Aromatic Plants Cultivation, Processing And Uses
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Aromatic plants have essential or aromatic oils naturally occurring in them. They help heal mental ailments and other diseases. India is endowed with a rich wealth of medicinal plants. Aromatic (Aroma Producing) plants are those plants which produce a certain type of aroma. Their aroma is due to the presence of some kind of essential oil with chemical constituents that contain at least one benzene ring in the their chemical configuration. The chemical nature of these aromatic substances may be due to a variety of complex chemical compounds. These plants have made a good contribution to the development of ancient Indian material medica. In recent years, there has been a tremendous growth of interest in plant based drugs, pharmaceuticals, perfumery products, cosmetics and aroma compounds used in food flavors and fragrances and natural colors in the world. There is a definite trend to adopt plant based products due to the cumulative derogatory effects resulting from the use of antibiotic and synthetics and except for a few cultivated crops, the availability of plant based material is mainly from the natural sources like forests and wastelands. There is a need to introduce these crops into the cropping system of the county, which, besides meeting the demands of the industry, will also help to maintain the standards on quality, potency and chemical composition. During the past decade, demand for aromatic plants and its products has attracted the worldwide interest, India being the treasure house of biodiversity, accounts for thousands of species which are used in herbal drugs. 90% of herbal industry requirement of raw material is taken out from the forests.

Some fundamentals of this book are botanical description of the plant, genetic improvement, harvesting, intercropping, transplantation, irrigation and weeding, vanilla cultivation in india, commercial cultivation of vanilla, distillation of herbage for essential oil, effect of growth hormones, jasmine crop improvement & agrotechniques, efforts for new vatiety of jasminum auriculatum, essential oils of agarwood, cinnamomum tamala leaves, eucalyptus citriodora and cautheria praigrantissima, past and future of sandal wood oil industry, by product development from turmeric and ginger rhizomes, isolation of essential oils and its flavour profile etc.

This book contains most of the important aspects related to aromatic plants. It is being published for those who are interested in growing, processing and trading of aromatic plants.

Tags
Aromatic plants cultivation India, Cultivation of aromatic plants, Aromatic plants farming, Cultivation of aromatic crops, List of aromatic plants in India, Names of aromatic plants, Aromatic plants, Processing of Aromatic Plants, Extraction of essential oils from aromatic plants, Extraction of essential oils by steam distillation, Essential oil extraction methods, How Are Essential Oils Extracted?, Essential oils, Extraction of Volatile Oil from Aromatic Plants, Steam distillation procedure, How to extract plant oils by distillation?, How to extract oil from plants?, List of aromatic plants and their uses, List of Important Aromatic Plants, Multiple Uses of Aromatic Plants, Commercial cultivation of aromatic plants

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Sample Chapter:
Cultivation of French Basil
(Ocimum Bacilicum L.)
About 60 Ocimum species are found to grow in tropical Asia, Africa, America and subtropical regions of the world, from sea level to an altitude of about 1800 m. Of these, Ocimum bacilicum Linn. Is considered the most important for its Sweet Basil Oil. It is known to have been cultivated for at least three thousand years by Europeans and Asians for folklore and religious rituals and got established wherever they migrated with extreme variation of its progeny. However, owing to a high degree of polymorphism exhibited by the species, as also abundant cross-pollination, a large number of sub-species, varieties and forms or strains have come into existence which make the botanical nomenclature extremely difficult. Thus, several names have been assigned to the same varieties and even to some of the lesser understood varieties and forms of other species. The genetical studies conducted to account for the difference in the composition of oils have indicated that the differences are not specific. This is due to the presence or absence of certain genes which control the biogenetic pathway at a particular stage of oil synthesis. In view of the great diversity, the various species and varieties have been classified, in accordance with their chemical composition and geographical source, into 4 major types as under:

1. European Type
The main constituents in the oil are methyl chavicol and linalool, but no camphor. This group comprises French and American Sweet Basil Oils which are laevorotatory in nature and are very much in demand in the trade because of high quality and the finest odour.

2. Reunion Type
The main constituents of the oil are methyl chavicol and camphor, but no linalool. This group comprises oils distilled in Reunion Island, Comoros, Madagascar and the Seychelles which are dextrorotatory and of somewhat lower quality.

3. Methyl Cinnamate Type
Whereas methyl chavicol and linalool form the principal constituents of this oil, methyl cinnamate is present in substantial amounts. The oils distilled in Egypt, Sicily, Bulgaria, erstwhile British East India and Haiti come under this group, which are laevorotatory.

4. Eugenol Type
The principal constituent of the oil is eugenol. This group comprises oils distilled in Java, Seychelles, Samoa and U.S.S.R., which are dextrorotatory.

Nine species are recorded from India, of which three are exotic. The more important of these species are:

1. Ocimum basilicum Linn. (Eng. - French or Sweet Basil, Hindi - Babui Tulsi). It has the following sub species and varieties:

2. O. basilicum Linn. subsp. minimum Danert (Syn. O. Minimum Linn.)
3. O. basilicum var. majus Benth.
4. O. basilicum var. difforme Benth. (curly-leafed Basil)
5. O. basilicum var. purpurascens Benth. (Violetred Basil)
6. O. basilicum var. glabratum Benth. (Common white Basil)
7. O. basilicum var. pilosum Benth. (Syn. O. pilosum Roxb.)
8. O. americanum Linn. (Syn. O. canum Sims) (Eng.-Hoary Basil, Hindi-Kala Tulsi)
9. O. gratissimum Linn. (Eng.-shrubby Basil, Hindi-Ban or Ram Tulsi)
10. O. kilimandscharicum Guerke. (Eng.-Camphor Basil, Hindi-Kapur Tulsi)
11. O. sanctum Linn. (Eng.-Sacred or Holy Basil, Hindi-Tulsi)
12. O. viride Willd. (Eng.-Fever Plant of Sierra Leone)

Of the above species, Ocimum basilicum Linn. alone is cultivated in India on a commercial scale. The oil of sweet basil owes its importance to its extensive use in condimentary products, cosmetic, toiletry, perfumery and confectionery industries, particularly in European countries.

Botany
Ocimum basilicum Linn. occurring in nature as a tetraploid (2n=48) belongs to the family Labiatae. It is an erect, almost glabrous herb, reaching a height of 30-90 cm and cultivated in major parts of the country. The plant has many oil glands which impart it a characteristic aromatic odour. Leaves ovate-lanceolate, 3.75-5 cm long; entire or dentate, adaxial and abaxial surfaces glabrous, glandular; petioles very slender, usually slightly hairy; flowers 0.72-1.25 cm long, borne in long terminal raemose inflorescences, simple or much branched, often thyrsoid, bracts stalked, ovate, minute, caducous; calyx 5-toothed, upper tooth rounded, shorter than others, 2 lower teeth ovate-lanceolate with a bristle point, 2 lateral shorter than the lower, calyx partly grown together with bracts, enlarges itself postflorally and remains with the latter dry on plant; corolla 0.72-1.25 cm long, white, pink or pale-purplish, 2-lipped, tube short, upper lip nearly equally 4-lobed, lower lip curved down, not lobed; stamens 4, protruding, twice as long as corolla, bent, hairy at bend; ovary bicarpellary, syncarpous, bilocular, becoming tetralocular later; stigma bifid; fruits nutlets, 4, ellipsoid, dark brown to nearly black, oblong with rounded ends, minutely dotted, convex on one side and flattened on the other, surface pitted, varying in size from 2.0-2.9 mm in length by 1.2-1.9 mm in width, mucilaginous covering from heavy to scant, swell in water within 10 minutes with no further swelling after 3 hours.

Soil and Climate
The plant thrives best on moderately fertile but well drained loamy or sandy-loam soils. The clavey or sandy soils are unsuitable for its cultivation. The best soils are those which are in good physical condition and have good water holding capacity. The waterlogged lands must invariably be avoided.
The plant is rather susceptible to frost and the crop growth is adversely affected in areas which experience heavy and continuous rainfall. In the hilly areas of north India, therefore, it is advisable to raise it as a Kharif crop. In the plains of north India or south India and Assam, it could, however, be grown both as Kharif and Rabi crops. In areas with a heavy rainfall, the crop could be raised provided the plants get well established prior to the break of monsoon and the rain water does not stagnate in the field.

Field preparation
The field in which the crop is to be raised should be disc ploughed once (if necessary), followed by two crosses harrowings and one planking. The operations may be so directed that the land is ready for planting in north Indian plains in May-June or October-November and in hills by the end of March or latest by the last week of April. The soil need not be prepared to a fine tilth but any stubbles of the previous crop should be removed. Convenient sized beds, which may be 15 m x 15 m, are laid out with proper provision for irrigation as well as interculture operations.

Propagation
The crop is raised through seeds, but direct sowing of seeds in the field is not advised. The usual practice is to raise the seedlings in the nursery first and then transplant them in the field.

(a) Raising of Nursery
The location of nursery should ensure adequate irrigation facilities. The land must be cleared of stubbles, weeds, etc. and soil worked well up to 30 cm in depth. Well rotted farmyard manure and leafmould each, at the rate of 1 kg per sq m, is applied and the soil is very well pulverised so as not to leave any clods.
Convenient sized beds of 1 m x 4 m, with irrigation channel systems, are laid out. The small size of nursery beds facilitates removal of weeds without entering the beds. As the seeds are minute, they must invariably be mixed with fine sand or wood-ash to ensure even distribution in the seedbeds. Seed rate per bed of size 1 m x 4 m should be 10-15 g. Since 1000 seeds weigh a little over 1 g and the germination percentage is 90-95, about 125 g seeds are required to give sufficient seedlings for transplanting in 1 hectare. The seeds may be sown in lines, about 6 cm apart, or broadcast over the beds and covered with thin layer of sand and farmyard manure. Care should however, be taken to avoid deep sowing which adversely affects the germination. In the plains of north India, sowing should be done either in the months of April-May or August-September and in the hilly regions in April. The germination of seeds starts 3 days after sowing and it is practically over in about 10 days. It is advisable to cover the seedbeds lightly with straw so as to conserve moisture, which may be removed when the seedlings emerge. In dry months, it may be necessary to water seedlings twice a day. The nursery must be kept clear of the weeds. The seedlings, when 6-10 cm tall, are carefully dug up for transplanting in the field.

(b) Planting

The field, at the time of planting, should have good tilth. If the transplanting is to be done in dry months, the seedlings should invariably be covered with moist gunny cloth, hessian or green leaves, soon after their removal from the nursery. This is necessary to protect them from strong sun especially on bright sunny days. The transplanting in such conditions must be done towards the evening and the field irrigated liberally thereafter. Cloudy weather and fine drizzle are considered ideal for transplanting. It is recommended to transplant the seedlings 40 cm apart, in rows, 60 cm apart.

Irrigation

When raised as a Kharif crop, irrigation is required once every week. With the onset of monsoon, the rains meet the water requirements of the crop fully till September. Thereafter, irrigation may be required once or twice a month.

Fertiliser Application

In order to raise a good crop, adequate supply of nutrients is essential. It is advisable to apply 20 kg N, 40 kg P2O5 and 40 K2O per hectare, as basal dose, before planting. 40 kg of Nitrogen should also be applied as top dressing in two equal split doses.

Interculture

The first weeding to the crop should be given about one month after planting, at the time when the seedlings are established well in the field. The second weeding-cum-hoeing may be necessary after another 4 weeks and thereafter; the plants become bushy thereby suppressing the weeds. Earthing of the plants is preferable. Expenditure on weeding may be considerably minimised in large plantations through the use of cultivator drawn by tractor.

Harvesting and Yield

The crop is harvested when the plant is in full bloom and lower leaves tend to turn yellowish. Harvesting can be done with the help of hand sickles. Depending upon a number of factors, the crop may come to full bloom 8-12 weeks after planting in different regions of the country. Corresponding to the part harvested, that is to say, flowers or the whole herb, two grades of oil are obtained. The oil produced from flowers alone has a superior note and fetches a higher price in the trade. In order to obtain high quality of oil, it is advisable to harvest only the flowering tops. In tarai regions, optimum yield of herb has been obtained by harvesting first four crops consisting of main as well as sub-inflorescences alone and the last crop of the whole herb. Of these four floral harvests, the first is taken when the plants are in full bloom and the second as well as the subsequent harvests after every 15-20 days thereafter. For the last harvest, the plant as a whole is cut close to the ground. In Assam
In (Jorhat), three harvests only are taken and the whole plant is harvested. The first harvest takes place 12 weeks after planting and two more at an interval of two months each. It is estimated that 3-4 floral harvests mentioned above give about 3-4 tonnes of flowers and the final harvest of the whole plant about 13-14 tonnes of herbage per hectare. Under certain situations, such as the shortage of labour, instead of flowers, the whole herb may have to be harvested, 3-4 times, at an interval of 1 month each from the first harvest. In that event, about 18-20 tonnes of herbage is obtained per hectare. While harvesting first and subsequent crops of the whole herb, utmost care must be exercised to cut the individual plants not less than 15 cm from the ground so that effective regeneration of the crop takes place. If the plants are cut too close to the ground, they may die altogether or produce rather poor second crop.

On an average, whereas the young inflorescences contain about 0.4 per cent oil, the whole herb contains only 0.10 to 0.25 per cent (Table-1). In actual practice, a yield of about 30-35 kg of oil per hectare, corresponding to 12-13 kg of flower oil and 18-22 kg of whole herb oil is obtained. If only whole herb is harvested and distilled, the yield of oil per hectare may be about 30 kg.

After the crop is harvested, it is advisable to allow it to wilt in the field for 4-5 hours so as to reduce the moisture in the herb. This helps reducing the herbage somewhat in bulk and facilitates its easy packing in distillation tubs. The herbage should however, not be exposed to sun for prolonged drying as it adversely affects the quality of oil. It may be pointed out here that both the yield of herb and percentage of oil contained therein may vary greatly depending directly upon the fertility of soil as well as seasonal conditions. Further, the more bushy types of plants with not too many large stems yield more oil for the simple reason that oil resides chiefly in the flowers and leaves. Also, bright sunny weather immediately preceding the harvest increases the oil while cloudy or rainy weather decreases it.

Distillation

The oil of sweet basil is obtained on distillation of young inflorescences and/or whole herb by both hydro-distillation and steam distillation. The latter is considered definitely better than the former in that it takes less time and effects better recovery of oil contained in herb. While the former carried on in a direct fire still is cheaper and more handy for small plantations, the latter is preferred for large plantations.

In steam distillation, the equipment consists of a boiler, a distillation vat or tub, a condenser and 1-3 operators. The steam is generated in the boiler that leads through a steam inlet pipe under a pressure of 18-32 kg into the distillation tub filled with the charge to be distilled. Through an outlet pipe, the other vapours along with the essential oil contained in the herb, pass over to the condenser. As the distillation proceeds, the distillate goes on collecting in the operator.

The oil being lighter than water and insoluble is floats on the surface and is periodically drawn off, then decanted and filtered to get rid of impurities. About 1-1½ hours are required to exhaust a charge completely. It is necessary that the distillate should be warm as it comes out of the condenser. After the oil has been separated from the distillation water, it is advisable to re-distill the latter to recover small count of oil held in suspension. This may be done to separate distillation tub or in the same tub after main charge has been distilled. It is most important that the distillation equipment must be clean before the distillation is started, otherwise the quality of the oil is affected imparting it a disagreeable odour or sometimes-undesirable colour.

Agronomical Studies

The reported life zone of sweet basil is 7 to 27 degrees centigrade, with 0.6 to 4.2 meters annual rainfall and a soil pH of 4.3 to 8.2. The crop which is susceptible to frost and cold-temperature injury, develops best in full sun and well-drained loamy or sandy-loam soils. In the hilly areas of the north India, it is advisable to raise it as a kharif crop. In the plains of north India or South India and Assam, it could however, be grown both as a kharif and rabi crops. In areas with heavy rainfall, the crop could be raised before the onset of monsoon.
Table-1
Physichemical Properties of Oil of Sweet Basil
(Ocimum bacilicum Linn.) Produced in Different Places

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Properties</th>
<th>Jammu Whole herb oil</th>
<th>Tarai of Naini Tal Flower oil</th>
<th>Uttar Pradesh Herb oil</th>
<th>Assam Whole herb oil</th>
<th>France Flower oil</th>
<th>America Whole herb oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Yield of oil %</td>
<td>0.5 - 0.66</td>
<td>0.22 - 0.55</td>
<td>0.10 - 0.28</td>
<td>-</td>
<td>0.09 -0.11</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Specific gravity (20°C)</td>
<td>0.9016</td>
<td>0.8792 - 0.9198(18 °C)</td>
<td>0.8896 - 0.9288(18 °C)</td>
<td>0.9183(29 °C)</td>
<td>0.8959 - 0.9168</td>
<td>0.9132 - 0.9278</td>
</tr>
<tr>
<td>3.</td>
<td>Refractive index (20°C)</td>
<td>1.4892</td>
<td>1.4582 - 1.4718(17°C)</td>
<td>1.4662 - 1.4757(17°C)</td>
<td>1.4798(29°C)</td>
<td>1.4770 - 1.4880</td>
<td>1.4883 - 1.4943</td>
</tr>
<tr>
<td>4.</td>
<td>Optical rotation</td>
<td>-10°7'</td>
<td>-6°36' to -9°36'</td>
<td>-4°0' to -7°0'</td>
<td>-9°0'</td>
<td>-10°14' to -6°21' to</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Ester value</td>
<td>1.2</td>
<td>4.73 - 6.86</td>
<td>4.60 - 17.10</td>
<td>7.20</td>
<td>3.50 - 9.80</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>Alcohols (calc.as linalool)</td>
<td>48.5%</td>
<td>57.60 - 60.10%</td>
<td>41.10 - 50.00%</td>
<td>54.70%</td>
<td>34.50 - 39.66%</td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>Methyl chavicol content</td>
<td>-</td>
<td>25.30 - 29.00%</td>
<td>35.20 - 40.50%</td>
<td>33.90%</td>
<td>55.00%</td>
<td>-</td>
</tr>
</tbody>
</table>

Cultivation practices of this crop in different parts of India have been studied. The crop is raised through seeds. Seeds are required @ 125 g/ha for raising nursery. 6-10 cm tall seedlings are transplanted in field and 40 cm x 60 cm of spacing is recommended for the plants. Fertilizers @ 20 kg N, 40 kg P2O5 and 40 kg K2O/ha are given as basal dose before planting. Two equal split doses of N @ 40 kg is applied as top dressing. Waheb et al (1983) reported 68-84% increase in herbage yield when NPK was applied @ 120,100,100 kg/ha, respectively. Singh et al (1987) studied the response of various doses of nitrogen to the crop. He reported that optimum nitrogen rates of 146.1, 120.2 and 128.2 kg/ha yielded essential oil @ 61.6, 54.6 and 56.6 kg/ha, respectively.

Irrigation is required once a week, when it is grown as a summer crop. Otherwise once or twice a month irrigation is found to be sufficient.

Depending upon the environment, sweet basil is harvested 2-5 times annually and grown as an annual or short-lived perennial. The first harvest is initiated just prior to open bloom of the white or purplish flower that appear in summer, 10-16 weeks after planting. As the quality of the product associated with colour and aroma retention is strongly influenced by post-harvest handling, leaves and flowering tops are dried at low temperatures to retain maximum colour before guiding to marketable size or distilling for essential oil. Floral harvests yield about 3-4 tonnes of flowers and the final harvest of the whole plant is about 13-14
tonnes of herbage per hectare. Putievsky have studied different harvesting schedules for basil in Israel. He has also studied influence of high frequency of harvest and the date of the first harvest on plant growth. Higher yields were obtained from later phenological stages. It was observed that higher yield of herbage and oil was recorded when harvesting was done between early seeding to late seeding stage of growth at Delhi conditions.

Losses of NH3, P & K with run off waters were insignificant when tobacco was rotated with sweet basil in comparison to growing it as a monoculture.

Physiological Studies

Heavy metal tolerance

Veeranjaneyulu studied heavy metal tolerance in basil. Ocimum bacilicum was found to be tolerant to higher concentrations of copper and zinc and is susceptible to copper and nickel. They also studied intrachloroplast localization of Zn and Ni in Ocimum bacilicum in order to investigate the mechanism and specificity of metal tolerance. It was observed that Zn activity was comparatively greater in chloroplast envelop membranes and stroma than the Ni. Ni was largely found in the lamellar and stroma fraction. Analysis of lamellar fraction revealed that photosystem II particles were richer in radioactivity than photosystem I particles. The photochemical events of photosynthesis were less affected in Zn-treated plants than in the Ni-treated plants.

Effect of growth hormones

Ahmed studied the effect of gibberellic acid and cycocel on the growth and essential oil content of Ocimum bacilicum. Gibberellic and @ 50, 100 and 200 ppm decreased the weight of plants, especially that of leaves in a concentration dependent manner.

Mineral contents

Gasparyan investigated the mineral contents of basil under open hydroponic conditions. The mineral content of vegetable parts decreased in Order K] Ca] Mg] P] S]Fe. Basil had the higher P contents. The yield of hydroponically cultivated herb plants was 3-10 fold that of soil culture and contains 3-10 folds as much mineral elements as the latter did.

Seed mucilage studies

Tharanathan investigated the polysaccharides from the seed mucilage of Ocimum bacilicum. D-glucose, D-galactose, D-mannose, L-arabinose, D-xylose, D-rhamnose and D-galacturonic and D-mannuronic acids were isolated. The mucilage was partly O-acylated and contained lipids and studied the distintegrative properties of the O. bacilicum mucilage. The seed powder of O. bacilicum has a superior disintegrating property for pharmaceuticals as compared to those of M-cellulase, starch and isabgol.

Effect of photoperiodism

It was observed the effect of photoperiodism on the growth and essential oil of O. bacilicum. Flower development was most rapid when exposed to 18 h of light daily. The optimum yield in herb was obtained under 24 h of light, for photoperiods of 15 to 18 h, the yield was slightly lower but the plants reached harvesting stage 10 days earlier.

Biosynthesis of Eugenol

Mannito showed through labelling experiments that eugenol was biosynthesized from L-phenylalenine by loss of the carboxylic C atom at the ferulic acid level and introduction of extra C without skeletol rearrangements. Methyl eugenol estragole and chavicol were biosynthesized similarly. Phenylalanine, cinnamic acid and ferulic acid were intermediates in the biosynthesis of eugenol. Mannito further observed incorporation of specifically labelled cinnamic acid into eugenol. The results were interpreted on the basis of a new biogenetic hypothesis.

Tissue Culture Studies

Lange studied production accumulation of essential oil in Ocimum bacilicum cell cultures.
morphologically differentiated callus and suspension cultures, both free monoterpenoids and phenylpropanoid components and their glycosides were found. They further observed that essential oil formation is apparently not related to the place of accumulation. The principal glycoside components were linalool, borneol, eugenol and thymol glycosides and considerable amount of monoterpenoid glucosides. Clonal propagation of Ocimum species has been studied. Apical nodal segments of Ocimum were cultured in revised MS medium supplemented with cytokinins, auxins individually and in combinations. The developed plantlets were transferred to field with 10-25% mortality. Uniform increase in shoot number from a single explant was observed during subculturing it at optimum conditions up to 40-45 days with an initial lag of 15-20 days, after which shoot number remained the same.

Dalton studied chlorophyll production and photosynthetic development in fedbatch cultures of Ocimum bacilicum. Sweet basil cell suspension were cultured in the glucose limiting conditions of fedbatch cultures and the glucoseexcess conditions of batch cultures. When compared, the cells in fedbatch culture had a higher specific production rate of total chlorophyll and a higher potential photosynthetic rate. Results from these and other fedbatch cultures indicated that total chlorophyll did not change much with specific growth rate. Thus, the inhibition of total chlorophyll at high glucose feed rates was not thought to be caused directly by the increase in specific growth rate.

Photosynthetic development of O. bacilicum on transition from phosphate to fructose limitation has also been studied. Phosphate in MS medium was found to be limiting growth; when PO4 concentration in the medium feed was doubled, the concentration of dry biomass and of all biomass elements increased. After doubling the phosphate concentration, fructose became limiting. O. bacilicum cells responded to the transition from phosphate limitation to fructose limitation by becoming greener and more photosynthetic; consequently the yield on fructose increased. Production rate of chlorophyll was inhibited when glucose concentration in the cell was above or threshold of about 1.2% dry biomass. The degree of inhibition was a function of glucose concentration above this threshold.

Genetical Studies
Cytological studies of Ocimum sp. has been done by many authors. Two basic chromosome number x=8 and x=12 has been reported. The species belonging to Basilicum group has x=12 chromosomes. The floral structure of Ocimum species is most suitable for pollination by insects, particular by bee. There is a strong tendency in the species to outbreed within the population. The frequency of intravarietal hybrids varied from 5.8% to 18.5% in O. bacilicum. Krishnan recorded outcrossing upto 66.7% in the experiments and emphasized the need for growing varieties in isolation to ensure varietal purity. They have also studied inheritance of field reaction to Cercospora disease. It was found that field reaction was oligogenically controlled and possibly by a single gene with the dominant allele conforming field resistance. In O. bacilicum, the most commonly operating mechanism against cross breeding between the different varieties is geographical isolation. Sobti did extensive hybridization experiments. The failure of formation of hybrids in interspecific crosses was due to differences in floral structure of the species physiological factors and genetic factors. The reciprocal crosses in these are successful.

The elucidation of genetics of pigmentation in seedling and adult plant parts in this crop has provided a valuable gene marker in seedling pigmentation for such studies.
Inheritance of chemical constituents of essential oils in O. bacilicum was studied. They showed that citral, linalool, geraniol, which are monoterpenes are inherited independently of methyl chavicol and eugenol which are phenolic in nature. Three chemical races rich in (1) camphor, (2) eugenol and (3) methyl chavicol have been isolated from O. bacilicum var. glabratum. Presence and absence of these constituents is controlled by a single gene which exists in three allelic responsible for the formation of methyl chavicol. Any of the two recessive alleles can be present in the plant in addition to the dominant gene but is not able to express it. Thus, no eugenol or camphor is formed in the plants having gene for methyl chavicol. They have
further showed that gene responsible for citral is dominant over geraniol and linalool. But the gene responsible for the formation of methyl cinnamate blocks formation of citral, geraniol linalool and methyl chavicol and eugenol. Kundu while studying interspecific variation in the amount of DNA in Ocimum L., showed that the diploid chromosome number and 4C nuclear DNA content of Ocimum species have no linear relationship. Chemical Composition

The volatile oil contains d-linalool and methyl chavicol as the major components; with the former up to 55% and the latter about 70%, depending on the sources. Other components include methyl cinnamate, which has been reported to be the major component of a variety of sweet basil, 1,8-cineole, eugenol, borneol, ocimene, geraniol, anethole, 10-cadinols, b-carophyllene, a-terpineol, camphor, 3-octanone, methyleugenol, safrole, sesquithujene and 1-epibicyclosesquiphellandrene among others. The percentage of major chemical constituents differ in oil obtained from different parts of the plant viz., flower, herb, diseased plants, etc., as evident from Table-4.

Table-1

<table>
<thead>
<tr>
<th>Diseases/Pests</th>
<th>Causal Organism</th>
<th>Symptoms</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blight</td>
<td>Corynospora cassicola (Berk. &amp; Curt.) Wie</td>
<td>Brown Coloured spots</td>
<td>-</td>
</tr>
<tr>
<td>Alternaria Sp.</td>
<td>Chlorotic spots</td>
<td>Dithane Z-78 on leaves</td>
<td>Dithane M- 45</td>
</tr>
<tr>
<td>Leaf Blight</td>
<td>- do -</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wilt</td>
<td>Fusarium oxysporum</td>
<td>Whole plant</td>
<td>Tafason Agalol</td>
</tr>
<tr>
<td>Scab</td>
<td>Elsinoe arxii sp. nov.</td>
<td>Defoliation</td>
<td>-</td>
</tr>
<tr>
<td>Rhizosphere</td>
<td>Aspergillus candidus</td>
<td>-</td>
<td>Agrimycin</td>
</tr>
<tr>
<td>Mycoflora</td>
<td>Penicillium humicola</td>
<td>Phytomycin</td>
<td></td>
</tr>
<tr>
<td>Humicola sp.</td>
<td>-</td>
<td>Dithane M- 45</td>
<td></td>
</tr>
<tr>
<td>Myrothecium sp.</td>
<td>-</td>
<td>Thiran</td>
<td></td>
</tr>
<tr>
<td>Alternaria tenuis</td>
<td>(Major ones among total of 33 reported)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Pests and Diseases

<table>
<thead>
<tr>
<th>Diseases/Pests</th>
<th>Causal Organism</th>
<th>Symptoms</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blight</td>
<td>Corynospora cassicola</td>
<td>Brown Coloured spots</td>
<td>-</td>
</tr>
<tr>
<td>Alternaria Sp.</td>
<td>Chlorotic spots</td>
<td>Dithane Z-78 on leaves</td>
<td>Dithane M- 45</td>
</tr>
<tr>
<td>Leaf Blight</td>
<td>- do -</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Wilt</td>
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<tr>
<td>Scab</td>
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<td>Rhizosphere</td>
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<td></td>
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<td>-</td>
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<td></td>
</tr>
<tr>
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<td>-</td>
<td>Thiran</td>
<td></td>
</tr>
<tr>
<td>Alternaria tenuis</td>
<td>(Major ones among total of 33 reported)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
There are great variations in concentrations of these components in the volatile oils from different sources. A comparative study of chemical composition of French, Italian and Moraccan basil oil was made. The results are tabulated in Table-2.

The results of the comparative quantitative studies on the chemical constituents of commercial basil oils of South Africa, France, Comoro Island & Egypt is given in Table-3. It is very clear from these comparative studies that the chemical composition and morphological characteristics of O. bacilicum are highly variable, depending largely upon the source. The basil oil of Chinese origin was also investigated. The major compounds identified were methyl chavicol, linalool, 1,8-cineole, ocimene, linalyl acetate, eugenol, menthone, cyclohexanol, cyclohexanone, nerol and myrcenol. Other constituents present in sweet basil include protein (14%), carbohydrates (61%), and relatively high concentrations of vitamins A and C.

Table-2

<table>
<thead>
<tr>
<th>Constituent</th>
<th>French</th>
<th>Italian</th>
<th>Moraccan</th>
</tr>
</thead>
<tbody>
<tr>
<td>a- Pinene</td>
<td>0.11</td>
<td>0.17</td>
<td>0.35</td>
</tr>
<tr>
<td>b- Pinene</td>
<td>0.07</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>Camphene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compound</td>
<td>Percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myrcene</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car-3-ene</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a-Terpinene</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limonene</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,8-Cineole + cis-Ocimene</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a-Terpinene + 3-Octanone + trans-Ocimene</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.02</td>
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</tr>
<tr>
<td></td>
<td>0.02</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compound</td>
<td>%</td>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>---</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>p - Cymene</td>
<td>1.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terpinolene</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cis - allo -Ocimene</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cis - 3 -Hexenol</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Menthone</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenchyl acetate</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copaene + β-bourbonene</td>
<td>0.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Linalool
39.10
43.80
41.90

Fenchyl alcohol + Bisabolene +

Isocaryophyllene + β-elemene
9.20
5.20
8.40

Caryophyllene + Terpinen - 4-ol
1.00
0.98
0.80

Menthol
0.27
0.32
0.24

Methyl chavicol
23.20
31.80
2.60

β-Terpineol
0.90
1.19
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Percentage in Basil Oils of Different Origins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terpinyl acetate</td>
<td>2.50</td>
</tr>
<tr>
<td>Citronellol</td>
<td>6.30</td>
</tr>
<tr>
<td>Geraniol</td>
<td>2.18</td>
</tr>
<tr>
<td>Methyl Eugenol</td>
<td>3.80</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>1.63</td>
</tr>
<tr>
<td>Eugenol</td>
<td>1.90</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>2.80</td>
</tr>
<tr>
<td>Methyl Eugenol</td>
<td>1.63</td>
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<tr>
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</tr>
<tr>
<td>Methyl Eugenol</td>
<td>0.39</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>0.28</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>0.05</td>
</tr>
<tr>
<td>Methyl Eugenol</td>
<td>0.49</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>0.07</td>
</tr>
<tr>
<td>Eugenol</td>
<td>0.50</td>
</tr>
<tr>
<td>Methyl Eugenol</td>
<td>0.16</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>6.60</td>
</tr>
<tr>
<td>Methyl Eugenol</td>
<td>3.40</td>
</tr>
<tr>
<td>Methyl cinnamate</td>
<td>19.20</td>
</tr>
</tbody>
</table>

Table-3
Chemical Composition of Basil Oils of Different Origins
[td Colspan = 4 align = center]Percentage in
Constituent
South Africa
Comoro Island
France
Egypt

a - Pinene
0.30
0.18
0.11
0.25

Camphene
0.07
0.06
0.02
0.07

b - Pinene
0.38
0.25
0.07
0.43

Myrcene
0.32
0.12
0.13
b 0.35

Limonene
4.94
<table>
<thead>
<tr>
<th>Compound</th>
<th>Value1</th>
<th>Value2</th>
<th>Value3</th>
<th>Value4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cis - ocimene</td>
<td>0.11</td>
<td>2.52</td>
<td>0.03</td>
<td>0.63</td>
</tr>
<tr>
<td>p - Cymene</td>
<td>-</td>
<td>0.06</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Cis- 3 -hexenol</td>
<td>-</td>
<td>0.02</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Fenchyl acetate</td>
<td>0.11</td>
<td>0.20</td>
<td>0.55</td>
<td>0.09</td>
</tr>
<tr>
<td>Camphor</td>
<td>0.75</td>
<td>0.37</td>
<td>1.43</td>
<td></td>
</tr>
</tbody>
</table>
Linalool
54.37
1.16
40.72
45.55

Fenchyl alcohol
6.29
1.20
6.70
5.52

Methyl chavicol
2.38
85.75
23.79
26.56

α - Terpiniol
0.83
0.84
0.84
0.84

Citronellol
2.77
0.65
0.65
3.57
3.57

Geraniol
Pharmacology and Biological Activities

The volatile oil of a variety of sweet basil is shown to have an antibacterial and insecticidal properties. The oil has important medicinal propents. The study was prompted by the reported use of the fresh juice of this plant to treat a maggots-infested nasal disease in India. Sweet basil oil is reported to be nontoxic. Essential oil of O. bacilicum and O. sanctum is also reported to have insecticidal and larvicidal action. Antitubercular and antimalarial action of oil is also reported. Estragole (methyl chavicol), a major component in some sweet basil oils, has been shown to produce hepatocellular carcinomas in mice.

USES

Cosmetic

Sweet basil is used as a fragrance ingredients in perfumes, hair dressings, dental creams and mouth washes.

Food

Used as a spice and in chartreuse liqueur. The oil and oleoresin are extensively used as a flavour ingredient in all major food products, usually in rather low use levels (mostly below 0.005 ppm).

Table-5

Physico-chemical properties of sweet basil oil of Indian origin

<table>
<thead>
<tr>
<th>Properties</th>
<th>Jammu</th>
<th>Herb oil of Uttar Pradesh</th>
<th>Assam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (%)</td>
<td>0.5 - 0.66</td>
<td>0.10 - 0.28</td>
<td>-</td>
</tr>
<tr>
<td>Sp.Gravity</td>
<td>0.9016 (20°C)</td>
<td>0.8896 - 0.9288 (17°C)</td>
<td>0.9183 (29°C)</td>
</tr>
<tr>
<td>Ref. Index</td>
<td>1.4892(20°C)</td>
<td>1.4662 - 1.4757 (17°C)</td>
<td>1.4798 (29°C)</td>
</tr>
<tr>
<td>Optical rotation</td>
<td>- 10°7'</td>
<td>- 4°0' to - 7°0'</td>
<td>- 9°C'</td>
</tr>
<tr>
<td>Ester value</td>
<td>1.2</td>
<td>4.60 - 7.10</td>
<td>7.20</td>
</tr>
<tr>
<td>Alcohol (%)</td>
<td>48.5</td>
<td>41.10 - 50.00</td>
<td>54.70</td>
</tr>
<tr>
<td>Methyl chavicol (%)</td>
<td>-</td>
<td>35.20 - 40.50</td>
<td>54.70</td>
</tr>
</tbody>
</table>

Folk medicine
Used for head colds and as a cure for warts and worms among other ailments. It is more widely used as a medicinal herb in the Far East, especially in China and India. It was first described in a major Chinese herbal around 1060 A.D. and has since been used in China for spasms of the stomach and kidney ailments, among others; it is especially recommended for use before and after parturition to promote blood circulation. The whole herb is also used to treat snake and insect bites.

Ayurvedic Properties

Pharmacology : Antimicrobial activity of the essential oil has been shown against M. tuberculosis and Staph aureus in vitro and other bacteria and fungi. Eugenol and methyleugenol showed a positive activity. Adaptogenic (antistress) activity has been found in mice and rats. The plant increased the physical endurance and prevented stress-induced ulcers. In general pharmacology, the aqueous extract showed hypotensive activity and inhibited the smooth muscle contraction induced by acetylcholine, carbachol and histamine. It also potentiated the hexobarbitone sleeping time. Protective action against histamine-induced bronchospasm has been shown in animals.

Safety : The fresh leaves are taken as prasad by millions of Indians for many years. The powdered leaves, 5-27 g per day were taken by 120 patients for 3 months. The only side effect was constipation. In animals with large dose of an extract, antispermatogenic activity has been shown.

Clinical Usage : A tea prepared with the leaves of Tulsi is commonly used in cough, cold, mild indigestion, diminished appetite and malaise. The solid extract of Tulsi in a dose of 500 mg x 3 for one week, significantly relieved the breathlessness in 20 patients with tropical eosinophilia. There was however no reduction in the eosinophil count in peripheral blood. It is commonly used with black pepper in bronchial asthma. An oil extracted from Tulsi is used as drops in ear infections. Fungal and bacterial infections of skin are treated with Tulsi juice. The seeds are used as a general tonic.

Indications :
1. Common cold and cough.
2. Bronchospasm.
4. Skin infections, wounds.
5. Indigestion and nausea.

Formulations and Dosage:
Fresh juice of leaves : 10-20 ml with honey b.i.d.
Seed powder : 5-10 gms b.i.d.
Tulsi oil : 2-3 drops in ear b.i.d.
World Production and Trade
Depending upon their geographical origin, a number of basil oils are offered for sale in the market. This is mainly because of the varying chemical composition of the oil. There are three main commercial types. The first is sweet basil oil, of which the principal constituents are cineole and d-linalool; the second is the Reunion-type basil oil, with cineole, d-camphor and methyl chavicol being the major constituent; the third, an intermediate type is comparatively rich in methyl cinnamate eugenol or thymol. All these types are distilled from varieties of the plant Ocimum basilicum. For the standpoint of production statistics, it is prudent to combine all the sources into one basil oil. As a consequence, the production of the year 1984 was summarised at about 14 metric tonnes with major producing countries being Comores contributing 6 tons, followed by Madagascar (2 tons), USA (1 ton), Albania (1 ton) and Egypt (1 ton). Undetermined quantities of oil were also produced in Pakistan, Italy, Yugoslavia, South Africa, Bulgaria, Reunion and Morocco.

The world production of different basil oil in 1986 stand at 12-14 tonnes. The world production of sweet basil was about 2 tonnes with Egypt accounting for nearly half of the production. Other principal producers of sweet basil being Yugoslavia, Morocco, Bulgaria, USA, Italy and Spain. World production of Reunion-type oil is around 10-12 tonnes with Comoros, Madagascar and South Africa being the main producers. Production of intermediate type oil is wide spread, the main areas being Eastern Europe, Egypt, South South-East Asia and China. The exact production figures are not available.