds are distilled and the vapours of jasmine are absorbed into sandal wood oil for production of attars. Solvent extraction, with petroleum ether or hexane, recovers practically all the odorous constituents. The solvent is recovered by vacuum distillation and the residue constitutes the concrete which is purified by extraction with 95% alcohol, whereby jasmine absolute is obtained. The usual yields are 0.30-0.35% concrete and 45-55% absolute. The annual yield of concrete is 4-5 kg/ha (Swaminathan *et al*, 1979). Jasmine oil is also separated from jasmine concrete by liquid carbon dioxide extraction method.

Physico-chemical properties of oil Jasmine concrete is a yellowish brown waxy mass with the characteristic odour of jasmine flowers. It has melting point 50-51 C, congealing point 54-55 C, acid value 0.23-0.27 and it is partly soluble in 95% alcohol. The approximate composition of jasmine flower oil obtained by enfleurage is benzyl acetate 65.0%, d-linalool 15.5%, linalyl acetate 7.5%, benzyl alcohol 6.0%, jasmone 3.0%, indole 2.5% and methyl anthranilate 0.5%. Benzyl benzoate, geraniol, nerol, terpineol, farnesol, nerolidol and p-cresol are also present in traces (Nigam and Misra, 1980). Jasmine

absolute is a viscous clear yellowish brown liquid possessing a delicate odour of fresh jasmine flowers. The absolute contains many of the above compounds (Dhingra *et al*, 1956).

3. TUBEROSE Polyanthes tuberosa Amaryllidaceae

Importance

Among the flowering plants which are valued much by the aesthetic world for beauty and fragrance of their flowers, tuberose occupies a very special position because of its prettiness, elegance and sweet pleasant fragrance. This bulbous plant is the source of tuberose oil of commerce which is very expensive and used in high grade perfumery. It is also cultivated for cut flowers and for preparing bouquets and garlands. The long flower spikes are excellent as cut flowers for table decoration. The individual florets are used for making garlands, floral ornaments, bouquets and button-holes.

Origin and distribution

Tuberose is believed to have originated in Mexico or Central America. It is widely cultivated in Southern France and also in Morocco for the extraction of its natural flower oil. For many years tuberose flower oil has been one of the most valuable and expensive of the perfumes raw materials. But later, it recorded a declining trend in production and utilization.

Botany

Tuberose *Polyanthes tuberosa* L. belongs to the family Amaryllidaceae. There are single as well as double flowered varieties. Single flowered type is mostly cultivated for the extraction of its perfume while the double flowered variety usually goes to the cut flower trade. The flowers on top of the long stalk are grouped in spike-shaped clusters 15 to 20 cm long. The flowering period begins in July reaching its maximum toward the middle of August and lasting to the end of September when a secondary blooming takes place.

There are four groups of cultivars of tuberose.

(i) Single: most widely cultivated. Flower is pure white and has got a single row of corolla segments. Eg. 'Calcutta single', 'Mexican single', 'Rejat Rekha' and 'Suvarna Rekha'.

(ii) Double : Flowers are white, tinged with pinkish red. Petals are in several whorls. Eg. 'Pearl' and 'Calcutta double'.

(iii)Semi-double: Similar to double but with only 2-3 rows of corolla segments.

(iv) Variegated: This has got variegated leaves with yellow margins.

Agrotechnology

Although tuberose can be grown under a wide range of climatic conditions, a mild climate with an average temperature ranging from 20 C to 30 C is considered ideal. Loam and sandy loam soils having a pH range of 6.5 to 7.5 with good aeration and drainage are best suited for its cultivation. The plant is propagated by bulbs. Spindle shaped disease free bulbs having a diameter of 1.5-3.0 cm are used for planting. Mother bulbs are the best for planting as they flower early. Finger or side bulbs take 2-3 years to come to flowering. Of the 4 types of tuberose, viz, single, double, semi-double and variegated, the single type has the maximum fragrance and is popular among the growers for the production of essential oil. Best time of planting is from May to July. Land is ploughed 2-3 times and soil is brought to fine tilth. Well-rotten FYM at 20-30 t/ha is applied and mixed well. Furrows are opened 25-30 cm apart and bulbs are planted at 25 cm spacing in furrows. About 1.25 lakhs (800-900 kg) of bulbs are required for planting a hectare of land. A fertilizer dose of 100:200:200 kg N, P_2O_5, K_2O/ha is generally recommended. Half the dose is applied basally and the other half as topdressing when the flower spikes start appearing. Weekly irrigation and regular weeding are required for best yield. Thrips are reported to attack the crop.

The flowering season is between June and October. Flowers will be ready for harvest in 3-3.5 months time. They are harvested by cutting the fully opened spikes from the base during the cool hours of the day either in the morning or evening. From single planting 2-3 ratoons can be taken for which the flower stalks of the main crop are headed back and the plot is manured and irrigated. The average yield comes to 5-10 tonnes/ha for planted crop, 9-12 tonnes/ha for first ratoon and 4-6 tonnes/ha each for subsequent ratoons.

Postharvest technology

Tuberose is one of those plants, the flowers of which continue to develop their natural fragrance for some time after they have been harvested. The flower oil is extracted by enfleurage and solvent extraction with petroleum ether. Distillation cannot be employed as steam or water distillation of the tuberose flowers directly gives only a very little yield of oil and it is of very poor odour. Freshly picked flowers, before they open are enfleuraged. About 150 kg of flowers yield 1 kg of absolute of enfleurage which contains 11-15% of steam volatile oil. Extraction of tuberose flowers with petroleum ether yields 0.08-0.14% of concrete. The concrete contains 3-6% of a steam volatile oil.

Physico-chemical properties of oil

The absolute of enfleurage is a brown, semi-solid, alcohol soluble liquid possessing a characteristic odour of tuberose flowers with a fatty by-note. It has specific gravity (15 C) 1.009-1.035, refractive index (20 C) 1.535-1.574, optical rotation -2 30', acid value 32.7 and ester value 243-280.

Concrete of tuberose is a light to dark brown waxy mass which is only partially soluble in high-proof alcohol. It has congealing point 49-57 C, melting point 57 C, specific gravity (60 C) 0.8951, refractive index (60 C) 1.4601, acid value 52-56, ester value 63-76 and saponification value 117-119.

The chemical constituents of tuberose flower oil include geraniol, nerol, farnesol, benzyl alcohol, methyl benzoate, benzyl benzoate, methyl salicylate, methyl anthranilate, eugenol and butyric acid.

4. MARIGOLDS Tagetes spp. Compositae

Importance

Marigolds gained popularity among florists on account of its easy culture, and wide adaptability. Its habit of free flowering, short duration to produce marketable flowers, wide spectrum of attractive colour, shape, size and good keeping quality attracted special attention. There are African, French, Sweet scented, Stinking Roger and Stripped marigolds. African marigold flower oil is a fly repellent and has been suggested as a modifier in hair lotions of the bay-sum type. French type finds use in perfumery particularly in certain types of herbaceous fragrances like fougere and lavender and also in florals, such as jasmine, gardenia and violet. This oil is also employed in aldehyde oriented tabac bases. Oil of stinking roger finds applications in germicidal and microbicidal preparations due to the presence of tagetone which is toxic. Planting of marigold is highly effective in controlling nematode population in the soil.

Origin and distribution

African marigold, though its name suggests its origin from Africa, had its origin in Mexico and in British society it connotes vulgarity of mind. Sweet scented and stripped types are again native of Mexico. Stinking Roger originated in South America, naturalized near waste places and on dry embankments in North-West Himalayas between altitudes of 1250 and 2500 m like Simla in Himachal Pradesh. French marigold is widely grown in France and India upto an altitude of 1350 m. Marigolds are also cultivated in Australia and Kenya.

Botany

Marigolds belong to the family Asteraceae (Compositae) and the genus *Tagetes*. Five species have been recognized in *Tagetes*.

(i) *Tagetes erecta* L., African or Aztec Marigold

They are erect and tall growing (upto 90 cm) plants having large globular flowers of diameter 15 cm and above, in shades of lemon yellow, bright yellow, golden yellow, orange and near white. The common cultivated varieties are 'Guinea Gold', 'Apricot', 'Primrose', 'Sun Giant', 'Fiesta', 'Golden yellow', 'Glitters', 'Happiness', 'Hawai', 'Crown of Gold', 'Honeycomb' and 'Cerpid'.

(ii) *Tagetes patula* L., French Marigold

These are bushy plants, 30-45 cm tall which flower profusely in singles or doubles. The flowers are in the colour range of deep scarlet, red, primrose, yellow, golden yellow, orange and their combinations. Important cultivars are 'Rusty Red', 'Flame', 'Spry', 'Naughty', 'Marietta', 'Star of India' and 'Harmony'.

(iii) *Tagetes lucida* Cav., Sweet Scented Marigold

This is a perennial plant 30-40 cm tall with oblong-lanceolate, serrulate leaves. The flower heads are orange yellow and are borne in dense terminal clusters. They are often planted in gardens as a border plant.

(iv) *Tagetes minuta* L. (*T. glandulifera* Schrank.), Stinking Roger

It is a highly aromatic annual 1-2 m tall, leaves 7-15 cm long, pinnatisect, leaflets 11-19, 4 cm long linear or lanceolate, flower heads pale yellow in corymbose clusters and black achenes.

(v) *Tagetes tenuifolia* Cav. (*T. signata* Bartl.), Stripped Marigold

It is a branching annual, 30-60 cm high with pinnately compound serrate leaves and sweet smelling, bright yellow flowers.

Interspecific hybrids between African and French marigolds are also developed in USA. They are 50-60 cm tall with double flowers of 5-7 cm. Eg: 'Nugget', 'Show Boat', 'Red Seven Star', 'Red' and 'Gold Hybrid'.

Agrotechnology

African and French marigolds are more widely cultivated as compared to other species. Marigolds, in general, require a mild climate between elevations of 700-1500 m. They come up well on well drained rich loam or sandy loam soils. They are propagated by seeds and cuttings; the former is preferred for establishing tall, vigorous and heavy yielding plantations. The land is cultivated well incorporating 20-30 tonnes/ha of well decomposed FYM or compost. Seeds are sown during May-June on nursery beds. One month old seedlings are transplanted at 30-45 cm spacing. A fertilizer dose of 400 kg N, 200 kg P_2O_5 and

200 kg K_2O/ha is suggested for higher yield. Regular irrigation, weeding and hoeing are required to obtain more of large flowers. Initial flower buds are disbudded to obtain bushy and compact growth. Flower heads are harvested when they have attained full size. Regular plucking of flowers increases the flower production. The flower yield is 8-12 tonnes/ha for French marigold and 11-18 t/ha for African marigold.

Postharvest technology

All parts of the plant contain essential oil in varying concentrations. The oil is commercially obtained by steam distillation for 3-4 hours, absorbing the distillate in petroleum ether or benzene. Prolonged distillation spoils the fragrance. Marigold yields 0.02-0.08% oil giving 8-15 kg oil/ha/year.

Physico-chemical properties of oil

African marigold flower oil is reddish yellow in colour, possessing characteristic marigold odour and polymerizing readily in air. It has specific gravity (30 C) 0.936, refractive index (30 C) 1.5025, optical rotation 1.2 , acid value 5.4 and ester value 33.5. The oil contains approximately ocimene 8.5%, limonene 14.03%, linalool 21.14%, linalyl acetate 13.75% and tagetone 40.38%. Leaf and stem oils are greenish yellow in colour.

French marigold oil is amber coloured, having a characteristic powerful fruity top note, reminiscent of green apples, with specific gravity (31 C) 0.8917, refractive index 1.492, optical rotation -3.4 , acid value 6.1 and ester value 25. Tagetone 40.4%, linalool 22.1%, limonene 14.0%, linalyl acetate 13.8% and ocimene 8.5% are the major constituents.

Oil of *T. lucida* is greenish yellow with specific gravity (15 C) 1.5218, acid value 6.0 and ester value 22. The major chemical constituent is estragol.

5. CHAMPAK Michelia champaca Magnoliaceae

Importance

Champak, Champa or Yellow Champa is a large evergreen tree valued for its beautiful flowers with long-lasting fragrance. The tree is a great favourite in Hindu gardens, the exquisitely scented flowers being used for *Pooja* particularly of the Lord Krishna. Besides, the ladies are very fond of champa flowers because of its pleasant fragrance. Champa attars are produced in India which are used in hair oils as a head coolant. The flowers also yield a dye which is used as a base for other colours and for dyeing silk and cotton fabrics. By virtue of the refreshing appearance of its foliage, champa looks elegant even when it is out of flowers.

Origin and distribution

Champak tree is believed to be originated in South East Asia where they bloom from April to June. By way of habitation it is found distributed in India and Nepal. In India, it is distributed over Eastern Himalayas, North East Assam, Western Ghats, Nilgiris, Madras, Southern Orissa, West Bengal and also in Nepal.

Botany

The genus *Michelia* belonging to the family Magnoliaceae comprises about 50 species of evergreen trees or shrubs. The most popular among them are *Michelia champaca* L. and *M. figo* L.

The evergreen tree, *Michelia champaca* grows upto a height of 8 m with ovate to lanceolate leaves of size 20 x 6.5 cm. Blooms appear during April-May and again during September-October. Buds are silky. Flowers are white, sovereign red or creamy light yellow in colour. 'Simhachalam' golden orange kind is the most sweet scented and is the most favoured of champas. The white flowered champa, though very sweet scented, lacks in substance and hence the fragrance does not last quite long.

Michelia figo is a bushy shrub growing upto 5 m with narrow, oval, dark green, smooth shining leaves. The flowers are brownish yellow with edges of carmine colour, about 4 cm in diameter, highly fragrant and borne in axillary and solitary manner.

Agrotechnology

Champa requires a mild climate and an elevation of 100-1000 m with partial shade for good growth. It can be grown on a wide variety of soils and well drained rich sandy loam soils are the best. The trees are propagated both by seeds and vegetatively by grafting. The creamy yellow variety is propagated by grafting on stocks of ordinary golden orange flowered variety which produces seeds in bunches and takes 7-8 years to flower. Seedlings of 'Simhachalam' golden orange type bear flowers in about 3 years and produce taller trees than grafts which bear fruits in a short period. Though large scale commercial cultivation of champa is not common, group planting is generally undertaken, particularly in informal gardens and homesteads. Care is to be taken till the grafts or seedlings are initially established in the field and thereafter not much attention is needed. The trees flower during April-May and again during September-October once they start blooming. A well grown tree yields 50-100 flowers daily during the peak season and 375 to 425 flowers weigh one kilogram.

Postharvest technology

The champak flowers are exquisitely fragrant. Owing to the presence of an oxidizing agent in the flowers they become brown within few hours after picking and are subject to odour deterioration. To prevent impairment of its odour by oxidation, the essential oil must be extracted soon after picking. The volatile oil is not generally extracted by steam distillation because of poor yield and the odour of that oil having no resemblance to that of the flowers. The concrete yield by solvent extraction is around 0.26% which in turn is capable of yielding 26% of steam volatile oil. Enfleuraged flowers in sesame oil yield an excellent attar.

Physico-chemical properties of oil

The champa flower concrete is a waxy solid having a low melting point of 29 C. The champa absolute has a very sweet smooth floral and velvety odour, closely resembling that of the live flowers. Champa oil has low saponification value and low solubility in 90% alcohol. The oil does not resinify during fractionation. It contains important perfumery constituents such as cineole, iso-eugenol, phenyl ethyl alcohol, benzaldehyde, methyl anthranilate, benzyl alcohol, p-cresol and its methyl ether (Mahindru, 1992).

VII. GLOSSARY

Absolute: An ethanol extract of a concrete or a resinoid which generally contains the odoriferous components together with very small proportion of colouring matter and is free from any solvent used in the process.

Absolute Oils: Refers to the steam volatile part of an absolute.

Acid value: It is numerically equivalent to the number of milligrams of potassium hydroxide required to neutralize the free acids present in 1g of the material.

Alcohol, Perfumery Grade: Rectified ethyl alcohol free from by-odours used in the manufacture of alcoholic extracts and perfumes.

Aldehydic Blend: Blends deriving their specific unique character through the superimposition of certain aldehydes.

Amber Note: A heavy, full-bodied warm powdery note.

Animal Note: Odours or notes with a sensuous character.

Aromatic Water: Aqueous odoriferous condensate of hydrodistilled and/or steamdistilled material of vegetable origin containing fully dispersed or partially floating essential oil.

Attar (Indian): A perfume concentrate characteristic of a single flower or a mixture of flowers and/or other materials of plant or animal origin with sandal wood oil as the base.

Balsam: An exudate from plants which flows either naturally or artificially through incision having characteristic odour associated with benzoic or cinnamic acid esters.

Blend: Harmonious combination of odoriferous materials.

Blend, Aldehydic: Blends deriving their specific unique character through the superimposition of certain aldehydes.

Blend, Cologne: Any harmonious combination of fragrances, the main characteristics of which are derived from citrus oils.

Blend, Oriental: A blend with heavy, full-bodied note.

Blend, Spicy: Any fragrance combination having carnation characteristics.

Blend, Woody: Any fragrance dominated by a woody character.

Boiling Range: It is the range of temperature within which a specified percentage of the material distils.

Bouquet: Generally a harmonious combination of two or more floral notes.

By-Note: A temporary or permanent odour effect additional to the main pattern of odour associated with the material.

Carbonyl Value: It is numerically equivalent to the number of milligrams of potassium hydroxide, that is, equivalent to the amount of hydroxylamine required to oxidise the carbonyl compounds present in 1 g of the material.

Cell: A unit of the plant tissue.

Cellular: Composed of cells.

Chypre: A mossy woody fragrance, complex with a characteristic sweet citrus top note, frequently encompassing some floral tones.

Citrus: Odours reminiscent of citrus fruits, such as orange, lemon, bergamot, grapefruit etc.

Cloying: An odour that satiates the senses beyond a natural desire.

Cologne: It is the strongest realization of a particular fragrance in aqueous alcohol.

Cologne Blend: Any harmonious combination of fragrances, the main characteristics of which are derived from citrus oils.

Concentrated Perfume: A nonalcoholic concentrated perfume blend.

Concentration: Method of separation of undesirable substance to improve the quality of the material.

Concrete: An extract of fresh plant parts by the use of a hydrocarbon solvent. It is rich in hydrocarbon soluble materials and devoid of water-soluble components. It is generally a waxy semisolid dark coloured material free from the original solvent

Condensate: Vapours that have been condensed.

Condenser: Part of the distillation apparatus where the hot vapours are cooled and condensed for recovery.

Congealing Point: It is the maximum constant temperature at which a liquefied solid resolidifies.

Deterpenized Oil: Natural essential oils which are free from terpenes and/or sesquiterpenes.

Diffusion: The ability of a fragrance to radiate and permeate the environment.

Distillation: A process of evaporation and recondensation used for purifying liquids.

Distillation Range: It is the range of temperature within which a specified percentage of the material distils.

Distillation, Dry: Distillation carried out completely in the absence of steam or water.

Distillation, Hydro: Distillation of a substance carried out in direct contact with boiling water.

Distillation, Steam: Distillation of a substance by bubbling steam through it.

Distillation, Vacuum: Distillation of a substance under reduced pressure.

Distillation, Water: Distillation of a substance carried out in direct contact with boiling water.

Dry distillation: distillation carried out completely in the absence of steam or water.

Dry Out: Final phase of the main fragrance.

Enfleurage: Process of extracting fragrance of fresh flowers by intimate contact with mixture of purified fats preferably at low temperatures.

Essential Oil: It is a volatile perfumery material derived from a single source of vegetable or animal origin by a process, such as hydrodistillation, steam distillation, dry distillation or expression.

Essential Oil, Synthetic: It is a composition generally consisting of natural essential oils, aromatic chemicals, resinoids, concretes, absolutes, etc., but excluding animal or vegetable non: essential oils and not having a nonvolatile residue in excess of 10 percent by mass. It is so composed that it bears a close resemblance primarily in odour to a naturally occurring essential oil.

Ester Value: It is numerically equivalent to the number of milligrams of potassium hydroxide required to neutralize the acids liberated by the hydrolysis of the esters present in 1 g of the material. It represents the difference between the saponification value and the acid value of the material.

Ester value After Acetylation: It is numerically equivalent to the number of milligrams of potassium hydroxide required to neutralize the acids liberated by the hydrolysis of 1 g of the acetylated material.

Evaporation Residue: Represents the percentage of a perfumery material which is not volatile when heated on a steambath under the specified conditions.

Expression: The process of extracting essential oil under pressure.

Extract: Concentrated produce obtained by treating a natural perfumery material with a solvent which is subsequently evaporated.

Extraction: The process of isolating essential oil with the help of a volatile solvent.

Extrait: A French word, now universally used in perfumery, meaning an alcoholic extract of odourous parts of a pommade.

Fixative: A substance which is compatible with and stabilizes a perfume composition by retarding the rate of evaporation of its volatile constituents.

Flavour: Refers to that characteristic quality of a material as affects the taste or perception.

Floral: The fragrance characteristic of an existing known flower type.

Fore-Running: The initial fractions of the distillation process.

Fougere: A fragrance combining a dominant sweet note with a mossy, lavender-like citrus character.

Fractionation: The process of distillation of the essential oil into various fractions.

Fruit, Flavour/Essence: Suitably blended mixtures of flavouring materials, permitted chemicals and food colours, in a solvent medium of either ethanol or the permitted nonalcoholic solvents.

Fruity Note: The impression of fruit odours within the fragrance theme.

Full Bodies: A well: roundedout fragrance that possesses depth.

Green Note: Notes that recall fresh cut grass, leaves and vines.

Gum: A natural water soluble anionic material often of glycoside-like structure and of high molecular weight which collects in or exudes from certain plants. It forms a neutral or slightly acid solution or a sol with water and has typical mild odour.

Gum (Aromatic): A substance that collects in or exudes from certain aromatic plants.

Gum Resin: Natural exudation from plants and trees consisting of gums and resin with very small amounts of essential oils.

Gum resin: A natural exudate obtained from a tree or plant. It is comprised of gums and resins. If the gum resin source also contains an essential oil it is called an oleogumresin.

Harmonious: Order, accord and unity in a fragrance.

Heavy: A forceful and intense effect.

Hydrodistillation: Distillation of a substance carried out in direct contact with boiling water.

Infusion: A process of treating a substance with water or organic solvent, with or without heating.

Infusion: A hot extract of either a plant part of its exudate with either water or an organic solvent.

Isolate: Either a single constituent or a multicomponent fraction or a composite fraction, rich in desired odoriferous components and derived from a natural perfumery material.

Lasting Qualities: The ability of a fragrance to retain its character over a given period of time.

Leathery Note: Any fragrance conveying the dominant characteristic of tanned leather.

Materials Perfumery, Natural: Perfumery materials of natural origin.

Melting Point: The temperature at which the material melts and becomes liquid throughout as shown by the formation of a definite meniscus.

Melting Range: The main overall odour effect experienced by olfactory nerves on smelling a strip impregnated with a material and exposed to the atmosphere for some time.

Mossy Note: It is a light musk lavender odour.

Natural perfumery Materials: Perfumery materials of natural origin.

Odour: That property of a substance which stimulates and is perceived by the olfactory sense.

Oil, Absolute: Refers to the steam volatile part of an absolute.

Oleogum Resin: Exudations from tree trunks or barks of trees and are characterised by the fact that these consist of entirely or mainly essential oil and resin.

Oleoresin: The natural tree trunk or bark exudate which is extremely rich in an essential oil.

Oriental Blend: A blend with heavy, full-bodied note.

Perfume: A suitably blended composition of various materials of synthetic and/or natural origin to give a desired odour effect. It is carried in a suitable medium to the extent of not more than 20 percent.

Perfume Concentrate: A nonalcoholic concentrated perfume blend.

Perfumery Compound: A concentrated base which is further diluted with or without toning and further modifications to suit various end uses.

Perfumery Grade Alcohol: Rectified ethyl alcohol free from by-odours used in the manufacture of a alcoholic extracts and perfumes.

Perfumery Material: A naturally occurring substance or a derived material or a preparation obtained by physical and/or chemical means, which diffuses or imparts an odour or a flavour.

Perfumery Materials, Symthetic: Man made perfumery materials by chemical processes.

Plant, Aromatic: Plant bearing a characteristic aroma.

Pomade: Refined and deodourised animal fat (s) saturated with volatile oils present in and exhaled from the flowers especially tuberose and jasmine.

Pommade: The product of the enfleurage fat extraction of fresh flowers.

Rectification: Method of separation of undesirable substance to improve the quality of the material.

Residual Note (Dry Out Note): An odour effect experienced by olfactorynerves on smelling a strip impregnated with a material and exposed to the atmosphere for a period of time when the top and middle notes have disappeared.

Resin: Solid or semisolid translucent exudation from trees or plants.

Resinoid: A semifluid or a solid material obtained from a single resinous source of vegetable or animal origin by extraction with a suitable solvent and is free from solvent used in the process.

Saponification Value: It is numerically equivalent to the number of milligrams of potassium hydroxide required to neutralize the free acids and the acids liberated by the hydrolysis of the esters present in 1 g of the material. It represents the sum of acid value and ester value.

Saponification Value After Acetylation: It is numerically equivalent to the number of milligrams of potassium hydroxide required to neutralize the free acids and the acids liberated by the hydrolysis of the esters present in 1g of the acetylated product.

Sesquiterpene: Terms denoting a hydrocarbon composed of one and a half terpene units, a single terpene unit being equal to two isoprene units.

Sesquiterpeneless Oil: An isolate obtained by suitably removing the sesquiterpenes ($C_{15}H_{24}$) from an essential oil.

Spice/Herb oleoresin: A solvent extract of dried spice or herb which is virtually free from the extracting solvent. It is used exclusively by the food and pharmaceutical industries as a replacement of ground spices and spice tinctures.

Spicy Blend: Any fragrance combination having carnation characteristics.

Steam Distillation: Distillation of a substance by bubbling steam through it.

Synthetic Perfumery Materials: Man made perfumery materials by chemical processes.

Tail Running: The last fraction in a distillation process.

Terpeneless Oil: An isolate obtained by removing almost all monoterpenes ($C_{10}H_{16}$) from an essential oil.

Thin: The lack of body and richness.

Tincture: A cold alcoholic extract of natural fragrant material of vegetable or animal origin, the solvent being left in the extract as a diluent.

Tissue: Plant structure composed of cells.

Toilet Water: It is the strongest realization of a particular fragrance in aqueous alcohol.

Top Note: The first odour effect experienced by olfactory nerves on smelling a strip freshly impregnated with a material.

Vacuum Distillation: Distillation of a substance under reduced pressure.

Volatile: A material is said to be volatile when it has the property of evaporating at room temperature when exposed to atmosphere.

Water Distillation: Distillation of a substance carried out in direct contact with boiling water.

Woody Blend: Any fragrance dominated by a woody character.

Woody Note: The impression of wood or woody odours within the fragrance theme.

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